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EFFICIENCY AND DOSE RESPONSE OF XYLANASE IN DIETS FOR FATTENING PIGS*

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Abstract

The efficiency of different levels of dietary xylanase on growth performance, nutrient digestibilities and carcass and meat quality was evaluated in 128 barrows. The performance study lasted from about 27 to 110 kg of body weight with pigs allocated to 4 groups (32 animals each), fed *ad libitum* and kept in straw-bedded pens (4 animals each). Pigs from group I (control) received standard feeds without any enzyme added, while pigs from groups II, III and IV received the same diet including additionally xylanase at levels of 8000, 16000 or 24000 BXU (Birch Xylan Unit) per kg, respectively. The digestibility experiment was carried out with 40 barrows not involved in the first part of the experiment. Pigs were allocated to 4 groups (10 animals each) receiving the same diets as in the performance experiment. Xylanase significantly improved body weight gains of pigs receiving diets with 16000 BXU/kg (P<0.05) and 24000 BXU/kg feed (P<0.01) by 4.2% and 6.2%, respectively. Final body weights of 111–112 kg were achieved in a significantly shorter feeding period and at a lower feed conversion ratio by pigs that received highest xylanase application (24000 BXU/kg feed, P<0.05). In younger pigs xylanase mainly improved fibre digestibility which was significant for pigs receiving 24000 BXU/kg (P<0.05). In the final feeding period dry matter, fat and fibre digestibility were improved by xylanase with effects getting more pronounced with the increase of xylanase inclusion rate. No differences in carcass and meat quality were observed between any feeding groups. Based on these results it is assumed that application of xylanase (Econase XT) can improve performance of grower-finisher pigs without having any impact on the carcass quality. Performance improvements were in line with better nutrient digestibility.

Key words: xylanase, nutrient digestibility, pig fattening

Feeds for grower-finisher pigs are commonly based on soybean meal and cereal grains. These ingredients contain non-starch polysaccharides (NSP) which in grains

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are part of seed hulls and cell walls that are poorly degraded in the pig intestine (Kim et al., 2005). NSP structures are digested by microorganisms in the lower part of the digestive tract, i.e. the large intestine (Wilfart et al., 2007). Products of this digestion can be utilized only to a limited degree as an energy source (Serena et al., 2008).

Enzymes degrading such unavailable carbohydrates are commercially produced (Ximenes et al., 2007) and can be used in animal feeding (Emiola et al., 2009; Kabel et al., 2006; Świątkiewicz and Hanczakowska, 2008). Xylanases and glucanases are usually the main components of such enzyme preparations. They mainly degrade arabinoxylans (Diebold et al., 2004) and β-glucans (Li et al., 1996), respectively. Beneficial effects of applying xylanase-based enzymes preparation on improving feeding value of piglet diets based on corn and soybean meal were found in the experiment of Kiarie et al. (2007). The beneficial effect of xylanase in feeding finisher pigs was reported by Hyun et al. (2001) and effects depended on the variety of cereal used. According to Bartelt et al. (2002), xylanase significantly lowered digesta viscosity and increased ileal digestibility of fibre in pigs fed wheat and rye based feeds.

Despite these positive findings results of experiments with xylanase in pig feeding are inconsistent. Mavromichalis et al. (2000) found no improvement in body weight of weaned piglets but only slightly better performance of fatteners in the last period of fattening, between 90 and 115 kg of body weight. According to Atakora et al. (2011), average daily gain of pigs, feed intake and feed conversion ratio were not affected by xylanase supplementation. In the experiment of Yin et al. (2000) apparent digestibility of dry matter (DM), crude protein (CP) and gross energy were only slightly improved.

As the effect of xylanase in pig feeding mainly depends on the diet composition and quality of the enzyme preparation, the aim of the present experiment was to evaluate the efficiency of a xylanase preparation when added to evaluate the efficiency of a xylanse preparation when added to triticale and rye diets on growth performance, nutrient digestibility and carcass and meat quality.

Material and methods

All procedures used in this experiment were approved by the responsible Ethics Committee for Experiments on Animals.

Animals and diet

The fattening experiment was carried out on 128 pigs (barrows) weighing about 27 kg at the beginning of the experiment. Fatteners originated from (LWP×PL) sows mated with (Du×Pi) boars. Animals were allocated to 4 groups, 32 animals each, receiving the same standard feed mixtures based on cereals and soybean meal (Table 1). Pigs were fed with the grower feed during the first fattening period (27–60 kg of body weight, BW) and finisher feeds during the second fattening period (60–110 kg of BW). Xylanase added was the only difference between the experimental diets.

Table 1. Composition of basal feed mixtures (g × kg^{-1})

Item	Grower	Finisher
Wheat	80	80
Triticale	306.8	333
Rye	200	200
Soybean meal	170	150
Wheat bran	220	220
Premix PT-1[1]/PT-2[2]	5	5
NaCl	2.5	2
Ground limestone	10	8
Phosphate 1-Ca	5	2
L-Lysine	0.7	-

[1] Premix PT-1: Ca – 27.8%, Mg – 0.30%, vit. A – 1800000 IE, vit. D_3 – 400000 IE, vit. E – 6000 mg, vit. B_1 – 300 mg, vit. B_2 – 700 mg, vit. B_6 – 600 mg, vit. B_{12} – 4 mg, vit. K – 400 mg, biotin – 4 mg, niacin – 4009 mg, folic acid – 50 mg, Ca pantothenate – 3000 mg, choline – 12000 mg, Mn – 8000 mg, Zn – 17000 mg, Co – 100 mg, Se – 60 mg, Cu – 4000 mg, Fe – 20000 mg, I – 200 mg, betaine – 14000 mg, antioxidant.

[2] Premix PT-2: Ca – 28.5%, Mg – 0.30%, vit. A – 1600000 IE, vit. D_3 – 300000 IE, vit. E – 6000 mg, vit. B_1 – 200 mg, vit. B_2 – 600 mg, vit. B_6 – 400 mg, vit. B_{12} – 3 mg, vit. K – 300 mg, biotin – 2 mg, niacin – 4009 mg, folic acid – 50 mg, Ca pantothenate – 2000 mg, choline – 6000 mg, Mn – 8000 mg, Zn – 17000 mg, Co – 100 mg, Se – 60 mg, Cu – 4000 mg, Fe – 20000 mg, I – 100 mg, betaine – 8000 mg, antioxidant.

Scheme of the experiment

Pigs from group I (control) received the standard feed without any enzyme added. Pigs from groups II, III and IV received the same feeds with xylanase at 8000, 16000 or 24000 BXU (Birch Xylan Unit) per kg, respectively. Xylanase preparation used was Econase® XT (AB Vista, Marlborough, UK).

The experiment lasted from about 27 kg to about 110 kg of body weight. Diets were fed *ad libitum*, and pigs were kept in group, straw-bedded pens, 4 pigs each. The body weight of all animals was controlled every 2 weeks. Feed was taken from an automatic feeder and calculated for particular periods. At the end of the experiment 60 pigs (15 animals per group) were slaughtered and parameters of their right carcass sides evaluated. Samples of *longissimus* muscle, obtained from the area of the last thoracic and first lumbar vertebrae, were removed for analysis of dry matter, protein and fat content, water holding capacity, colour and pH.

Digestibility trial

The experiment was carried out using 40 barrows not involved in the first part of the experiment. Pigs were allocated to 4 groups, 10 animals each that received the same diets as in the fattening experiment. This experiment was done in two phases, separately for grower and finisher diets. Animals were kept and fed in individual balance crates. The initial period lasted 10 days followed by 5 days of the sampling period (faeces collection). The sampling periods were started at an average body weight of 40 kg in the grower period and 70 kg body weight in the finisher period. Faeces of each barrow were collected once a day at the same time and frozen at –20ºC. At the end of the sampling periods all faeces collected daily were pooled to one sample per animal per sampling period.

Chemical analysis

The gross analyses of feed, meat and faecal samples were performed according to AOAC (2005) standard methods. In slices of fresh meat its colour (lightness, redness, yellowness) was measured with a Minolta CR-310 colorimeter. Water holding capacity index was estimated in freshly minced meat according to Grau and Hamm (1953) methods. Fatty acid profile was analysed using Varian 3400 gas chromatograph. Thiobarbituric Acid Reactive Substances (TBA-RS) content was measured after 1 month of frozen storage (–20ºC) according to Pikul et al. (1989). Activity of xylanase was analysed by method B-066 A (validated method of the enzyme producer).

Statistical analysis

All data obtained in the performance and digestibility experiment were subjected to one-way analysis of variance (ANOVA) with comparison of means by Duncan's multiple range test at $P \leq 0.05$ and $P \leq 0.01$ levels of significance using the Statistica 5.1 package.

Results

Xylanase activity linearly increased with the amount of enzyme preparation added (Table 2). Analysed enzyme activities were close to the targets and comparable in both feeding phases.

Table 2. Content of nutrients in diets

Item	Enzyme supplement			
	0	8000BXU/kg	16000BXU/kg	24000BXU/kg
	Grower			
Dry matter (g)	875.8	874.2	874.8	875.9
Crude protein (g)	180.1	176.3	181.0	178.7
Crude fat (g)	14.8	16.1	18.7	15.4
Crude fibre (g)	37.3	36.5	35.5	37.1
Crude ash (g)	45.9	45.8	45.0	46.8
N-free extractives (g)	597.7	599.5	594.6	597.9
Metabolizable energy[1] (MJ)	12.3	12.4	12.5	12.5
Activity of xylanase FAXU/kg feed	916	6910	17600	25300
	Finisher			
Dry matter (g)	886.4	886.4	886.4	885.8
Crude protein (g)	167.9	168.7	166.6	170.5
Crude fat (g)	17.2	16.9	17.0	19.8
Crude fibre (g)	35.0	35.2	33.5	33.7
Crude ash (g)	40.8	40.2	40.2	40.5
N-free extractive (g)	625.5	624.0	629.1	621.3
Metabolizable energy[1] (MJ)	13.0	13.0	13.1	13.2
Activity of xylanase FAXU/kg feed	1220	6860	16100	27100

[1]ME calculated using Hoffmann and Schiemann (1980) equation.

Xylanase supplementation significantly improved body weight gains of pigs in experimental groups III and IV (Table 3). In the initial fattening period (27–60 kg body weight) statistically significant differences (P≤0.05) were only found for the highest xylanase dose, which improved weight gains by 7.1% when compared to the control group. In fatteners receiving 16000 BXU/kg the improvement was 5.1% (P>0.05). During the following periods (60–90 kg and 90–110 kg body weight) weight gains of experimental groups were numerically superior to the control animals but differences were not significant. However, these differences accumulated over the whole fattening period (27–110 kg body weight), being significant between the control group and groups receiving 16000 BXU/kg (P≤0.05) or 24000 BXU/kg (P≤0.01). Due to these improvements in the fattening period, the final weight of 110 to 112 kg was achieved 4 or 6 days sooner by animals from groups III and IV, respectively.

Table 3. Fattening results

Item	Enzyme supplement				SEM[1]
	0	8000BXU/kg	16000BXU/kg	24000BXU/kg	
Number of fatteners	32	32	32	32	-
BW at the beginning (kg)	27.5	26.1	27.3	27.3	0.29
BW at slaughter (kg)	111.1	111.7	112.2	111.9	0.23
Fattening period (days)	106 b	106 b	102 ab	100 a	0.88
Average daily body weight gains in fattening periods (g):					
27–60 kg	705 a	711 a	741 ab	755 b	6.81
60–90 kg	894	910	909	940	8.93
90–110 kg	879	908	925	924	10.63
27–90 kg	782 Aa	790 ABa	811 ABab	832 Bb	6.53
27–110 kg	801 Aa	813 ABab	835 ABbc	851 Bc	6.43
Feed intake in fattening periods (kg/pen):					
27–60 kg	400.7	412.7	387.2	363.7	11.25
60–90 kg	395.9	390.4	390.7	384.4	5.97
90–110 kg	281.0	280.0	281.9	271.1	7.00
27–90 kg	796.6	803.1	777.9	748.1	14.83
27–110 kg	1077.6	1083.1	1059.8	1019.2	13.31
Feed conversion per kg of body weight gain (kg):					
27–60 kg	3.08	3.06	2.96	2.70	0.07
60–90 kg	3.30	3.25	3.25	3.11	0.05
90–110 kg	3.33	3.23	3.19	2.99	0.07
27–90 kg	3.18	3.15	3.10	2.90	0.05
27–110 kg	3.23 Bb	3.17 ABb	3.13 ABb	2.92 Aa	0.04

a, b, c – mean values in rows with different letters differ significantly at P≤0.05.
A, B – mean values in rows with different letters differ significantly at P≤0.01.
[1]Standard error of the mean.

There was no significant difference in feed consumption between treatments but feed conversion ratios of the pigs were significantly (P≤0.01) improved by the highest xylanase application compared to the control and to the other enzyme inclusion rates (P≤0.05).

Table 4. Apparent digestibility coefficients of nutrients (%)

Item	Enzyme supplement				SEM[1]
	0	8000BXU/kg	16000BXU/kg	24000BXU/kg	
No. of fatteners	10	10	10	10	
Grower diet					
Dry matter	83.7	84.0	84.2	84.7	0.24
Protein	82.2	83.2	83.2	83.8	0.36
Fat	30.3	34.0	35.7	39.8	2.12
Fibre	33.6 A	37.4 AB	37.6 AB	40.7 B	0.89
N-free extractives	87.2	87.3	87.7	87.8	0.22
Finisher diet					
Dry matter	85.8 Aa	86.1 ABab	86.8 ABbc	87.0 Bc	0.14
Protein	84.0	84.9	84.5	85.2	0.25
Fat	38.1 Aa	47.9 ABb	49.0 ABb	51.3 Bb	1.64
Fibre	37.6	38.7	40.1	41.1	0.64
N-free extractives	89.6 a	89.5 ab	90.2 b	90.2 b	0.11

a, b, c – mean values in rows with different letters differ significantly at P≤0.05.
A, B – mean values in rows with different letters differ significantly at P≤0.01.
[1]Standard error of the mean.

In younger pigs (grower period) the highest xylanase application significantly (P≤0.01) improved fibre digestibility (Table 4). In the case of other nutrients in this feeding period, only numerical improvements by xylanase were noticed (P>0.05). During the finisher period apparent digestibility of fat was higher (P≤0.05) in animals for all xylanase treatments. In addition, significant differences were found in N-free extract digestibility when pigs received 16 000 or 24000 BXU/kg feed (P≤0.05).

Table 5. Carcass quality characteristics

Item	Enzyme supplement				SEM[1]
	0	8000BXU/kg	16000BXU/kg	24000BXU/kg	
Body weight (kg)	111	111	111	112	0.34
Cold dressing yield (%)	77.60	77.41	77.40	77.77	0.08
Meat of neck (kg)	5.85	5.81	5.68	5.90	0.07
Meat of ham (kg)	7.68	7.68	7.60	7.86	0.06
Meat of loin (kg)	7.07	6.88	6.94	7.13	0.07
Loin eye area (cm^2)	56.54	56.39	56.35	56.57	0.55
Meat of primal cuts (kg)	23.34	23.16	23.03	23.68	0.16
Meatiness of carcass (%)	55.69	55.45	55.29	56.04	0.31
Average backfat thickness (cm)	2.01	1.89	2.01	2.02	0.04

[1]Standard error of the mean.

There were no significant differences in carcass and meat quality (Tables 5 and 6). Average meat content of the carcasses ranged between 55.3 and 56.0%, being graded as class E according to pig carcass classification system (S)EUROP. Meat in primal cuts and loin eye area were similar in all groups and amounted to about 23 kg and 56 cm^2, respectively. The experimental treatments did not affect the meat quality. The meat colour, water holding capacity index, the content of protein and fat, as well as fatty acids profile were similar in the control and experimental groups as well.

Table 6. Meat quality traits

Item	Enzyme supplement				SEM[1]
	0	8000BXU/kg	16000BXU/kg	24000BXU/kg	
Meat colour on Hunter's scale:					
lightness	46.86	46.63	46.94	47.38	0.26
redness	13.53	13.69	13.30	13.46	0.07
yellowness	2.27	2.39	2.21	2.42	0.05
Water holding capacity (%)	20.66	20.77	20.06	20.34	0.28
pH 45 min after slaughter	6.39	6.35	6.36	6.38	0.02
pH 24h after slaughter	5.54	5.51	5.53	5.54	0.01
Dry matter (%)	24.95	24.67	24.87	25.06	0.09
Protein (%)	22.64	22.41	22.62	22.77	0.08
Fat (%)	1.38	1.30	1.29	1.34	0.04
TBA–RS (mg/kg)	0.434	0.443	0.433	0.401	0.01
Fatty acids					
SFA	36.75	37.33	38.47	38.49	0.31
UFA	63.25	62.67	61.53	61.51	0.31
MUFA	42.25	42.26	41.45	42.31	0.49
PUFA	20.09	20.37	19.64	20.16	0.51
PUFA *n6*	17.12	17.46	16.80	17.37	0.49
PUFA *n3*	1.11	1.13	1.13	1.05	0.03
PUFA *n6/n3*	15.70	15.76	15.20	16.46	0.26

[1]Standard error of the mean.

Discussion

The negative correlation between fibre content and digestibility of nutrients in monogastric animals is well described in literature (Jørgensen et al., 1996; Zijlstra et al., 2010). Xylanase supplementation of piglet feed containing wheat and triticale can improve digestibility of crude protein, fat and fibre as well as body weight gain (Hanczakowska et al., 2006). Whereas in the experiment of Mavromichalis et al. (2000) supplement of xylanase did not lead to any effect in weaned piglets but slightly improved weight gains in finisher pigs. In the present experiment xylanase significantly improved pig body weight gains in the earlier weight range (27–60 kg), but less distinctly in the later feeding period (60–90 kg). Recently published trial results regarding the effect of the same xylanase in grower-finisher pigs showed in the beginning of the fattening period no change in weight gain but a clear improvement in the final fattening period, whereas the effect on feed efficiency was more distinct in the first feeding period (Tossenberger and Kühn, 2011).

Because in this experiment there was no difference in feed consumption, it is concluded that higher body weight gains of pigs fed diets with xylanase are due to their better nutrient utilization. Improvement of crude protein digestibility was negligible, which is in accordance with the results of Yin et al. (2000) but not with those of Wolford et al. (2001), who found improved nitrogen digestibility when adding xylanase to a wheat-based diet. These discrepancies can be due to different factors like feed composition, enzyme preparation, animal breed, or growth status.

Based on the higher fat digestibility observed in the present experiment, apparent though not significant in the grower but significant (P≤0.01) in the finisher period, and due to the low performance level of the pigs, it can be assumed that energy was limiting in the basic diet. It is known that fat absorption is negatively affected by pentosans (Choct and Annison, 1992); thus, xylanase could improve utilization of fat present in feed. In the current experiment there were also differences in fibre digestibility, not significant in the finisher but significant in the grower period. Similar improvements of fat and fibre digestibility by Econase® XT were evaluated by Babinsky et al. (2010). It is likely that improved nutrient digestibility led to the differences in weight gain, whereas Noblet and Shi (1994) found fibre digestibility of feeds to be higher in heavier pigs. They postulated that products of fibre hydrolysis can supply pigs with 15–18% of energy, but as digestibility of other nutrients as fat were improved as well, it is likely that enzymatic degradation of arabinoxylan structures improved accessibility of nutrients to enzymatic degradation by intestinal enzymes. Also changes in the retention time cannot be excluded as a reason for better weight gains of pigs receiving xylanase.

In summary, it could be stated that the xylanase supplied to a diet with appropriate fibre content improves fibre and also fat digestibility. In turn it increases body weight gains and feed conversion ratio. It has no impact on carcass and meat quality. With an increased dose level, xylanase effects are more distinct. These results suggest that using this enzyme in growing pig feeding is profitable from the point of view of pig production.

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Efektywność dodatku różnych ilości ksylanazy do paszy dla tuczników

STRESZCZENIE

Na 128 wieprzkach badano wpływ różnych dawek ksylanazy na wskaźniki produkcyjne, strawność składników odżywczych paszy oraz jakość tuszy i mięsa. Doświadczenie prowadzono od masy ciała zwierząt 27 do 110 kg. Świnie przydzielono do 4 grup (po 32 sztuki w każdej), żywiono *ad libitum* i trzymano w kojcach wyścielonych słomą po 4 sztuki. Grupa I (kontrolna) otrzymywała paszę standardową bez dodatku enzymu, a grupy II, III i IV otrzymywały tę samą paszę z dodatkiem odpowiednio 8000, 16 000 lub 24 000 BXU (Birch Xylan Unit) ksylanazy w kg. Doświadczenie strawnościowe przeprowadzono na 40 wieprzkach niepochodzących z doświadczenia wzrostowego, przydzielonych do 4 grup po 10 zwierząt w każdej i otrzymujących pasze identyczne jak w pierwszej części doświadczenia.

Ksylanaza istotnie poprawiła przyrosty masy ciała tuczników otrzymujących 16 000 BXU/kg ($P<0.05$) i 24 000 BXU/kg paszy ($P<0.01$) – wzrost odpowiednio o 4.2 i 6.2%. Wagę ubojową 111–112) w najkrótszym czasie osiągnęły tuczniki otrzymujące najwyższą dawkę ksylanazy (24 000 BXU/kg, $P<0.05$). U młodszych świń ksylanaza poprawiła głównie strawność włókna, istotnie w przypadku świń otrzymujących 24000 BXU/kg ($P<0.05$). W późniejszym okresie tuczu ksylanaza poprawiła strawność suchej masy, tłuszczu i włókna w stopniu wzrastającym wraz ze wzrostem dawki. Nie stwierdzono różnic w ocenie tuszy i jakości mięsa pomiędzy grupami.

Otrzymane wyniki wskazują, że stosowanie ksylanazy (Econase XT) poprawia wskaźniki produkcyjne rosnących świń, nie mając wpływu na jakość tuszy. Poprawa tych wyników idzie w parze z poprawą strawności składników odżywczych paszy.