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The effects of xylanase on grower pig performance, concentrations of volatile fatty acids and peptide YY in portal and peripheral blood.

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Short title: Optimum inclusion level of xylanase in pig diets

Abstract

Non-starch polysaccharides (NSP) present in wheat and barley can act as anti-nutrients leading to an increase in digesta viscosity and a reduction in nutrient digestibility. Xylanase, an NSP degrading enzyme, has been shown to increase nutrient digestibility in pigs. The objectives of this study were: 1) to identify the optimum inclusion level of xylanase in grower pig diets by measuring the effect of increasing enzyme levels on growth performance, the concentration of volatile fatty acids (VFA) and peptide YY concentration in portal and peripheral blood of grower pigs and 2) to increase our understanding of the interrelationships between xylanase inclusion, VFA production and peptide YY secretion. Five hundred and twelve grower pigs ((Large White x Landrace) x MAXGRO) were allocated to pens creating 32 replicates of 4 pigs per pen per treatment. Pigs were allocated to trial weighing 14.2 ± 0.31 kg and remained on trial until approximately 41.5 ± 3.31 kg. The experiment was a dose response design with 4 inclusion levels (0, 8 000, 16 000 or 32 000 BXU/ kg) of xylanase (Econase XT). Diets were cereal based wheat, barley mix formulated to meet or exceed the nutrient requirements of grower pigs. Body weight and feed intake were recorded to calculate growth performance. Pen faecal samples were collected to estimate DM, organic matter (OM) and crude fibre (CF) apparent total tract digestibility**.** At the end of the trial 16 pigs per treatment were euthanised by schedule 1 procedures. Peripheral and portal blood samples were collected for peptide YY and VFA analysis. The addition of xylanase to the diet had no effect on growth performance, DM, OM or CF total tract digestibility, however xylanase tended to have a quadratic effect on ileum pH with higher pH values recorded for pigs fed a diet supplemented with 8 000 and 16 000 BXU/kg xylanase ($P < 0.1$). Xylanase had no effect on peptide YY levels or VFA concentration. Total VFA concentration was

higher in portal compared to peripheral blood ($P < 0.05$). In conclusion, the addition of xylanase had no effect on grower pig performance, nutrient digestibility, VFA concentration or peptide YY concentration when fed up to 32 000 BXU/ kg over a 35 d period. Pig performance was good for all treatments throughout the trial suggesting that diet quality was sufficient thus there were no beneficial effects of adding xylanase.

Keywords: Digestibility, Enzyme, Fibre, Growth performance, Nutrition

Implications

The presence of non-starch polysaccharides (NSP) in wheat exerts anti nutritional effects in pigs, increasing digesta viscosity and reducing nutrient digestibility through encapsulation which results in poor feed efficiency and growth. The addition of NSP degrading enzymes such as xylanase to wheat based diets can help to reduce these effects. However the addition of xylanase as high as 32 000 BXU/ kg to wheat-barley cereal based diets formulated to meet or exceed the nutrient requirements of grower pigs had no effect on growth performance or nutrient utilisation. This suggests that the addition of xylanase to good quality wheat based grower pig diets has no beneficial effects.

Introduction

Exogenous enzymes are used in livestock diets in order to maximise utilisation of nutrients and improve feed efficiency. The presence of non-starch polysaccharides

71 (NSP) in wheat (predominately arabinoxylans) have been shown to have anti
72 nutritional effects in pigs (Yin *et al.*, 2000, Nortey *et al.*, 2007). Non-starch
73 polysaccharides increase digesta viscosity and reduce nutrient digestibility through
74 encapsulation (Kim *et al.*, 2005). The incorporation of NSP degrading enzymes can
75 help to alleviate the negative effects of NSP. Xylanase, an NSP degrading enzyme,
76 works by removing the nutrient encapsulating effects of the cell wall in feed by the
77 breakdown of long-chain arabinoxylans, releasing nutrients for digestion by the
78 animal and by reducing digesta viscosity (Masey O'Neill *et al.*, 2014b). An additional
79 mechanism has been suggested as the addition of xylanase to maize–soybean
80 based broiler diets consistently increased serum peptide YY (Singh *et al.*, 2012)
81 suggesting a neuro-hormonal mechanism through the production of the satiety-
82 related gut hormone peptide YY. Peptide YY slows down gastric emptying increasing
83 gastric digestion of nutrients (Allen *et al.*, 1984) with a consequential increase in feed
84 efficiency. Arabinoxylo-oligosaccharides, produced from enzymatic hydrolysis of
85 arabinoxylans, are non-digestible oligosaccharides with prebiotic activity that can be
86 fermented by intestinal microbiota (Grootaert *et al.*, 2009, Neyrinck *et al.*, 2012),
87 resulting in an increase in volatile fatty acid (VFA) production, predominately acetate,
88 propionate and butyrate (Goodlad *et al.*, 1987). Cuche *et al.* (2000) found that ileal
89 VFA infusion increased peptide YY concentrations in pigs suggesting the production
90 of VFAs stimulates the release of the gut hormone peptide YY from entero-endocrine
91 cells.

92 The use of xylanase in pig diets has been extensively studied, however inconsistent
93 results have been reported. Passos *et al.* (2015) found that xylanase
94 supplementation from 0 to 1 400 LXU/kg enhanced ileal digestibility of neutral
95 detergent fibre (NDF), dry matter (DM), organic matter (OM) and energy when fed to

grower pigs. Woyengo *et al*. (2008) found that xylanase supplementation had no effect on grower pig performance, however they did find that xylanase supplementation at 4 000 XU/kg increased amino acid ileal digestibility and Ca digestibility. Olukosi *et al*. (2007) found no effect of xylanase supplementation on performance or nutrient digestibility when added to wheat-barley-soybean meal-based diet for grower pigs. The inconsistent results reported may result from differences in the level of xylanase used. Inconsistent results along with limited information on the role of a xylanase enzyme on VFA production in grower pigs and the activity of peptide YY suggests there is a need for further investigation.

The current study was designed to test the hypotheses that hydrolysis of NSPs by xylanase creates shorter chain oligosaccharides altering caecal fermentation. Changes in caecal fermentation will alter VFA production which in turn will affect peptide YY secretion. The objectives of this study were: 1) to identify the optimum inclusion level of xylanase (Econase XT) in grower pig diets by measuring the effect of increasing enzyme levels on growth performance, the concentration of VFA and peptide YY concentration in portal and peripheral blood of grower pigs and 2) to increase our understanding of the interrelationships between xylanase inclusion, VFA production and peptide YY secretion in grower pigs.

Material and methods

117 *Animals*

118 This experiment was carried out at the University of Leeds, Spen farm. This
119 experiment received ethical approval from the University of Leeds Animal Welfare
120 and Ethical Review Committee. Five hundred and twelve grower pigs ((Large White
121 x Landrace) x MAXGRO) were allocated to pens on the basis of litter of origin, sex
122 and liveweight (32 reps of 4 treatments with 4 pigs per pen). Pigs were allocated to
123 trial at 7 weeks of age (14.2 ± 0.31 kg) and remained on trial until 12 weeks of age
124 (approximately 41.5 ± 3.31 kg). Pigs were housed in fully slatted grower
125 accommodation throughout the trial with 16 pens per room. Each pen measured 135
126 cm x 155 cm. Heating and ventilation were controlled to maintain temperature at
127 approximately 22℃ (Dicam system). Pigs had free access to feed and water.

128

129 *Experimental design*

130 The experiment was a dose response design with four inclusion levels of xylanase
131 (0, 8 000, 16 000 or 32 000 BXU/kg). The xylanase was a beta 1-4, endo-xylanase
132 (Econase® XT, AB Vista, Marlborough, Wiltshire, UK) and its main function is to
133 break down the fibre fraction from cereals, mainly arabinoxylan (European Food
134 Safety Authority, 2008). Diets were a cereal based wheat, barley mix formulated to
135 meet or exceed the nutrient requirements of grower pigs (BSAS, 2003) and
136 contained 500 FTU Quantum Blue per kg diet (AB Vista, Marlborough, Wiltshire,
137 UK). The diet composition is shown in Table 1. Titanium dioxide was added in all
138 diets at 5 g/kg as an indigestible marker to determine apparent total tract digestibility
139 of nutrients. Feed was analysed for crude protein, lysine, crude fibre, fat, ash,
140 phosphorus and calcium (Sciantec Analytical Services Ltd. Stockbridge Technology

Centre, UK). Diets were also analysed for xylanase activity by ELISA method using Quantiplate Kits for Econase XT (Enzyme Services & Consultancy, Innovation & Technology Centre, Ystrad Mynach, UK).

Measurements

Pigs were individually weighed at the start of the trial (7 weeks of age) and at 10 and 12 weeks of age. Average daily intake (ADI), average daily gain (ADG) and feed conversion ratio (FCR) were recorded on a pen basis. Mean pen health scores were taken each morning throughout the experiment on a scale of 1-4 (1= no signs of poor health, 4= serious signs of poor health) as described by Taylor *et al.* (2013). Scores were assessed by the same trained individuals. A record was kept of any veterinary interventions and any mortality.

Pen faecal samples (250-300 g) were collected on the second last day of the trial. Samples from two pens of the same treatment were pooled to give 16 replicates per treatment and stored at -20°C for subsequent analysis. All feed and pooled faecal samples underwent wet ash sample preparation (method 975.03 AOAC 2012) for analysis of TiO_2 (Short *et al*., 1996). Digestibility values for DM, organic matter (OM) and crude fibre (CF) were calculated using TiO_2 as a marker. Briefly, each sample was oven dried at 102°C for 24 hours. Samples were then ashed in a muffle furnace for 16 hours at 550°C. Ashed samples were then digested in 7.4 M H_2SO_4. This solution was filtered and used for TiO_2 determination. Crude Fibre was determined using the Foss fibre Cap 2021 Fibre Analysis System (Foss Analytical, Hilleroed, Denmark).

At the end of the trial 16 pigs per treatment were euthanised by schedule 1 procedures. Pigs were stunned using captive-bolt and then exsanguinated in

accordance with the Animals (Scientific Procedures) Act 1986. Pigs were selected by randomly choosing 16 of the 32 replicates. Within each replicate, one pig from each pen was selected based on performance. The performance of the sampled pig was as close to the mean for that treatment replicate as possible. Immediately following death, blood samples were collected from both portal and peripheral circulations into heparinized tubes. The blood was centrifuged at 2 000 x g, 4℃ for 15 minutes. Plasma was removed and stored at -20℃ prior to analysis. The gastrointestinal tract was removed and the pH of the distal ileum and caecum digesta were measured (HI-99163 Handheld Meat pH Meter, Hanna Instruments, UK).

Plasma samples were analysed for peptide YY concentration using a commercial ELISA kit (Pig Peptide YY (PYY) ELISA kit (CSB-EL019128PI)). The assay has high sensitivity for the detection of pig PYY with no significant cross-reactivity or interference between pig PYY and analogues. The intra-assay CV was <15% and the inter-assay CV was <15%. Plasma samples were also analysed for VFA concentrations (acetate, propionate, butyrate) using gas chromatography (Varian 3400). Helium was used as carrier gas. Caproic acid was used as the internal standard. The sample was deproteinized using ultrafiltration (Amicon 0.5ml 10K; MerckMillipore, Darmstadt, Germany). Samples were spun at 14 000 x g for 20 minutes. Phosphoric acid was then added to the ultrafiltrate. This ultrafiltrate was directly injected into the system.

Statistical analysis of results

Mean pen data for liveweight, feed intake, daily gain, FCR and pH were analysed by ANOVA using the general linear model (GLM) procedure SPSS, version 22 (IBM

190 SPSS Statistics for Windows, Version 20.0. Armonk, NY: IBM Corp). All data were
191 tested for normality of residuals and outliers. Orthogonal polynomial contrasts were
192 applied to test for linear and quadratic responses to the inclusion of xylanase (SPSS,
193 version 22). Responses were considered significant when $P \leq 0.05$, and trends were
194 noted when $P \leq 0.10$. The number of pigs treated with antibiotics were analysed by
195 the non-parametric Kruskal–Wallis one-way ANOVA. Any pigs removed from the trial
196 due to ill health were weighed before removal. An ANOVA was run to compare
197 treatment effects on portal and peripheral levels of peptide YY and total VFA,
198 whereas a Repeated-Measures ANOVA was performed to compare portal and
199 peripheral concentrations. Peptide YY data were not normally distributed and were
200 log transformed in order to normalise the data for analysis. Total VFA data were not
201 normally distributed and were transformed using square root transformation in order
202 to normalise the data for analysis. Post analysis, any data which had been
203 transformed was then reverse transformed prior to presentation in the results.
204 Composition of VFA (%) in portal and peripheral blood were analysed by the non-
205 parametric Kruskal–Wallis one-way ANOVA. The individual pig was the experimental
206 unit for blood analysis.

207 **Results**

208 *General observations and health.*

209 The results of the dietary chemical analysis confirmed that analysed values were
210 similar to the calculated values (Table 1). There was no difference between
211 treatments for health score or in the numbers of pigs that were treated with
212 antibiotics. Growth performance of pigs was considered normal throughout the trial
213 with an ADG of 781 ± 50.7 g/day. Two pigs were removed from the trial (8 000

214 BXU/kg) due to ill health. All remaining individual pig data was included for statistical
215 analysis.

216

217 *Growth performance and digestibility*

218 At the start of the experiment there was no difference in liveweight between any of
219 the dietary treatments. Performance data are shown in Table 2. The addition of
220 xylanase to the diet had no effect on performance over the 35 days. The addition of
221 xylanase had no effect on DM, OM or CF total tract digestibility

222

223 *pH of the gastrointestinal tract and blood analysis*

224 Supplementation of xylanase to the diet tended to have a quadratic effect on ileal pH
225 with higher pH values recorded for pigs fed a diet supplemented with 8 000 and 16
226 000 BXU/kg xylanase ($P < 0.10$). pH levels returned to control levels when
227 supplemented with 32 000 BXU/kg xylanase. Xylanase had no effect on caecal pH.

228 Xylanase had no effect on peptide YY levels in the portal ($P = 0.967$) or the
229 peripheral ($P = 0.846$) blood (Figure 1). There was no significant difference in
230 peptide YY concentrations between portal and peripheral blood ($P = 0.355$). Total
231 VFA concentration was higher in portal compared to peripheral blood ($P < 0.05$;
232 Table 3). In terms of the distribution of individual VFA in portal blood, acetate was
233 present at the highest level (2.24 ± 0.216 mM/l), followed by propionate (0.494 ± 0
234 .0891 mM/l) and then butyrate (0.175 ± 0.0345 mM/l). In contrast to this, the

235 composition of individual VFA in peripheral blood was predominately acetate.
236 Xylanase had no effect on total VFA concentration.

237

238 **Discussion**

239 Supplementing wheat-barley based diets with xylanase had no effect on growth
240 performance or nutrient digestibility of grower pigs over a 35 d trial period, however
241 pig performance across all treatments was good which may suggest that diet quality
242 was sufficient or that there were no antinutritional effects from NSPs and thus there
243 were no beneficial effects from adding xylanase. Yin *et al.* (2000) found that
244 xylanase addition (5 000 U/kg) to grower pigs fed wheat based or wheat byproduct
245 based diets improved nutrient digestibility. However they observed the greatest
246 improvement in digestibility in pigs fed diets containing wheat plus bran which had a
247 higher fibre and NSP content compared to wheat alone. Nortey *et al.* (2007) also
248 found that the addition of xylanase (4 375 U/ kg) to grower pigs improved nutrient
249 digestibility, however pigs were fed diets containing wheat millrun which again had a
250 higher concentration of NSP in comparison to wheat. Dry matter digestibility of the
251 control pigs in the current study was 86%. In the study by Yin *et al.* (2000), DM
252 digestibility for pigs fed the wheat based diet was 89% whereas DM digestibility for
253 pigs fed the wheat plus bran diet was 75.8%. Nortey *et al.* (2007) found that millrun
254 inclusion reduced total tract DM digestibility in pigs from 86.7% (wheat control diet)
255 to 74.2% (millrun diet). The addition of xylanase improved DM digestibility in the
256 millrun diets (80.1%) but digestibility remained lower than that of the wheat control
257 diet. Studies have shown an inverse relationship between control performance and
258 exogenous enzyme response and thus the better the performance of the control

259 animals, the poorer the response to exogenous enzymes (Rosen, 2006, Rosen,
260 2010). The age of the pig may also influence the pigs' response to xylanase. Olukosi
261 *et al.* (2007) found that NSP-degrading enzymes increased nutrient digestibility when
262 fed to weaner pigs, however NSP-degrading enzymes did not affect nutrient
263 digestibility when fed to grower pigs. They suggested that this was due to an
264 increase in the gut microbial population of grower pigs resulting in microbes capable
265 of breaking down NSP.

266 In the current study xylanase tended to increase ileal pH values for pigs fed a diet
267 supplemented with 8 000 and 16 000 BXU/kg xylanase. The higher ileal pH levels
268 observed at 8 000 and 16 000 xylanase BXU/kg are difficult to explain. In contrast
269 Sheng *et al.* (2013) found that xylanase increased microflora proliferation and
270 fermentation when fed to broiler chicks resulting in a reduction in ileal digesta pH.
271 An increase in caecal fermentation has been shown to stimulate the release of
272 peptide YY from enterocyte cells (Keenan *et al.*, 2012). As peptide YY slows both
273 gastric emptying and transit time it has been proposed that the release of peptide YY
274 increases gastric digestion of nutrients. Masey O'Neill *et al.* (2014a) investigated the
275 effects of xylanase supplementation (16 000 and 32 000 BXU/ kg) to wheat and corn
276 based broiler diets on broiler performance, nutrient digestibility and caecal VFA
277 content. They found that xylanase supplementation improved FCR irrespective of
278 cereal or enzyme dose and improved nutrient digestibility. They also found that
279 caecal VFA content was higher when broiler diets were supplemented with xylanase.
280 Yin *et al.* (2000) found a numerical increase in apparent ileal VFA production with the
281 addition of xylanase to grower pig diets, increasing VFA production by 38% when
282 added to wheat plus bran based diets which had a high fibre and NSP content. This
283 is in contrast to the current study where the addition of xylanase to wheat based

diets did not affect VFA concentrations in plasma. Volatile fatty acids were measured in portal blood in order to obtain information on the end products of fermentation in the gastrointestinal tract. The fact that xylanase had no effect on VFA concentrations suggests that the fermentation of fibre was already optimised in the control diet and therefore the addition of xylanase could not enhance this process. Alternatively it may be that the cereals in this experiment were resistant to xylanase attack. The higher levels of VFAs observed in the portal blood compared to peripheral blood was expected as the portal blood reflects the production of VFAs in the gastrointestinal tract and not consumed by colonocytes before uptake by the liver and peripheral tissues (Hooda *et al.*, 2010, den Besten *et al.*, 2013)

The current study also found no effect of xylanase on plasma peptide YY levels which is not surprising as VFA concentrations were not affected. Singh *et al.* (2012) observed an increase in serum levels of peptide YY when broilers were fed a maize soybean meal based diet under *ad libitum* conditions when diets were supplemented with xylanase (16 000 u/ kg Econase XT). However in the same experiment xylanase addition reduced total caecal VFA concentration. The increase in peptide YY was more pronounced for the broilers fed an energy deficient diet, thus the production of peptide YY may have been the result of the energy limiting diets in order to increase nutrient digestion.

In conclusion, the addition of xylanase had no effect on grower pig performance, nutrient digestibility, VFA concentration or peptide YY concentration when fed up to 32 000 BXU/ kg over a 35 d period. The lack of response in the current study may suggest that NSP levels were low and diet quality was sufficient and as a result the addition of xylanase had no beneficial effects.

Acknowledgements

None.

Declaration of interest

There are no conflict of interests.

Ethics statement

This experiment received ethical approval from the University of Leeds Animal Welfare and Ethical Review Committee

Software and data repository resources

Data is not deposited in an official repository.

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Table 1 *Ingredient composition and nutrient content of experimental diets fed throughout the trial.*

Xylanase, BXU/kg	0	8 000	16 000	32 000
Raw Material (%)				
Raw Wheat	41.229	41.224	41.219	41.209
Barley 62 kg/hl	20	20	20	20
Wheatfeed	5	5	5	5
Hypro soya	26.32	26.32	26.32	26.32
Herring meal	1.25	1.25	1.25	1.25
Soya Oil	1.71	1.71	1.71	1.71
Dicalcium Phosphate	1.41	1.41	1.41	1.41
Salt	0.39	0.39	0.39	0.39
L-Lysine-HCL	0.402	0.402	0.402	0.402
DL-Methionine	0.171	0.171	0.171	0.171
L-Threonine	0.166	0.166	0.166	0.166
L-Tryptophan	0.016	0.016	0.016	0.016
Vitamin/mineral supp	0.501	0.501	0.501	0.501
Lignobond	0.625	0.625	0.625	0.625
Quantum Blue 5G	0.01	0.01	0.01	0.01
Econase XT	0	0.005	0.01	0.02
Benzoic acid	0.5	0.5	0.5	0.5
Limestone flour	0.3	0.3	0.3	0.3
Calculated nutrient content				
Net energy (MJ/kg)	9.97	9.97	9.97	9.97
Digestible energy (MJ/kg)	14.17	14.17	14.17	14.17
Protein (%)	21.32	21.32	21.32	21.32
Fibre (%)	3.14	3.14	3.14	3.14
Salt (%)	0.65	0.65	0.65	0.65
Calcium (%)	0.71	0.71	0.71	0.71
Phosphorous (%)	0.68	0.68	0.68	0.68
Sodium (%)	0.18	0.18	0.18	0.18
SID[1] lysine	1.25	1.25	1.25	1.25
SID methionine	0.28	0.28	0.28	0.28
SID met + cys	0.58	0.58	0.58	0.58
SID theronine	0.8	0.8	0.8	0.8
SID tryptophan	0.24	0.24	0.24	0.24

Analysed[2]				
Crude protein (%)	21.5	21.1	21.2	20.8
Lysine, total (%)	1.42	1.51	1.46	1.37
Calcium (%)	0.61	0.6	0.63	0.61
Phosphorous (%)	0.68	0.69	0.74	0.67
Xylanase activity, BXU/kg[3]	<2 000	10 900	22 800	42 500

438

439

440 **Table 2** *Effects of increasing concentrations of xylanase on liveweight, average daily gain,*

441 *average daily intake, feed conversion ratio and pH of the ileum and caecum.*

Xylanase BXU/kg[1]	0	8 000	16 000	32 000	SE	Linear	Quadratic
Wk 7 wt, kg	14.2	14.2	14.2	14.2	0.31	0.955	0.956
Wk 10 wt, kg	29.2	28.9	29.1	28.8	0.54	0.432	0.754
Wk 12 wt, kg	41.4	41.9	41.3	41.4	0.62	0.626	0.628
7-10 weeks							
ADI 7-10, kg	1.034	1.029	1.031	1.024	0.0141	0.869	0.965
ADG 7-10, kg	0.716	0.699	0.708	0.693	0.0153	0.400	0.899
FCR 7-10	1.45	1.49	1.47	1.50	0.027	0.351	0.794
10-12 weeks							
ADI 10-12, kg	1.507	1.559	1.518	1.51	0.0272	0.739	0.690
ADG 10-12, kg	0.870	0.923	0.876	0.898	0.0181	0.639	0.855
FCR 10-12	1.74	1.7	1.76	1.70	0.044	0.618	0.668
7-12 weeks							
ADI 7-12, kg	1.223	1.24	1.226	1.218	0.0164	0.783	0.563
ADG 7-12, kg	0.777	0.788	0.774	0.774	0.0082	0.688	0.984
FCR 7-12	1.57	1.58	1.58	1.58	0.018	0.815	0.722
Health score	1.411	1.426	1.411	1.400	0.0292	0.677	0.741
Ileum pH	6.85	6.99	6.98	6.87	0.069	0.837	0.057
Caecum pH	5.67	5.73	5.69	5.62	0.069	0.371	0.333
Total-tract digestibilities (%)							
DM	86.90	86.22	84.01	84.75	1.011	0.105	0.238
OM	88.43	87.74	86.01	86.45	0.936	0.077	0.552
CF	50.67	45.74	39.07	39.85	4.829	0.105	0.313

442 [1] BXU = xylanase units, *n = 32.*

443 Wk = week; Wt = weight; ADFI = average daily feed intake; ADG = average daily gain; FCR
444 = feed conversion ratio; DM = dry matter; OM = organic matter; CF = crude fibre
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450 **Table 3** *Volatile fatty acid (VFA) concentrations in portal and peripheral plasma of weaner-*
451 *grower pigs fed four levels of xylanase (d 35)*
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Xylanase BXU/kg[1]	0	8 000	16 000	32 000	SE	P-value
Total VFA Portal, mM/l	2.52	2.180	2.55	2.55	0.627	0.993
Total VFA Peripheral mM/l	1.00	0.72	0.86	0.52	0.890	0.501
Molar VFA proportion (%) Portal						
Acetate	82.8	88.8	84.1	79.9	5.48	0.474
Propionate	10.3	8.2	12.5	15.0	3.15	0.378
Butyrate	7.0	3.0	3.4	5.1	2.30	0.368
Molar VFA proportion (%) Peripheral						
Acetate	95.3	100	100	100	3.2	0.121

453 [1] BXU = xylanase units, *n = 16*.
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Figure 1 Peptide YY concentrations in portal and peripheral plasma of grower pigs fed either 0, 8 000, 16 000 or 32 000 BXU/kg xylanase at d 35 *(n = 16).*