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Xylanase supplementation improves energy digestibility of wheat by-products in grower pigs ☆

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Abstract

Value-added processing of cereals produces high-value fractions for food and bio-processing application and by-products that are used in animal nutrition to reduce feed costs. Wheat by-products contain arabinoxylans that might limit nutrient digestibility. Effects of xylanase supplementation (0 or 4375 U/kg feed) on energy digestibility were studied in a wheat control and by-product diets (30% millrun, middlings, shorts, screenings, and bran) in a 2×6 factorial arrangement. The wheat control diet was formulated to contain 3.34 Mcal digestible energy (DE)/kg and 2.8 g apparent digestible lysine/Mcal DE, and included 0.4% chromic oxide as a marker for digestibility. Twelve ileal-cannulated pigs (32.5±2.5 kg) were each fed seven of 12 diets. Faeces and then digesta were each collected for 2 d, and diet digestibility values are reported. Wheat had higher ileal and total-tract energy digestibility than by-products ($P<0.01$). Xylanase improved energy digestibilities for by-products ($P<0.001$) but not for wheat. Among by-products, ileal energy digestibility was lowest for middlings (62%), then bran<screenings<millrun, and highest for shorts (66%). Xylanase improved ($P<0.05$) ileal energy digestibility of millrun by 19% to 76%. Total-tract energy digestibility of millrun improved from 72 to 79% (similar to wheat) with xylanase ($P<0.05$). In summary, xylanase improved energy digestibility in the selected wheat by-product diets, indicating that arabinoxylans in wheat by-products limit nutrient digestibility.

Keywords: Energy digestibility; Pig; Wheat by-product; Xylanase

1. Introduction

The production of flour for human food from the dry milling of wheat produces different by-products (Holden and Zimmerman, 1991). Wheat by-products have higher concentrations of non-starch polysaccharides (NSP), CP and minerals than the parent wheat grain (Slominski et al., 2004), resulting in reduced digestibilities for nutrients such as amino acids (AA) and energy. Wheat by-products can reduce swine feed costs but vary in nutritional value (Slominski et al., 2004), partly due to arabinoxylans that act as anti-nutritional factors (ANF) and thereby limit nutrient digestibility (Ravindran et al., 1998; Barrera et al., 2004). Swine do not digest feedstuffs with a high-NSP content well (Barrera et al., 2004); therefore, the DE content of most grain by-products is low (NRC 1998).

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Replacing conventional energy-providing feedstuffs such as wheat in swine diets with low-cost by-products may be attractive economically. However, low digestibility of nutrients caused by NSP in wheat by-products suggests that special formulations and/or xylanase supplementation are necessary to increase nutrient utilization. This study tests the hypothesis that wheat by-products contain arabinoxylans that limit nutrient digestibility and that these limitation can be alleviated with xylanase supplementation.

The objectives of the present study were to 1) measure energy digestibility in grower pigs for diets containing selected wheat by-products, and 2) determine improvements in energy digestibility with supplemental xylanase.

2. Materials and methods

2.1. Experimental design, diets and procedures

Twelve diets based on wheat (basal control) and 30% wheat by-products (millrun, middlings, shorts, screening, bran) without enzyme, or with xylanase were tested in a 2×6 factorial arrangement of treatments (Table 1). The by-product diets were compounded by replacing 30% of the basal diet with each by-product. Xylanase (Danisco Animal Nutrition, Marlborough, UK) was included at 167 g/1000 kg of finished feed, to reach an activity of 4000 Units/kg feed. Chromic oxide was added (0.4%) as an indigestible marker. The animal protocols were approved by the University of Saskatchewan Committee on Animal Care and Supply, followed principles established by the Canadian Council on Animal Care (1993), and were conducted at Prairie Swine Centre Inc., Saskatoon, SK, Canada.

Twelve barrows (BW 32.5±2.5 kg, mean±SD) fitted with a T-cannula at the distal ileum and housed in individual metabolism cages were fed seven of twelve experimental diets each according to a seven-period change-over design in one set of twelve pigs to reach seven observations per pig, for a total of 84 observations. Daily feed allowance was adjusted to 3×maintenance (3×110 kcal DE/kg $BW^{0.75}$; NRC 1998), which was fed in two equal meals.

Table 1
Ingredient and nutrient composition of diets

Ingredient (%)	Wheat basal diet[a]
Wheat	82.86
Basal diet	
Wheat by-product	–
Soybean meal	12.50
Dicalcium phosphate	1.20
Limestone	0.85
L-Lysine HCl	0.49
Other[b]	2.10
Calculated nutrient content	
DE (Mcal/kg)	3.34
Dig. Lysine (g/Mcal DE)	2.80
Calcium (%)	0.70
Total phosphorus (%)	0.60

[a] The experimental diets for the by-products millrun, screening, shorts, bran and middlings were created by mixing 70% of the wheat basal diet with 30% of each of the wheat by-products.

[b] Other includes (%): chromic oxide, 0.40; sodium bicarbonate, 0.29; vitamin premix, 0.50; mineral premix, 0.50; salt, 0.20; L-threonine, 0.15; DL-methionine, 0.06.

2.2. Sample collection, chemical analyses, and nutrient digestibility

The seven 10-d experimental periods consisted of a 6-d acclimation to experimental diets, followed by a 2-d collection of faeces and a 2-d collection of ileal digesta. Collected digesta and faeces were pooled by pig and frozen at −20 °C. Prior to analyses, faeces and digesta were thawed, homogenized, sub-sampled, and freeze-dried. During the study, feed samples were pooled and stored at −20 °C. Feed and freeze-dried faeces and digesta were ground finely in a Retch mill (model ZMI, Brinkman Instruments, Rexdale, ON, Canada) over a 1-mm screen and analyzed for DM, chromic oxide, energy, and AA. The wheat by-product samples were analyzed for ash, ADF, and nitrogen. Apparent ileal digestibility of AA, ileal and total-tract digestibility of energy and DM and DE content were calculated using the chromic oxide concentration of feed, digesta and faeces via the indicator method. Differences in measured variables were analyzed by ANOVA using the GLM procedure of SAS as a 2×6 factorial arrangement. Pig was considered the experimental unit. The statistical model included the following effects: ingredient (wheat, by-product), xylanase (with, without) and their interaction terms, and collection period. Treatment means were separated using the probability of difference ($P<0.05$).

3. Results

Compared to the wheat diet, inclusion of by-products reduced ileal energy digestibility from 72.0% to 62.3% ($P<0.01$) and DE content from 3.12 to 2.76 Mcal/kg ($P<0.05$). Xylanase improved energy digestibility among

Table 2
Ileal and total-tract digestibility of nutrients of experimental diets containing wheat and wheat by-products with or without xylanase supplementation

Variable	Wheat		Millrun		Middlings		Shorts		Screening		Bran		Pooled	P-value[g]		
	−X[f]	+X	−X	+X	−X	+X	−X	+X	−X	+X	−X	+X	SEM	1	2	3
Ileal																
Energy digestibility (%)	72.0^{abc}	71.7^{abc}	64.0^{bc}	75.8^{a}	62.3^{c}	66.5^{abc}	65.5^{bc}	66.9^{abc}	63.9^{bc}	73.3^{ab}	63.2^{bc}	62.0^{c}	2.32	**	**	**
Digested energy (kcal/kg DM)	3115^{abc}	3112^{abc}	2831^{bc}	3366^{a}	2756^{c}	2914^{bc}	2909^{bc}	2976^{abc}	2835^{bc}	3244^{ac}	2817^{bc}	2748^{c}	102.5	*	**	**
Apparent AA digestibility (%)																
Lysine	86.8^{a}	84.3^{abc}	81.3^{abcd}	85.1^{ab}	84.2^{abc}	84.3^{abc}	81.6^{abcd}	81.9^{abcd}	76.9^{d}	82.9^{abc}	78.9^{cd}	80.7^{bcd}	1.19	**	**	*
Methionine	82.9^{a}	80.9^{ab}	77.4^{ab}	78.8^{ab}	71.4^{b}	77.2^{ab}	75.0^{ab}	78.7^{ab}	75.6^{ab}	80.3^{ab}	75.8^{ab}	72.4^{ab}	2.56	**		
Threonine	77.9^{a}	71.7^{ab}	72.2^{ab}	76.6^{ab}	76.5^{ab}	73.1^{ab}	70.7^{abc}	69.9^{abc}	62.9^{c}	73.5^{ab}	67.2^{bc}	68.9^{abc}	2.05	*		†
Total-tract																
Energy digestibility (%)	81.8^{a}	81.5^{ab}	72.1^{e}	78.9^{abc}	78.0^{abcd}	79.1^{abc}	76.2^{cde}	77.1^{abcde}	73.1^{de}	74.4^{cde}	75.7^{cde}	76.4^{bcde}	1.23	**	**	**
DE (kcal/kg DM)	3537^{a}	3534^{a}	3190^{c}	3506^{a}	3453^{ab}	3466^{ab}	3385^{abc}	3426^{ab}	3246^{bc}	3292^{abc}	3374^{abc}	3387^{abc}	54.7	**	*	**

[abcde] Means within the same row with the same letter are not different $P>0.05$. [f] X is Xylanase. [g] The following three contrast were made: 1, basal diet versus by-product diets; 2, with xylanase versus without xylanase for all diets; 3, with xylanase versus without xylanase for the by-product diets. The level of significance is: *, $P<0.05$; **, $P<0.01$; †, $P<0.10$.

all the diets ($P<0.01$) except for wheat (Table 2). For the millrun diet, xylanase improved energy digestibility by 18.4% from 64 to 75.8% ($P<0.01$) and DE content by 18.9% from 2.83 to 3.36 Mcal/kg ($P<0.01$). The improved energy digestibility and DE content of the millrun diet were similar to the wheat-based diet.

Inclusion of by-products tended to reduce digestibility of Lys by 9.7%-units ($P<0.10$; Table 2). Compared to the wheat diet, by-product diets had a reduced apparent ileal digestibility of Lys, Met ($P<0.01$), and Thr ($P<0.05$). Addition of xylanase to all the diets improved digestibility of Lys, ($P<0.05$), and tended to improve the digestibility of Thr ($P<0.10$). Xylanase improved ileal digestibility of Lys in by-product diets, especially for screenings ($P<0.05$).

4. Discussion

Wheat by-products were used to partially replace a wheat basal diet and were fed either without or with xylanase to test the effects of wheat by-products and xylanase addition on nutrient digestibility in grower pigs. By-product addition reduced the digestibility of energy, AA and the DE content of the diets due to a change in macronutrient (particularly energy) composition and an increased NSP content.

In the present study, xylanase addition improved energy digestibility and thus the DE content of the by-product diets to values that were similar to that of the wheat basal diet. The improvements are strictly due to the addition of exogenous enzymes, because pigs lack the endogenous enzymes to digest NSP. Therefore, supplementation of enzymes that digest NSP in high-NSP diets for young pigs can reduce detrimental effects of NSP and potentially improve the value of such diets for swine (Li et al., 1996).

Digestibility of the essential AA Lys, Met and Thr tended to reduce as the NSP content of the diet increased. In cereals, arabinoxylans and β-glucans are the main NSP found in the cell walls (Basic and Stone, 1991). These NSP have encapsulating effects on other nutrients and can act as a physical barrier to effective nutrient hydrolysis and absorption. A high level of these NSP (arabinoxylans) in the by-product diets may therefore be responsible for the reduced digestibilities of AA. Inclusion of xylanase, in addition to hydrolyzing the NSP may have also released AA which was otherwise bound and unavailable to the pig.

Xylanase improved energy and AA digestibility and the DE content in wheat by-product diets, indicating that arabinoxylans limited nutrient digestibility in wheat by-products. To maximize opportunities to include wheat by-products in swine diets, negative effects of by-product arabinoxylans on nutrient digestibility can be alleviated using xylanase supplementation.

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