SHORT COMMUNICATION

# Effect of xylanase supplementation of diets containing wheat distiller's dried grains with solubles on energy, amino acid and phosphorus digestibility and growth performance of grower-finisher pigs

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Widyaratne, G. P., Patience, J. F. and Zijlstra, R. T. 2009. **Effect of xylanase supplementation of diets containing wheat distiller's dried grains with solubles on energy, amino acid and phosphorus digestibility and growth performance of grower-finisher pigs**. Can. J. Anim. Sci. **89**: 91–95. Wheat-based diets with or without wheat distiller's dried grains with solubles (DDGS) were tested with or without supplementary xylanase (4000 U $kg^{-1}$ feed) in a $2 \times 2$ factorial arrangement. In eight ileal-cannulated barrows, xylanase improved the apparent ileal digestibility of energy and threonine in wheat ($P < 0.05$), but not in wheat DDGS diets ($P > 0.10$). Xylanase did not affect total tract digestibility of energy or P ($P > 0.10$). In 72 grower-finisher pigs, xylanase did not increase growth performance of pigs fed either wheat or wheat DDGS ($P > 0.10$). The differential response of supplementary xylanase to wheat versus wheat DDGS diets indicates that the arabinoxylans in wheat DDGS did not match the specific xylanase activity.

**Key words:** Distiller's dried grains with solubles, digestibility, energy, pig, xylanase

Widyaratne, G. P., Patience, J. F. et Zijlstra, R. T. 2009. **Incidence de l'addition de xylanase aux rations contenant des drèches de distillerie et des solubles du blé sur la digestibilité de l'énergie, des acides aminés et du phosphore ainsi que sur la croissance des porcs d'engrais et de finition**. Can. J. Anim. Sci. **89**: 91–95. Les auteurs ont testé des rations à base de blé avec ou sans drèches de distillerie avec solubles (DDGS) de blé enrichies ou pas de xylanase (4 000 U par kg d'aliment) dans le cadre d'une expérience factorielle $2 \times 2$ sur huit castrats canulés à l'iléon. La xylanase améliore la digestibilité apparente de l'énergie et de la thréonine dans l'iléon pour les rations à base de blé ($P < 0{,}05$), mais pas celles faites de DDGS de blé ($P > 0{,}10$). La xylanase n'affecte pas la digestibilité totale de l'énergie ni celle du P dans le tube digestif ($P > 0{,}10$). Chez 72 porcs d'engrais ou de finition, la xylanase n'a pas accru la croissance des sujets, que ce soit avec la ration de blé ou celle de DDGS de blé ($P > 0{,}10$). La réaction différente de la ration de blé et de celle de DDGS de blé au supplément de xylanase indique que les arabinoxylanes dans les DDGS de blé ne sont pas aussi actifs que la xylanase.

**Mots clés:** Drèches de distillerie avec solubles, digestibilité, énergie, porc, xylanase

Distiller's dried grains with solubles (DDGS) produced from wheat is available in western Canada for inclusion in swine feeds. During the fermentation process, most of the cereal starch is consumed, producing ethanol and carbon dioxide. The remaining fibre, protein, and fat are concentrated. Arabinoxylans are the predominant component of fibre or non-starch polysaccharide (NSP) in wheat and wheat DDGS (Widyaratne and Zijlstra 2007).

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The inverse relationship between NSP content and nutrient digestibility in pigs has been well documented. Supplemental xylanase may hydrolyze arabinoxylans and thereby increase energy digestibility of wheat (Diebold et al. 2004) and wheat by-products from dry

**Abbreviations:** **ADFI**, average daily feed intake; **ADG**, average daily gain; **AID**, apparent ileal digestibility; **ATTD**, apparent total tract digestibility; **CP**, crude protein; **DDGS**, distiller's dried grains with solubles; **DE**, digestible energy; **NSP**, non-starch polysaccharide

milling (Nortey et al. 2007). The ability of xylanase to improve nutrient digestibility of a wheat by-product that has undergone fermentation and subsequent drying is not known.

The hypothesis was that the nutritional value of wheat DDGS can be enhanced using supplementary xylanase, by improving nutrient digestibility or feed intake. The objectives were to determine the effects of supplementing xylanase in wheat and wheat DDGS diets on the digestibility of energy, amino acids and P and on the growth performance of grower-finisher pigs.

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 the Prairie Swine Centre Inc. (Saskatoon, SK). In two experiments, wheat-based diets with or without wheat DDGS were tested with or without supplemental xylanase (4000 units $kg^{-1}$ of feed; Danisco Animal Nutrition, Marlborough, UK) as a $2 \times 2$ factorial arrangement. The wheat DDGS and originating Canada Prairie Spring wheat were obtained from an ethanol plant using old fermentation and drying technology that has since been decommissioned (Mohawk Canada, Minnedosa, MB) to compare chemical characteristics directly. Hard red spring wheat was obtained via a commercial mill.

In exp. 1, hard red spring wheat was considered the sole source of energy and amino acids in wheat-based diets, whereas in the wheat DDGS diets, 40% of wheat DDGS was included as an energy and amino acid source by replacing wheat [see Table 1 in Widyaratne and Zijlstra (2007)]. Diets contained 0.4% chromic oxide as an exogenous digestibility marker and were fortified to meet or exceed vitamins and mineral requirements [National Research Council (NRC) 1998]. In a double $4 \times 4$ Latin square, eight barrows ($29.4 \pm 2.0$ kg; PIC Canada Ltd., Airdrie, AB) were fitted with a T-cannula at the distal ileum, providing eight observations per diet. Each 11-d period consisted of a 6-d acclimation to diets followed by a 3-d collection of faeces and 2-d collection of ileal digesta. Pigs were housed in individual metabolism pens (Widyaratne and Zijlstra 2007). The room was maintained within the thermo-neutral zone of the pigs, with a 14-h light (0700 to 2100) cycle. Diets were provided in wet-mash form, in a 1:1 water to mash ratio. Feed allowance was $2.6 \times$ the maintenance requirement for energy [$2.6 \times 110$ kcal digestible energy (DE) $kg^{-1}$ body $weight^{0.75}$; NRC 1998]. Diets were fed in two equal meals at 0800 and 1600. Pigs had free access to water. Faeces were collected for 3 d twice per day (0800 and 1600) using plastic bags fixed around the anus. Digesta samples were collected in 4% formic acid every 2 h for 10 h $d^{-1}$ during 2 d, using plastic bags affixed to the open barrel of the T-cannula. Collected faeces and digesta were pooled per pig observation and stored at $-20^{\circ}C$.

For exp. 1, samples were ground through a 1-mm screen and analysed for DM by drying at 135°C for 2 h (AOAC 2006). Feed, faeces and digesta were analysed for chromic oxide by spectrophotometry and gross energy by bomb calorimetry. Ingredient, feed and faeces were analysed for P using a nitric-perchloric acid digestion. Ingredient, feed and digesta were analysed for amino acids and available lysine (AOAC 2006). Nutrient digestibility was calculated using the indicator method. Ingredients were analyzed for crude protein (CP) and crude fat (AOAC 2006), and neutral detergent fibre using a fibre analyzer (model $ANKOM^{200}$, Ankom Technology, Fairport, NY) and Na sulphite and α-

**Table 1. Chemical characteristics of wheat used in the basal diet, wheat used to produce the wheat distiller's dried grains with solubles (DDGS), and wheat DDGS of the digestibility study (exp. 1)**

| | Wheat[z] | | |
|---|---|---|---|
| Variable,% DM | Hard red spring | Canada prairie spring | Wheat DDGS |
| Moisture | 14.2 | 15.6 | 8.9 |
| Gross energy (Mcal $kg^{-1}$ DM) | 4.63 | 4.48 | 5.32 |
| Crude protein | 16.8 | 13.6 | 37.3 |
| Crude fat | 1.9 | 1.8 | 5.0 |
| Neutral detergent fibre | 14.9 | 13.2 | 38.8 |
| Phosphorus | 0.40 | 0.34 | 0.99 |
| Phytate[y] | 1.08 | 1.15 | 0.65 |
| *Amino acid* | | | |
| Lysine | 0.56 | 0.40 | 0.81 |
| Threonine | 0.48 | 0.37 | 1.05 |
| Available lysine | 0.49 | 0.37 | 0.56 |
| Total NSP | 11.70 | 8.16 | 16.65 |
| Xylose | 4.82 | 2.89 | 8.06 |
| Arabinose | 3.04 | 1.86 | 4.89 |

[z]Hard red spring was used in basal diet and Canada prairie spring produced the wheat DDGS.
[y]Apart from phytate (inositol hexaphosphate), wheat DDGS but not wheat also contained the following inositol phosphates (IP,%): IP2, 0.20; IP3, 0.30,; IP4, 0.22; IP5, 0.35.

amylase, inositol hexaphosphate (phytate) and lower inositol phosphates by high performance liquid chromatography, and NSP and constituent sugars by gas-liquid chromatography.

In exp. 2, wheat, field pea, and soybean meal were main ingredients in the wheat diet [see Table 2 in Widyaratne and Zijlstra (2007)]. In the wheat DDGS diet, 25% of wheat DDGS was included by replacing a portion of wheat, soybean meal, and dicalcium phosphate. Diets were formulated to meet or exceed the requirements for amino acids, minerals, and vitamins, but not energy (NRC 1998) to 3.375 Mcal DE $kg^{-1}$ and 2.50 g standardized ileal digestible lysine $Mcal^{-1}$ DE. Other essential amino acids were formulated as a ratio to lysine (NRC 1998). The four diets were fed to 72 grower-finisher pigs (36 barrows and gilts; $49.8 \pm 3.2$ kg; PIC Canada Ltd., Winnipeg, MB), randomized within gender, and housed individually. Diets were each fed to nine barrows and nine gilts, for 18 observations per diet. The 6-wk study had a 1-wk adaptation to the pen followed by 5-wk feeding of experimental diets. Pens had fully-slatted concrete flooring, a single-space feeder, and a nipple-drinker. The room was maintained within the thermo-neutral zone of the pigs, with a 14-h light (0700 to 2100) cycle. Diets were provided as a dry mash; diets and water were supplied ad libitum. Pigs were weighed on days 0 and 35 and feed disappearance was measured to calculate average daily gain (ADG), average daily feed intake (ADFI), and feed efficiency (G:F).

For statistical analyses, pig was the experimental unit. The apparent total tract digestibility (ATTD) of energy and DE content of diets was calculated using the difference method. Variables were analysed by analysis of variance using the MIXED procedure (SAS, SAS Institute, Inc. Cary, NC). Means were reported as least-square means. The model for exp. 1 included effects of diet, xylanase, and diet × xylanase and for exp. 2 also included initial body weight as a covariate. In cases of interactions (or trends), means were separated using the probability of difference. Overall, $P < 0.05$ was significant, trends ($0.05 < P < 0.10$) were reported, and $P > 0.10$ was considered non-significant.

In exp. 1, the content of CP, crude fat, neutral detergent fibre, and P was more than double for wheat DDGS than the parent wheat (Table 1); however, phytate content was 45% lower for wheat DDGS. Wheat DDGS but not wheat contained the lower inositol phosphate forms of phytate. Lysine and threonine contents were higher in wheat DDGS than in wheat, but lysine availability averaged 91% for the wheat samples and was 69% for wheat DDGS. The constituent sugars of NSP, arabinose and xylose, were higher in wheat DDGS than in wheat.

In exp. 1, diet and xylanase interacted for apparent ileal digestibility (AID) of energy and threonine ($P < 0.05$; Table 2), and tended to interact for lysine ($P < 0.10$). Xylanase improved the AID of energy and threonine for wheat by 16 and 9%, respectively ($P < 0.05$), but not for wheat DDGS ($P > 0.10$). The ATTD of energy was 8% higher ($P < 0.05$) for the wheat than for wheat DDGS diet; xylanase did not affect ATTD of energy ($P > 0.10$). Total tract DE content tended to be 6% higher ($P < 0.10$) for the wheat DDGS than wheat diet; xylanase did not affect total tract DE content ($P > 0.10$). The ATTD of P was 60% lower for wheat than for wheat DDGS diet ($P < 0.05$), and was not affected by xylanase ($P > 0.10$). The ATTD of energy was higher for wheat than for wheat DDGS ($P < 0.05$; 79.1 vs. 66.7%), but their DE content was not different ($P > 0.10$; 3.67 vs. 3.55 Mcal $kg^{-1}$).

In exp. 2, ADG of pigs fed wheat was 10% higher than that of pigs fed wheat DDGS diets ($P < 0.05$) for days 0 to 35, and was not affected by xylanase or a diet × xylanase interaction ($P > 0.10$). A diet × xylanase interaction affected ADFI ($P < 0.05$); xylanase reduced ADFI of pigs fed wheat ($P < 0.05$), but not of pigs fed wheat DDGS diets. Feed efficiency was higher for wheat

**Table 2. Effect of xylanase supplementation of apparent energy, lysine, threonine, and phosphorus digestibility of diets containing wheat and wheat distiller's dried grains with solubles measured in grower-finisher pigs (exp. 1)**

| | Wheat | | Wheat DDGS | | Pooled | *P* value | | |
|---|---|---|---|---|---|---|---|---|
| Variable[z] | − xylanase | + xylanase | − xylanase | + xylanase | SEM | Diet | Xylanase | Interaction |
| *Apparent ileal digestibility (%)* | | | | | | | | |
| Energy | 57.5*b* | 66.8*a* | 59.6*ab* | 57.3*b* | 3.54 | 0.163 | 0.153 | 0.026 |
| Lysine | 60.3*ab* | 64.7*a* | 61.3*ab* | 58.6*b* | 2.55 | 0.220 | 0.646 | 0.062 |
| Threonine | 56.5*b* | 65.3*a* | 68.6*a* | 65.1*a* | 2.70 | 0.044 | 0.330 | 0.025 |
| *Apparent total tract digestibility (%)* | | | | | | | | |
| Energy | 79.4 | 78.8 | 73.1 | 73.2 | 2.21 | 0.017 | 0.903 | 0.891 |
| Phosphorus | 19.29 | 19.85 | 49.26 | 48.41 | 4.03 | <0.001 | 0.973 | 0.871 |
| *Digested energy (Mcal $kg^{-1}$ DM)* | | | | | | | | |
| Ileal | 2.65*b* | 3.09*a* | 3.16*a* | 3.05*a* | 0.18 | 0.087 | 0.209 | 0.038 |
| Total tract | 3.68 | 3.65 | 3.87 | 3.89 | 0.11 | 0.066 | 0.904 | 0.904 |

[z]Means are least-square means based on eight observations per treatment mean.
*a*, *b* Within a row for each factor, means without a common letter differ ($P < 0.05$).

**Table 3. Growth performance and body weight of grower-finisher pigs fed diets containing wheat or 25% wheat distiller's dried grains with solubles, with and without supplementary xylanase (exp. 2)**

| | Wheat | | Wheat DDGS | | Pooled | *P* value | | |
|---|---|---|---|---|---|---|---|---|
| Variable[z] | − Xylanase | + Xylanase | − Xylanase | + Xylanase | SEM | Diet | Xylanase | Interaction |
| *Body weight (kg)* | | | | | | | | |
| Day 0 | 50.02 | 49.78 | 49.99 | 49.44 | 0.53 | 0.550 | 0.218 | 0.622 |
| Day 35 | 84.53 | 83.36 | 81.06 | 80.85 | 0.75 | 0.058 | 0.660 | 0.757 |
| *Growth performance (day 0 to 35)* | | | | | | | | |
| ADG (kg $d^{-1}$) | 1.02 | 0.99 | 0.92 | 0.91 | 0.04 | 0.022 | 0.585 | 0.749 |
| ADFI (kg $d^{-1}$) | 2.89*a* | 2.62*b* | 2.62*b* | 2.70*b* | 0.06 | 0.124 | 0.117 | 0.004 |
| Feed efficiency | 0.36 | 0.37 | 0.31 | 0.28 | 0.03 | 0.032 | 0.929 | 0.465 |

[z]Means are least-square means based on 18 observations per treatment mean.
*a*, *b* Within a row, means without a common letter differ ($P < 0.05$).

than for wheat DDGS diets ($P < 0.05$). Xylanase did not affect feed efficiency ($P > 0.10$).

In the present study, wheat and wheat DDGS diets were contrasted for nutrient digestibility and growth responses to supplemental xylanase. Xylanase increased nutrient digestibility for wheat, but not wheat DDGS diets. Xylanase did not affect growth responses.

Wheat DDGS had a higher protein, fat, and fibre content than wheat, similar to previous studies (Nyachoti et al. 2005; Widyaratne and Zijlstra 2007). Starch removal via fermentation, and perhaps the yeast used for fermentation, increased the content of remaining constituents in wheat DDGS, except phytate, which was higher in wheat. The wheat samples differed in nutrient profile, but wheat composition varies widely among samples.

The CP and amino acid content of wheat DDGS can vary based on the wheat used for ethanol production (Nyachoti et al. 2005). The CP content of wheat DDGS was 7%-units lower than previously reported (Widyaratne and Zijlstra 2007), because the wheat DDGS originated from Canada prairie spring wheat, which has a lower CP content, rather than hard red spring wheat. Consequently, the content of amino acids in wheat DDGS was also lower than previously reported, except for lysine. As a percentage of CP, lysine content in wheat DDGS was 2.17% instead of 1.62% as previously reported (Widyaratne and Zijlstra 2007), indicating that lysine in wheat DDGS was less damaged in the present study. Still, lysine remained clearly damaged in wheat DDGS (Lan et al. 2008), because lysine availability was markedly lower than in wheat.

The ATTD of energy was higher for wheat than wheat DDGS diets, even though the AID of energy did not differ, similar to Widyaratne and Zijlstra (2007). The data provides strong evidence that the fibre fraction in wheat DDGS was drastically different than in wheat, because hindgut utilization of energy was higher for the wheat than wheat DDGS diet. Increasing wheat DDGS levels from 0 to 25% linearly reduced ATTD of energy in diets fed to grower pigs (Thacker 2006), providing further evidence that energy in wheat DDGS is digested less well than energy in wheat, with NSP in wheat DDGS likely a contributing factor. The DE content of wheat DDGS was equal to previous data (3.55 Mcal $kg^{-1}$ DM; Widyaratne and Zijlstra 2008).

The ATTD of P was higher for wheat DDGS than for wheat diets (Nyachoti et al. 2005; Widyaratne and Zijlstra 2007). The wheat DDGS in the present study contained less intact phytate and more less-complex forms of phytate than wheat, likely due to breakdown of phytate during fermentation. Inclusion of wheat DDGS in swine diets may include environmental benefits for management of P excretion in swine manure.

Inclusion of 25% wheat DDGS in swine diets reduced growth performance in the present study. Feeding wheat DDGS to group-housed grower pigs may reduce growth due to reduced ADFI or feed efficiency (Thacker 2006; Widyaratne and Zijlstra 2007). In the present study with individually housed pigs, reduced ADG was caused solely by reduced feed efficiency.

In the present study, xylanase improved the AID of energy and threonine of wheat, but not of wheat DDGS diets. The response of wheat to xylanase was consistent with the improved AID of amino acids in diets containing 98% wheat supplemented with up to 16 500 U $g^{-1}$ xylanase fed to grower pigs (Barrera et al. 2004). Supplementation of 4000 U $g^{-1}$ xylanase tended to increase DM digestibility of wheat-based diets (Mavromichalis et al. 2000). Similarly, supplementation of xylanase to diets based on wheat and wheat millrun improved AID of amino acids and energy and ATTD of energy in grower pigs (Nortey et al. 2007). The xylanase thus hydrolyzes wheat arabinoxylans in either ground wheat or dry processed wheat by-products.

The analyzed content of arabinoxylans is higher in wheat DDGS than in wheat (Widyaratne and Zijlstra 2007), indicating that a xylanase should have been effective. However, wheat is exposed to fermentation and drying in producing DDGS that may change the nature of NSP, including arabinoxylans, thereby preventing xylanase from being effective. For example,

the ratio of xylose to arabinose was 1.55 to 1 in Canada prairie spring wheat yet 1.60 to 1 in wheat DDGS. As a result, the substrate for xylanase, the original wheat arabinoxylans, might not be the factor limiting nutrient digestibility. Finally, unidentified factors associated with wheat DDGS may hinder effectiveness of xylanase.

Supplementary xylanase did not improve ADG of pigs. In pigs fed a protein-deficient wheat diet, xylanase tended to improve ADG (Barrera et al. 2004), whereas xylanase did not improve ADG of pigs fed a balanced diet (Mavromichalis et al. 2000). Growth responses to xylanase supplementation of diets containing wheat NSP are not as consistently positive as nutrient digestibility responses (Nortey et al. 2007). Xylanase reduced ADFI but not ADG of pigs fed the wheat diet in the present study, indicating that improved nutrient digestibility was balanced with reduced ADFI. The breakdown of arabinoxylans may have solubilised extra NSP, thereby reducing ADFI. Xylanase did not act similarly for the wheat DDGS diet, providing further evidence that NSP in wheat DDGS is different than in the wheat.

In conclusion, the differential response of supplementary xylanase to wheat versus wheat DDGS diets indicates that the specific xylanase activity used in the present study matches the arabinoxylans in wheat, but not in the wheat DDGS. As a note of caution, the digestible lysine content of wheat DDGS from an old-style ethanol plant that was studied in the present study may not reflect wheat DDGS produced in new generation ethanol plants. Further studies are required to assess the impact of improved DDGS production methods on nutrient digestibility of wheat DDGS in swine, to improve nutrient digestibility in pigs fed diets containing wheat DDGS, or to identify factors associated with reduced nutrient digestibility of wheat DDGS.

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