Effects of Xylanase Supplementation to Wheat-based Diet on the Performance and Nutrient Availability of Broiler Chickens

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ABSTRACT : A trial was conducted to evaluate the level of wheat substituted for corn in a traditional corn-soy diet and the xylanase supplementation effect on the growth performance and nutrient digestion of broiler chickens. This experiment was a randomized design with a 4×2 factorial arrangement with four levels of wheat substitution and two levels of enzyme inclusion in the diet. Wheat replaced 0, 25, 50 or 100% corn with or without 1 g/kg xylanase supplementation in iso-nitrogenous and iso-calorific experimental diets. The results showed that in the growing period, broilers attained the highest ($p<0.05$) body weight gain, feed intake, and relative small intestine weight when wheat was substituted at 25% for corn. The relative caecum weight increased ($p<0.05$) linearly with increasing levels of wheat substitution for corn. However, during the finishing period and entire experimental period from 0 to 6 weeks, no significant difference was shown in the growth performance among all treatments. Xylanase inclusion significantly improved the body weight gain, fat availability ($p<0.01$) and diet metabolisable energy ($p<0.1$) but decreased ($p<0.05$) the relative GI tract weight during the growing period. The digesta viscosity of 6-week old broilers was also decreased ($p<0.05$). It appears that wheat substituted for corn did not affect the growth performance, nutrient digestion, and the digesta viscosity of chickens. It is acceptable to completely substitute wheat for corn. Xylanase supplementation improved performance. ***(Asian-Aust. J. Anim. Sci. 2005. Vol 18, No. 8 : 1141-1146)***

Key Words : Broiler, Digestibility, Performance, Viscosity, Wheat, Xylanase

INTRODUCTION

Previous researches have shown that a wheat-rich broiler diet would lead to high digesta viscosity (Choct and Annison, 1992a, b; Veldman and Vahl, 1994). Adding non-starch polysaccharide (NSP) to a broiler diet showed the same result (Choct et al., 1996). Wheat and corn provide similar energy in diet. The cell wall structures of wheat and corn are different, making their nutritional value different from each other (Marquardt et al., 1994).

The 50% to 80% NSP in wheat is water-soluble pentosan, of which arabinoxylans and xylans are the main anti-nutritive factors (Choct and Annison, 1990a, b). Arabinoxylans is a kind of branched polysaccharide and is stored in the primary cell wall of the wheat endosperm. Xylan is stored in the xyloid cell wall in the pericarp and testa (Schooneveld-Bergmans et al., 1999). The arabinoxylan or xylan content is highly related to the apparent metabolisable energy (AME) of wheat. Xylanase supplementation to the diet can lower the antinutritive ability of wheat NSP and improve the growth performance of broiler chickens (Choct and Annison, 1992b; Selle et al., 2003).

From the managerial and nutritional points of view, using corn as the major dietary grain may encounter difficulties, e.g. a shortage of corn and pollution from mycotoxins. It is therefore necessary to utilize other kinds of cereals for dietary grain sources. This study was conducted to examine the effects of different levels of wheat substituted for corn and xylanase supplementation on growth performance and nutrient availability in broilers.

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MATERIALS AND METHODS

Growth trial

This experiment was a randomized design with a 4×2 factorial arrangement for wheat replacing 0, 25, 50 or 100% corn with or without 1 g xylanase/kg diet (AVIZYME 1,300®, containing 2,500 units xylanase/g and 800 units protease/g, Finnfeeds International, Marborough, Wilts, UK) supplementation in iso-nitrogenous and iso-calorific experimental diets. Eight hundred day-old chicks of Arbor Acres commercial strain were selected by sex into 32 pens with equal numbers of male and female groups. Four pens, two male and two female, were allocated into each of the eight dietary treatments for a 6-week feeding trial on growing (0 to 3 weeks) and finishing (4 to 6 week) periods. The experimental diet is presented in Table 1. Chickens were permitted free access to feed and water at all times during the experimental period. The individual live-weight and group feed consumption were measured after fasting overnight at the end of the third and sixth week.

Digestion trial

Sixty-four male broiler chickens were used for the growing period and thirty-two were used for the finishing period. All chickens were allocated into individual cages for eight dietary treatments with four replicates for each treatment. The excreta of growing chicks were combined

Table 1. The composition of experimental diet for 0 to 3 and 4 to 6 week-old broilers (g/kg)

Item	Level of wheat substitute for corn (%)							
	Growing period				Finishing period			
	0	25	50	100	0	25	50	100
Corn	600	450	300	0	600	450	315	0
Wheat	0	150	300	600	0	150	315	600
Soybean meal, 44%	232	230	210	168	329	318	276	250
Full fat soybean	0	0	35	102	0	23	35	90
Corn gluten meal	58	60	46	14	11	0	0	0
Fish meal, 65%	50	50	46	51	0	0	0	0
Tallow	27	27	30	30	25	25	25	25
Dicalcium phosphorus	11	11	11	11	12	11	11	10.5
Limestone	15	15	15	17	16	16	16	16
Salt	3	3	3	3	3	3	3	3
DL-methionine	0.7	0.6	0.9	1.0	1.0	1.0	0.9	0.6
Vitamin premix[1]	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Mineral premix[2]	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Total	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Calculate analysis (%)								
Dry matter	87.9	88.2	88.5	89.0	87.7	88.0	88.2	88.8
Ether extract	5.36	5.18	5.79	6.50	4.76	4.94	4.95	5.44
Crude protein	22.5	22.5	22.5	22.5	20.0	20.0	20.0	20.0
Available phosphorus	0.45	0.45	0.45	0.48	0.35	0.35	0.35	0.35
ME (kcal/kg)	3,100	3,100	3,100	3,100	3,000	3,000	3,000	3,000
Lysine	1.16	1.12	1.14	1.19	1.11	1.12	1.10	1.11
Methionine	0.6	0.6	0.6	0.6	0.78	0.78	0.78	0.78
In vitro analysis (%)								
Total dietary fiber	16.5	17.0	17.8	19.6	17.2	17.4	18.2	18.5
Soluble dietary fiber	2.9	3.0	4.4	5.1	2.9	2.9	3.9	4.8

[1] Vitamin premix (content per kg diet): Vit. A, 15,000 IU; Vit. D_3, 3,000 ICU; Vit. E, 30 mg; Vit. K_3, 4 mg; Thiamine, 3 mg; Riboflavin, 8 mg; Pyridoxine, 5 mg; Vit. B_{12}, 25 mcg; Ca-pantothenate, 19 mg; Niacin, 50 mg; Folic acid, 1.5 mg; Biotin, 60 mcg.

[2] Mineral premix (content per kg diet): Co ($CoCO_3$), 0.255 mg; Cu ($CuSO_4 \cdot 5H_2O$), 10.8 mg; Fe ($FeSO_4 \cdot H_2O$), 90 mg; Mn ($MnSO_4 \cdot H_2O$), 90 mg; Zn (ZnO), 68.4 mg; Se (Na_2SeO_3), 0.18 mg.

from two birds' as one sample because of their small amount. Birds were adjusted for three days for each period, 14 to 16 days of age at growing and 35 to 37 days of age at finishing period followed by 4 days of total excreta collection. Feed was provided *ad libitum* during the preliminary period and 70% of the *ad libitum* intake during the collection period. The collected excreta was dried at 60°C and ground through 20 mesh screens for analysis. The availability of nutrients was determined because the broilers' excreta were the combination of faeces and urine.

Determination of intestinal weight

Six 3-week-old or 6-week-old chickens from each treatment group were selected with equal numbers of males and females. These chickens were sacrificed to measure the weight of various intestinal segments.

Determination of viscosity in the duodenal content

Twenty-four 3-week-old and twelve 6-week-old chickens from each treatment group were selected with equal numbers of males and females. Their live-weights were measured and they were provided with feed for 1 h. These chickens were then slaughtered to sample the duodenal content for viscosity measurement.

The duodenal contents were centrifuged at 12,000×g for 3 min at 25°C. The viscosity of the supernatant was measured using the Brookfield digital viscometer (Model Lvidv-110P, USA) at 25°C according to the method of Fengler et al. (1988).

Determination of composition in feed and excreta

The proximate composition of feed and excreta was analyzed according to AOAC (1990). Dietary fiber contents were analyzed *in vitro* according to Lee et al. (1992).

Statistical analysis

Analysis of variance was calculated using the general linear model procedure of the Statistical Analysis Systems Institute Inc. (1989). Least square means and orthogonal contrasts were used to compare differences between the treatment means.

RESULTS AND DISCUSSION

Growth performance

There was no interaction shown between the different

Table 2. Effect of substitute wheat for corn and enzyme supplement in diet on growth performance of broilers

	Level of wheat substitute for corn, %				Enzyme[1]		MSE	P-value	
	0	25	50	100	+	-		W[2]	E
0 to 3 weeks									
Body weight gain (g/bird)	615^b	634^a	606^b	617^b	626^x	610^y	75.5	0.0068(C)[3]	0.0045
Feed intake (g/bird)	893	924	889	901	909	894	29.0	NS	NS
Feed/gain	1.46	1.47	1.49	1.45	1.47	1.47	0.036	NS	NS
Digesta viscosity (cps)	2.94	3.15	3.33	3.30	3.12	3.24	0.235	NS	NS
4 to 6 weeks									
Body weight gain (g/bird)	1,269	1,267	1,276	1,277	1,277	1,267	169.7	NS	NS
Feed intake (g/bird)	2,764	2,778	2,715	2,969	2,763	2,713	134.6	NS	NS
Feed/gain	2.22	2.20	2.11	2.19	2.19	2.17	1.140	NS	NS
Digesta viscosity (cps)	2.84	2.83	3.23	3.26	2.78^y	3.26^x	0.478	NS	0.0346
0 to 6 weeks									
Body weight gain (g/bird)	1,887	1,908	1,887	1,902	1,903	1,880	242.9	NS	NS
Feed intake (g/bird)	3,658	3,703	3,604	3,598	3,673	3,608	284.5	NS	NS
Feed/gain	1.94	1.92	1.88	1.91	1.92	1.91	0.075	NS	NS

NS: no significant: (c) regression effect of the level of wheat substitute for corn: C: cubic.

$Y = aX^3-bX^2-cX+d$: Y: trait: X: Level of wheat substitute for corn (g/100 g).

[1] −: with xylanase (1 g/kg): -: without xylanase.

[2] W: wheat: E: enzyme supplement.

[3] $Y = 615X^3-880X^2-268X+609$ ($p = 0.0038$).

[a, b] Means within same rows at different level of wheat substitute for corn without same superscripts are significantly different ($p<0.05$).

[x, y] Means within same rows of enzyme supplementation without same superscripts are significantly different ($p<0.05$).

MSE: Mean square of error.

levels of wheat and xylanase supplementation on growth performance. Table 2 shows the broiler growth performance. Under iso-nitrogenous and iso-calorific diets. the body weight gain and feed intake were affected by different levels of wheat, as shown by the cubic curve response as the amount of wheat increased ($p<0.05$) during the growing period. The results showed that the growing broilers had the highest body weight gain and feed intake when the wheat substitution level for corn was 25%. However. during the finishing period and the entire experimental period from 0 to 6 weeks of age, no significant difference was detected among all treatments. This suggests that when the diets contained similar ME. wheat could completely substitute for corn without affecting the broiler growth performance. This result does not agree with other studies (Choct and Annison. 1992b; Preston et al., 2001). Preston et al. (2001) and Allen et al. (1997) indicated that a high wheat inclusion rate significantly decreased dry matter intake, weight gain, and gain/feed in broilers. but not when a lower level (35%) was included. The soluble NSPs present in wheat, especially at high inclusion rates, exert anti-nutritive activities in broiler chickens (Choct and Annison, 1992b). This is thought to be predominantly through increasing the digesta viscosity. which decreases the nutrient availability, and then reduces weight gain and feed conversion rate in broilers. The highest rate of wheat inclusion was 60% in the present study, but the digesta viscosities were not affected ($p>0.05$) by the levels of wheat substitution for corn (Table 2). From this feed formulation (Table 1), it is acceptable to completely substitute wheat for corn.

Enzyme inclusion significantly improved the body weight gain during the growing period. and the digesta viscosities of 6-week old broilers ($p<0.05$). The extents of the improvements were 2.60% and 14.72%. respectively. Xylanase decreases the digesta viscosity by hydrolyzing the arabinoxylans. The *in vitro* dietary fiber (DF) determination results (Table 1) showed that the amount of water-soluble dietary fiber (SDF) increased as the levels of wheat substitution for corn increased. Xylanase supplementation significantly decreased the amount of total dietary fiber, especially the amount of soluble dietary fiber. The SDF were 2.0, 2.3, 2.5. and 2.9% in growing diets and 2.6, 2.7. 2.8, and 3.1% in finishing diets with 0. 25. 50, and 100% of wheat substitution level for corn, respectively. Steenfeldt et al. (1998) and He et al. (2003) indicated that enzyme supplementation to barley or wheat-based diet improved broiler body weight gain. Most of the enzyme addition response is confined to the first four weeks of age because younger chickens have more difficulty coping with high cereal content diets. The intestinal viscosity is increased by wheat, but enzyme supplementation improves digestion in young chickens (Veldman and Vahl. 1994; Vranjes et al.. 1994). This might be due to the fiber-hydrolyzing enzymes from microflora, which are induced by more polysaccharide intake during the growing period.

Nutrient availability

Table 3 shows the effects of wheat substitution for corn and enzyme supplementation on the nutrient availability. The levels of wheat substitution for corn did not affect the availabilities of dry matter. protein. fat, and energy ($p>0.05$). Enzyme supplementation increased ($p<0.01$) the fat

Table 3. Effect of substitute wheat for corn and enzyme supplement in diet on nutrient availability of broilers (%)

	Level of wheat substitute for corn, %				Enzyme[1]		MSE	P-value	
	0	25	50	100	+	-		W[2]	E
0 to 3 weeks									
Dry matter	76.94	74.04	73.42	72.86	75.99	72.64	6.603	NS	NS
Protein	62.02	56.66	52.90	55.67	59.90	53.73	11.714	NS	NS
Fat	77.46	70.71	72.00	69.02	76.57^{x}	68.02^{y}	7.803	NS	0.0051
Energy	80.00	75.09	76.44	75.88	79.89^{x}	73.81^{y}	7.529	NS	0.0653
4 to 6 weeks									
Dry matter	74.48	73.85	72.38	71.66	72.77	73.42	7.983	NS	NS
Protein	55.11	56.75	56.97	55.42	58.60	54.05	10.580	NS	NS
Fat	64.61	70.41	70.94	60.66	66.60	66.70	11.998	NS	NS
Energy	74.84	74.75	74.73	71.05	73.96	73.73	8.248	NS	NS

[1] +: with xylanase (1 g/kg); -: without xylanase.
[2] W: wheat; E: enzyme supplement; B×E: interaction of wheat and enzyme.
[x, y] Means within same rows of enzyme supplementation without same superscripts are significantly different ($p<0.05$).
MSE: Mean square of error. NS: no significant.

Table 4. Effect of substitute wheat for corn and enzyme supplement in diet on the relative weight of GI tract of broilers, g/100 g body weight

	Level of wheat substitute for corn (%)				Enzyme[1]		MSE	P-value		
	0	25	50	100	+	-		W[2]	E	W×E
0 to 3 weeks										
Duodenum	1.37^{ab}	1.43^{ab}	1.33^{b}	1.48^{a}	1.34^{y}	1.47^{x}	0.032	0.0650	0.0017	NS
Jejunum	2.03^{b}	2.41^{a}	1.95^{b}	2.09^{b}	2.13	2.11	0.179	0.0099(C)[3]	NS	NS
Ileum	1.73^{ab}	1.95^{a}	1.68^{b}	1.74^{ab}	1.70^{y}	1.85^{x}	0.101	0.0643(C)[4]	0.0451	NS
Caecum	0.90^{b}	0.90^{b}	0.97^{ab}	1.11^{a}	0.82^{y}	1.12^{x}	0.048	0.0213(L)[5]	0.0001	NS
Colonic-rectum	0.29	0.28	0.35	0.29	0.25^{y}	0.35^{x}	0.039	NS	0.0365	NS
4 to 6 weeks										
Duodenum	0.78	0.89	0.84	0.86	0.85	0.83	0.014	NS	NS	NS
Jejunum	1.53	1.70	1.54	1.62	1.59	1.61	0.058	NS	NS	NS
Ileum	1.47^{a}	1.49^{a}	1.29^{b}	1.43^{ab}	1.45	1.39	0.029	0.0315	NS	NS
Caecum	0.51^{b}	0.50^{b}	0.67^{a}	0.69^{a}	0.52^{y}	0.67^{x}	0.024	0.0055(L)[6]	0.0015	0.0546
Colonic-rectum	0.20	0.16	0.21	0.18	0.19	0.20	0.003	NS	NS	NS

NS: no significant; (c to f) regression effect of the level of wheat substitute for corn; L: linear. $Y = aX+b$; C: cubic. $Y = aX^3+bX^2+cX+d$; Y: trait; X: Level of wheat substitute for corn.
[1] +: with xylanase (1 g/kg); -: without xylanase.
[2] W: wheat; E: enzyme supplement; B×E: interaction of wheat and enzyme.
[3] $Y = 9.55X^3-13.89X^2+4.40X+2.03$ ($p = 0.0012$).
[4] $Y = 5.49X^3-8.03X^2+2.54X-1.73$ ($p = 0.0145$).
[5] $Y = 0.22X+0.87$ ($p = 0.0127$).
[6] $Y = 0.21X+0.50$ ($p = 0.0076$).
[a, b] Means within same rows at different level of wheat substitute for corn without same superscripts are significantly different ($p<0.05$).
[x, y] Means within same rows of enzyme supplementation without same superscripts are significantly different ($p<0.05$).
MSE: Mean square of error.

availability by 12.5%. The energy availability exhibited an increasing trend ($p<0.1$) in 3-week old broilers. The barley-enriched or wheat-enriched diets would display significantly reduced nutrient digestibility (Choct et al., 1996; Preston et al., 2001). The AME and nitrogen digestibility of wheat diets were markedly improved by xylanase supplementation (Hew et al., 1998; Selle et al., 2003). Annison (1992) also showed that enzyme supplementation to diets containing 80% wheat improved the AMEn by 6% to 9%. The mechanisms by which exogenous enzymes enhance wheat nutrient digestion and utilization might be due to the fact that they disrupt the endosperm cell wall integrity and break down the highly viscous NSP. In this study, fat availability was more affected by the enzyme supplementation. This is consistent with our study on barley diets with β-glucanase supplementation (Yu et al., 2002).

Bile salts are required for fat emulsification to form micelles (Erlinger, 1987). The viscosity caused by SDF in wheat depressed the fat emulsification and the enterohepatic circulation of bile salts (Cameron-Smith et al., 1994; Pasquier et al., 1996). Therefore, the effects of substituted wheat for corn and enzyme supplementation on fat availability were greater than effects on other nutrients. The growth performances of chicks fed wheat-enriched diets were decreased maybe due to the decreased fat availability.

Relative weight of GI tract

Table 4 shows the effects of substituting wheat for corn and enzyme supplementation on the relative GI tract weight in broilers. The levels of wheat substitution for corn significantly affected ($p<0.05$) the relative weight of the small intestine and caecum in 3-week-old broilers and the ileum and caecum in 6-week-old broilers. The current results present the highest relative small intestinal weight when the level of wheat substitution for corn was 25%. This result was identical to the feed intake trend. The feed appears to stimulate GI mucosal tissue development and increase the volume and relative weight of the GI tract. Greater feed intake causes a faster digesta transit rate (Buchsbaum et al., 1986), and then promotes GI tract development.

The relative caecum weights of 3 and 6-week-old broilers increased linearly ($p<0.05$) with increasing levels of wheat substitution for corn. Yu et al. (1998; 2002) also reported that de-hulled barley inclusion increases the relative intestinal weight in broilers. In other words, enzyme supplementation decreased ($p<0.05$) the relative weights of the duodenum, ileum, caecum, and colonic-rectum in 3-week-old broilers, and the caecum in 6-week-old broilers. This shows that the effects of xylanase on the relative weight of caecum were more marked than the effects on the other GI tract fragments.

Besides the physical mechanism, DF increases the amount of osmotically active material in the intestinal content. This further results in an increase in water retention, and the caecum distends into a larger than normal size (Leegwater et al., 1974). It has been shown that a significantly greater small intestine length, mucosal layer thickness, and DNA content occurs in the intestinal tissue of rats fed soluble-polysaccharides (Brown et al., 1979; Jacob and White, 1983). This suggests that the faster intestinal mucosa development increases tissue proliferation and intestinal weight. Although the digestive organs represent approximately 6% to 10% of body weight, estimates indicate that the digestive organs account for 40% to 50% of the entire body cardiac output, protein synthesis and heat production (Burrin et al., 1990). SDF-hydrolyzing enzyme supplementation decreased the viscosity of the digesta, and decreased the relative weight of the intestine, then increased the growth performance which was reflected in lower availability and energy loss by SDF.

CONCLUSION

The growing broilers exhibited the highest body weight gain, feed intake and relative small intestine weight increase when the level of wheat substitution for corn was 25%. When the levels were 50% or more, the SDF content increased, and the growth performance of growing broilers decreased. However, the increased levels of wheat did not affect the growth performance of broilers during the finishing period. The xylanase supplementation resulted in SDF hydrolysis and decreased digesta viscosity, and improved fat and energy availability. The results indicated that wheat could substitute for corn without any negative effects when dietary energy was compensated by other means.

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