

Whole Body Nutrient Accretion, Growth Performance and Total Tract Nutrient Retention Responses of Broilers to Supplementation of Xylanase and Phytase Individually or in Combination in Wheat-Soybean Meal Based Diets

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Growth performance, total tract nutrient retention and whole body nutrient accretion rates responses of broilers to supplementation of enzymes containing phytase or xylanase activities were investigated using 300 broilers. At day old, 280 broilers were assigned to 5 dietary treatments which were: 1) positive control (PC) diet which met NRC (1994) nutrient requirement for broilers, 2) negative control (NC) diet which was marginally deficient in phosphorus and ME, 3) NC plus phytase added at 1,000 FTU/kg, 4) NC plus xylanase added at 4,000 U/kg and, 5) NC plus phytase and xylanase added at 1,000 and 4,000 units/kg, respectively. Each treatment had 8 replicate cages with 7 birds per replicate cage. Comparative slaughter technique was used for determination of whole-body nutrient accretion rate. Twenty broilers with the same initial body weight as the 280 broiler chicks used in the growth trial made up the initial slaughter group killed at day 0. A final slaughter group of 40 birds, one bird from each cage, were slaughtered on day 21. The birds selected were those with body weight closest to the average body weight of the birds in each replicate cage. Phytase alone or combined with xylanase improved weight gain and bone ash ($P < 0.05$). Phytase alone improved ($P < 0.5$) total tract P retention and ME, phytase and xylanase combined improved ($P < 0.01$) total tract dry matter and ME. Phytase alone improved ($P < 0.5$) whole body daily accretion rates of dry matter, protein, fat, P, and Ca in comparison to NC treatment. Overall, phytase in wheat-based diet improved growth performance and whole body accretion of minerals and protein, the improvement in protein accretion is an indication of improvement in nutrient utilization resulting from phytase use.

Key words: Accretion, broilers, enzymes, retention, wheat

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Introduction

Wheat-based diets benefit from supplementation of microbial phytase and xylanase because of the high level of phytin and arabinoxylans in wheat. Combination of phytase and xylanase has been reported to result in improved nutrient digestibility and retention in broilers (Esteve-Garcia *et al.*, 1997; Wu *et al.*, 2004a). Zyla *et al.* (1999) showed that a combination of carbohydrases and protease improved bone mineralization of broiler chicks receiving wheat-based diet.

The response of broilers to dietary intervention in general and enzyme supplementation in particular is usually measured using growth performance responses or ileal nutrient digestibility and total tract nutrient retention. These can be adequate for measuring gross efficiency of

nutrient utilization, but to further characterize the efficiency of nutrient utilization it is important to delineate the weight gain into the compositions of gain, i.e. protein or fat especially because of the differences in the efficiency with which these nutrients are deposited. With regards to the effects of enzyme supplementation on body composition, Ketaren *et al.* (1993) showed that phytase increased protein deposition in growing pigs receiving soybean meal diets. Angel *et al.* (2006) reported the effect of phytase supplementation on carcass yields in broilers receiving phytase supplementation. However, there is a dearth of information on possible influence of phytase or xylanase on whole body nutrient accretion in broilers.

Therefore the objective of these experiments is to study the influence of phytase and carbohydrases on growth, total tract nutrient retention and carcass nutrients accretion in broiler chickens.

Materials and Methods

Enzymes

An *Escherichia-coli* derived phytase (Phyzyme XP,

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Danisco Animal Nutrition, Marlborough, UK) supplemented in the diet to provide 500 FTU/kg and a xylanase enzyme (Porzyme 9300, Danisco Animal Nutrition, Marlborough, UK) added to supply 4,000 U/kg were used individually or in combination in the experiment. The xylanase was an endo-xylanase produced by *Trichoderma reesei* and expressed in the same organism. One phytase unit (FTU) was defined as the quantity of enzyme required to liberate 1 μ mol of inorganic P/min, at pH 5.5, from an excess of 15 μ M sodium phytate at 37°C. One unit (U) of xylanase was defined as the quantity of the enzyme that liberates 1 μ mol of xylose equivalent per minute.

Animals and Diets

A total of 300 (280 for growth trial, 20 birds as initial slaughter group in comparative slaughter) male broilers chicks (Ross 308) were used for this study. At day old (day 0), 280 broiler chicks were allocated to 5 dietary treatments in a randomized complete block design such that the average body weight across dietary treatments was approximately equal (38.4 ± 0.04 g). Each of the treatments had 8 replicate cages with 7 birds per replicate cage. The treatments were: (1) positive control (PC) formulated to meet NRC (1994) requirement for ME, Ca and P for broilers with inorganic P added in the form of dicalcium phosphate, (2) negative control (NC) that met 96% and 85% of NRC (1994) requirements for ME and P, respectively, (3) NC plus phytase added to supply 500 phytase units per kg diet (as-fed basis); (4) NC plus xylanase added to supply 4,000 xylanase units per kg diet (as-fed basis); (5) NC plus phytase and xylanase supplemented at the rates indicated for 3 and 4 above. The diets were wheat-based and were fed as mash; chromic oxide was added to the diets as an indigestible marker to enable determination of total tract nutrient retention by index method. The compositions of the positive and negative controls diets are presented in Table 1.

Body weight and feed intake data of the chickens were taken weekly. Excreta collection was done on d 19–21. On d 21, 240 chickens (6 birds from each replicate cage) were euthanized by CO₂ asphyxiation. The left tibia from each chicken was removed and used for determination of bone ash content.

Whole body nutrient accretion was assessed using comparative slaughter technique. At day-old, 20 chicks were randomly allocated into four cages such that average weight was approximately the same for each cage and such that the average weight for the 20 birds is the same as for the 280 birds used for the growth trial. These 20 chicks, constituting the initial slaughter group, were killed at d 0 without feeding them. On d 21, a total of 40 chickens, one from each replicate cage, were selected to make up the final slaughter group. The selected chickens were those with body weight closest to the average body weight of each replicate cage.

Feed was withdrawn from the selected birds for at least 4 h before asphyxiation by CO₂. The birds were subse-

Table 1. **Ingredient composition of the experimental control diets**

Ingredients, g/kg	Positive Control	Negative Control
Wheat	571.4	594.4
Wheat middlings	15.0	15.0
Soybean meal	321.0	321.0
Canola meal	9.0	9.0
Soybean oil	48.0	30.8
Dicalcium phosphate ¹	9.0	4.0
Limestone (38% Ca)	15.0	14.2
Salt	3.0	3.0
Chromic oxide marker	3.0	3.0
Vitamin-mineral premix ²	1.5	1.5
DL-Methionine	3.0	3.0
Lysine HCl	1.1	1.1
Phytase premix ³	0.0	0.0
Xylanase premix ⁴	0.0	0.0
Total	1000	1000
Calculated nutrients and energy		
Protein, g/kg	227.1	223.9
ME, kcal/kg	3124	3026
Ca, g/kg (analyzed)	14.1	16.7
P, g/kg (analyzed)	5.9	4.8
Non-phytate P, g/kg	3.5	2.7

¹ Contained 20% Ca, 18.5% P.

² Vitamin-mineral premix contained per gram of premix: vitamin A, 1,828 IU; vitamin D₃, 881 ICU; vitamin E, 3.67 IU; menadione sodium bisulfite, 1.46 mg; vitamin B₁₂, 4.4 μ g; biotin, 18.4 μ g; choline chloride, 257 mg; folic acid, 330 μ g; niacin, 14.69 mg; d-pantothenic acid, 3.67 mg; pyridoxine hydrochloride, 1.1 mg; riboflavin, 1.83 mg; thiamine mononitrate, 735 μ g; Cu (as copper sulfate), 1.48 mg; I (as calcium iodate), 370 μ g; Fe (as ferrous sulfate), 14.69 mg; Mn (as manganese oxide), 22.02 mg; Se (as sodium selenite), 100 μ g; Zn (as zinc oxide), 14.69 mg.

³ Phytase (Phyzyme XP 5,000) premix formulated to contain 100 FTU/g replaced wheat.

⁴ Xylanase premix formulated to contain 400 U/g replaced wheat.

quently frozen after slaughter and prior to processing. All animal handling procedures were approved by the Purdue University Animal Care and Use Committee.

Chemical Analysis

The diets were analyzed for enzyme activity and nutrients composition. Excreta and diet samples were analyzed for gross energy in order to determine the ME. Samples were dried at 105°C in a drying oven (Precision Scientific Co., Chicago, Illinois, USA) for 24 h for DM determination. Gross energy was determined in bomb calorimeter (Parr 1261 bomb calorimeter, Parr Instruments Co., Moline, Illinois, USA) using benzoic acid as a calibration standard. Chromium concentration in the diet and excreta samples was determined using the method of Fenton and Fenton (1979). Nitrogen was determined using combustion method (Leco FP analyzer Model 602600, Leco Corp., St. Joseph, Michigan, USA) using EDTA as a calibration standard. Feed and excreta samples were digested in concentrated nitric acid and 70% perchloric acid to solubilize Ca and P. The concentration of P in the

supernatant was measured by spectrophotometry. The Ca content of the supernatant was determined using flame atomic absorption spectrometry (Varian FS240 AA Varian Inc., Palo Alto, California, USA). The left tibia bone from each chicken was dried in an oven, defatted by ether extraction, dried again, and then ashed in a muffle furnace to determine the bone ash as an indication of bone mineralization.

The whole intact chicken was frozen immediately after euthanasia and later processed. Chickens were processed individually (except for the initial SG chicks that were processed on cage basis). The ground carcass samples were analyzed for gross energy, ether extractable fat, nitrogen, ash, Ca, and P. Phosphorus and Ca in carcass samples were determined by dry ash technique.

Calculations

Apparent total tract nutrient retention (ANR) was calculated as follows:

$$ANR = 1 - \left(\frac{C_i}{C_o} \times \frac{N_o}{N_i} \right)$$

Where:

C_i is the concentration of chromium in the diet

C_o is the concentration of chromium in the excreta

N_o is the concentration of the nutrient in excreta

N_i is the concentration of the nutrient in the feed

Carcass nutrients accretion calculations were made as follows:

$$NC_{I, g} = NC_{IP} (\%) \times \text{Wt. of chick (g)} \quad [1]$$

$$NC_{F, g} = NC_{FP} (\%) \times \text{Wt. of chick (g)} \quad [2]$$

$$NC_A, g = \text{equation [2]} - \text{equation [1]}$$

$$NC_{AR} = \frac{NC_A}{n}$$

Where:

NC_I is nutrient content in the initial carcass, g

NC_{IP} is nutrient concentration in initial carcass, %

NC_F is nutrient content in the final carcass, g

NC_{FP} is nutrient concentration in final carcass, %

NC_A is carcass nutrient accretion, g

NC_{AR} is carcass nutrient accretion rate, g/d

n is the number of days, 21 d

Statistical Analysis

Data on growth performance of broilers were analyzed as a randomized complete block design using the General Linear Model (GLM) procedures of SAS (2006). Specific orthogonal contrasts were used to compare the enzyme or PC treatments with the NC treatment.

Results

The result of enzyme analysis in the diets revealed that phytase activity was 960 FTU/kg and 834 FTU/kg for treatments 3 and 5, respectively whereas xylanase activity was 3,035 U/kg and 1,647 U/kg for treatments 3 and 5, respectively. Phytase activity was approximately 340 FTU/kg in PC and NC whereas xylanase activity was less than 100 U/kg in PC and NC treatments.

The effect of enzymes addition to the NC diet on growth performance and left tibia bone mineralization is shown in Table 2. Weight gain tended to be greater ($P=0.064$) in the PC than the NC diets; but was not different between NC and the treatment with xylanase. Phytase alone or combined with xylanase improved ($P<0.05$) weight gain compared to NC treatment. There were no effects of any of the treatments on feed intake or gain: feed. Tibia ash weight tended to be greater ($P=0.071$) in the PC than the NC diets. Supplementation of phytase alone or combined with xylanase increased ($P<0.01$) bone ash content in comparison to the NC treatment, but xylanase alone did not improve bone ash compared to NC treatment.

Compared to the NC treatment, total tract DM retention was higher ($P<0.01$) in PC and in diet with combination of phytase and xylanase, but neither phytase nor xylanase alone improved total tract DM retention (Table 3). Total tract N retention was lower ($P=0.05$) in the diet with supplemental xylanase alone than NC diet; combination of phytase and xylanase tended to improve total tract N retention ($P=0.059$). Total tract P retention was higher ($P<0.05$) in diet with supplemental phytase, but the other dietary treatments had no effect on either P or

Table 2. Growth performance and bone mineralization of broilers receiving wheat-soybean meal diet with or without phytase and xylanase alone or in combination for 21 d¹

	Weight gain, g	Feed intake, kg	Gain/feed, g/kg	Tibia ash, g/kg
Positive control (PC)	444.8	700.9	634.2	434.9
Negative control (NC)	399.7	663.1	603.3	425.1
Phytase	467.2	727.3	642.2	458.7
Xylanase	395.3	649.4	607.4	430.5
Phytase + Xylanase	449.1	706.3	634.7	456.2
SEM	46.8	64.7	43.9	26.2
<i>P</i> -values for contrasts				
PC vs. NC	0.064	0.253	0.171	0.071
NC vs. Phytase	0.008	0.057	0.088	<0.001
NC vs. Xylanase	0.850	0.676	0.854	0.344
NC vs. Phytase + Xylanase	0.044	0.193	0.164	<0.001

¹ Data are means of 8 replicate cages consisting of 7 birds per replicate cage.

Table 3. Apparent total tract nutrient retention of dry matter, nitrogen, metabolizable energy, phosphorus and calcium of broiler chicks receiving phytase or xylanase individually or in combination in wheat-based diet¹

	Dry matter, %	Nitrogen, %	Metabolisable energy, kcal/g	Phosphorus, %	Calcium, %
Positive Control (PC)	67.0	47.9	2.95	43.6	57.3
Negative Control (NC)	63.8	45.1	2.78	39.2	71.4
Phytase	63.9	42.9	3.12	45.7	71.3
Xylanase	64.5	39.7	2.80	40.4	74.6
Xylanase+Phytase	66.1	50.3	2.87	40.8	71.4
SEM	0.19	0.76	0.01	0.82	0.47
<i>P</i> -values for the contrasts					
PC vs. NC	<0.001	0.293	<0.001	0.138	0.275
NC vs. Phytase	0.926	0.399	<0.001	0.031	0.346
NC vs. Xylanase	0.367	0.050	0.423	0.672	0.191
NC vs. Phytase+Xylanase	0.002	0.059	0.003	0.589	0.647

¹Data are means of 8 replicate cages consisting of 7 birds per replicate cage.

Table 4. Percentage composition and whole body daily accretion (g/d) of dry matter, crude protein and fat (dry matter basis) in broilers receiving phytase or xylanase individually or in combination in wheat-based diets¹

	Dry matter		Crude Protein		Fat	
	%	g/d	%	g/d	%	g/d
Positive Control (PC)	67.3	13.6	59.4	8.05	33.9	4.62
Negative Control (NC)	64.2	12.0	57.4	6.91	32.0	3.85
Phytase	63.4	14.0	58.6	8.16	33.1	4.61
Xylanase	63.6	12.1	59.8	7.25	31.9	3.82
Phytase+Xylanase	63.1	13.1	58.7	7.70	33.0	4.32
SEM	2.67	0.82	1.24	0.50	1.57	0.31
<i>P</i> -values for contrasts						
PC vs. NC	0.313	0.096	0.162	0.050	0.289	0.035
NC vs. Phytase	0.782	0.044	0.426	0.032	0.532	0.037
NC vs. Xylanase	0.769	0.967	0.112	0.593	0.933	0.858
NC vs. Phytase+Xylanase	0.704	0.248	0.367	0.165	0.560	0.185

¹Data are means of 8 replicates consisting of 1 bird per replicate.

Ca retention. Metabolizable energy was higher ($P < 0.01$) in PC compared with NC and in diets with supplemental phytase alone or in combination with xylanase. Supplemental xylanase alone did not improve ME.

Whole body nutrient composition, on a dry matter basis, at day 0 was 20.9% for fat, 65.2% for protein, 7.0% for ash, 1.4% for Ca, and 0.6% for P. The dry matter concentration was 39.8% in the one-day old birds. In Table 4 are the data on daily accretion rates of DM, protein and fat of the broilers. There were no effects of dietary treatments on concentrations of DM, protein and fat being on the average 64.4%, 58.7% and 32.8% for DM, protein and fat, respectively. Daily accretion of DM was greatest ($P < 0.05$) in phytase-supplemented diet, there was a trend ($P = 0.096$) for higher DM accretion in PC compared to NC treatment. Protein and fat daily accretion rates were greater ($P < 0.05$) in PC and in diet with supplemental phytase compared to NC. There were no effects of xylanase alone or combined with phytase on

daily accretion rates of fat and protein.

There were no effects of dietary treatments on whole body percentage compositions of ash, P and Ca, whereas there was a trend ($P = 0.061$) for greater whole body P concentration in phytase supplemented diet compared to NC treatment (Table 5). Daily accretion of ash was not affected by any dietary treatment, P accretion was greater ($P < 0.05$) in PC and phytase-supplemented diet compared to the NC treatment, but there were no effects of other treatments on P accretion. Calcium accretion was greater in phytase-supplemented diet but not in diets supplemented with xylanase alone or combined with phytase. There was a trend ($P = 0.064$) towards a higher Ca accretion in the PC compared to NC diet.

Discussion

In view of the impact of plant anti-nutrients (phytic acid and arabinoxylans were the targets in the current study) on nutrient utilization and excretion, there will

Table 5. Whole body percentage composition and daily accretion of ash, calcium and phosphorus (dry matter basis) in broilers receiving phytase or xylanase individually or in combination in wheat-based diets¹

	Ash		Phosphorus		Calcium	
	%	mg/d	%	Mg/d	%	mg/d
Positive Control (PC)	5.28	706.4	0.76	107.5	1.02	136.4
Negative Control (NC)	5.61	661.4	0.70	85.5	0.90	103.2
Phytase	5.73	785.2	0.79	112.5	1.06	145.3
Xylanase	5.54	657.3	0.67	81.2	0.93	108.0
Phytase + Xylanase	5.70	730.8	0.74	99.0	1.01	127.7
SEM	0.30	67.2	0.04	9.38	0.09	15.4
<i>P</i> -values for contrasts						
PC vs. NC	0.325	0.554	0.184	0.045	0.223	0.064
NC vs. Phytase	0.727	0.111	0.061	0.016	0.115	0.021
NC vs. Xylanase	0.861	0.953	0.661	0.757	0.818	0.802
NC vs. Phytase + Xylanase	0.805	0.363	0.343	0.209	0.293	0.165

¹Data are means of 8 replicates consisting of 1 bird per replicate.

continue to be the need to investigate ways of counteracting their deleterious effects on nutrient utilization as well as assess the effectiveness of these dietary interventions. One of the ways in which wheat arabinoxylans act as antinutrient is by increasing digesta viscosity thus impairing nutrients utilization (Evers *et al.*, 1999). In addition, all cereals have aleurone layer which shields the starchy endosperm thus presenting a first barrier to digestibility and nutrient availability. Although not exclusively confined to the aleurone layer, phytate-bound phosphorus and other minerals are found within aleurone cells (Frølich, 1990). The cell wall of the aleurone layer is resistant to milling action and thus presents a second layer of barrier to nutrient availability. Carbohydrases may hydrolyze the aleurone layer thus reducing barrier to nutrient digestibility and thus enhance the utilization of the feedstuff. Parkkonen *et al.* (1997) observed in vitro that xylanase increased the permeability of the aleurone layer, this increase in permeability may enhance contact of digestive or exogenous enzymes and their substrates.

In the current study, phytase supplementation improved growth performance of the broilers up to d 21. The improvement in growth performance when phytase is used in wheat-based diets is well documented. In spite of the intrinsic phytase activity in wheat (Eeckhout and De Paepe, 1994; Weremko *et al.*, 1997), the improvement observed in growth when phytase was added suggests that there are additional benefits to the use of exogenous enzyme even in diets based on wheat. The impact of the intrinsic phytase of the wheat is shown in the similarity between the bone ash content of PC and NC. In the PC diet, supplemental P was added in the form of di-calcium phosphate, this should increase bone mineralization when compared with the NC diet which was deficient in P. However, the similarity in bone ash between these two treatments suggests that the intrinsic phytase activity in wheat contributed to P availability in the diets. Analysis for phytase activity in NC and PC treatments showed that

phytase activity was approximately 340 FTU/kg in these diets strongly indicating a high background phytase activity. Pan *et al.* (1998) reported higher tibia ash in wheat-based diet compared to rye based diet in layers possibly because wheat has greater phytase activity than rye. However, bone mineralization and total tract P retention in the current study were higher in phytase supplemented diet than the NC treatment and this can likely be explained, as for effect of phytase on growth performance. Similar observations were made previously by Wu *et al.* (2004a, b) and Zyla *et al.* (1999). An explanation for the additional benefit of exogenous phytase in wheat-based diets could be because of greater potency of exogenous phytase in comparison with plant phytases. It has been demonstrated that plant phytases are less resistant to denaturation in the stomach of nonruminant animals and to proteolysis by pancreatic protease when compared with microbial phytases (Phillippy, 1999).

The result of total tract nutrient retention shows minimal effect of enzymes supplementation on nutrient retention. Again, it is likely that the effects of exogenous phytase and xylanase were tempered by intrinsic phytase and xylanase activities in the wheat. Dornez *et al.* (2006) pointed out the implication in animal feeding of the presence of endoxylanase in the outer layer of wheat because it may be responsible for part of the degradation of arabinoxylans observed during digestion. High total tract nutrient retention values, not much lower than observed in the PC treatment, were observed in the xylanase supplemented diets. It is likely that the intrinsic endoxylanase and phytase activities of wheat (Cleemput *et al.*, 1997) are responsible for the high retention making it less likely to observe a response to supplementation of both phytase and xylanase.

The study of Ten Doeschate *et al.* (1993) indicated that there may be sex differences in the digestive ability of broilers, higher nutrient digestibility was observed in female than in male chickens. Similar observation was

made by Mignon-Grasteau *et al.* (2004) in male and female broilers receiving wheat-based diet. Sebastian *et al.* (1997) reported that female broilers had increased ileal amino acid digestibility with phytase supplementation whereas the male broilers did not. Ravindran *et al.* (1999) using only male broilers reported that male broilers responded positively to phytase supplementation using ileal amino acid digestibility as response criterion. It can be speculated that possibility for effect of sex on response of broilers to enzyme supplementation exists, but because only male broilers were used in this study this proposition can not be confirmed or refuted.

We have previously reported improvement in the growth performance of broilers receiving diets supplemented with phytase and carbohydrases (Olukosi *et al.*, 2007; Olukosi *et al.*, 2008). Others have similarly documented the impact of phytase and xylanase on the performance of broilers (Esteve-Garcia *et al.*, 1997; Wu *et al.*, 2004a; Meng *et al.*, 2005). In the current study, there was an improvement in whole-body DM accretion rate in phytase supplemented diet. Further partitioning of the DM into compositions of gain revealed that the majority of the DM accretion was protein rather than fat. In fact, irrespective of the treatment, protein accretion was approximately twice fat accretion. In the PC and phytase treatments, protein accretion made up approximately 58% of the total DM accretion. On the other hand, fat was 34% of the DM accretion in PC diet but 32% of the DM accretion in phytase supplemented diet. Protein and fat accretion rates in phytase-supplemented when compared to that of the NC diet revealed that the increase in DM accretion as protein was approximately twice that accreted as fat (1.25 g/d compared to 0.76 g/d for protein and fat, respectively). It is also important to note that protein accretion was numerically higher in phytase-supplemented diet and fat accretion was numerically lower in all enzyme-supplemented diet compared with the PC diet in the current study. This is an important observation because of the higher efficiency with which lean tissue is accreted compared to that of fat tissue (Van Milgen and Noblet, 2003). This study thus helps to establish the fact that majority of DM accretion (weight gain) resulting from the phytase used in this study was protein rather than fat.

Meng *et al.* (2005) using *in vitro* techniques showed that degradation of non-starch polysaccharides accompanied incubation of wheat and soybean meal with carbohydrase preparations. Similarly, Tervilä-Wilo *et al.* (1996) observed that there was hydrolysis of wheat cell walls with increasing concentrations of cell wall degrading enzymes produced by *Trichoderma reesei*. The study of Bergman *et al.* (1997) and Lestienne *et al.* (2005) also revealed the potential of phytin and insoluble-fiber content of cereals to bind up minerals and thus make them unavailable to the animal. The use of enzymes that are able to hydrolyze phytate or cell wall structures can lead to improvement in availability of the minerals. The current study shows there was no effect of the enzyme treatments on ash

accretion rates in the broilers. However, there was significant effect of phytase on the accretion rates of P and Ca whereas the PC diet improved P accretion rates in the birds. Phosphorus and Ca are only two of the many minerals, which availability can be improved by phytase supplementation.

In conclusion, the current experiment shows that exogenous phytase and xylanase could improve growth performance of broilers receiving wheat-based diet in spite of significant intrinsic activities of these enzymes in wheat. Stronger bone as indicated by greater bone mineralization when the two enzymes were used is also indicated. Of perhaps the greatest importance is the observation that phytase enhanced greater whole body protein deposition compared to fat deposition. Thus, in view of greater efficiency of deposition of lean tissue, it may be surmised that the improvement in weight gain due to phytase supplementation is in effect an improvement in efficient utilization of nutrients for whole body accretion.

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