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Feeding dietary non-starch polysaccharides supplemented with xylanase could improve the performance of broilers

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Abstract

The impact of dietary non-starch polysaccharides (NSP) on performance and carcass traits of broilers fed wheat-bran substituted into corn-soybean meal-based diets supplemented with xylanase was investigated. A total of 280 (7-day-old) Ross 308 broilers were randomly allotted to one of five dietary treatments with 8 replicates, 7 chicks per pen. Treatments were; i) CON: Control diet, ii) CON-X (CON + 3,000 U/kg xylanase), iii) L-X: low NSP (2% wheat bran in CON + 3,000 U/kg xylanase), iv) M-X: medium NSP (4% wheat bran in CON + 3,000 U/kg xylanase), v) H-X: higher NSP (8% wheat bran in CON+ 3,000 U/kg xylanase). Birds fed the H-X diet increased ($p < 0.05$) daily gains, and average daily feed intake and had marginally improved body weights ($p = 0.074$) on day 35. Relatively, the H-X diet tended to increase the average daily gains ($p = 0.053$; $p = 0.073$) of birds during the grower phase (d 24–35) and the entire experimental period (d 8–35), respectively. Moreover, there were no significant differences among treatments in the feed conversion ratio of birds throughout the entire experiment period. Birds fed diets CON-X, L-X, and M-X had improved ($p < 0.05$) the ileal digestibility of energy on d 24 and 35 compared to those fed the H-X diet. Furthermore, birds fed diet CON-X improved ($p < 0.05$) N digestibility on d 24. Improved carcass moisture content and lowered crude fat of leg meat ($p < 0.05$) were noted in birds fed the diet M-X and H-X on d 35, respectively. The intestinal viscosity was reduced ($p < 0.05$) in xylanase-supplemented treatments CON-X, L-X, M-X, and H-X diets when compared to CON. Our results suggest that supplementing 3,000 U/kg xylanase in a higher NSP (8% wheat bran substituted level) diet could improve the intestinal viscosity and growth performance of broilers.

Keywords: Broiler, Digestibility, Non-starch polysaccharide, Wheat bran, Xylanase

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Availability of data and material
Upon reasonable request, the datasets of this study can be available from the corresponding author.

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The experimental protocol and procedures for this study were reviewed and approved by the Animal Care and Use Committee of Chungnam National University (Protocol Number; 202103A-CNU-029), Korea.

INTRODUCTION

The provision of nutrient-dense diets that aim to utilize the full genetic potential of modern fast-growing broilers is a costly affair. It is well known that feeds constitute the largest portion of farm expenditure [1, 2]. Thus, it has been a fixation for nutritionists to investigate strategies to lower feed costs while including other feed alternative resources and additives that might be more sustainable and relatively inexpensive. In the face of high feed costs and erratic supply, wheat bran has been considered an alternative energy source in poultry diets because of its higher starch level and reasonable N content [3,4].

Nevertheless, the maximum utilization of nutrients from wheat bran by monogastric is constrained by the presence of anti-nutritive, water-soluble non-starch polysaccharides (NSP) [5] in the form of arabinoxylan and beta-glucan fractions that could have detrimental impacts on the productive performance of broilers [6]. The anti-nutritive effect of water-soluble NSP is attributed to the increase in the viscosity of the intestinal digesta. Increased digesta viscosity has been reported to impede enzymatic digestion by endogenous enzymes, resultantly limiting nutrient digestion and bioavailability [7]. However, dietary NSP have received attention for their capacity to elicit positive impacts on broiler performance and normal gut function [8,9]. As a result, monogastric diets are formulated with a 2-3% fiber level to strike a balance between the deleterious effects of high fiber in diets and the desired gut-modulating effects of dietary fiber.

It is also well-established that specific enzyme supplementation in the form of xylanase could improve the nutritional value of dietary fiber. Xylanse works to degrade arabinoxylans, and in turn, reduce chyme viscosity, facilitate enzymatic nutrient digestion, and potentially release xylo-oligosaccharides that could induce beneficial prebiotic effects to the gut. Xylanase supplementation in higher dietary NSP diets has also been reported to improve the performance of broilers by increasing the availability of nutrients [6,10]. Nonetheless, the degradation ability of xylanase differs with the inclusion levels of dietary NSP in the diet. It is imperative to evaluate the effect of xylanase supplementation on broilers fed different NSP levels to determine the optimal inclusion level for improved performance. In this study, we hypothesized that feeding broilers with a diet containing higher dietary NSP levels supplemented with xylanase would lower intestinal viscosity, improve nutrient utilization, and improve broiler performance.

MATERIALS AND METHODS

The experiment was conducted at the Daejeon Poultry Research Unit of Chungnam National University, Daejeon, Korea. The rearing practices followed the recommendations of the Ross 308 Specification Management Guide [11]. The experimental protocol and procedures for the study were reviewed and approved by the Animal Care and Use Committee of Chungnam National University (Protocol Number; 202103A-CNU-029). The novel xylanase enzyme used in the current study was supplied by CJ CheilJedang BIO, Seoul, Korea.

Animals and housing

A total of 280 one-day-old Ross 308 were purchased from a commercial hatchery to be used in the current study. The birds were allowed a one-week adaptation period and then randomly allocated based on the average body weight (BW; 115.01 g ± 1.55) on day 8. Seven birds were housed in each raised wire floor enriched cage (85 × 55 × 35 cm^3). The room was lit continuously during the whole experimental period and the room temperature started at 32℃ for the first day and lowered by 2℃ per week until a final temperature of 28℃ on day 35. Each pen was equipped with three nipple drinkers and a metal feeding trough for the *ad libitum* access to clean drinking water and feed.

Experimental design and dietary treatments

Birds were assigned to one of five dietary treatments with 8 replicates per treatment in a completely randomized design. Following the Ross 308 Nutritional Specifications, a corn-soybean meal basal diet was formulated for the five dietary treatments with different NSP levels (i.e. low, medium, and high NSP) using wheat bran and supplemented with xylanase. The mash diets were as follows; i) CON: Control diet, ii) CON-X (CON + 3,000 U/kg xylanase), iii) L-X: low NSP (corn replaced to 2% wheat bran in CON + 3,000 U/kg xylanase), iv) M-X: medium NSP (corn replaced to 4% wheat bran in CON + 3,000 U/kg xylanase), v) H-X: high NSP (corn replaced to 8% wheat bran in CON+ 3,000 U/kg xylanase). Chromium oxide powder (99.9% purity, Sigma-Aldrich, St. Louis, MO, USA) was added as an external indigestible marker at the proportion of 0.3% in all experimental diets.

In addition, diet samples were collected and analyzed for the gross energy, and crude protein to verify closeness to the standard values. NSP fractions in dietary treatments were balanced using the dietary NSP profile estimator (iNSPect: inspect.canadianbio.com; Canadian Bio-system). The experimental diets were provided in two distinct phases, the starter phase (8 to 24 days) and the grower phase (25 to 35 days). The dietary composition of the experimental diet utilized during all phases is illustrated in (Table 1). The amount of xylanase unit in the experimental diet was determined using Xylazyme AX tablets (Megazyme International, Bray, County Wicklow, Ireland) according to the method described by Wickramasuria et al. [12]. One xylanase unit is defined as the amount of enzyme that liberates 1μmol of xylose per minute under the conditions of the assay (pH 5.3 and 50℃). The assay is based on a 5-minute hydrolysis of xylan substrate which is stopped by the addition of dinitrosalicylic acid.

Growth performance evaluation

The BW and feed consumption of birds were recorded weekly. Using the feed consumed and recorded BW, the average daily gain (ADG), mortality-corrected average daily feed intake (ADFI), and the feed conversion ratio (FCR) to depict the efficiency of converting feed supplied to lean muscle was conducted.

Nutrient digestibility, viscosity, and carcass characteristics

One bird per cage (closer to the mean BW) was selected and sacrificed by cervical dislocation for ileal digesta sample collection on days 24 and 35. Following the procedure of Wickramasuriya et al. [13], the collected samples were pooled and stored at −20℃ until further analysis for nutrient digestibility and viscosity. The contents of the chromium oxide, crude protein, and energy contents of the feed and digesta samples were analyzed according to the standard procedures [14]. The apparent ileal digestibility of gross energy and crude protein was determined to estimate the rate of nutrient disappearance at the terminal ileum using the following equation stipulated by Oketch et al. [15].

$$\text{Digestibility \%} = 100 - \left[100 \times \left(\frac{M_{diet} \times N_{digest}}{M_{digest} \times N_{diet}}\right)\right], \text{whereby},$$

M_{diet} is the marker concentration in the diet, N_{digest} is the nutrient concentration in ileal digesta, M_{digest} is the marker concentration in ileal digesta, and N_{diet} is the nutrient concentration in the diet. For carcass characteristics analysis, samples of leg meat were collected from each selected bird per

Table 1. Composition (g/kg, as-fed basis) of the experimental diets

Items	Starter phase (d 8–24)					Grower phase (d 25–35)				
	CON[1)]	CON-X	L-X	M-X	H-X	CON	CON-X	L-X	M-X	H-X
Ingredient (%)										
Corn	61.45	61.45	59.46	57.48	53.50	63.79	63.79	58.01	52.22	40.65
Wheat bran	-	-	2.00	4.00	8.00	-	-	2.00	4.00	8.00
Soybean meal (SBM, 48 %)	31.62	31.62	30.94	30.25	28.88	27.44	27.44	27.62	27.81	28.17
Fish meal	1.30	1.30	1.60	1.90	2.50	1.90	1.90	2.05	2.20	2.50
Vegetable oil	1.20	1.20	1.78	2.35	3.50	2.45	2.45	2.84	3.23	4.00
Corn starch	-	-	-	-	-	-	-	3.25	6.50	13.00
Limestone	1.78	1.78	1.59	1.39	1.00	1.84	1.84	1.67	1.50	1.15
Mono-calcium phosphate	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
Salt	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Vitamin-mineral premix[2)]	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Lys-HCl	0.25	0.25	0.25	0.25	0.25	0.20	0.20	0.19	0.18	0.15
DL-methionine	0.30	0.30	0.29	0.28	0.27	0.28	0.28	0.28	0.28	0.28
Calculated composition										
Metabolizable energy (kcal/kg)	3,050	3,050	3,050	3,050	3,050	3,150	3,150	3,150	3,150	3,150
Crude protein (%)	21.50	21.50	21.50	21.50	21.50	20.00	20.00	20.00	20.00	20.00
Non-starch polysaccharides (%)	8.33	8.33	8.70	9.07	9.82	7.89	7.89	8.15	8.40	8.91
Lysine (%)	1.32	1.32	1.32	1.32	1.33	1.20	1.20	1.20	1.20	1.20
Methionine + cystine (%)	0.99	0.99	0.99	0.99	0.99	0.94	0.94	0.94	0.94	0.94
Analyzed composition										
Analyzed xylanase unit (U/g)	-	3.01	3.00	3.00	3.01	-	3.00	2.99	3.00	3.00

[1)]CON, control diet; CON-X, CON + 3,000 U/kg xylanase; L-X, corn replaced to 2% wheat bran in CON + 3,000 U/kg xylanase; M-X, corn replaced to 4% wheat bran in CON + 3,000 U/kg xylanase; H-X, corn replaced to 8% wheat bran in CON+ 3,000 U/kg xylanase.

[2)]Vitamin and mineral mixture provided the following nutrients per kg of diet: vitamin A, 24,000 IU; vitamin D3, 6,000 IU; vitamin E, 30 IU; vitamin K, 4 mg; thiamin, 4 mg; riboflavin, 12 mg; pyridoxine, 4 mg; folacine, 2 mg; biotin, 0.03 mg; vitamin B8 0.06 mg; niacin, 90 mg; pantothenic acid, 30 mg; Fe, 80 mg (as $FeSO_4 \cdot H_2O$); Zn, 80 mg (as $ZnSO_4 \cdot H_2O$); Mn, 80 mg (as $MnSO_4 \cdot H_2O$); Co, 0.5 mg (as $CoSO_4 \cdot H_2O$); Cu, 10 mg (as $CuSO_4 \cdot H_2O$); Se, 0.2 mg (as Na_2SeO_3); I, 0.9 mg (as $Ca(IO_3) \cdot 2H_2O$).

cage on day 35. Thereafter, the proximate analysis of leg meat samples was conducted to determine the composition of moisture content, crude protein, crude fat, and ash according to the standard methods of AOAC [14].

Statistical analyses

All data for growth performance, digestibility, and carcass characteristics with respect to the treatments were analyzed by using the general linear model (GLM) of the SPSS 26.0 (SPSS, Chicago, IL, USA). The pen was used as the experimental unit for the assessment of the growth performance parameters such as BW, ADG, ADFI, and FCR. The individual bird was used as the statistical unit for ileal digestibility, digesta viscosity, and carcass characteristics. The results were presented by mean values and the standard error of the mean (SEM). All statements of significance were declared on a probability value of less than 0.05. Marginal effects were measured at $0.05 < p < 0.10$. Significant means were separated using Tukey's multiple range test.

RESULTS

Growth performance

Birds fed the highest NSP levels plus xylanase in the H-X diet recorded marginally higher BW (p =

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0.074) on day 35 compared to birds fed with other diets (Table 2). Feeding diet H-X increased ($p < 0.05$) ADG of birds on day 35. Moreover, marginal improvements of the ADG ($p = 0.053$; $p = 0.073$) were noted from birds fed the H-X diet during the grower phase (day 24–35) and for the entire experimental period (day 8–35), respectively. Birds fed the H-X diet also increased ($p < 0.05$) ADFI on day 35. Neither significant effects nor trends were noted for the FCR of the birds over the entire experimental period.

Nutrient digestibility and viscosity

Regarding the ileal digestibility of nutrients and energy, birds fed on diet CON-X, L-X, and M-X

Table 2. Effects of different dietary non-starch polysaccharide (NSP) level diets on the growth performance of broilers[1)]

Items	Treatments[2)]					SEM[3)]	*p*-value
	CON	CON-X	L-X	M-X	H-X		
Body weight (g)							
Day 8	114.8	115.1	115.1	114.7	115.4	1.555	0.992
Day 14	268.8	276.6	275.7	283.0	281.1	9.655	0.626
Day 21	597.2	598.0	597.1	587.7	615.3	23.476	0.832
Day 24	769.4	776.1	799.6	779.4	814.8	30.246	0.550
Day 28	1,052.1	1,064.7	1,120.2	1,077.6	1,131.9	44.355	0.310
Day 35	1,630.6	1,650.6	1,708.9	1,669.5	1,806.7	64.405	0.074
Average daily gain (g/day)							
Day 14	22.00	23.06	22.94	24.04	23.68	1.376	0.633
Day 21	46.91	45.93	45.91	43.53	47.75	2.803	0.641
Day 28	70.67	72.16	80.14	74.54	79.27	0.562	0.360
Day 35	82.64[b]	83.70[ab]	84.11[ab]	84.55[ab]	96.40[a]	4.537	0.026
Day 8–24	38.51	38.88	40.26	39.10	41.15	1.790	0.567
Day 25–35	78.29	79.50	82.67	80.91	90.17	4.117	0.053
Day 8–35	54.14	54.84	56.92	55.53	60.41	2.287	0.073
Average daily feed intake (g/day)							
Day 14	31.36	32.47	32.91	32.65	31.97	1.194	0.715
Day 21	67.52	64.98	66.73	64.21	61.56	2.031	0.049
Day 28	105.05	101.42	115.88	105.55	112.48	8.208	0.400
Day 35	116.97[ab]	108.51[b]	124.58[ab]	113.99[ab]	125.96[a]	6.060	0.041
Day 8–24	56.61	55.99	57.57	55.91	54.73	1.530	0.316
Day 25–35	112.74	106.53	115.74	110.85	121.73	5.817	0.141
Day 8–35	78.50	75.68	80.26	77.74	80.95	2.992	0.426
Feed conversion ratio (g/g)							
Day 14	1.44	1.42	1.44	1.37	1.36	0.070	0.621
Day 21	1.46	1.44	1.47	1.50	1.30	0.107	0.404
Day 28	1.49	1.41	1.46	1.42	1.44	0.104	0.950
Day 35	1.42	1.30	1.49	1.35	1.31	0.072	0.334
Day 8–24	1.47	1.44	1.43	1.43	1.33	0.066	0.269
Day 25–35	1.44	1.34	1.40	1.37	1.35	0.058	0.388

[1)] Values are the mean of eight replicates per treatment.

[2)] CON, control diet; CON-X, CON + 3,000 U/kg xylanase; L-X, corn replaced to 2% wheat bran in CON + 3,000 U/kg xylanase; M-X, corn replaced to 4% wheat bran in CON + 3,000 U/kg xylanase; H-X, corn replaced to 8% wheat bran in CON+ 3,000 U/kg xylanase.

[3)] Pooled standard error of the mean.

[a,b] Values in a row with different superscripts differ significantly ($p < 0.05$).

improved ileal digestibility of energy ($p < 0.05$) on days 24 and 35 than birds fed the H-X diet (Table 3). However, an increase in protein digestibility ($p < 0.05$) was only noted at day 24 within birds fed on diet CON-X when compared to the other treatments. Feeding different levels of NSP did not show any increase in protein digestibility on day 35. Considering the ileal digesta viscosity, reductions were noted ($p < 0.05$) in birds fed the H-X diet when compared to the other diet-fed birds (Table 3). There was a general reduction in digesta viscosity in the xylanase-supplemented diets when compared to the non-supplemented CON diet.

Carcass composition

Data showing the effects of different dietary NSP levels on carcass composition of broilers are summarized in Table 4. Feeding M-X and H-X diets had improved the moisture content ($p < 0.05$) of leg meat on day 35 than other treatments. Furthermore, birds fed on diet H-X lowered the crude fat content of leg meat on day 35 ($p < 0.05$). However, feeding different NSP levels showed no effects on crude protein and ash content of leg meat.

Table 3. Effects of different dietary non-starch polysaccharide (NSP) level diets on nutrient digestibility and viscosity of broilers on day 24 and 35[1)]

Items	Treatments[2)]					SEM[3)]	*p*-value
	CON	CON-X	L-X	M-X	H-X		
Energy digestibility (%)							
d 24	86.86[a]	83.80[ab]	86.27[a]	86.62[a]	80.21[b]	2.011	< 0.001
d 35	87.72[a]	88.15[a]	86.45[ab]	83.70[bc]	82.75[c]	1.013	0.002
Protein digestibility (%)							
d 24	73.37[b]	75.25[a]	72.47[a]	72.22[b]	72.95[b]	1.605	< 0.001
d 35	75.58	76.82	75.62	75.43	75.71	0.710	0.596
Viscosity (mPa/s)							
d 24	2.63[a]	2.50[ab]	2.45[abc]	2.37[bc]	2.28[c]	0.467	< 0.001
d 35	2.58[a]	2.56[a]	2.41[b]	2.30[c]	2.18[d]	0.326	< 0.001

[1)]Values are the mean of eight replicates per treatment.

[2)]CON, control diet; CON-X, CON + 3,000 U/kg xylanase; L-X, corn replaced to 2% wheat bran in CON + 3,000 U/kg xylanase; M-X, corn replaced to 4% wheat bran in CON + 3,000 U/kg xylanase; H-X, corn replaced to 8% wheat bran in CON+ 3,000 U/kg xylanase.

[3)]Pooled standard error of the mean.

[a–d]Values in a row with different superscripts differ significantly ($p < 0.05$).

Table 4. Effects of different dietary non-starch polysaccharide (NSP) level diets on carcass composition of broilers on day 35[1)]

Items	Treatments[2)]					SEM[3)]	*p*-value
	CON	CON-X	L-X	M-X	H-X		
Leg meat (%)							
Moisture	70.51[e]	71.42[c]	70.78[d]	73.15[a]	72.42[b]	1.072	<0.001
Crude protein	19.14	19.48	20.15	19.55	18.99	0.638	0.463
Crude fat	8.19[a]	7.79[b]	7.67[b]	7.72[b]	6.16[c]	1.087	<0.001
Ash	1.13	1.17	1.24	1.20	1.21	0.712	0.587

[1)]Values are the mean of eight replicates per treatment.

[2)]CON, control diet; CON-X, CON + 3,000 U/kg xylanase; L-X, corn replaced to 2% wheat bran in CON + 3,000 U/kg xylanase; M-X, corn replaced to 4% wheat bran in CON + 3,000 U/kg xylanase; H-X, corn replaced to 8% wheat bran in CON+ 3,000 U/kg xylanase.

[3)]Pooled standard error of the mean.

[a–e]Values in a row with different superscripts differ significantly ($p < 0.05$).

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DISCUSSION

Dietary NSPs have gained more interest in monogastric feed formulation due to their influence on nutrient availability, digesta viscosity, gut health function, and overall productive performance. The current study investigated the impact of dietary NSPs supplemented with xylanase on the performance and nutrient utilization of broilers. It was hypothesized that feeding broilers with a diet containing higher dietary NSP content supplemented with xylanase would satisfy a necessary enzyme-substrate concentration and in turn, enhance the broiler's performance. As hypothesized, BW, ADG, and daily feed intake increased when birds were fed a higher NSP level diet supplemented with xylanase in the present study. These results are consistent with several previous studies which indicated positive results on growth performance by feeding higher NSP diets supplemented with xylanase [6,16]. The improvement in the broiler's performance is affected by the varying nature and the quantities of NSP present in monogastric diets, and thus careful consideration should be taken to achieve improved performance.

It is well documented that the total fiber content of wheat bran ranges from 36.5% to 52.4%, with the most constituent of this fiber being NSP and the main NSPs present are arabinoxylan, cellulose, and beta-glucan at proportions of 70%, 20%, and 6% respectively [17]. Wheat bran is also known to have both insoluble and soluble fiber content which ranges from 35.0% to 48.4% and 1.5% to 4.0% respectively [18]. Considering the NSP constituents present in wheat bran, broilers are unable to optimally utilize nutrients in wheat bran due to insufficiency of endogenous NSP degrading enzymes [19]. It is well-known that, despite their adverse effects on nutrient and energy digestibility, dietary NSPs can elicit nutritional value by directly providing energy; and indirectly by improving gut health and immune function. The growth-improving capability of NSP digestion with xylanase is linked to the role played by xylanase to internally cleave the xylan molecule, releasing oligosaccharides such as xylose and arabinose; and resultantly mitigating the deleterious impacts of dietary NSPs in the diets. The improved BW and feed intake of birds fed higher dietary NSP supplemented with xylanase has been reported elsewhere [20,21]. A higher NSP level diet was advantageous to satisfy an ideal enzyme-substrate concentration for optimal enzymatic activity. In addition, the fraction of water-soluble NSP in the diet can function as a source of beneficial fermentable substrates for gut microbiota through selective fermentation, which promote the integrity of the intestinal lining, improving the digestibility of nutrient and energy, and reducing the ability of pathogenic bacteria to proliferate therefore improving the growth performance of birds [22,23].

Moreover, nutrient digestibility in poultry is closely related to the amount of digested protein, fat, and starch that disappears at the ileum [24]. A couple of studies have demonstrated that the addition of xylanases to wheat-bran-based diets could increase nutrient digestibility by partially hydrolyzing NSPs available in wheat bran, resulting in improvements in nutrient utilization and growth performance of broilers [25,26]. In the current study, birds fed dietary NSP supplemented with xylanase recorded improved ileal digestibility of energy and crude protein. The improvements in nutrient digestibility are caused by reduced intestinal viscosity and the breaking down of the arabinoxylan backbone into arabinose and xylose at different segments of the broiler gastrointestinal tract [3]. As earlier reported, both the nature and the level of NSP present in wheat bran may also impair endogenous amino acid release and suppress amino acid digestibility [27]. The current findings, along with those results from Esmaeilipour et al. [28] suggest that xylanase can reduce nutrient entrapment and increase the digestibility of mostly starch and protein at the early stages of a chick's life. It was not unusual to have no improvement in crude protein digestibility on day 35 as was also previously reported by Esmaeilipour et al. [28]. The efficacy of the exogenous xylanase to the diet was significantly observed in broiler chickens fed wheat bran-based diets during the early growth stage. The improvements could be attributed to the capacity of xylanase to mitigate the deleterious effects of low levels of endogenous protease that have been reported at the early stages of a chick's life that coincides with the common use of a higher crude protein diet at the starter stage as compared to the grower stage.

Concerning the ileal digesta viscosity, a reduction in ileal digesta's viscosity with xylanase supplementation was noted. This is in agreement with Gorenz et al. [29] who reported that xylanase supplementation in broiler diets both linearly and quadratically decreased ileal digesta viscosity. These results are also consistent with the work of Barasch and Grimes [30] who reported that the xylanase enzyme supplementation generally reduces digesta viscosity and increases nutrient digestibility. Additionally, xylanase reduces intestinal viscosity, increases endogenous amino acid secretion, releases nutrients, and increases cell wall permeability to absorb utilizable nutrients. According to Van Hoeck et al. [20], compared to the control diets, xylanase decreased viscosity and pH at various intestinal segments; and was beneficial for the carcass traits. In this current study, xylanase supplementation significantly reduced the intestinal viscosity in broilers at both days 24 and 35 of age. The highest decrease in digesta viscosity was observed with a higher NSP diet. This reduction in intestinal viscosity was believed to be associated with available substrates of dietary NSP concerning the enzyme.

It was also observed that feeding dietary NSP supplemented with xylanase exerted an impact on the carcass composition of broilers in this study. Our findins showed that birds fed a higher NSP diet plus xylanase had the lowest crude fat content compared to other dietary treatments. In addition, a significant improvement in the moisture content of leg meat was noted in birds fed the M-X and H-X diet. The results of this study are in line with the findings of Alam et al. [31]. The addition of xylanase enzymes in wheat bran-based diets improved carcass yield and composition of broiler chicken and this was attributed to higher muscle development. This is consistent with another report from Williams et al. [32] which indicated a reduction in carcass crude fat content of birds when a wheat bran and corn diet was supplemented with carbohydrase enzyme. However, the present study contradicts the findings of Hussein et al. [33] who revealed that carcass yield and retail cuts chemical composition showed no significant difference with dietary xylanase supplementation. In this experiment, there were no notable major effects or marginal effects of xylanase supplementation on crude protein and ash content of leg meat. This can be attributed to the amount of energy level that was available concerning the amount of xylanase level supplemented. Another potential evidence is that feeding a fibrous diet moderates nutrient density which provides an opportunity to maintain the nutrient requirements thus resulting in reduced fat deposition in muscles [34,35].

In conclusion, our results showed that the impact of dietary NSPs on broiler's performance can be alleviated by xylanase supplementation, and could differ depending on the formulated NSP proportions in the diet. In this study, it was determined that higher NSP levels in diets supplemented with 3,000 U/kg xylanase led to improved BW and feed intake of birds. The improved performance is associated with an influence of higher NSP levels to satisfy a requisite enzyme-substrate concentration that ultimately facilitates the lowering of intestinal viscosity and improves nutrient utilization. From a practical point of view, elevated dietary NSP levels from the substitution of corn with wheat bran (up to 8%) in the control diet indicated the potential of higher inclusion of alternative feed resources with specific enzyme supplementation to replace a fraction of corn in diets without compromising broiler performance.

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