Spanish Journal of Agricultural Research
13(1), e06-003, 9 pages (2015)
eISSN: 2171-9292
http://dx.doi.org/10.5424/sjar/2015131-5416
Instituto Nacional de Investigación y Tecnología Agraria y Alimentaria (INIA)

RESEARCH ARTICLE

OPEN ACCESS

Effect of corn replacement with graded levels of wheat screening and enzyme supplementation on performance, blood lipids, viscosity and jejunal histomorphology of finisher broilers

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Abstract

An experiment was carried out to study the effect of corn replacement with five levels of wheat screening (0, 150, 300, 450 and 600 g/kg of diet) with (0.5 g/kg of diet) or without xylanase-glucanase enzyme on performance, blood lipids, viscosity and jejunal histomorphology of finisher broilers (25-42 days of age). Five hundred day-old Ross-308 male broiler chicks were fed by a standard commercial diet up to 24 days of age, then randomly assigned to 10 diets. Each diet was fed to five groups of ten chicks each. There was not significant differences in body weight gain (BWG), feed intake, and feed conversion ratio of birds fed with different levels of wheat screening (WS), whereas enzyme increased (p<0.05) BWG. Different levels of WS and enzyme did not have a significant effect on relative weights of carcass, breast, thigh, and abdominal fat of broilers. Relative weights of gizzard, pancreas, small and large intestine, and relative length of jejunum and jejunal and ileal viscosity were increased (p<0.05) by WS, while were decreased (p<0.05) by enzyme. The serum cholesterol level decreased (p<0.05) by increasing levels of WS. Jejunal histomorphological observations showed (p<0.05) shorter and thicker villus and lower crypt depth by increasing levels of WS, while addition of enzyme to the diets, affected (p<0.05) reversely to these parameters. The results showed that the addition of wheat screening up to an inclusion level of 600 g/kg of diet had no adverse effect on broiler performance in the finisher (25-42 d) phases whereas decreased serum cholesterol levels, increased viscosity and villus atrophy. The dietary administration of exogenous enzyme improved performance parameters and decreased viscosity and villus atrophy of broiler jejunum.

Additional key words: body weight gain; jejunum; villus height; crypt depth; cholesterol; broiler nutrition .

Abbreviations used: BW (body weight); BWG (body weight gain); DGR (daily growth rate); FCR (feed conversion ratio); FI (feed intake); HDL (high density lipoprotein); LDL (low density lipoprotein); NSP (non-starch polysaccharides); WS (wheat screening).

Citation: Mazhari, M.; Golian, A.; Kermanshahi, H. (2015). Effect of corn replacement with graded levels of wheat screening and enzyme supplementation on performance, blood lipids, viscosity and jejunal histomorphology of finisher broilers. Spanish Journal of Agricultural Research, Volume 13, Issue 1, e06-003, 9 pages. http://dx.doi.org/10.5424/sjar/2015131-5416.
Received: 06 Dec 2013. **Accepted:** 11 Feb 2015
http://dx.doi.org/10.5424/sjar/2015131-5416

Funding: Ferdowsi University of Mashhad, Iran.
Competing interests: The authors have declared that no competing interests exist.

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Introduction

Although diets fed to broiler chickens are generally based on corn, wheat is an important ingredient in broiler diets because of its high starch and crude protein contents, and is sometimes being the only cereal in grower and finisher diets. Wheat screening (WS) is a by-product obtained after harvesting and processing wheat in flour and macaroni factories and seed breeding centers accounting for 8-12% of annual wheat production in Iran (Rajabzadeh, 2001). Shrunken and broken wheat kernels should have a nutritional value similar to that of wheat and make a large portion of wheat screenings (Audren *et al.,* 2002). Wheat screenings can be used to replace a portion of cereal in poultry diets, reducing the production costs.

Mazhari *et al*. (2011b) used graded levels (0, 6, 12, 18 and 24%) of wheat screening in starter broiler diets (1-10 d) and found that increasing levels of WS up to 24% caused a decreasing of body weight gain (BWG), concluding that WS can be used in the starter period up to an dietary inclusion level of 18%, having higher levels a possible adverse effect on performance. Stapleton *et al*. (1980) indicated that fed 62% of wheat screening to 6 week chickens had no significant adverse

(p>0.05) effect on daily growth rate (DGR), feed conversation ratio (FCR) and body weight (BW). Saki & Alipana (2005) reported that feeding diet supplemented with 30% wheat screening had no minus effect on BWG, feed intake (FI), and FCR of broiler chickens at 28 and 35 days of age. Finisher broilers fed diet supplemented with 75% wheat screening showed no difference in their BWG and FCR compared to control group (Audren *et al*., 2002).

However, some research data have indicated that satisfactory performance can be obtained with diets containing up to 45% of wheat screenings for laying hens (Proudfoot & Hulan, 1988), and up to total replacement of wheat for broiler chickens (Bragg & Biely, 1977; Stapleton *et al*., 1980). The above data indicated a high degree of potential for the use of wheat screenings in broiler diets.

Wheat contains considerably higher levels of anti-nutritional factors consisting mainly of non-starch polysaccharides (NSP) compared to corn. Slominski *et al*. (2004) in a study on 16 different samples of wheat screening showed that NSP content of samples varied from 72 to 118 g/kg with the mean of 100 g/kg. The NSP fraction increases digesta viscosity and protects lipids, starch, and protein, thereby decreasing nutrient digestibility, modifying intestinal microflora in the digestive system, reducing physiological and morphological changes, and depressing the growth performance (Preston *et al*., 2001; Basmacioglu *et al*., 2010). The use of NSP-degrading enzymes as dietary supplements, may positively affect poultry health and productivity fed diets containing grains such as wheat, rye, barley and oats (Basmacioglu *et al*., 2010). Many studies have shown that an appropriate exogenous enzyme product supplemented to wheat-based diets removed anti-nutritional factors from feeds, reduced intestinal viscosity, increased nutrients digestibility, and resulted in a better feed efficiency in broilers (Wang *et al*., 2005; Basmacioglu *et al*., 2010).

Therefore, the following study was designed to study the effect of different levels of wheat screenings with or without a blend enzyme on performance, carcass characteristics, gastrointestinal parameters, serum lipid metabolites, and jejunal histomorphology of finisher broilers.

Material and methods

Sampling

A grade-1 wheat screening sample known as Gaskojen with high dispersion in Khorasan province (Iran) was obtained from Mashhad Seed Production Factory. The chemical composition and metabolisable energy value of this sample were measured in another study (Mazhari *et al*., 2011a) and data were used in the present study to formulate the diets (crude protein: 15.04%, ether extract: 1.67%, crude fiber: 3.88%, natural detergent fiber: 40.17%, acid detergent fiber: 6.11%, gross energy: 4107.36 kcal/kg and true metabolisable energy: 3090.61 kcal/kg).

Birds and management

Experimental procedures followed the principles of the Animal Care Committee of the Ferdowsi University of Mashhad. A total of 500 day-old male broiler chickens (Ross 308) obtained from a commercial hatchery, were fed by standard commercial mash diet up to 24 days of age, then weighed and randomly assigned to 10 dietary treatments with 5 replicates of 10 birds each for the interval 25-42 days of age. Pens of 1×1 m, were covered with wood shavings on the floors. Feed and water were provided *ad libitum*. Birds were exposed to a light:darkness cycle of 23 h light:1 h darkness for the whole experiment. Room temperature was 21°C at day 25and kept constant throughout the study.

Experimental design and diets

A completely randomized design with a factorial arrangement of five wheat screening levels (0, 150, 300, 450 and 600 g/kg of diet) with (0.5 g/kg of diet) or without xylanase-glucanase enzyme was conducted. The enzyme blend (Endofeed W, GNC Bioferm Inc., Saskatoon, Canada) consisted of 1200 U/g xylanase and 440 U/g β-glucanase. Diets were formulated to be isoenergetic and isonitrogenous (Table 1), based on the nutrient requirements of Ross-308 (95% of Ross requirement) rearing guideline (Aviagen, 2007).

Measurements

Performance traits. The growth performance was evaluated by recording BWG, FI and FCR at days 25 and 42. The feeds and feed residuals were weighed to determine the FI. The FCR was calculated as the amount of feed consumed per unit of BWG. Mortality was recorded and used to correct the performance criteria accordingly.

Blood metabolites. One bird per replicate (pen) was randomly selected and blood samples were collected from the wing vein by a syringe at day 42 after 4 hours fasting. Blood samples were collected in labeled sterile

Table 1. The ingredients and calculated nutrient contents of diets (g/kg as-fed basis unless stated otherwise) included different levels of wheat screening (in g/kg) fed to finisher broilers (25-42 d)[1].

	Wheat screening				
	0	**150**	**300**	**450**	**600**
Ingredients					
Corn	671.9	548.7	425.6	302.4	179.3
Soybean meal, 440 g CP/kg	272.1	244.1	216.1	188.1	160.1
Wheat screening	0	150	300	450	600
Soybean oil	18.5	19.7	20.9	22.1	23.2
Limestone	10.7	11.0	11.2	11.4	11.7
Dicalcium phosphate	14.1	13.9	13.8	13.8	13.3
Salt (NaCl)	3.4	3.1	2.8	2.6	2.3
DL-Methionine, 980 g/kg	2.3	2.2	2.1	2.0	1.9
L-Lysine-HCl, 780 g/kg	1.6	1.8	2.0	2.3	2.5
L-Threonine, 999 g/kg	0.4	0.5	0.5	0.6	0.7
Vit-Min premix[2]	5.0	5.0	5.0	5.0	5.0
Total	1000	1000	1000	1000	1000
Calculated nutrient contents					
Apparent metabolisable energy (MJ/kg)	12.73	12.73	12.73	12.73	12.73
Crude protein	180	180	180	180	180
Calcium	8.1	8.0	8.1	8.1	8.1
Available phosphorus	3.9	4.0	4.0	4.0	4.0
Lysine	10.3	10.0	10.0	10.0	10.0
Methionine+Cystine	8.2	8.0	8.0	8.0	8.0
Threonine	7.0	7.0	7.0	7.0	7.0

[1] Diets were divided into two parts of with or without enzyme supplementation. In diets supplemented with enzyme, 0.05 kg corn/100 kg of diet was replaced with 0.05 kg enzyme. [2]Supplied per kg of diet: vitamin A, 10000 IU; vitamin D3, 3500 IU; vitamin E, 60 mg; vitamin K3, 3 mg; vitamin B12, 0.1 mg; thiamine, 3 mg; riboflavin, 6 mg; niacin, 40 mg; pyridoxine, 5 mg; pantothenic acid, 11 mg; folic acid, 1 mg; and biotin, 0.15 mg; cholin chloride, 500 mg; etoxycoin, 150 mg; Mineral mix provided the following per kg of diet: Fe, 60 mg; Zn, 60 mg; Mn,100 mg; Cu, 10 mg; I, 1.6 mg; and Se, 0.15 mg.

test tubes and centrifuged at 3000 × *g* for 10 min to isolate serum. After centrifugation, serum was collected and stored at –20°C for later analysis. Serum lipid metabolites including triacylglyceride, cholesterol, high density lipoproteins (HDL), and low density lipoproteins (LDL) were determined enzymatically in an autoanalyzer (Selectra E Vital Scientific).

Viscosity. One bird per replicate was euthanized by sodium thiopental for digesta viscosity at day 42. The intestinal tract was immediately removed to obtain digesta by gently finger stripping of the intestinal segments. The small intestine was divided into three segments: the duodenum (from gizzard to pancreo-biliary ducts), the jejunum (from pancreo-biliary ducts to Meckel's diverticulum) and the ileum (from Meckel's diverticulum to ileo-caecal junction). For viscosity measurement, the digesta taken from jejunum or ileum was pooled and homogenized thoroughly and centrifuged at 12700 × *g* for 5 min to obtain the supernatants where the viscosity was measured in a Brookfield Digital viscometer (Model DV-III) at 37°C expressing the results in centipoises (cPs). Each sample was measured twice, and the average value was used for the statistical analysis.

Jejunal histomorphology. Also, the mid part of jejunum was excised for histomorphologic analysis. Samples of jejunum (0.5 cm × 0.5 cm segments) were obtained at its midpoint and immersed in a 10% buffered formalin solution for 72 h. Then they were excised and washed with physiological saline solution. The samples were treated in tissue processor apparatus and embedded in paraffin wax (Bancroft & Gamble, 2002). Transverse sections were cut (6 µm) using a rotary microtome (Leica RM 2145), placed on a glass slide and stained with hematoxylin and eosin, then they were analyzed under a light microscope to determine morphometric indices. Morphological parameters were measured using the Image Pro Plus v 4.5 software package. The measured morphometric variables (Aptekmann *et al*., 2001) included: villus height (measured from the villus-crypt junction); villus width (measured at midvillus height); and crypt depth (measured from the villus-crypt junction until the end of gland). The mean from 10 villus per sample was used as the average value for further analysis.

Carcass and gastrointestinal parameters. Also, one bird per replicate whose body weight was closest to the mean weight of the pen was selected, killed by cervical dislocation, plucked, and eviscerated of gastrointestinal

tract, giblets and other inner organs to determine the carcass characteristics and gastrointestinal parameters.

Statistical analysis

All data were analyzed by ANOVA using GLM procedure of SAS (SAS, 1999-2000). Analysis of variance was performed using a completely randomized design with a factorial arrangement of treatments. Percentage data were arc sine transformed before statistical analysis. Data were statistically tested for main effects of wheat screening levels and enzyme supplementation. Means were compared for significant differences using the Tukey multiple range test ($p<0.05$).

Results

Body weight gain, feed intake and FCR

The effect of different levels of wheat screening (WS) and NSP-degrading enzyme supplementation on BWG, FI, and FCR of finisher broilers (during 25-42 days) is shown in Table 2. Increasing levels of WS had no significant effect on BWG, FI and FCR of birds, whereas enzyme increased BWG ($p<0.05$).

Carcass characteristics and gastrointestinal parameters

The effect of different levels of WS and enzyme on relative weight (g/100 g of live body weight) and relative length (cm/100 g of live body weight) of different parts of carcass, gastrointestinal tract and gastrointestinal organs of finisher broilers at day 42 is shown in Tables 3 and 4. Different levels of WS and enzyme did not have a significant effect on relative weights of carcass, breast, thigh, and abdominal fat of broilers. Relative weights of gizzard, pancreas, small and large intestine, increased ($p<0.05$) with graded levels of WS, while decreased ($p<0.05$) with enzyme. Relative length of small intestine or its three segments (duodenum, jejunum and ileum) and large intestine were reduced *(*$p<0.05$) by enzyme, but graded levels of WS only increased ($p<0.05$) the relative length of jejunum.

Jejunal and ileal viscosity

The effect of different levels of WS and enzyme on jejunal and ileal viscosity of finisher broilers at day 42 is shown in Table 5. Jejunal and ileal viscosity were increased ($p<0.01$) by graded levels of WS, whereas were decreased ($p<0.01$) by enzyme.

Serum lipid metabolites

The effect of different levels of WS and enzyme on serum lipid metabolites of finisher broilers at day 42 is shown in Table 6. Different levels of WS and Enzyme indicated no significant effect on triacylglyceride, and HDL and LDL contents. The serum cholesterol level decreased ($p<0.05$) by graded levels of WS, whereas decreased by enzyme supplementation ($p<0.05$).

Histomorphological observations of jejunum

The effect of three levels of WS (0, 300 and 600 g/kg) and enzyme on histomorphological observations of jejunum of finisher broilers at day 42 is shown in Table 7. Jejunal histomorphological observations showed ($p<0.05$) shorter and thicker villus and lower crypt depth by increasing levels of WS, while addition of enzyme to the diets, affected ($p<0.05$) reversely on these histomorphological parameters.

Discussion

Body weight gain, feed intake and FCR

Data in the present study are in agreement with the results of several studies. Saki & Alipana (2005) reported that feeding diet supplemented with 30% wheat screening had no effect on BWG, FI, and FCR of broiler chickens at days 28 and 35. Finisher broilers fed diet supplemented with 75% wheat screening showed no difference in their BWG and FCR compared to control group (Audren *et al*., 2002). Mathlouthi *et al*. (2001) reported that the arabinoxylan content of wheat screening is lower than that of wheat, triticale, oats, wheat bran, and other wheat by-products. Thus, the viscosity of wheat screening is lower than that of the mentioned cereals, what can explain the lower effects of wheat screening on performance data in the present study and in other reports than used wheat-based diets. The BWG of broiler chickens was improved when enzyme was added to wheat-based diets (Hadorn & Wiedmer, 2001; Angelovicova *et al*., 2005). The mode of action of exogenous enzyme to enhance

broiler performance is by reducing intestinal viscosity and improving nutrient digestibility.

Carcass characteristics and gastrointestinal parameters

In accordance with the present study, Saki & Alipana (2005) observed heavier pancreas, gizzard and small intestine and longer small and large intestine in birds fed diets supplemented with 30% wheat screening. The increase in relative weight and relative length of gastrointestinal tract and gastrointestinal organs may be related to an increase in the intestinal function, due to an increase in NSP and digesta viscosity which led to increasing gut motility and digestive excretions and therefore to increasing the size of this tract or organs. Other researchers have also pointed out that fiber ingestion leads to increased size and length of the digestive organs in chickens (Iji *et al*., 2001), pigs (McDonald, 2001), and rats (Ikegami *et*

Table 2. Effect of wheat screening (WS) and enzyme addition on body weight (BW), body weight gain (BWG), feed intake (FI), and feed conversion ratio (FCR) in finisher broilers (25-42 d). Data are means of 5 replicates

Effects	BW (g)		BWG (g/b/d)	FI (g/b/d)	FCR
	(25 d)	(42 d)			
WS (g/kg)					
0	581.81	1745.94	64.67	125.38	1.94
150	626.10	1765.38	63.29	124.51	1.97
300	611.36	1735.75	62.47	123.26	1.98
450	610.71	1735.13	62.46	123.64	1.98
600	598.68	1711.81	61.84	122.88	1.99
SE	22.35	26.38	0.85	1.89	0.03
Enzyme					
–	618.63	1737.07	62.13[b]	123.64	1.99
+	592.84	1740.53	63.76[a]	126.23	1.94
SE	14.14	16.68	0.54	1.22	0.01
***p*-value**					
WS	0.70	0.71	0.18	0.88	0.77
Enz.	0.20	0.88	0.04	0.73	0.11
WS × Enz.	0.75	0.82	0.98	0.99	0.96

[a,b] Means within the same column with different superscripts differ significantly ($p<0.05$).

Table 3. Effect of wheat screening (WS) and enzyme addition on relative weight (g/100 g of live body weight) of different parts of carcass, gastrointestinal tract and gastrointestinal organs in finisher broilers at day 42. Data are means of 5 replicates.

Effects	Carcass	Breast	Thigh	Abdominal fat	Crop	Proventriculus	Gizzard	Liver	Pancreas	Small intestine	Large intestine
WS (g/kg)											
0	56.79	20.99	18.18	1.77	0.42	0.39	1.55[b]	2.98	0.24[b]	3.15[b]	0.54[b]
150	58.18	21.03	18.26	1.73	0.44	0.44	1.71[ab]	3.11	0.29[a]	3.56[ab]	0.62[ab]
300	58.49	20.58	18.69	1.59	0.46	0.45	1.70[ab]	3.10	0.28[ab]	3.54[ab]	0.61[ab]
450	57.95	19.71	18.92	1.39	0.46	0.45	1.74[ab]	2.88	0.30[a]	3.69[a]	0.63[ab]
600	57.41	19.61	18.23	1.35	0.54	0.44	1.81[a]	2.86	0.31[a]	3.94[a]	0.69[a]
SE	0.68	0.42	0.35	0.19	0.04	0.02	0.05	0.19	0.01	0.13	0.03
Enzyme											
–	57.27	20.28	18.25	1.40	0.50[a]	0.46[a]	1.77[a]	3.07	0.30[a]	3.64	0.69[a]
+	58.26	20.49	18.67	1.73	0.42[b]	0.41[b]	1.65[b]	2.90	0.26[b]	3.51	0.57[b]
SE	0.43	0.27	0.22	0.12	0.02	0.01	0.03	0.12	0.01	0.08	0.02
***p*-value**											
WS	0.43	0.06	0.48	0.45	0.19	0.18	0.023	0.81	0.001	0.002	0.006
Enz.	0.11	0.58	0.19	0.06	0.03	0.004	0.008	0.32	0.002	0.24	0.0003
WS× Enz.	0.95	0.11	0.73	0.37	0.22	0.004	0.007	0.80	0.0002	0.09	0.088

[a,b] Means within the same column with different superscripts differ significantly ($p<0.05$).

Table 4. Effect of wheat screening (WS) and enzyme addition on relative length (cm/100 g of live body weight) of different parts of gastrointestinal tract in finisher broilers at day 42. Data are means of 5 replicates.

Effects	Duodenum	Jejunum	Ileum	Small intestine	Large intestine
WS (g/kg)					
0	1.45	3.53^{b}	3.70	8.68^{b}	0.82^{b}
150	1.49	3.73^{ab}	3.72	8.95^{b}	0.85^{b}
300	1.45	3.79^{ab}	3.73	8.97^{b}	0.86^{b}
450	1.56	4.03^{a}	3.88	9.48^{a}	0.94^{a}
600	1.57	4.10^{a}	3.94	9.61^{a}	0.96^{a}
SE	0.05	0.11	0.11	0.24	0.03
Enzyme					
–	1.54^{a}	4.06^{a}	3.96^{a}	9.59^{a}	0.93^{a}
+	1.45^{b}	3.61^{b}	3.63^{b}	8.68^{b}	0.84^{b}
SE	0.03	0.07	0.07	0.15	0.02
***p*-value**					
WS	0.22	0.005	0.45	0.05	0.02
Enz.	0.01	0.0001	0.002	0.0002	0.008
WS× Enz.	0.72	0.001	0.07	0.02	0.06

^{a,b} Means within the same column with different superscripts differ significantly ($p<0.05$).

al., 1990). The reduction in weight and length of gastrointestinal tract and gastrointestinal organs of birds fed WS diets supplemented with enzyme in the present study, may be attributed to the decrease of intestinal digesta viscosity as a consequence of exogenous enzyme. The presence of grains such as wheat, barley and rye in diets tends to increase the relative weight and relative length of gastrointestinal tract and gastrointestinal organs and supplemental enzyme to diets significantly decreases their weight and length (Silva & Smithard, 2002).

Table 5. Effect of wheat screening (WS) and enzyme addition on jejunal and ileal viscosity (cPs) in finisher broilers at day 42. Data are means of 5 replicates.

Effects	Jejunum	Ileum
WS (g/kg)		
0	1.22^{b}	1.49^{b}
150	1.27^{b}	1.66^{b}
300	1.49^{b}	2.45^{ab}
450	1.62^{ab}	2.69^{ab}
600	2.06^{a}	3.21^{a}
SE	0.17	0.28
Enzyme		
-	1.74^{a}	2.71^{a}
+	1.32^{b}	1.89^{b}
SE	0.11	0.17
***p*-value**		
WS	0.0002	0.003
Enz.	0.0005	0.006
WS × Enz.	0.12	0.55

^{a,b} Means within the same column with different superscripts differ significantly ($p<0.05$).

Jejunal and ileal viscosity

Increasing intestinal viscosity has been previously reported by other researches that used WS in their experiments. Saki & Alipana (2005) reported a significant increase in the intestinal viscosity of broilers fed the diets with different levels of WS compared to control diets. Slominski *et al*. (2004) reported that the NSP content in wheat and wheat screening was 91 and 100 g/kg respectively, which can explain the increase in viscosity. The reduction ($p<0.05$) of intestinal digesta viscosity has been recorded in broiler chickens fed wheat or barley-based diets supplemented with NSP-degrading enzymes (Fuente *et al*., 1998; Shirzadi *et al*., 2010), which might be a consequence of the breakdown of polysaccharides into smaller polymers, thereby reducing viscosity (Wang *et al*., 2005).

Serum lipid metabolites

Moharrery (2006) indicated that barley-based diets reduced serum cholesterol in broilers. A negative correlation has been found between dietary fiber and serum cholesterol level (Pettersson & Aman, 1992). Adrizal & Ohtani (2002) found that fiber has a binding property with bile acids and can act directly by increasing bile acid excretion, leading to increased fecal and reduced serum cholesterol levels. Hajati *et al*. (2009) reported that dietary enzyme inclusion

Table 6. Effect of wheat screening (WS) and enzyme addition on serum lipid metabolites (mg/dl) in finisher broilers at day 42. Data are means of 5 replicates.

Effects	Triglyceride	Cholesterol	HDL	LDL
WS(g/kg)				
0	155.83	141.16[a]	86.66	21.67
150	155.50	135.00[ab]	84.57	19.50
300	147.33	131.83[ab]	87.70	19.16
450	147.66	131.50[ab]	89.13	18.50
600	145.83	128.00[b]	90.83	18.16
SE	3.00	2.97	2.17	1.01
Enzyme				
–	147.73	129.00[b]	88.79	18.80
+	153.13	138.01[a]	86.77	20.01
SE	1.89	1.87	1.37	0.64
***p*-value**				
WS	0.07	0.05	0.34	0.16
Enz.	0.06	0.003	0.31	0.19
WS × Enz.	0.94	0.91	0.93	0.99

HDL: high density lipoprotein. LDL: low density lipoprotein. [a,b] Means within the same column with different superscripts differ significantly ($p<0.05$).

increased ($p<0.05$) the concentration of blood total cholesterol, HDL-cholesterol and triacylglyceride levels. The hyper-cholesterolaemic effect of NSP-degrading enzyme has been related to (i) the alleviation of the limitations in the function of bile salts and in the emulsifying properties of them in intestinal chyme (Hajati *et al*., 2009), and/or (ii) the digestion of big molecules of carbohydrates by enzyme which can change the viscous nature of intestinal chyme and therefore improves fat digestibility (Van Der Klis *et al*., 1995).

Table 7. Effect of wheat screening (WS) and enzyme addition on histomorphological observations of jejunum in finisher broilers at day 42. Data are means of 5 replicates.

Effects	Villus height (µm)	Villus width (µm)	Crypt depth (µm)
WS (g/kg)			
0	646.23[a]	74.57[b]	147.05[a]
300	587.92[a]	87.22[ab]	133.70[ab]
600	491.84[b]	101.64[a]	120.52[b]
SE	21.09	3.94	5.27
Enzyme			
–	547.19[b]	94.38[a]	125.29[b]
+	603.47[a]	81.23[b]	142.23[a]
SE	17.22	3.22	4.30
***p*-value**			
WS	0.0008	0.001	0.013
Enz.	0.04	0.013	0.02
WS × Enz.	0.94	0.27	0.06

[a,b] Means within the same column with different superscripts differ significantly ($p<0.05$).

Histomorphological observations of jejunum

Similarly to the results found in the current study, Jaroni *et al*. (1999) showed shorter and thicker villus in birds fed with 8% and 16% wheat middlings. The NSP in wheat-based diets caused an increase in the viscosity of intestinal digesta which stimulates the growth of anaerobic microflora in caeca. Microorganisms migrate from caeca to small intestine where the absorption of most nutrients takes place (Campbell & Bedford, 1992), thereby this high bacterial concentration can irritate the gut lining and caused to thickening and atrophy of villus (Visek, 1978). Enzyme supplementation can reduce both microbial population (Choct *et al*., 1995) and atrophy of villus (Brenes *et al*., 1993). This is in agreement with the results of Santos *et al*. (2004) and Wu *et al*. (2004) who observed longer and narrower villus and deeper crypts in birds fed wheat or rye-based diets supplemented with enzyme.

The villus play a crucial role in the digestion and absorption processes of the small intestine, as they are the first to make contact with nutrients in the lumen (Gartner & Hiatt, 2001). Longer villus increase the absorptive surface of intestine, and deeper crypts indicate an increase of enterocyte replacement and tissue turnover and a higher demand for tissue development as well. In other words, increasing villus height and crypt depth is directly correlated with enhanced epithelial cell turnover (Fan *et al*., 1997). The crypts of the villus contain several specialized cells such as absorptive cells, goblet cells, and regenerative cells that are responsible for the production of mucus and

replacement of old cells. As it happened in the present investigation the increased crypt depth may also be due to a higher number of goblet cells particularly concentrated in the crypt, which can result in increased mucus secretion (Langhout *et al*., 1999).

As conclusions, data obtained in this study showed no significant differences in BWG, FI and FCR of finisher broilers fed diets with graded levels of wheat screening (0-60% of diet). Therefore we can use wheat screening to 60% in finisher (25-42 d) broiler diets without any adverse effect on performance, to reduce the food cost. Although graded wheat screening levels led to bigger size of digestive tract and digestive organs, higher viscosity levels, and shorter and thicker villus size, the dietary administration of exogenous enzyme removed the lower effects of NSP in wheat screening.

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