Acta Scientiarum

http://www.uem.br/acta
ISSN printed: 1806-2636
ISSN on-line: 1807-8672
Doi: 10.4025/actascianimsci.v39i1.33070

Effect of using the Matrix Values for NSP-degrading enzymes on performance, water intake, litter moisture and jejunal digesta viscosity of broilers fed barley-based diet

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ABSTRACT. In this study, we have evaluated the effect of three multi-enzymes nutrient matrix values and compared the results with that fed barley and the corn diets without enzyme. In entire period, addition of all enzymes to the barley-based diet significantly ($p < 0.05$) increased feed intake (FI) and the highest intake was for birds that fed enzyme A ($p < 0.05$). Overall, from 0 to 42 days, average daily gain (ADG) was significantly ($p < 0.05$) increased by enzyme and birds fed enzyme A had the highest body weight ($p < 0.05$). Generally, from 0 to 42 d of age, feed conversion ratio (FCR) was significantly ($p < 0.05$) improved when enzyme added to barley-based diet, but there were no significant differences among diets containing enzymes A and C and the corn-based diet. The carcass weight, and the relative weight of the abdominal fat were significantly increased by enzyme, while small intestine and cecum decreased with enzyme addition ($p < 0.05$). Enzyme significantly decreased jejunal viscosity at Day 23 ($p < 0.05$), whereas pH of jejunal digesta was not changed ($p > 0.05$). Litter moisture and water to feed ratio at 15, 25, and 33 days of age significantly decreased by addition of all enzymes ($p < 0.05$). In conclusion, considering nutrient matrix values for all used enzymes improved performance of broilers and can be used in formulating diets commercial broiler diets based on barley.

Keywords: carbohydrase, broiler, performance, nutrient matrix value.

Efeito do uso de valores de tabela para enzimas degradadoras de PNA sobre o desempenho, ingestão de água, umidade da cama e viscosidade da digesta jejunal de frangos de corte alimentados com dieta à base de cevada

RESUMO. Este estudo avaliou o efeito de três valores da matriz para nutriente multi-enzimático e comparou os resultados com os obtidos com dietas baseadas em cevada e milho sem enzima. Em todo o período, a adição de todas as enzimas à dieta à base de cevada aumentou significativamente ($p < 0,05$) a ingestão de ração, sendo a maior ingestão observada nas aves alimentadas com a enzima A ($p < 0,05$). No geral, de 0 a 42 dias, o ganho médio diário foi significativamente aumentado ($p < 0,05$) pelo uso de enzimas e as aves alimentadas com a enzima A apresentaram o maior peso corporal ($p < 0,05$). De modo geral, de 0 a 42 dias de idade, o índice de conversão alimentar foi significativamente maior ($p < 0,05$) com a adição de enzima à dieta a base de cevada, mas sem diferenças significativas entre as dietas contendo enzimas A e C e à dieta a base de milho. O peso da carcaça e o peso relativo da gordura abdominal foram significativamente aumentados pela enzima, enquanto o intestino delgado e o ceco diminuíram com a adição de enzima ($p < 0,05$). A adição de enzima reduziu significativamente a viscosidade do jejuno no dia 23 ($p < 0,05$), ao passo que o pH da digesta jejunal não foi alterado ($p > 0,05$). A umidade da cama e a razão água: ração aos 15, 25 e 33 dias de idade foram significativamente reduzidos pela adição de todas as enzimas ($p < 0,05$). Em conclusão, considerando os valores da matriz de nutrientes para todas as enzimas utilizadas melhoraram o desempenho de frangos de corte, indicando que podem ser utilizadas na formulação de dietas à base de cevada para frangos de corte comerciais.

Palavras-chave: carboidrase, frango de corte, desempenho, valor da tabela de nutrientes.

Introduction

Due to instability of the world corn prices, the producer's propensity to use the other types of cereals, such as barley, in broiler chickens diet has been rapidly increased during the last few years. High fiber concentration and low energy level, however, are of utmost importance limiting factors for using barley in broilers feed (Ribeiro et al., 2011). These problems have been demonstrated to be attributable to the presence of non-starch polysaccharide (NSP) particularly ß-glucan (Abdulilah, 1995; Gracia, Latorre, Garcia, Lazaro, & Mateos, 2003; Józefiak et al., 2010). Inclusion of ß-glucans in the poultry diets create a viscous environment within the intestinal lumen, which can interfere with the activity of intestinal enzymes in the gastrointestinal tract and result in lower growth rate, poor feed utilization (Salarmoini, Campbell, Rossnagel, & Raboy, 2008), and higher sticky droppings (Sharifi, Barin, Yaghobfar, & Shariatmadari, 2007). According to Shakouri, Iji, Mikkelson, and Cowieson (2009) there is a linear relationship between increasing of intestinal viscosity and depressing growth in broiler. Enzyme supplementation reduces intestinal viscosity and improves total tract apparent retention of nutrients and Feed intake, thereby increasing broiler productivity. The hydrolysis of the polysaccharide structure of the cell wall components causes this reaction, which results in an improvement of nutrients availability as well as in a reduction in digesta viscosity and hence drier droppings and litter. There are large number of projects that have carried out to investigate the effects of enzyme supplementation on broiler performance only by adding enzyme over on top of diet without any consideration of matrix values for the enzyme (Vukic-Vrajes & Wenk, 1995; Kiarie, Romero, & Ravindran, 2014; Ravindran, Tilman, Morel, Ravindran, & Coles, 2007). In this way enzyme will be added to poultry feed after formulation of diet. Therefore, enzyme addition will have extra cost for producers. However, to fully realize the economic potential of enzyme, the amount of ME and Amino acid released by enzyme needs to be evaluated. The nutrient matrix values for enzyme indicate the amount of nutrient that could be released when the enzyme is added to diet. Documentation of such information has the potential to help the producers to add less protein and metabolizable energy (ME) in diet for poultry, to reduce the cost of required feed. As a variety of commercial enzymes are available, there is a challenge for the producers to choose the most appropriate enzyme for improvement of their flock performance. Therefore, the purpose of this experiment was to investigate the effect of using matrix values for three NSP-enzymes on broilers performance that fed barley-based diets and also to compare these matrix values at similar energy and protein level of diet at same nutritional management.

Material and methods

Birds and management

A total of 260 day-old male broiler chicks of commercial strain (Ross 308) were studied with 5 treatments at 4 replications that each replication consisted of 13 birds in floor pen. The average initial body weight of chicks in each pen was 42 g. Environment temperature was kept at 34°C during the first 3 days of the trial and then reduced gradually according to age until reaching 22°C at 21 days and was kept constant throughout the study. During the whole study period, the birds were exposed to continuous lighting.

Dietary treatments

Once birds were randomly distributed among pens, each 4 pen assigned to one of the five formulated treatments to meet all nutrient recommendations published in the Ross rear guideline (Aviagen, 2007). The five dietary treatments in starter and grower (until day 28) period consisted of: (a) 60 percent corn-based ration without enzyme, (b) 60 percent barley supplemented with and without enzyme (enzyme A[1], B[2] and C[3]). Nonetheless, in finisher period, amounts of barley and corn were increased in diets. The ingredient calculated nutrient contents of the experimental diets at starter, grower and finisher period are shown in Table 2, 3 and 4 respectively. Mash feed and water were available for ad libitum consumption. Before formulating, all of the major dietary ingredients were analyzed for AME_n, amino acid (AA) profiles (according to prediction formula existing in National Research Council [NRC], 1994), crude protein (CP), crude fiber (CF), ether extract (EE) and macro mineral contents as described by Association of Official Analytical Chemists (AOAC, 2000). Starch of barley was determined by an enzymatic method.

Enzyme usage

In order to add the enzymes to diets nutrient matrix values including the amount of Metablizable energy and the percentage of crude protein, threonine, lysine, methionine and cyctine, that are anticipated to be released from diet by manufacturer, were considered (Table 1). Then, this amounts were subtracted from levels of the same nutrient of formulated diet which are presented at Table 2, 3 and 4. Finally, the enzyme was added to diet as ingredient to provide these quantity of nutrients. This method was used for each period. All of multi-enzymes contained mainly β-glucanase and xylanase activities and added to diet in powder form.

[1]Grind enzyme.
[2]Rovabio.
[3]Safizyme.

Table 1. Nutrient matrix values of enzme A for broilers.

Nutrient	Enzyme A[1]		Enzyme B[2]		Enzyme C[3]	
	value	Amount provided in the diet	Value	Amount provided in the diet	Value	Amount provided in the diet
ME, kcal kg^{-1}	88047	14.9679	347240	208.344	2800000	140
Crude protein, %	312.66	0.06569	11	0.0066	86.5	0.04325
Threonine, %	6.33	0.0010761	6.33	0.0010761	7.22	0.00361
Lysine, %	7.66	0.0013022	0.23	0.00013	30	0.015
Methionine + Cystine, %	6	0.00102	0.46	0.00027	23	0.0115

[1]Enzyme A was added at 0.017 of the diet, which provided endo-1,4-b-glucanase: 1500 BGU kg^{-1} diet; endo-1,4-b-xylanase 3600 FXU kg^{-1}. [2]Enzyme B was added at 0.06 of the diet, which provided β-glucanases 1420 units kg^{-1} diet and xylanases 660 units kg^{-1} diet. [3]Enzyme C was added at 0.05 of the diet, which Provide endo-1,3(4)-b-glucanase: 100 AGL kg^{-1} diet; endo-1,4-b- xylanase: 70 AXC units kg^{-1} diet.

Table 2. Ingredient and calculated nutrient contents (%) of the experimental diets given to broiler chickens at starter period.

	Starter (0 to 10 days)				
Ingredient	Barley	Enzyme A	Enzyme B	Enzyme C	Corn
Barley	60	60	60	60	-
Corn	-	-	-	-	60
Soybean meal	24	17.86	23.52	25.67	24.35
Gluten meal	6	11.92	8.20	6.78	9.50
Soya oil	4.28	4.80	3.50	2.79	1
L-lysine-HCL	0.56	0.76	0.61	0.57	0.68
DL-methionine	0.24	0.26	0.28	0.32	0.27
Dicalcium phosphate	2.10	1.74	1.71	1.70	1.91
Limestone	2	1.82	1.3	1.30	1.45
Sodium chloride	0.32	0.32	0.32	0.32	0.34
Vitamin premix[1]	0.25	0.25	0.25	0.25	0.25
Mineral premix[2]	0.25	0.25	0.25	0.25	0.25
Calculated nutrient contents			Barley		Corn
AME, kcal kg^{-1}			2860		2860
Crude protein, %			21.40		21.40
Lysine, %			1.36		1.36
Methionine+cyctine, %			1.03		1.03
Crude fiber, %			4.39		1.88
Calcium, %			0.95		0.95
Available phosphorus, %			0.57		0.57
Sodium, %			0.15		0.15

[1]Provided the following (per kg of diet): vitamin A (transretinyl acetate), 9,000 IU; vitamin D3 (cholecalciferol), 2,000 IU; vitamin E (allrac- tocopherol acetate), 18 IU; vitamin K (bisulfate menadione complex), 2 mg; riboflavin, 6.6 mg; pantothenic acid (D-calcium pantothenate), 10 mg; pyridoxine (pyridoxine HCl), 3 mg; folic acid, 1 mg; thiamin (thiamin mononitrate), 1.8 mg; vitamin B12 (cyanocobalamin), 15 μg; D-biotin, 0.1 mg; niacin, 30 mg; choline (choline chloride), 500 mg and ethoxyquin, 0.1 mg. [2]Provided the following (per kg of diet): Se (Na_2SeO_3), 0.2; I (KI), 1; Cu ($CuSO_4 .5H_2O$), 10; Fe ($FeSO_4 .7H_2O$), 50; Zn (ZnO), 85 and Mn ($MnSO_4.H_2O$), 100 mg.

Productive performance traits

The growth performance was evaluated by recording Feed intake (FI), body weight (BW) at days 10, 28, and 42. Then and feed conversion ratio (FCR) was calculated from these data by period and totally. At day 23, two bird per pen were killed and the experiment continued with 11 bird for each replicate. Also, birds that died during the experiment were weighed. Feed wastage and Mortality recorded and used to correct the performance criteria accordingly.

Carcass and gastrointestinal parameters

On 42 days, two birds whose body weight were closest to the mean weight of the pen was selected were wing-banded, slaughtered and eviscerated in order to determine carcass characteristics. To determine small intestine parameters content of intestine were removed. Then, empty weights and lengths of the duodenum (pancreatic loop), jejunum (from the pancreatic loop to Meckel's diverticulum) and the ileum (from Meckel's diverticulum to the ileocecal junction) were measured.

Table 3. Ingredient and calculated nutrient contents (%) of the experimental diets given to broiler chickens at grower period.

	Grower (11 to 28 days)				
Ingredient	Barley	Enzyme A	Enzyme B	Enzyme C	Corn
Barley	60	60	60	60	-
Corn	-	-	-	-	60
Soybean meal	26	21.05	22.24	24.36	26.65
Gluten meal	2.53	8.10	8.35	6.15	9.24
Soya oil	6.20	6.70	5.36	5.48	045
L-lysine-HCL	0.26	0.46	0.34	0.31	0.19
DL-methionine	0.21	0.14	0.15	0.17	0.11
Dicalcium phosphate	2	1.49	1.47	1.46	1.46
Limestone	1.90	1.22	1.21	1.20	1.06
Sodium chloride	0.30	0.32	0.32	0.32	0.34
Vitamin premix[1]	0.25	0.25	0.25	0.25	0.25
Mineral premix[2]	0.25	0.25	0.25	0.25	0.25
Calculated nutrient contents			Barley		Corn
AME, kcal kg^{-1}			2900		2900
Crude protein, %			21.16		21.16
Lysine, %			1.01		1.01
Methionine+cyctine, %			0.77		0.77
Crude fiber, %			4.32		1.92
Calcium, %			0.83		0.83
Available phosphorus, %			0.41		0.41
Sodium, %			0.15		0.15

[1]Provided the following (per kg of diet): vitamin A (transretinyl acetate), 9,000 IU; vitamin D3 (cholecalciferol), 2,000 IU; vitamin E (allrac- tocopherol acetate), 18 IU; vitamin K (bisulfate menadione complex), 2 mg; riboflavin, 6.6 mg; pantothenic acid (D-calcium pantothenate), 10 mg; pyridoxine (pyridoxine HCl), 3 mg; folic acid, 1 mg; thiamin (thiamin mononitrate), 1.8 mg; vitamin B12 (cyanocobalamin), 15 μg; D-biotin, 0.1 mg; niacin, 30 mg; choline (choline chloride), 500 mg and ethoxyquin, 0.1 mg. [2]Provided the following (per kg of diet): Se (Na_2SeO_3), 0.2; I (KI), 1; Cu ($CuSO_4 .5H_2O$), 10; Fe ($FeSO_4 .7H_2O$), 50; Zn (ZnO), 85 and Mn ($MnSO_4.H_2O$), 100 mg.

Determination of water intake and litter moisture

Water intake of chicks and feed consumption were recorded at 5, 15, 25, 33 and 40 days of age in a 24 hours interval. Then water to feed ratio (W: F) was calculated from these data by days 5, 15, 25, 33, and 40 days of age. Litter moisture was measured by sampling from four point of each pen 42 days of age. The 200 g samples were taken in approximately the same place in each pen, this being a reasonable distance from feed and water to ensure non contamination with these items. These samples were weighed wet and then dried at 60°C to constant weight. Percent moisture of litter was calculated.

Table 4. Ingredient and calculated nutrient contents (%) of the experimental diets given to broiler chickens at finisher period.

	Finisher (29 to 42 days)				
Ingredient	Barley	Enzyme A	Enzyme B	Enzyme C	Corn
Barley	63.20	63.92	64	64	-
Corn	-	-	-	-	65
Soybean meal	18.28	17	20.94	23.16	19.53
Gluten meal	7.43	7.88	5.36	3.88	9.59
Soya oil	7.31	7.37	5.80	5.27	1.51
L-lysine-HCL	0.33	0.35	0.24	0.20	0.38
DL-methionine	0.14	0.14	0.14	0.17	011
Dicalcium phosphate	1.32	1.32	1.47	1.29	1.51
Limestone	1.17	1.18	1.17	1.16	1.53
Sodium chloride	0.32	0.32	0.32	0.32	0.34
Vitamin premix[1]	0.25	0.25	0.25	0.25	0.25
Mineral premix[2]	0.25	0.25	0.25	0/25	0.25
Calculated nutrient contents			Barley		Corn
AME, kcal kg^{-1}			2900		2900
Crude protein, %			21.16		21.16
Lysine, %			1.01		1.01
Methionine+cyctine, %			0.77		0.77
Crude fiber, %			4.32		1.92
Calcium, %			0.83		0.83
Available phosphorus, %			0.41		0.41
Sodium, %			0.15		0.15

[1]Provided the following (per kg of diet): vitamin A (transretinyl acetate), 9,000 IU; vitamin D3 (cholecalciferol), 2,000 IU; vitamin E (allrac- tocopherol acetate), 18 IU; vitamin K (bisulfate menadione complex), 2 mg; riboflavin, 6.6 mg; pantothenic acid (D-calcium pantothenate), 10 mg; pyridoxine (pyridoxine HCl), 3 mg; folic acid, 1 mg; thiamin (thiamin mononitrate), 1.8 mg; vitamin B12 (cyanocobalamin), 15 µg; D-biotin, 0.1 mg; niacin, 30 mg; choline (choline chloride), 500 mg and ethoxyquin, 0.1 mg. [2]Provided the following (per kg of diet): Se (Na_2SeO_3), 0.2; I (KI), 1; Cu ($CuSO_4 .5H_2O$), 10; Fe ($FeSO_4 .7H_2O$), 50; Zn (ZnO), 85 and Mn ($MnSO_4.H_2O$), 100 mg.

Determination of intestinal viscosity

0n 23 days, jejunal viscosity and pH were measured. 2 birds per pen with body weights near the mean of each pen were selected and euthanized by cervical dislocation. The jejunum was dissected aseptically, and the digesta contents were collected and pooled by replicate as described by Lazaro, Latorre, Medel, Gracia, and Mateos (2004). The digesta was homogenized, and two Eppendorf tubes were filled (1.5 g of sample) and centrifuged (12,500 × g, 3 min). The viscosity (in centipoises, cPs) of a 0.5-ml aliquot obtained from the supernatant solution was determined at 23 days of age with a digital viscometer (ModelDV-III, Brookfield Engineering Laboratories Inc., Stoughton, MA) at 25°C. Each sample was read four times and the average value was used for the statistical analysis. The pH values of the jejunal digesta were directly measured in situ using the glass electrode of a portable pH meter.

Statistical analysis

All data were analyzed as a randomized completeesign using the general linear models procedure of SAS procedure of Statistical Analysis System (SAS, 2002) and Duncan's multiple range test was used to compare treatments ($p < 0.05$).

Results and discussion

Productive performance

Mortality for all groups was within the expected range and was not related to treatment. Effect of dietary treatments on the performance of broiler chicks in all periods is shown in Table 5. Throughout the entire experiment, feed intake (FI) of broiler significantly ($p < 0.05$) increased when barley supplemented with enzyme. Body weight of broilers fed enzyme were significantly ($p < 0.05$) higher than those fed control diets at all experimental periods. Only during 0 to 11 days, birds fed corn-based diet demonstrated significant ($p < 0.05$) weight gain over those received enzymes B and C. ($p < 0.05$). There was difference among ADG of birds fed enzyme in this experiment. except from finisher period, birds fed enzyme A had the highest weight gain among enzymes at all experimental period. Enzyme addition to barley diets significantly ($p < 0.05$) improved FCR of broilers at all ages. Compared to corn diet, enzyme significantly ($p > 0.05$) decreased FCR at 11 to 28 days. But at finisher period, birds fed the diet containing enzymes A or C utilized feed more efficiently than did those fed corn or enzyme B ($p > 0.05$). In general, from 0 to 42 day of age, only birds fed diet containing enzyme A or C did not differ in feed efficiency from birds fed corn but were superior to birds fed enzyme B ($p > 0.05$).

Carcass characteristics and gastrointestinal parameters

As shown in Tables 6 and 7, significant increase in carcass weight of broiler chickens fed diet with added enzyme ($p < 0.05$) were observed. Relative weights of pancreas and relative weight and length of Duodenum, jejunum, ileum and cecum decreased with the use of matrix values for enzyme, while abdominal fat decreased ($p < 0.05$). In addition, carcass yield, relative weight of the breast, of liver and gizzard were not significantly ($p > 0.05$) affected by enzyme.

Intestinal pH and viscosity

The effect of using nutrient matrix values for enzymes on intestinal pH and viscosity at day 23 is presented in table 8. Digesta viscosity decreased with enzyme supplementation ($p < 0.05$). However, there was no difference ($p > 0.05$) in intestinal viscosity among enzyme treated groups and corn-based diet. In the case of jejunal pH, there was no difference among all treatments ($p > 0.05$).

Litter moisture and water intake

Table 8 presents data of the effects of treatments on water intake and litter moisture of broiler chickens. Enzyme addition significantly decreased water-feed ratio of the birds at 15, 25 and 33 days of age, while this effect has not been seen at day 5 and 40.

Table 5. Effect of dietary treatments on the performance of broiler chicks at all periods*.

Treatment	Starter period (0 to 10 days)			Grower period (11 to 28 days)			Finisher period (28 to 42 days)			Over all period (0 to 42 days)			Final BW
	FI	ADG	FCR	FI	ADG	FCR	FI	ADG	FCR	FI	ADG	FCR	
Barley	17.65^{c}	8.62^{d}	2.04^{a}	72.05^{d}	36.45^{d}	1.97^{a}	147.39^{b}	70.46^{c}	2.07^{c}	80.68^{d}	39.47^{d}	2.04^{a}	1657.93^{d}
Enzyme A	26.44^{a}	16.44^{a}	1.61^{d}	102.30^{a}	62.24^{a}	1.64^{c}	174.41^{a}	92.32^{a}	1.87^{a}	104.50^{a}	59.50^{a}	1.75^{c}	2499.07^{a}
Enzyme B	24.91^{b}	13.68^{c}	1.82^{b}	93.98^{b}	56.30^{b}	1.67^{c}	173.78^{a}	89.28^{a}	1.94^{b}	100.20^{b}	54.96^{b}	1.82^{b}	2308.39^{b}
Enzyme C	23.53^{b}	13.26^{c}	1.77^{bc}	97.15^{b}	57.49^{b}	1.69^{c}	165.19^{a}	91.04^{a}	1.81^{d}	99.72^{b}	56.30^{b}	1.77^{c}	2364.65^{b}
Corn	24.59^{b}	14.67^{b}	1.67^{cd}	87.51^{c}	48.90^{c}	1.79^{b}	151.12^{b}	76.78^{b}	1.96^{b}	89.83^{c}	50.37^{c}	1.78^{c}	2115.8^{c}
SEM	0.433	0.295	0.038	1.24	0.523	0.026	3.27	1.971	0.02	1.239	0.609	0.012	25.592

$^{a-d}$Means within a column without common superscripts differ significantly, $p < 0.05$. *ADG = average daily gain (g), FI = feed intake (g), FCR = feed conversion ratio.

Table 6. Effect of dietary treatments on different parts of carcass characteristics of broiler chicks at 42 day.

Treatment	Carcass weight g	Carcass Yield	Breast	Thigh	Abdominal	Liver	Gizzard	Pancreas
		g 100 g^{-1} of live body weight						
Barley	1103.06^{d}	67.62	22.55	21.41	0.98^{a}	2.28	2.061	0.30^{a}
Enzyme A	1698.08^{a}	69.74	22.67	22.07	1.79^{b}	2.19	1.87	0.25^{b}
Enzyme B	1571.63^{b}	69.16	21.97	21.87	1.47^{b}	2.20	1.85	0.26^{b}
Enzyme C	1610.89^{b}	69.81	21.46	22.21	1.72^{b}	2.18	1.91	0.26^{b}
Corn	1444.74^{c}	69.01	21.68	21.84	1.51^{b}	2.24	1.92	0.26^{b}
SEM	17.991	0.747	0.527	0.639	0.051	0.079	0.095	0.006

$^{a-c}$Means within a row without common superscripts differ significantly, $p < 0.05$.

Table 7. Effect of dietary treatments on relative weight and length of small intestine and cecum of broiler chicks at 42 day.

Treatment	Weight				Length			
	Duodenum	Jejunum	Ileum	Cecum	Duodenum	Jejunum	Ileum	Cecum
	g 100 g^{-1} of live body weight				cm 100 g^{-1} of live body weight			
Barley	0.712^{a}	1.413^{a}	1.435^{a}	0.309^{a}	1.723	4.55	4.75	1.062
Enzyme A	0.522^{b}	1.292^{b}	1.109^{b}	0.22^{b}	1.347	3.518	3.537	0.912
Enzyme B	0.516^{b}	1.11^{c}	1.088^{b}	0.208^{b}	1.03	3.318	3.364	0.829
Enzyme C	0.488^{b}	1.143^{c}	1.018^{b}	0.246^{b}	1.216	3.257	3.234	0.922
Corn	0.531^{b}	1.185^{bc}	1.021^{b}	0.224^{b}	1.366	3.633	3.521	0.952
SEM	0.027	0.039	0.072	0.019	0.028	0.094	0.119	0.042

$^{a-c}$Means within a row without common superscripts differ significantly, $p < 0.05$.

Table 8. Effect of treatments on water intake, intestinal viscosity, and litter moisture.

Item	Barley	Enzyme A	Enzyme B	Enzyme C	Corn	SEM
	Water to feed ratio, mL g^{-1}					
5 days	3.02	2.41	2.51	2.50	2.38	0.208
15 days	3.28^{a}	1.83^{c}	2.31^{bc}	2.47^{b}	2.14^{bc}	0.158
25 days	2.96^{a}	2.16^{b}	2.26^{b}	2.14^{b}	2.22^{b}	0.067
33 days	2.96^{a}	2.24^{b}	2.26^{b}	2.19^{b}	2.13^{b}	0.04
40 days	2.58	2.31	2.36	2.37	2.57	0.135
Viscosity (cps), day 23	2.36^{a}	1.73^{b}	1.72^{b}	1.78^{b}	1.98^{b}	0.068
pH, day 23	6.21	5.98	6.05	6.06	6.11	0.086
litter moisture (%), day 42	25.74^{a}	16.96^{b}	18.13^{b}	18.98^{b}	14.36^{b}	1.725

$^{a-c}$Means within a row without common superscripts differ significantly, $p < 0.05$.

Productive performance

The results of present research approve previous study showing dramatic increase in feed intake of broiler chicks fed barley-based diets when provided with dietary enzyme (Salarmoini et al, 2008; Garcia, Lazaro, Latorre, Gracia, & Mateos, 2008). The reduction of feed Intake for broiler fed barley without enzyme could be partly explained by Water-soluble β-glucan found in the barley since it causes an increase in the viscosity of the intestinal contents (Svihus, Uhlen, & Harstad, 2005). This condition reduces passage rate and the mixing of intestinal contents and will alters the transport properties of the nutrients at the mucosal surface. The positive effects of Enzyme supplementation in barley based diets on poultry growth and feed intake have been reported by many researchers (Jamroz, Jakobsen, Knudsen, Wiliczkiewicz, & Orda, 2002). In accordance to our study, Lazaro et al. (2004) observed that body weight and FCR of broiler chickens were improved when β-glucanase and xylanase was added to rye-based diets. In this study ADG was greater in barley-based diets supplemented with enzyme, probably because of an increase in FI in diets as already noted by Wang, Qiao, Lu, and Li (2005). Also, the improvement in body weight and FCR in enzyme containing diets related to enzyme breakdown physical barrier of endosperm cell wall and nutrient encapsulation resulting an increase in the availability and digestibility of fat, protein and carbohydrate (Ravindran et al., 2007).

Carcass characteristics and gastrointestinal parameters

Data of carcass characteristics are consistent with earlier studies (Biswas, Mandal, & Sarker, 1999). Heavier weight of carcass for broiler fed enzyme may be related to higher final body weight of these birds. As our result, Alam, Howlider, Pramanik, and Haque (2003) observed that there is no difference in carcass yield of bird fed diet containing enzyme or without enzyme. Similar to present study, Sieo, Abdullah, Tan, and Ho (2005) observed heavier pancreas, small intestine and longer small and cecum in birds fed barley without enzyme. In their study, supplementing diet with β-glucanase that was produced by transformed *Lactobacillus* strains significantly reduced the size of gastrointestinal tract. Viveros, Brenes, Pizzaro, and Castano (1994) observed that the viscous and fibrous grains in poultry diet would increase the relative size and length of the digestive tract. Prolonged accumulation of undigested material in the gut could cause an increase in size of gastrointestinal tract and organs as a response to intestinal motility and digestive excretions (Shakouri, Iji, Mikkelson, & Cowieson, 2009). The increase in pancreas weight for birds fed barley could be related to an increase in endogenous enzyme activities and secretion volume required to digest barley, as reported earlier by Fan, Han, Xu, Wang, & Shi (2008). The reduction in the size and weight of the intestine and pancreas is related to the decrease of digesta viscosity and rapid digestion of nutrients (Wang, Qiao, Lu, and Li, 2005). Furthermore, it has been suggested that carcass weight of birds fed enzyme increased due to reduction that occurred in size of gastrointestinal tract and organs. Increased abdominal fat weight in present study could be related to improvement in nutrient availability and potential energy of diet that occurred when enzyme added to diet. This condition may result in conversion extra energy to abdominal fat.

pH and viscosity of intestinal contents

Decreasing the viscosity of digesta in enzyme added diet has been previously reported. Gracia, Latorre, Garcia, Lazaro, and Mateos (2003) reported that addition of enzyme to barley-based diet reduced viscosity of jejunum in broilers at 4, 8, 15, and 21 days of age. Intestinal viscosity of broiler chickens fed barley-based diet was reduced by supplemented β-glucanase-producing transformed *Lactobacillus* strains (Sieo, Abdullah, Tan, & Ho, 2005). Svihus, Herstad, Newman, and Newman (1997) reported similar decrease in intestinal viscosity in whole, rolled and ground barley with added enzyme between 14 and 28 days of age. Also similar effects have been reported with heat-processing barley (Gracia et al., 2003) and with wheat grain (Gao, Jiang, Zhou, Conan, & Han, 2007). Barley, viscosity, caused by NSP soluble components., The breakdown of NSP into smaller polymers prevents them from forming viscous networks (Boguhn & Rodehutscord, 2010)., Viscosity is highly dependent on several factors, including the size of the molecule, whether it is branched or linear, and the concentration present. Enzyme supplementation reduced the size of this structure and, thus, reduced viscosity (Boguhn & Rodehutscord, 2010). Data of jejunal pH is in agreement with Hadorn and Wiedmer (2001).

Water consumption and litter moisture

Results of Water-feed ratio were supported with Shirzadi, Moravej, and Shivazad (2009), who showed that use of four enzymes decreased water intake of broilers fed barley without considering nutrient matrix value for these enzymes. In theirs experiment enzyme reduced water-feed ratio at 16, 24 and 33 days of age. Vukic-Vrajes and Wenk (1995) reported that enzyme supplementation reduced water intake from 7 to 21 d of age in chicks fed barley. In addition, enzyme reduced water intake at 21 d of age (Garcia et al., 2008). Also, Mathlouthi, Lalles, Lepercq, Juste, and Larbier (2002) reported that water-feed ratio of broiler chickens that fed rye-based diets with added enzyme was significantly lowered in comparison with birds that fed same diet without enzyme from 4 to 18 days of age similar to birds fed corn-based diet, but water intake was not affected by enzyme supplementation. Litter moisture at 42 day was significantly lower for enzyme-fed birds compared to those fed barleys without enzyme. These results are in agreement with Abdulilah (1995). It has been reported that soluble-β-glucans content of barley bind with water in the intestines, resulting in the formation of gels, which increases the viscosity of the intestinal contents (Svihus et al., 2005). Improvement in water intake and litter moisture of birds could account for decrease in viscosity of intestinal content and degrading β-glucan structure as a result of enzyme supplementation (Li, Feng, Xu, & Yang, 2004).

Conclusion

Nutrient matrix values for all enzymes improved performance and lowered water intake and litter moisture of broilers and can be used in formulating diet which is based on barley.

Although all of enzymes that used in this study had almost similar effective materials (β-glucanase and xylanase) and diets were formulated based on fix nutrients and energy requirement from birds fed enzyme, but the performance of enzyme were different in the case of overall FCR and body weight of birds.

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Received on August 12, 2016.
Accepted on October 5, 2016.