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Research Article
Effect of β-mannanase on the Performance and Digestibility of Broilers

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Abstract

Objective: This experiment was conducted to assess the use of low energy diet which contains β-mannanase (Hemicell® HT) for its ability to improve the gross energy digestibility, dry matter digestibility and broiler performance. **Methodology:** About 301 days-old hubbard broiler male chicks were procured from local hatchery and 180 chicks with mean body weight of 40±2 g were selected and randomly assigned to one of three dietary treatment consisting of Standard Ration (SR), low energy ration (LE) and low energy diet supplemented with β-mannanase (LE+E) divided into 18 experimental units of 10 birds each. **Results:** Results demonstrated that LE+E diet improved ($p<0.05$) average body weight from 14-42 days and feed conversion ratio from 1-35 days. Different treatments did not affect the feed intake and mortality of the broilers. European production index was improved in LE+E fed birds as compared to the LE. Slaughter parameters including dressing, carcass, thigh, abdominal fat and gizzard percentage were not affacted by the dietary treatments. However, breast meat percentage was higher in SR fed broilers. The dietary treatments did not affect dry matter and gross energy digestibility of broiler. **Conclusion:** The study was completed, concluding that β-mannanase supplementation in low energy diet had beneficial effect on the body weight, feed conversion ratio, European production index and had no effect on the dry matter and gross energy digestibility.

Key words: Broiler, β-mannanase, growth performance, carcass characteristics, digestibility

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

In modern poultry production, feed has prime importance for nutritionists as it has 70% share of total production cost[1]. More than 80% of the feed is blend of ingredients from the plant source[2]. These cereals contain non starch polysaccharides (NSPs) in their cell wall such as cellulose, hemicellulose, pentosans and oligosaccharides which are poorly digested in poultry[3]. The NSPs are high molecular weight complex sugars present in the cell walls of cereal grains[4,5]. Cereals have variable quantities of NSPs. Soybean meal and corn, for example, contain 29 and 9% NSPs, respectively[6].

The β-mannans are NSPs present in plant cell wall in the form of glucomannan, galactomannan, glucogalactomannan and glucurono-mannans[7]. The β-mannans have ability to bind water molecules in large quantity which ultimately results in increased digesta viscosity. This higher viscosity of digesta causes a reduction in the diffusion of digestive enzymes and stimulates prolife diet of bacteria inside the gastrointestinal tract[5,2]. Higher digesta viscosity also results in poor enzyme substrate interaction and thus reduces nutrient availability to the birds. The NSPs are not digested by the endogenous enzymes of the bird's intestinal tract[8,5]. The presence of β-mannans in the feed reduces metabolizable energy and nitrogen retention and increases fecal output of birds[9]. In poultry nutrition, early study trials conducted on exogenous enzymes focused on NSPs degrading enzymes, specifically β-glucanase and xylanase, in wheat, barley and rye containing diets[10]. Now a days, exogenous enzymes supplementation in poultry diets is a universal strategy to improve nutrient utilization, body weight uniformity, growth performance and thus reduced feed cost[11]. Exogenous enzyme is likely to supplement the digestive capacity of younger birds[11] and can also compensate negative effect of feeding low energy diets[12]. Dietary β-mannanase supplementation improves efficiency of feed utilization by reducing the fecal output and improves nutrient absorption in the gut and improves feed conversion, weight gain and body weight uniformity in birds[13,14]. The mode of action of β-mannanase is hydrolyzing β-1,4-glycosidic linkages in β-mannans[15]. The β-mannanase splits randomly inside the 1,4-β-D-mannan key chains of mannan, galactoglucomannan and galactomannan[16]. Hemicell® is a fermentation product of *Bacillus lentus*, its active part is β-mannanase, which hydrolyzes β-mannan[17]. So, this study was planned to investigate the effects of Hemicell® HT as carbohydrase on growth performance, digestibility and carcass characteristics of broilers up to 42 days of age.

MATERIALS AND METHODS

Experimental design and housing: All experimental procedures were approved by the Animal Husbandry Committee of University of Agriculture, Faisalabad. About 301 days old hubbard male broiler chicks were procured from Sadiq Brother's hatchery and reared at their Research and Development Center, Islamabad. About 180 chicks with mean body weight of 40±2 g were selected and randomly divided into three treatment groups of 60 birds in each. Each treatment group was further divided into 6 replicates of 10 birds each. The shed was thoroughly cleaned and disinfected with phenol and then by formalin solution 2 weeks prior to the arrival of chicks. The temperature was maintained at 32.2-35°C for 1st week and then lowered by 2.8°C each week till it reached 23.9±2.8°C in 5th week, the same temperature was maintained in the 6th week. Lighting hours were 23, 18, 16, 18 and 22 h from day 1-4, 5-9, 10-19, 20-29 and 30-42, respectively. The birds were vaccinated against various viral diseases like Newcastle Disease (ND) and Infectious Bursal Disease (IBD). Fresh water and feed were offered *ad libitum* during the whole life of birds. The trial lasted for 42 days.

Experimental diets: The three iso-nitrogenous diets were formulated to contain CP 19% and ME 2750 kcal kg^{-1} standard diet (SR), 2660 kcal kg^{-1} low energy diet (LE) and LE supplemented with 0.03% of Hemicell® HT (LE+E), respectively (Table 1). The SR and LE diets served as positive and negative controls, respectively. Diets were pelleted at SB Feed's Research and Development Center. Dry Matter (DM), crude protein, crude fiber, ether extract, ash and nitrogen free extract of experimental diets were determined using proximate analysis methods described in Cunniff[18].

Data recording and measurements: Body weight and feed intake of chicks were recorded at the end of every week from each replicate to calculate Feed Conversion Ratio (FCR) and European Production Index (EPI) calculated as:

$$EPI = \frac{\text{Daily weight gain (g)} \times \text{percentage livability}}{\text{Age in days} \times \text{FCR}} \times 100$$

Data on mortality was recorded from each replicate throughout the experiment. At the age of 42 days, six birds from each treatment were selected randomly and slaughtered to obtain data on carcass characteristics like dressed weight, breast meat weight, thigh meat weight and organs weight.

Table 1: Ingredients and composition of experimental diets

	Experimental diets		
Ingredients (%)	SR*	LE**	LE+E***
Maize	55.9	52.1	52.1
Soybean meal	17.5	17.5	17.5
Rice polishing	10.0	10.0	10.0
Canola meal	5.7	4.2	4.2
Sunflower meal	5.2	8.0	8.0
Rapeseed meal	2.0	2.0	2.0
Wheat bran	0.0	2.3	2.2
Limestone (ground)	1.2	1.4	1.4
Mono di-ca phosphate	1.1	1.1	1.1
Lysine sulphate	0.4	0.4	0.4
Vitamin and mineral premix#	0.3	0.3	0.3
Salt (NaCl)	0.3	0.3	0.3
DL-methionine	0.2	0.2	0.2
Sodium-bi-carbonate	0.1	0.1	0.1
L-threonine	0.039	0.035	0.035
Phyzyme	0.005	0.005	0.005
Hemicell® HT##	0.000	0.000	0.030
Calculated chemical composition			
Crude protein	19.0	19.2	19.2
Metabolizable energy (kcal kg^{-1})	2750	2660	2660
Crude fiber	5.8	6.6	6.6
Lysine	1.14	1.14	1.14
Methionine	0.50	0.51	0.51
Calcium	0.85	0.90	0.90
Available phosphorus	0.38	0.38	0.38
Analyzed values			
Dry matter	91.4	91.4	91.4
Crude protein	18.8	19.0	19.0
Gross energy (kcal kg^{-1})	3942	3866	3866
Ether extract	3.8	4.2	3.8
Crude fiber	7.0	6.6	6.7
Ash	6.8	6.6	6.6

*SR: Standard diet (positive control) having (2750 kcal kg^{-1}), **LE: Low energy diet (negative control) having (2660 kcal kg^{-1}), ***LE+E: Low energy diet+enzyme (Hemicell® HT) having (2660 kcal kg^{-1}), #Vitamin and mineral premix: Consists of vitamin A: 10 mg, vitamin E: 50 mg, vitamin K: 3 3.6 mg, vitamin B1: 1.7 mg, vitamin B2: 10 mg, vitamin B3: 35 mg, vitamin B5: 11.1 mg, vitamin B6: 3.1 mg, vitamin B9: 1.1 mg, vitamin B12: 1.2 mg, vitamin H: 5 mg and carrier, ##Hemicell® HT: Light brown powder form product of ChemGen: Corp. USA. It contains β-mannanase (EC 3.2.1.78) from *Bacillus lentus* 160,000,000 U kg^{-1}, minimum

The digestibility trial was performed using total collection method at 36th day. Fecal samples were collected from 30 (3 replicates) birds of each treatment. Birds were placed on polythene sheets for collection of fecal samples. The samples of each replicate were composited over 2 days. All the samples were placed in hot air oven at 60°C for drying until constant weight attained. Dry matter and GE of feces were determined using proximate analysis methods described in Cunniff[18]. The Gross Energy (GE) of the feed and fecal samples was measured with the help of CAL2k bomb calorimeter.

Digestibility was calculated using the following formula:

$$\text{Digestibility (\%)} = \frac{\text{Nutrient intake} - \text{Nutrient outgo}}{\text{Nutrient intake}} \times 100$$

Statistical analysis: Data of this experiment were analyzed by two way analysis of variance for completely randomized design and differences among treatments were compared using Duncan's multiple range tests. Probabilities having the value less than 0.05 ($p<0.05$) were considered significant.

RESULTS

Broiler performance: The effects of dietary treatments on the body weight, feed intake, mortality, mortality corrected FCR and EPI are shown in Table 2. Average body weight at day 14, 21, 28, 35, 42 was greater ($p \leq 0.05$) for broilers fed LE+E diet compared to LE. Body weight of the birds fed SR was higher than the LE fed birds at 28th day. Dietary treatments had no effect on the feed intake of the broilers. Feed conversion ratio of the broilers fed diet LE+E was significantly lower than the LE fed birds at day 14, 21, 28 and 35. Contrary to this, mortality corrected FCR was similar ($p>0.05$) in birds fed SR, LE and LE+E diets at 42 day. However, FCR tended to be better in diets supplemented with Hemicell® HT, than SR and LE diets. Mortality percentage was similar ($p>0.05$) in birds fed SR, LE and LE+E diets. However, it tended to be higher in birds fed SR diet followed by birds fed LE+E and LE diet. Mortality of the broilers was not significantly different among the dietary treatments. European production index was significantly affected by the treatments. It was higher ($p>0.05$) for the LE+E fed birds as compared to LE fed.

Carcass characteristics: Effect of the feeding of the SR, LE and LE+E on the carcass characteristics including dressing percentage, carcass percentage breast, thigh, abdominal fat, liver and gizzard are summarized in the Table 3. Dietary rations did not affect the dressing, carcass, thigh, abdominal fat and gizzard percentage of broilers. There was significant effect on the breast meat percentage by the dietary treatments and it was maximum for the SR group followed by the on the LE and LE+E.

Digestibility: Dry matter digestibility was similar ($p>0.05$) in birds fed SR, LE and LE+E diets. However, it tended to be higher in birds fed SR diet than those offered LE+E and LE diet (Table 4). Gross energy digestibility was similar ($p>0.05$) in birds fed SR, LE or LE+E diets. However, GE digestibility tended to be higher in birds fed SR diet followed by birds offered LE+E and LE diet (Table 4).

Table 2: Effect of β-mannanase on performance of broilers

Treatments	SR*	LE**	LE+E***	p-value	PSEM
Body weight (kg)					
14 days	0.40^{ab}	0.39^{b}	0.42^{a}	0.06	0.00
21 days	0.78^{ab}	0.73^{b}	0.80^{a}	0.03	0.01
28 days	1.28^{a}	1.17^{b}	1.32^{a}	0.01	0.02
35 days	1.71^{ab}	1.62^{b}	1.81^{a}	0.01	0.03
42 days	2.11^{ab}	1.98^{b}	2.21^{a}	0.03	0.04
Average feed intake per chick					
14 days	0.52	0.51	0.53	0.81	0.05
21 days	1.19	1.22	1.23	0.63	0.02
28 days	2.15	2.15	2.24	0.40	0.03
35 days	3.30	3.29	3.46	0.08	0.04
42 days	4.63	4.53	4.78	0.20	0.06
Mortality	8.33	6.66	3.33	0.61	2.00
Mortality-corrected feed conversion ratio					
1-14 days	1.27	1.29	1.27	0.85	0.02
1-21 days	1.51^{b}	1.64^{a}	1.55^{ab}	0.04	0.02
1-28 days	1.66^{b}	1.82^{a}	1.71^{b}	0.00	0.02
1-35 days	1.88^{b}	2.00^{a}	1.90^{b}	0.02	0.02
1-42 days	2.12	2.26	2.13	0.10	0.03
European production index					
	221.87^{ab}	202.86^{b}	236.44^{a}	0.02	5.28

^{a,b,c}Column means with different superscripts differ significantly at p<0.05, *SR: Standard diet (positive control) having (2750 kcal kg^{-1}), **LE: Low energy diet (negative control) having (2660 kcal kg^{-1}), ***LE+E: Low energy diet+enzyme (Hemicell® HT) having (2660 kcal kg^{-1}), PSEM: Pooled standard error of mean

Table 3: Effect of the β-mannanase on carcass characteristics of broilers

Treatments	SR*	LE**	LE+E***	p-value	PSEM
Live weight	2175^{b}	2066^{c}	2283^{a}	0.00	28.65
Dressing (%)	62.93	62.29	62.73	0.91	0.59
Carcass (%)	59.02	58.41	58.75	0.93	0.62
Breast (%)	24.03^{a}	22.11^{b}	21.79^{b}	0.05	0.41
Thigh (%)	4.15	3.96	4.33	0.15	0.08
Abdominal fat (%)	2.09	1.88	2.06	0.66	0.09
Liver (%)	2.34	2.21	2.41	0.40	0.06
Gizzard (%)	1.05	1.15	1.07	0.55	0.04

^{a,b,c}Column means with different superscripts differ significantly at p<0.05, *SR: Standard diet (positive control) having (2750 kcal kg^{-1}), **LE: Low energy diet (negative control) having (2660 kcal kg^{-1}), ***LE+E: Low energy diet+enzyme (Hemicell® HT) having (2660 kcal kg^{-1}), PSEM: Pooled standard error of mean

Table 4: Effect of the β-mannanase on dry matter and gross energy digestibility of broilers

Treatments	SR*	LE**	LE+E***	p-value	PSEM
Dry matter digestibility (%)	73.85	68.17	73.04	0.28	1.51
Gross energy digestibility (%)	76.37	71.78	75.04	0.25	1.13

*SR: Standard diet (positive control) having (2750 kcal kg^{-1}), **LE: Low energy diet (negative control) having (2660 kcal kg^{-1}), ***LE+E: Low energy diet+enzyme (Hemicell® HT) having (2660 kcal kg^{-1}), PSEM: Pooled standard error of mean

DISCUSSION

The results are consistent with the findings of Daskiran *et al.*[13] who reported that commercially available endo-β-D-mannanase (Hemicell®) supplementation with different fractions of guar meal in broiler diets improved body weight of the broiler chickens. Supplementation of the β-mannanase in corn-soybean meal based diet improved body weight gain in broilers[14,17]. The better performance may be associated with more energy availability by the enzyme, since it reduces intestinal viscosity by acting on the NSP's, allowing for better nutrient absorption, consequently favoring higher weight gain. On the other hand these results are contraditory to many findings[13,19-21] which indicates β-mannanase supplementation has no negative effect on body weight gain of broiler chickens.

Feed intake of the broiler in current study was not affected by the dietary treatments. Similar results of no effect have been reproted in multiple publications[21,22]. However, Lee *et al.*[9] reported that supplementation of β-mannanase with different fractions of guar meal in broiler diets resulted in higher feed intake as compared to birds fed un-supplemented guar meal-based diets.

Addition of β-mannanase in low energy ration significantly improved the FCR early in the trial upto 35 days but this effect was not significant at 42 days. These results were in agreement with the findings of Zou *et al.*[17] and Latham *et al.*[23], who reported that higher level of hemicell in broiler diets resulted in improved FCR in broilers during the early growth of broilers. But contrary to this, Mussini *et al.*[21] reported that using different levels of commercially available β-mannanase had no affect on FCR.

Carcass percentage and abdominal fat content was similar (p>0.05) in birds fed SR, LE or LE+E diet. Similarly, there was no difference in thigh weight percentage and gizzard and heart weights in birds fed SR, LE or LE+E diet. The results are analogous to the findings of Mathlouthi *et al.*[24] who reported that carcass yield, abdominal fat, gizzard, proventriculus, heart and liver weights were not affected by the addition of β-glucanase in broiler feed. Cho *et al.*[25] reported that weight of the breast meat, liver; gizzard and abdominal fat were not affected by multi-enzymes mixture supplementation. But contrary to the Cho *et al.*[25] this study indicated significant effect on the breast meat percentage that may be due to the fact that breast muscle fibers are different than the other muscles[26]. However, Mushtaq *et al.*[27] reported that enzyme supplemented broiler diets depressed breast weight in broilers.

Authors observed non-significant effect of beta mannanase on the DM and GE digestibility of the broilers. In agreement with our results, previous studies also reported that beta mannanase supplementation had no effect on digestibility[23,28]. Contrary to the current findings other researchers[20,29,30] reported that supplementation of enzyme in low energy diets improved energy utilization in broiler chickens than control diet.

CONCLUSION

This study clearly demonstrated that reduction in the dietary energy negatively affected broiler performance and β-mannanase supplemented low energy diet improved the weight gain and FCR of broilers. However, there was no significant effect of β-mannanase on the carcass percentage, DM and GE digestibility in broilers. Therefore, β-mannanase supplementation should be considered when low energy diets are formulated.

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REFERENCES

1. Haitook, T., 2006. Study on Chicken Meat Production for Small-Scale Farmers in Northeast Thailand. Kassel University Press, Kassel, Germany, ISBN-13: 9783899582383 Pages: 164.
2. De Barros, V.R.S.M., G.R.Q. Lana, S.R.V. Lana, A.M.Q. Lana, F.S.A. Cunha and J.V.E. Neto, 2015. β-mannanase and mannan oligosaccharides in broiler chicken feed. Ciencia Rural, 45: 111-117.
3. Choct, M., R.J. Hughes, J. Wang, M.R. Bedford, A.J. Morgan and G. Annison, 1996. Increased small intestinal fermentation is partly responsible for the anti-nutritive activity of non-starch polysaccharides in chickens. Br. Poult. Sci., 37: 609-621.
4. Annison, G. and M. Choct, 1991. Anti-nutritive activities of cereal non-starch polysaccharides in broiler diets and strategies minimizing their effects. World's Poult. Sci. J., 47: 232-242.
5. Bedford, M.R. and H. Schulze, 1998. Exogenous enzymes for pigs and poultry. Nutr. Res. Rev., 11: 91-114.
6. Malathi, V. and G. Devegowda, 2001. *In vitro* evaluation of nonstarch polysaccharide digestibility of feed ingredients by enzymes. Poult. Sci., 80: 302-305.
7. Aman, P. and H. Graham, 1990. Chemical Evaluation of Polysaccharides in Animal Feeds. In: Feedstuff Evaluation, Wiseman, J. and D.J.A. Cole (Eds.). Chapter 9 but terworths, London, UK., ISBN-13: 9780408049719, pp: 161-177.
8. Graham, K.K., M.S. Kerley, J.D. Firman and G.L. Allee, 2002. The effect of enzyme treatment of soybean meal on oligosaccharide disappearance and chick growth performance. Poult. Sci., 81: 1014-1019.
9. Lee, J.T., C.A. Bailey and A.L. Cartwright, 2003. β-mannanase ameliorates viscosity-associated depression of growth in broiler chickens fed guar germ and hull fractions. Poult. Sci., 82: 1925-1931.
10. Choct, M., 2006. Enzymes for the feed industry: Past, present and future. World's Poult. Sci. J., 62: 5-16.
11. Bedford, M.R., 2000. Exogenous enzymes in monogastric nutrition-their current value and future benefits. Anim. Feed Sci. Technol., 86: 1-13.
12. Rabie, M.H., F.S.A. Ismail and S.K. Sherif, 2010. Effect of dietary energy level with probiotic and enzyme addition on performance, nutrient digestibility and carcass traits of broilers. Egypt. Poult. Sci. J., 30: 179-201.
13. Daskiran, M., R.G. Teeter, D. Fodge and H.Y. Hsiao, 2004. An evaluation of endo-β-D-mannanase (Hemicell) effects on broiler performance and energy use in diets varying in β-mannan content. Poult. Sci., 83: 662-668.
14. Jackson, M.E., D.M. Anderson, H.Y. Hsiao, F.L. Jin and G.F. Mathis, 2005. Effect of β-mannanase (Hemicell®) on performance and body weight uniformity in broiler chickens provided with corn-soybean meal diets and economic ramifi cations. Poult. Sci., 84 (Suppl. 1): 82-83.
15. Ooi, T. and D. Kikuchi, 1995. Purification and some properties of β-mannanase from *Bacillus* sp. World J. Microbiol. Biotechnol., 11: 310-314.
16. McCleary, B.V., 1986. Enzymatic modification of plant polysaccharides. Int. J. Biol. Macromol., 8: 349-354.
17. Zou, X.T., X.J. Qiao and Z.R. Xu, 2006. Effect of β-mannanase (hemicell) on growth performance and immunity of broilers. Poult. Sci., 85: 2176-2179.
18. Cunniff, P.A., 2000. Official Methods of Analysis of AOAC International. 17th Edn., Vol. 1-2, AOAC International, Arlington, VA., USA., ISBN-13: 978-0935584547, Pages: 1200.
19. Vahjen, W., T. Busch and O. Simon, 2005. Study on the use of soya bean polysaccharide degrading enzymes in broiler nutrition. Anim. Feed Sci. Technol., 120: 259-276.
20. Kong, C., J.H. Lee and O. Adeola, 2011. Supplementation of β-mannanase to starter and grower diets for broilers. Can. J. Anim. Sci., 91: 389-397.
21. Mussini, F.J., C.A. Coto, S.D. Goodgame, C. Lu, A.J. Karimi, J.H. Lee and P.W. Waldroup, 2011. Effect of β-mannanase on broiler performance and dry matter output using corn-soybean meal based diets. Int. J. Poult. Sci., 10: 778-781.
22. Silversides, F.G. and M.R. Bedford, 1999. Effect of pelleting temperature on the recovery and efficacy of a xylanase enzyme in wheat-based diets. Poult. Sci., 78: 1184-1190.
23. Latham, R.E., M. Williams, K. Smith, K. Stringfellow, S. Clemente, R. Brister and J.T. Lee, 2016. Effect of β-mannanase inclusion on growth performance, ileal digestible energy and intestinal viscosity of male broilers fed a reduced-energy diet. J. Applied Poult. Res., 25: 40-47.
24. Mathlouthi, N., N. Ballet and M. Larbie, 2011. Influence of β-glucanase supplementation on growth performances and digestive organs weights of broiler chickens fed corn, wheat and barley-based diet. Int. J. Poult. Sci., 10: 157-159.

25. Cho, J.H., P.Y. Zhao and I.H. Kim, 2012. Effects of emulsifier and multi-enzyme in different energy densitydiet on growth performance, blood profiles and relative organ weight in broiler chickens. J. Agric. Sci. 4: 161-168.
26. Ibuki, M., Y. Yoshimoto, H. Yamasaki, K. Honda and K. Fukui *et al*., 2013. Effect of dietary β-1,4-mannobiose on the growth of growing broiler chicks. J. Poult. Sci., 50: 120-125.
27. Mushtaq, T., M. Sarwar, G. Ahmad, M.A. Mirza, H. Nawaz, M.M.H. Mushtaq and U. Noreen, 2007. Influence of canola meal-based diets supplemented with exogenous enzyme and digestible lysine on performance, digestibility, carcass and immunity responses of broiler chickens. Poult. Sci., 86: 2144-2151.
28. Omojola, A.B. and A.O.K. Adesehinwa, 2007. Performance and carcass characteristics of broiler chickens fed diets supplemented with graded levels of roxazyme G®. Int. J. Poult. Sci., 6: 335-339.
29. Zhou, Y., Z. Jiang, D. Lv and T. Wang, 2009. Improved energy-utilizing efficiency by enzyme preparation supplement in broiler diets with different metabolizable energy levels. Poult. Sci., 88: 316-322.
30. Cho, J.H. and I.H. Kim, 2013. Effects of β-mannanase supplementation in combination with low and high energy dense diets for growing and finishing broilers. Livestock Sci., 154: 137-143.