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Research Article
Potential Application of Guar Meal in Broiler Diet

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Abstract

Objective: Guar Meal (GM) is the main by-product of guar gum production with a high protein content. The high amino acid content of the guar meal make it a useful protein supplement for broilers and layers. **Methodology:** This study was conducted to evaluate the effects of feeding 2 levels of guar meal (7.5 and 10% of the diet) with or without two types of enzymes supplementation (Hemicelle and Avimex 200 g t^{-1} on growth performance, immunity, nutrients digestibility, carcass traits and blood biochemistry of broilers chickens. A total of 210 (Cobb) day old chicks were randomly allotted into 7 treatments, each treatment comprised 3 replicates with 10 birds each. **Results:** The results indicated significant positive effects of enzymes on body weight gain and feed conversion ratio, which was clear in groups fed on GM at level 7.5% with either hemicelle or Avimex. No significant differences were recorded in serum total protein, albumin and total cholesterol however, birds in groups of 10% GM revealed higher triglycerides and lower glucose level when compared with control. Moreover, enzyme supplementation resulted in significant higher serum High Density Lipoprotein (HDL) and dressing percentage. All treatments were increased in relative liver and gizzard weight and decreased in abdominal fat compared to control. Inclusion of GM in broiler diet decreased serum antibody titer at 21 and 42 day of age compared to control but enzyme supplementation significantly alleviate this bad effect. Lower nutrients digestibility due to GM was noticed but both two enzymes supplementation significantly improved it at 7.5% GM but at level 10%, only Avimex was more valuable. **Conclusion:** It was concluded that broiler diet containing GM at a level of 7.5 and 10% should be supplemented with carbohydrase enzymes, such as hemicelle and Avimex.

Key words: Guar meal, enzymes, broiler, performance, hemicelle

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

INTRODUCTION

Nowadays using unconventional feeds in poultry diets to replace some of the expensive feed ingredients is the most important interest for the nutritionist to reduce production cost. Guar meal is a cheap and high protein meal produced from guar gum. It contains crude protein from 36-60% depending on type of fraction included in the meal[1]. Hassan *et al.*[2] suggested that the whole ground guar bean is an economic feed for broilers and reduce production cost provided it is available at economic price.

Guar meal contains chemical compounds called saponins. Saponins are presently used for antibacterial, antiprotozoal and antifungal activities[3]. The nutritional value of plant protein sources depends on the extent, to which nutrients are digested and absorbed in the body. Defeciency of digestive enzymes in and presence of antinutritional factors are preventing the digestion, absorption and utilization of nutrients[4,5]. Although, guar meal may be used as a source of proteins in poultry diets but it lead to adverse affects on growth performances when fed at high concentrations[6].

Guar gum residue in guar meal could be the cause of negative effects in poultry as severe growth depression, pasty vents and sticky feces, which is due to it increasing intestinal viscosity and decreasing the nutrient absorption in the gastrointestinal tract[7,8]. Increasing intestinal viscosity also decreases nutrients digestibility and enzyme activity in the small intestine[9]. Turki *et al.*[10] reported negative effect of guar germ at levels above 5% in broiler diet.

Supplementation of enzymes to the poultry diets containing guar meal was a favorable way to reduce guar gum effects. Enzymes destroy the antinutritional compounds present in feed, which may include single compound or class of compounds[4,11,12]. Mohayayee and Karimi[13] found that optimal levels of guar meal are (6, 9 and 12%) when supplemented with β-mannanase without any adverse effects on growth performance and blood parameters of broiler chickens.

The aim of this study was to examine the effect of diet containing guar meal supplemented by two types of enzymes on performance, immunity, digestibility, carcass traits and blood biochemistry of broilers.

MATERIALS AND METHODS

Birds and experimental design: The experiment was carried out under the protocol approved by the Faculty of Veterinary Medicine, Sadat City University, Egypt. A total of 210 one-day-old cobb broiler chicks of mixed sex were used in this experiment. They were obtained from a local Egyptian private hatchery. The broiler chicks were randomly allotted into 7 treatments, each treatment comprised 3 replicates with 10 birds each. The enzymes used in this study are single enzyme hemicelle produced by fermentation of *Bacillus lentus* bacteria. The active ingredient is Endo-1,4-β-D-mannanase produced by Elanco Animal Health, Multienzyme Avemix commercial cocktail enzyme containing mannanase, β-xylanase, β-glucanase, pectinase and cellulase) produce by Biochem.

The birds were fed starter mash diets until 21 days of age and followed by a grower diet from 22-42 days of age. Diets were formulated to meet NRC recommendations[14]. Table 1 presents the ingredients and the composition of the basal diets, which were in mash form. Proximate analysis, which was conducted according to AOAC[15], showed no major deviation from calculated values. The used guar meal contained 2652 kcal kg^{-1} ME, 45% crude protein, 0.7% calcium, 0.75% available phosphorus, 1.8% lysine and 0.45% methionine. Seven isocalaric and isonitrogenous diets were prepared. The effects of guar meal and enzyme levels were studied with a 2×3 factorial arrangement for 2 GM levels (7.5 and 10) with or without enzymes (0, hemicelle and Avemix). The 7 treatment diets were (1) Basal diet (CON), (2) 7.5% GM diet with 0 enzyme (T1), (3) 7.5% GM diet with 200 g t^{-1} of hemicelle (T2), (4) 7.5% GM diet with 200 g t^{-1} Avemix (T3), (5) 10% GM diet with 0 enzyme (T4), (6) 10% GM diet with 200 g t^{-1} hemicelle (T5) and (7) 10% GM diet with 200 g t^{-1} of Avemix (T6). All birds were reared in the floor pens using wood shavings as litter. Temperature was adjusted at 32°C±2 in the 1st week then lowered 2°C each successive week and then maintained at 28°C±2. Relative humidity was about 60-80%. Chicks were kept on a 23 h light program. Birds were vaccinated against Newcastle Disease (ND) and the most common viral diseases, which infect broiler chicks. Access to feed (mash form) and water was provided on an *ad libitum* basis.

Chicken performance measurements: Body Weight (BW) and feed intake were monitored on a pen basis weekly, while Body Weight Gain (BWG) and Feed Conversion Ratio (FCR) values were consequently calculated. Mortality was also recorded on a daily basis in each pen. Chickens were killed by cervical dislocation at the end of the trial. Six birds per treatment group (2/replicate) were randomly selected for tissue sampling and for determining carcass yield. They were defeathered, eviscerated and dressed. Abdominal fat, tissues of liver, gizzard, heart, spleen, thigh and breast meat were collected by removing skin and connective tissue.

Table 1: Ingredients and nutrient composition (DM%) of broiler starter and finisher rations

	Feed types					
	Starter diet (guar inclusion)			Grower diet (guar inclusion)		
Ingredients	0.0	7.5%	10	0.0	7.5%	10
Yellow corn grain	54.00	54.50%	54.55	63.40	64.19	64.6
Soybean meal	31.08	23.72%	21.19	24.50	16.80	14.10
Corn gluten	7.20	7.10%	7.20	6.00	6.00	6.00
Vegetable oil	3.97	3.43%	3.30	2.65	2.07	1.85
Guar meal	0	7.5	10	0	7.50	10
MCP[1]	1.44	1.43%	1.45	1.27	1.25%	1.27%
Limestone[2]	1.40	1.64%	1.60	1.60	1.52%	1.48%
Lysine[3]	0.10	0.16%	0.19	0.11	0.18%	0.21%
DL-methionine[4]	0.05	0.07%	0.07	0.02	0.04%	0.04%
Salt	0.20	0.2	0.2	0.20	0.2	0.2
Premix[5]	0.25	0.25	0.25	0.25	0.25	0.25
Total	100	100	100	100	100	100
Analysis and calculated nutrient						
ME (kcal kg^{-1})	3119.3	3119.5	3123	3127	3129.2	3129.6
Crude protein	22.7	22.8	22.9	20	19.9	19.9
Calcium	0.98	0.98	0.98	0.9	0.9	0.9
Available phosphorus	0.45	0.45	0.45	0.4	0.4	0.4
Methionine	0.45	0.45	0.45	0.38	0.38	0.38
Lysine	1.15	1.15	1.16	1	1	1

[1]MCP: Monoicalcium phosphate (contain 22% P and 21% Ca), [2]Limestone: Contain 34% calcium, [3]Lysine: Lysine hydrochloride (contain 98.5% lysine), [4]DL-methionine: Produced by Evonic Co and contain 99.5% methionine, [5]The premix used was pharama mix produced by (Egypt pharma for premix and feed additives industries) and composed of (per 3 kg) vitamin A: 12000000 IU, vitamin D3: 5000000 IU, vitamin E: 65000 mg, vitamin K3: 4000 mg, thiamin 4000 mg, riboflavin 9000 mg, pyridoxine 5000 mg, cyanocobalamine 20 mg, niacin 55000 mg, biotin 200 mg, folic acid 2000 mg, pantothenic acid 15000 mg, betain 400000 mg, manganese 60000 mg, zinc 1000000 mg, iron 40000 mg, copper 16000 mg, iodine 1250 mg, selenium 100 mg and cobalt 100 mg (batch NO 07834527)

Blood sampling and analysis: At 21 and 42 days of age, 6 birds from each treatment (2/replicate) were randomly selected for blood analysis. Blood samples were obtained from wing vein and directly aliquoted into 2 mL sterile vials and allowed to clot for 4 h. After centrifugation (20 min, 1500 rpm), the serum was aliquoted into 1 mL vials and stored at -20°C for serum antibody measurements using haemagglutination inhibition test as described[16]. The serum samples at 42 days of age were also used for total serum protein, albumin, concentrations, serum glucose, cholesterol and triglyceride, High Density Lipoprotein (HDL), Low Density Lipoprotein (LDL) and Very Low Density Lipoprotein (VLDL) using commercially available kits (Biosystem S.A, Costa Brava, 30, Barcelona, Spain) according to manufacturer's instructions.

Nutrient digestibility: In order to determine dietary nutrient digestibility, excreta samples were collected every 12 h for 3 consecutive days after 40 days. Excreta were placed in plastic bags and stored at -20°C. At the end of the collection period, excreta samples were thawed, homogenized and pre-dried in a forced ventilation oven at 55°C for 72 h, after which they were ground for subsequent analyses. Dry Matter (DM), Organic Matter (OM) and Crude Protein (CP) contents were determined according to the methodology recommended by the AOAC[15] and the coefficients of digestibility were calculated according to the method proposed by Matterson *et al.*[17].

Statistical analysis: Data obtained in this study were statistically analyzed for variance (ANOVA) with confidence limits set as 95% (significance at p<0.05 probability level) described by Duncan. The results were reported as Mean±Standard Error (SE), multiple range tests should be performed to compare among different groups or different weeks of experiment. Statistical analysis were performed using SPSS student version 16.00, June, 2000.

RESULTS AND DISCUSSION

Growth performance: The results of replacing SBM with different levels of guar meal (0, 7.5 and 10%) with or without enzyme supplementation on growth performance parameters illustrated in Table 2. There were no significant differences in initial body weight. During starter period, there were significant differences in body weight and body weight gain (p<0.05) in different treatments when compared with the control one. Guar contained groups (T1, T4 and T5) showed the lowest body weight and body weight gain. Concerning

Table 2: Body Weight (BW), Body Weight Gain (BWG), Feed Intake (FI) and Feed Conversion Ratio (FCR) values of broiler chickens in response to diet and age

	Treatments						
Age	CON	T1	T2	T3	T4	T5	T6
Initial weight	51.20±0.21[a]	51.18±0.22[a]	51.15±0.22[a]	51.18±0.24[a]	51.16±0.18[a]	51.15±0.20[a]	51.05±0.28[a]
0-21 (days)							
BW (g)	1090.20±18.52[a]	876.90±17.91[cd]	979.65±25.96[b]	953.20±26.96[bc]	817.35±39.13[d]	876.45±25.70[cd]	998.35±27.59[b]
BWG (g)	1038.95±18.35[a]	825.65±17.75[cd]	928.40±25.79[b]	901.95±26.78[bc]	766.10±38.96[d]	825.20±25.54[cd]	947.10±27.44[b]
FI (g)	1224.80±1.95[b]	1175.20±2.69[d]	1175.60±2.69[d]	1228.10±1.31[b]	1213.15±1.40[c]	1135.95±1.24[e]	1251.55±2.2[a]
FCR	1.19±0.02[c]	1.44±0.03[b]	1.29±0.04[bc]	1.39±0.05[b]	1.69±0.11[a]	1.40±0.05[b]	1.34±0.04[bc]
22-42 (days)							
BW (g)	2325.60±63.93[a]	1936.30±34.05[c]	2207.50±80.44[ab]	2173.30±77.39[ab]	2060.90±69.22[bc]	2053.00±50.30[bc]	2036.45±63.91[bc]
BWG (g)	1235.40±45.91[a]	1059.40±17.88[b]	1227.85±55.52[a]	1220.10±51.39[a]	1243.55±32.58[a]	1176.55±26.09[a]	1038.10±38.53[b]
FI, (g)	3175.27±1.89[c]	3226.13±2.71[a]	2953.90±2.68[f]	3059.49±1.35[e]	3128.30±5.52[d]	3195.19±1.32[b]	3134.67±2.20[d]
FCR	2.65±0.11[b]	3.06±0.05[a]	2.51±0.13[b]	2.60±0.11[b]	2.55±0.07[b]	2.74±0.07[b]	3.10±0.11[a]
0-42 (days)							
BWG (g)	2274.35±63.75[a]	1885.05±33.90[c]	2156.25±80.27[ab]	2122.05±77.22[ab]	2009.65±69.05[bc]	2001.75±50.13[bc]	1985.20±63.77[bc]
FI (g)	4400.07±0.21[a]	4401.33±0.16[a]	4129.50±0.18[f]	4287.59±0.19[e]	4341.45±5.24[c]	4331.14±0.40[d]	4386.22±0.19[b]
FCR	1.97±0.06[c]	2.35±0.04[a]	1.97±0.08[c]	2.07±0.08[bc]	2.21±0.08[ab]	2.19±0.06[ab]	2.25±0.07[ab]

[a-d]Values in the same row with a different superscript differ significantly at $p<0.05$

feed intake during this period, groups fed on guar meal only at levels 7.5 and 10% (T1 and T4) showed significant decrease ($p<0.05$) in amount of feed intake when compared with the control. Birds fed on T3 (7.5% GM+Avemix) and T6 (10% GM+Avemix) were significantly had higher feed intake than CON, while the reverse was observed in birds fed on T2 and T5 (7.5 and 10% GM+hemicelle). In the same manner, birds fed on guar meal only at levels 7.5 and 10% (T1 and T4) showed significant increase ($p<0.05$) in feed conversion ratio when compared with control, but other treatment groups showed no significant differences when compared with the control. The detrimental effect of guar meal in starter period may be due to an increase in intestinal viscosity which in turn leads to a reduction in body weight gain of broiler chickens[18]. Some indigestible polysaccharides, such as pectin and guar gum, increase intestinal viscosity, which decreases growth, feed intake and increases feed conversion[19]. Since increases in intestinal viscosity are more detrimental to young chickens, addition of viscous ingredients may be utilized in grower and finisher diets at higher concentrations than in starter diets for broiler chicks. These results agreed with Lee *et al.*[6] found that average body weight decreased incrementally as the level of guar inclusion was increased at approximately 3 weeks of age. Additionally, they proved that a significant depressed feed consumption was observed with birds receiving 10% guar. The effects of enzyme supplementations did not appear clearly during this period except effect of cockatile enzyme (Avemix) with both levels of GM in feed intake which lead to significant increase in feed intake in birds fed on diets contained 10% GM. The improvement on FCR on group fed 7.5% GM+hemicelle and Avemix with 10% GM was partly in line with the finding of Patel and McGinnis[20].

During the growing period, there are significant decrease in body weight ($p<0.05$) in birds fed on guar at 7.5 % (T1), guar meal at 10% with or without enzyme when compared with the control one. There are significant decrease in body weight gain ($p<0.05$) in birds of T1 and T6, whose fed on diets contained GM 7.5 and 10% with Avemix when compared with the control one. All treated groups showed significant differences in feed intake ($p<0.05$) when compared with the control group. It was observed that (T1 and T6) significantly deteriorate FCR throughout the grower experimental period by about 15.5 and 17%, respectively when compared with the control, while other treated groups showed no significant differences.

Inclusion of guar germ significantly increased viscosity of duodenal, jejunal and ileal contents, which in turn decreased body weights[21]. The marked improvement in feed: gain ratio is presumably due to degradation of residual gum leading to reduced viscosity[6].

Carcass traits: The effects of feeding different GM levels with or without enzyme supplementation on carcass characteristics were presented in Table 3. Dressing percentage of birds fed on guar meal with 7.5 and 10% (T1 and T4) was significantly lower than CON and other treatments. Addition of enzymes hemicelle and Avimex to guar groups resulted in dressing percentage comparable to control group. This result was in agreement with Kamran *et al.*[4] reported decreased dressing percentage in birds fed with diets containing guar meal. However, Mishra *et al.*[11] found a subtle effect ($p>0.05$) of guar korma and β-mannanase supplementation on carcass traits.

All groups were increased in relative liver weight compared to control and this increment was significant in

Table 3: Effects of experimental diets on some carcass traits (dressing percentage and organs weight relative to body weight) of broilers at 42 days age

	Treatments						
Parameters	CON	T1	T2	T3	T4	T5	T6
Dressing (%)	76.06 ± 1.36^{ab}	69.36 ± 2.71^{c}	78.27 ± 0.61^{ab}	76.72 ± 0.07^{ab}	67.75 ± 1.59^{c}	70.64 ± 1.25^{b}	69.94 ± 0.57^{b}
Liver	1.64 ± 0.04^{bc}	1.46 ± 0.09^{c}	1.79 ± 0.03^{ab}	1.67 ± 0.11^{bc}	1.96 ± 0.11^{a}	1.83 ± 0.05^{ab}	1.69 ± 0.09^{bc}
Gizzard	1.05 ± 0.01^{c}	1.33 ± 0.09^{ab}	1.41 ± 0.04^{a}	1.23 ± 0.05^{abc}	1.16 ± 0.06^{bc}	1.17 ± 0.04^{bc}	1.18 ± 0.11^{bc}
Heart	0.35 ± 0.02^{ab}	0.33 ± 0.00^{ab}	0.39 ± 0.02^{a}	0.30 ± 0.01^{b}	0.35 ± 0.04^{ab}	0.36 ± 0.03^{ab}	0.38 ± 0.02^{a}
Spleen	0.07 ± 0.00^{c}	0.09 ± 0.01^{b}	0.11 ± 0.01^{a}	0.08 ± 0.01^{bc}	0.08 ± 0.00^{bc}	0.08 ± 0.00^{bc}	0.08 ± 0.01^{bc}
Breast meat	18.03 ± 0.95^{ab}	17.34 ± 0.57^{b}	19.97 ± 0.61^{a}	14.19 ± 0.76^{d}	14.91 ± 0.44^{cd}	16.61 ± 0.84^{bc}	16.10 ± 0.21^{bcd}
Thigh	4.68 ± 0.08^{abc}	5.09 ± 0.08^{a}	4.56 ± 0.14^{c}	5.01 ± 0.13^{ab}	4.55 ± 0.17^{c}	4.70 ± 0.19^{abc}	4.64 ± 0.06^{bc}
Abdominal fat	1.38 ± 0.03^{ab}	1.34 ± 0.08^{abc}	1.20 ± 0.05^{cd}	1.33 ± 0.04^{bc}	1.50 ± 0.03^{a}	1.12 ± 0.05^{d}	1.20 ± 0.07^{cd}

$^{a-d}$Values in the same row with a different superscript differ significantly at $p<0.05$

birds of T4 (GM 10%). However, birds on T1 showed no significant decrease in liver relative weight compared to CON. These findings co-related with the findings of Zhang[22] reported an increment in liver relative weight of laying hen when GM is used by 10 and 15% with and without enzyme. The results were also parallel with that of Lee *et al*.[21] found increase in relative liver mass at the 7.5% inclusion rate of guar hull fraction. Contradictorily, Bakshi *et al*.[23] and Brahma *et al*.[24] reported no abnormalities or significant changes in relative weights of liver and spleen when 10% raw or up to 16% toasted guar meal was fed to laying hens or broiler chickens, respectively. Regarding gizzard, all groups revealed an increase in gizzard percentage compared to CON. The data revealed lowering the effect for dietary treatments on heart percentage, the highest heart percentage was found in T2 (GM 7.5%+hemicelle). For spleen, the data showed significant increase in spleen relative weight in groups T1 (GM 7.5%) and T2 (GM 7.5%+hemicelle) comparing to CON, while all other groups showed no significant increase in spleen weight percentage comparing to CON. These results matched partially the results of Mishra *et al*.[11] reported less effect of guar meal with or without the hemicelle on gizzard, heart and spleen and with Ahmed *et al*.[12] reported that replacement of SBM with canola meal at a level of 5, 10 and 20% with or without enzyme supplementation did not affect carcass traits.

Regarding breast meat percentage, birds in group T2 revealed no significant increase in breast meat percentage compared to CON group, however, all other groups showed decrease in breast meat yield compared to control. The results were parallelled with that of Lee *et al*.[6] found that broilers receiving 2.5% dietary guar yielded significantly more carcass weight, breast meat weight and breast meat yield than chickens consuming higher concentrations.

For thigh percentage, T1, T3 and T5 resulted in no significant increase in thigh percentage, however, all other groups showed insignificant decrease in thigh percentage comparing to CON. Dietary inclusion of GM by 7.5% with or without enzymes and GM by 10% with enzymes supplementation decreased abdominal fat than control, which are significant for groups T2, T5 and T6. While only using GM by 10% without enzyme showed numerical increase in abdominal fat percentage compared to CON. This can be due to energy and protein balance deficiency. Mohayayee and Karimi[13] found a significant increase of abdominal fat in broiler chicken fed guar meal at rate 12% with or without enzyme supplementation than the lower level rate of GM inclusion 2, 4 and 6%.

Serum parameters: The effects of feeding different GM levels with or without enzyme supplementation on some serum parameters were presented in Table 4. It was observed that a significant decrease ($p\geq0.05$) in total protein (g dL^{-1}) in birds of T5, which fed on diets contained (GM 10% without enzyme supplementation), when compared with the control. But other treated groups showed no significant difference when compared with the control. There was no significant difference in all treated groups in albumin content when compared with the control. All groups supplemented with enzyme showed improvement in protein level. Enzymes destroy the antinutritional compounds present in feed which may include single compound or class of compounds[4].

Regarding glucose, there is significant decrease in glucose level in birds of groups contain 10% GM with or without enzyme compared to control but this decrease is insignificant for groups contain 7.5% GM with or without enzyme. Enzyme supplementation showed numerical lower cholesterol (mg dL^{-1}) levels in groups fed on diets contained (GM 7.5%) when compared with those fed on diet contained (GM 7.5%) without enzyme. But other treated groups showed insignificant difference when compared with the control one. Concerning triglyceride (mg dL^{-1}) groups fed on diets contained (GM 7.5% without or with enzyme supplementation) showed non-significant difference when compared with the control. But birds fed on diets contained GM 10% without or with

Table 4: Effects of experimental diets on some serum parameters of broiler chickens at 42 days of age

	Treatments						
Parameters	CON	T1	T2	T3	T4	T5	T6
Total protein (g dL^{-1})	5.63 ± 0.43^{a}	5.33 ± 0.29^{ab}	5.64 ± 0.26^{a}	5.59 ± 0.30^{a}	4.32 ± 0.48^{b}	5.04 ± 0.40^{ab}	4.53 ± 0.40^{ab}
Albumin (g dL^{-1})	2.48 ± 0.09^{ab}	2.36 ± 0.05^{b}	2.35 ± 0.06^{b}	2.35 ± 0.07^{b}	2.46 ± 0.09^{ab}	2.63 ± 0.03^{a}	2.56 ± 0.03^{a}
Glucose (g dL^{-1})	88.63 ± 5.28^{a}	79.72 ± 4.65^{ab}	77.67 ± 10.36^{ab}	71.66 ± 4.41^{ab}	64.56 ± 3.52^{b}	64.86 ± 3.45^{b}	69.79 ± 2.57^{b}
Cholesterol (mg dL^{-1})	188.33 ± 7.86^{a}	193.05 ± 13.21^{a}	176.94 ± 9.87^{a}	183.61 ± 9.07^{a}	193.05 ± 6.76^{a}	194.72 ± 6.84^{a}	192.77 ± 9.63^{a}
Triglyceride (mg dL^{-1})	153.95 ± 5.50^{b}	162.15 ± 7.86^{ab}	151.71 ± 4.63^{b}	161.58 ± 9.08^{ab}	189.83 ± 4.00^{a}	172.88 ± 7.29^{a}	183.33 ± 7.08^{a}
HDL (mg dL^{-1})	52.25 ± 0.63^{c}	57.14 ± 0.39^{b}	55.92 ± 0.39^{bc}	54.69 ± 1.55^{bc}	67.06 ± 2.52^{a}	56.37 ± 0.68^{b}	58.36 ± 0.39^{b}
LDL (mg dL^{-1})	98.12 ± 7.91^{a}	101.70 ± 14.66^{a}	86.45 ± 10.50^{a}	94.05 ± 7.90^{a}	102.39 ± 8.09^{a}	95.39 ± 11.41^{a}	107.56 ± 6.90^{a}
VLDL (mg dL^{-1})	37.96 ± 0.80^{a}	36.67 ± 1.41^{a}	34.57 ± 1.46^{ab}	32.43 ± 1.57^{b}	32.31 ± 1.82^{b}	30.79 ± 1.10^{b}	30.32 ± 0.94^{b}

a-cValues in the same row with a different superscript differ significantly at $p<0.05$

enzyme supplementation) showed high levels of triglyceride when compared with the control.

In the same pattern the level of HDL (mg dL^{-1}) increased significantly in groups fed on diets contained GM at 7.5 and 10%, but enzyme supplementation in diets contained low level of GM 7.5% (T2 and T3) showed non significant difference when compared with the control. Enzyme supplementation in diets contained high level of GM 10% (T5 and T6) showed significant increase in HDL (mg dL^{-1}) when compared with the control. These results were agreed with those of Mohayayee and Karimi[13], found that plasma cholesterol concentrations in enzyme-less intermediate and high GM diets were higher than the control group, it became similar to the control group when the birds were fed on these diets supplemented with β-mannanase enzyme. Plasma HDL was higher than the control group in the birds fed on the enzyme-less diet and contained high levels of GM, but when β-mannanase enzyme was added to this diet, the mentioned parameter reduced and reached to the control groups. These probably were due to the eating of high levels of guar meal germ fraction. The NSPs like guar gum destroy the intestinal micro-flora and this effect on amino acid intestinal-hepatogenic cycle maybe caused to increase HDL. Also these results were agreed with those of Ahmed *et al.*[12] found that inclusion of CM with multi-enzyme supplement decreased serum total cholesterol and total triglyceride compared to CON and enzyme-un supplemented groups.

Antibody titer: Table 5 shows effect of replacing SBM with different levels of guar meal (0, 7.5 and 10%) with or without enzyme supplementation (Hemicelle and Avemix) on antibody titer against ND. At end of starter and grower periods, the diets contained GM only T1 and T4 showed significantly ($p\geq0.05$) decrease in antibody titer against ND when compared with the control but enzyme supplementation improved antibody titer in other guar contained groups T2, T3 and T5. These results showed bad effects of GM contained diets only without enzyme in immune response, while enzyme supplementation overcomes the bad effects. The results were agreed with Zangiabadi and Torki[25] found that dietary supplementation by mannanase-enzyme significantly improved the Ab in response to NDV.

Table 5: Effects of experimental diets on antibody titer against ND

	Age	
Treatments	21 days of age	42 days of age
CON	8.25 ± 0.25^{bc}	6.50 ± 0.50^{b}
T1	5.75 ± 0.25^{e}	5.50 ± 0.29^{b}
T2	8.50 ± 0.50^{c}	5.75 ± 0.25^{b}
T3	7.50 ± 0.29^{cd}	8.75 ± 0.48^{a}
T4	6.75 ± 0.25^{de}	6.00 ± 0.58^{b}
T5	8.00 ± 0.41^{c}	6.00 ± 0.00^{b}
T6	7.00 ± 0.41^{a}	8.50 ± 0.65^{a}

a-eValues in the same column with a different superscript differ significantly at $p<0.05$

Table 6: Effects of experimental diets on digestibility percentage of nutrients

	Parameters		
Treatments	DM (%)	OM (%)	CP (%)
CON	70.72 ± 0.29^{b}	70.07 ± 0.23^{b}	66.90 ± 0.63^{b}
T1	68.75 ± 0.62^{b}	68.15 ± 0.52^{c}	58.64 ± 0.60^{d}
T2	73.95 ± 0.52^{a}	71.69 ± 0.81^{ab}	67.44 ± 0.05^{b}
T3	74.09 ± 0.46^{a}	72.36 ± 0.51^{a}	69.22 ± 0.30^{a}
T4	64.54 ± 0.86^{c}	61.96 ± 0.51^{e}	55.35 ± 0.50^{e}
T5	65.46 ± 0.53^{c}	62.52 ± 0.46^{e}	60.42 ± 0.45^{c}
T6	69.80 ± 0.90^{b}	65.46 ± 0.69^{d}	66.53 ± 0.91

a-eValues in the same column with a different superscript differ significantly at $p<0.05$

Nutrient digestibility: Impact of enzyme supplementation on nutrients (DM, OM and CP) digestibility of diets contained GM at 7.5 and 10% illustrated in Table 6. Birds fed on diets contained GM 10% only or with hemicelle (T4 and T5) showed significant decrease in DM digestibility when compared with the control one. Both enzyme preparations supplementation on low level of GM 7.5% (T2 and T3) showed significant increase in DM digestibility and birds fed in diet with high level of GM 10% with Avemix (T6) also showed significant increase in DM digestibility when compared with the control one. In the same manner, the same effect of enzyme on diets contained GM 7.5% with enzyme and cocktail enzyme Avemix positively appear on high level of GM at 10% on OM and CP digestibility. Presence of GM affect nutrient digestibility may be due to intestinal viscosity. High intestinal viscosity decreases nutrients digestibility and decreases enzyme activity throughout the small intestine[9]. Hemicelle (β-D-mannanase) supplementation increased DM and CP digestabilities when added to diets contained GM at 7.5% but have no effect at diets contained GM at 10%. Avemix (mannanase, β-xylanase, β-glucanase, pectinase and cellulase) have positive effect on both levels of GM. These results are agree with those of Azarfar[5] found that ileal digestibility of protein was significantly improved by hemicelle enzyme. The cocktail enzymes Avemix (containing mannanase, β-xylanase, β-glucanase, pectinase and cellulose) showed more positive effect on diets due to these several enzymes, which act on different substrate.

CONCLUSION

Positive effects of enzyme supplementation on BWG and FCR were clear in groups fed on GM at level 7.5% (T2 and T3), but guar meal contained treatments on 7.5 and 10% showed negative effects on BWG and FCR. Addition of enzymes hemicelle and Avimex to guar groups resulted in dressing percentage comparable to control group and lowering abdominal fat. Lower digestibility of DM, OM and CP% in broilers fed diet supplemented with 7.5 or 10% GM was noticed. However, both hemicelle and Avimex supplementation significantly improve nutrients digestibility at 7.5% GM but at level 10% only Avimex was more valuable. The present results support the need for carbohydrase enzyme complexes in broiler diet containing GM at a level of 7.5 and 10%.

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