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Effect of Microbial Enzyme Supplementation to Guar *(Cyamopsis tetragonoloba)* Meal Based Diets on Performance, Bone Mineral Parameters and Carcass Characteristics of Free Range Chickens during Nursery Phase

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ABSTRACT

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Two experiments were conducted to examine the possibility of utilizing toasted guar meal (GM) with microbial enzymes in the diets of *Vanaraja* chicken. During the experiment I, soybean meal control diet (SBCD) was formulated to contain 2600 ME kcal/kg and 20% protein. Basal diet (BD) was formulated to contain 20% GM with similar energy and protein. The GMBD was supplemented with five microbial enzymes independently and in combination. Each diet was fed *ad libitum* up to 42 days of age. Inclusion of GM depressed ($P<0.01$) the body weight gain (BWG) compared to the group fed SBCD. Supplementation of individual enzymes (except protease) or combination increased ($P<0.01$) BWG compared to GMBD groups . The feed conversion ratio (FCR) in groups fed GMBD with combination of enzymes was similar to SBCD fed group. During the experiment II, the GMBD was supplemented with three concentrations each of mannanase and xylanase, which was compared with the SBCD and GMBD. Inclusion of GM depressed ($P<0.01$) the BWG and FCR. However, enzyme supplementation to GMBD improved the BWG and FCR compared to the group fed GMBD. Supplementation of mannanase and xylanase (6000 and 3250 or 4875 U/kg; 4000 and 3250 U/kg, respectively) to GMBD improved performance, which was similar to SBCD fed birds. Based on the data, it is concluded that toasted GM could be included up to 20% diet without affecting body weight gain and feed efficiency in *Vanaraja* chicken by supplementing the diet with higher concentrations of mannanase and xylanase.

Keywords: Bone ash, Guar meal, Microbial enzymes, Performance, Vanaraja birds.

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INTRODUCTION

Continuous increase in food cost due to shortage of conventional food ingredients (maize and soybean meal) has become a persistent stumbling block for the growth of poultry industry. This situation is compelling the nutritionists to search for alternate food resources for using in place of conventional ingredients. Guar (*Cyamopsis tetragonoloba*) is a drought tolerant legume crop extensively grown in tropical countries. Guar meal (GM), the by-product after degumming the seeds, contains 330-500 g crude protein/kg (Lee e*t al.,* 2005). Increased production and availability of GM and scarcity of soybean meal (SBM) may favour utilization of GM in poultry diets. Majority of protein in GM is true protein and rich in arginine, but low in methionine and lysine (Lee e*t al.,* 2003; 2005) compared to SBM. However, the residual gum (galactomannans) is mainly responsible for the ill effects of feeding GM on chicken performance (Lee e*t al.,* 2003; 2005). Addition of 200 g guar gum/kg diet is reported to depress the growth in broiler chicken (Conner, 2002). However, inclusion of guar seed germ fraction at 75 g/kg diet supported growth and food conversion similar to that observed with maize-SBM based diet in broilers (Lee e*t al.,* 2005). Higher levels of GM (150 g/kg) in diet causes diarrhea, reduces growth rate and increases mortality of broilers (Patel and McGinnis, 1985).

Vanaraja, a multi-coloured chicken variety suitable for free range poultry farming, is being widely reared across India under diversified agro-climatic regions (Zuyie e*t al.,* 2009; Swain e*t al.,* 2011). Before allowing the birds for free range rearing at 7 weeks of age, the birds need brooding and balanced feeding (Rama Rao e*t al.,* 2006) during nursery phase (0-6 weeks of age). The results of previous experiments conducted in the authors' laboratory suggest the possibility of including GM up to 15% of the diet without any adverse effects, while 20% GM significantly reduced the performance of *Vanaraja* chicken during the nursery phase (Rama Rao e*t al.,* 2014). Supplementation of microbial enzymes appears to be an effective method to enhance feeding value of GM in poultry diets (Gharaei e*t al.,* 2012; Shahbazi, 2012; Rama Rao e*t al.,* 2014). Fortification of GM based diets with β-mannanase was reported to reduce intestinal viscosity and alleviate the deleterious effects of GM on bird performance (Lee e*t al.,* 2003). Therefore, the present study was designed to test the possibility of including higher levels of GM (200 g/kg) with supplemental microbial enzymes in *Vanaraja* chicken diet.

MATERIALS AND METHODS

Two experiments were conducted to study the effect of enzyme supplementation to diets containing GM on performance of *Vanaraja* chicken. In experiment I, enzymes, i.e. xylanase, β-mannanase, β-glucanase, cellulase or protease were supplemented individually or in combination (E mix) to diet containing 20% of GM. The primary focus of the experiment was to identify the effective enzyme(s) in GM based diets. In experiment II, mannanase and xylanase were supplemented to GM based (20%) diet at different concentrations to evaluate their effective combinations in alleviating the ill effects of GM supplementation. The energy and protein levels used in the experimental diets were lower than the levels used for commercial broilers due to their lower requirement for *Vanaraja* birds during the initial 6 weeks of age (Rama Rao *et al.,* 2005). The GM used in the present experiment was of toasted (110°C/20 minutes) variety that was procured from Maharashtra Feed Pvt. Ltd., Azadpur, New Delhi, India.

Experiment I

A total of 432 day-old *Vanaraja* chicks were randomly and equally distributed into 72 battery brooder pens (610 mm×762 mm×475 mm) having 9 replicates with each treatment. At day one, chicks were wing banded and housed in wire-floored stainless steel battery brooders. The brooder temperature was maintained at 35±0.5°C until 7 days of age and gradually decreased to 27°C by 21 days of age, after which the chicks were maintained at room temperature (20 to 27° C).

Birds were vaccinated against Newcastle (7th and 28th day) and infectious bursal diseases (15d and 22d). Guar meal, SBM and sunflower meal were analyzed (Llames and Fontaine, 1994) for amino acid content, whilst for maize and deoiled rice bran published amino acid composition were used to achieve the desired levels of lysine and methionine in the experimental diets. The experimental protocol was approved by the Institutional Animal Ethics Committee.

Maize-soybean meal control diet (SBCD) was prepared to contain 2600 kcal ME and 20% crude protein (Table 1). GM basal diet (GMBD) containing 20% of GM was prepared containing similar energy and protein levels. The GMBD was supplemented with individual microbial enzymes (Advanced Bio-Agro Tech Limited, Pune, India), xylanase (3250 U), glucanase (1200 U), cellulase (890 U), mannanase (4000 U), protease (4000 units/kg), or combination of the enzymes (E mix) with the same concentrations. The GMBD without enzyme supplementation was fed to examine the effect of feeding GM on performance of the birds. Body weight gain (BWG) and feed intake were recorded at 42d of age, and feed conversion ratio (FCR) per pen was calculated as BWG per unit feed intake.

Experiment II

In experiment II, a total of 462 day-old *Vanaraja* chicks were distributed randomly into 77 battery brooder pens. The brooder temperature during first week was maintained at 35°C and subsequently, the ambient temperature increased due to summer, which ranged between 27 to 39°C. A control diet was formulated based on maize, SBM, sunflower, and deoiled rice bran to contain 2600 kcal ME and 200 g CP/kg (SBCD). A basal diet was prepared with 20% of GM (GMBD) containing similar energy and crude protein as that of the control diet. The results of the experiment I indicated that mannanase and xylanase supplementation to the GMBD showed higher feed efficiency compared to other enzymes, and therefore these two enzymes were selected in experiment II. The GMBD was supplemented with mannanase (2000, 4000 or 6000 U/kg) and xylanase (1625, 3250 or 4875 U/kg) at varied concentrations in a 3×3 factorial manner. The basal diet without the enzyme supplementation was fed to another group. Each diet was allotted randomly and fed *ad libitum* to seven replicates from day one to 42d of age.

Table 1. Ingredient and nutrient composition of experimental diets

	Experiment I and II	
	SBCD	GMBD
Ingredient (g/kg)		
Maize	528	532
Soybean meal	186	-
Sunflower meal	248	169
Guar meal	-	200
De-oiled rice bran	-	56.9
Salt	4.53	4.50
Dicalcium phosphate	14.8	17.5
Oyster shell grit	10.93	9.30
DL-methionine	1.87	1.82
L-lysine HCl	1.99	3.41
Additives†	5.00	5.00
Analyzed nutrients (%)		
ME (kcal/kg)‡	2600	2600
Crude protein‡	20.0	20.0
Lysine§	1.00	1.00
Methionine§	0.50	0.50
Calcium¶	0.90	0.90
Non phytate phosphorus	0.45	0.45

SBCD= soybean meal control diet; GMBD= guar meal basal diet.

†Additives provided (in milligrams/kilogram diet): thiamin 1; pyridoxine, 2; cyanocobalamine, 0.01; niacin, 15; pantothenic acid, 10; a-tocopherol, 10 IU; riboflavin, 10; biotin, 0.08; enadione, 2; retinol acetate, 2.75; cholecalciferol, 0.03; choline, 650; copper, 8; iron, 45; manganese, 80; zinc, 60; selenium, 0.18; monensin sodium, 50; hydrated sodium calcium alumino silicates, 800 mg.

‡Calculated values.

§Analyzed values.

¶Calculated based on analyzed ingredient composition.

In both the experiments, one bird from each replicate weighing nearer to the mean body weight of the respective group was selected at 42d of age and slaughtered by cervical dislocation to study the carcass traits. The ready to cook yield (RTC) and relative weight of breast and liver were recorded and expressed as g/kg live weight of the respective bird. In experiment II, samples of liver and thigh muscle were collected for estimation of protein and fat (AOAC, 1980). Fat free dried tibia was utilized for estimation of total ash. Both the tibia were collected and boiled in water for 45 min. Bones were freed of cartilages and muscles and dried in oven at 70°C. Dried tibiae were vertically soaked in petroleum ether for 72 h to remove fat from the bone. Fat free and dried bones were ignited at 600°C for 3 h in microwave muffle furnace (Phoenix Muffle

Furnace, CEM Innovators in Microwave Technology, Buckingham, UK) for estimation of total ash. Calcium (Atomic Absorption Spectrophotometer, Perkin Elmer AAnalyst 400, USA) and phosphorus (AOAC, 1980) contents.

Statistical analysis

The variations in data of different parameters were analyzed using the general linear model procedure of SAS version 9.2 (2008; SAS Institute Inc., Cary, North Carolina, USA). The model included different dietary treatments as source of variation. The diet effects were tested for possible linear and quadratic effects using orthogonal polynomials. The influence of adding enzymes was tested using orthogonal contrast. Treatment means were compared using Tukey's test.

RESULTS

Composition of Guar meal

The GM contained higher levels of CP, crude fibre, crude fat, Ca and arginine as compared to SBM. On the contrary, concentrations of P, methionine, cysteine, lysine, threonine and isoleucine were lower in GM as compared to SBM (Table 2).

Experiment I: Performance

Inclusion of GM at 20% level without enzyme supplementation GMBD significantly ($P<0.01$) depressed BWG and increased FCR compared to the SBCD (Table 3). Supplementation of the GMBD with either individual enzymes (except protease) or combination of enzymes significantly ($P<0.01$) improved BWG compared to those groups fed GMBD. Supplementation of enzyme mix (E mix) resulted in higher BWG than

Table 2. Analyzed nutrient composition of protein sources (% of DM)

	Guar meal	Soybean meal	Sunflower meal
Nutrient (%)			
Crude protein	48.62	47.51	28.60
Crude fibre	11.97	5.89	16.01
Crude fat	0.259	0.123	0.181
Calcium	0.456	0.201	0.030
Phosphorus	0.070	0.650	0.570
Methionine	0.512	0.671	0.572
Cysteine	0.560	0.721	0.463
Lysine	1.990	2.960	0.992
Threonine	1.350	1.870	0.984
Arginine	6.010	3.481	2.214
Isoleucine	1.370	2.120	1.047
Leucine	2.580	3.740	1.665

Table 3. Effect of supplementing different non-starch polysaccharide hydrolyzing enzymes in guar meal (20%) based diet on performance and slaughter variables in Vanaraja chicken (Experiment I)

Diet	Enzyme	Performance		Slaughter variables, g/kg LW		
	(U/kg diet)	BWG, g	FCR	RTC	Liver	Breast
SBM control	-	731[a*]	2.24[c]	701	20.2[b]	138
GM basal	-	554[c]	2.50[a*]	682	30.7[a]	135
GM xylanase	890	601[b*]	2.42[ab*]	678	30.9[a]	138
GM glucanase	1200	604[b*]	2.44[ab*]	675	29.7[a]	130
GM cellulase	3250	600[b*]	2.47[ab*]	686	28.0[a]	134
GM mannanase	4000	618[b*]	2.41[ab*]	677	31.5[a]	141
GM protease	4000	588[bc]	2.47[ab*]	682	27.5[a]	137
GM E mix[†]		621[b*]	2.34[bc]	684	27.7[a]	124
SEM		7.4	0.012	2.3	1.31	2.6
P value		0.001	0.001	NS	0.05	NS

BWG=body weight gain; FCR=feed conversion ratio (food intake/BW); SEM= standard error of the mean; SBM= soybean meal; GM=guar meal (200 g/kg); RTC= ready to cook yield.

[†]Enzyme cocktail contained xylanase 3250, glucanase 1200, cellulase 890, mannanase 4000 and protease 4000 U/kg diet).

[abc]Means not sharing common superscript in a column differ significantly (P<0.05); *(P<0.01).

individual enzymes, while the FCR in this group was similar to the SBCD fed groups. Among the individual enzyme supplemented groups, mannanase and xylanase fed groups yielded numerically better FCR compared to the other enzymes supplemented GMBDs.

Slaughter variables

The ready to cook yield and breast were not affected (P>0.05) by either inclusion of GM or supplementation of enzymes to the GMBD (Table 3). However, the relative weight of liver increased significantly (P<0.05) in birds fed GM based diets. Supplementation of enzymes to GMBD did not influence the liver weight.

Experiment II: Performance

The interaction between GM and SBM supplementation (P<0.05) influenced BWG, FCR, liver weight and breast weight (Table 4). At 42 d of age, BWG and feed efficiency were significantly reduced in birds fed the GMBD compared to the SBCD. Supplementation of mannanase and xylanase even at the lowest concentrations (2000 and 1625 U/kg, respectively) significantly (P<0.05) improved BWG and reduced FCR compared to those fed the GMBD. Further, increasing dietary concentration of mannanase linearly and quadratically improved (P<0.05) the BWG and FCR. However, increasing the concentrations of xylanase linearly improved the FCR. The BWG and FCR in all the groups fed GM based diet with mannanase 4000 U and xylanase 3250 U, mannanase

Table 4. Effect of supplementing varying concentration of mannanase (M) and xylanase (X) in guar meal (20%) based diet on performance and slaughter variables in Vanaraja chicken (Experiment II)

Diet	Enzyme (U/kg diet)		Performance		Slaughter variables (g/kg LW)		
	M	X	BWG (g)	FCR	RTC	Liver	Breast
SBM	Nil	Nil	642[a]	2.321[bc]	698	21.43[b]	138
GM	Nil	Nil	478[c]	2.610[a]	671	31.47[a]	123
GM	2000	1625	575[b]	2.373[bc]	671	29.27[ab]	123
GM	2000	3250	575[b]	2.410[bc]	651	33.39[a]	121
GM	2000	4875	593[ab]	2.420[bc]	664	31.26[a]	117
GM	4000	1625	593[ab]	2.380[bc]	643	29.34[ab]	109
GM	4000	3250	608[ab]	2.353[bc]	668	29.94[a]	131
GM	4000	4875	579[ab]	2.370[bc]	673	29.44[ab]	131
GM	6000	1625	582[ab]	2.430[b]	675	30.67[a]	127
GM	6000	3250	612[ab]	2.333[bc]	667	28.83[ab]	128
GM	6000	4875	629[ab]	2.273[c]	674	27.74[ab]	119
SEM			13.58	0.032	18.6	1.77	5.74
P values			0.001	0.001	NS	0.01	NS
SBM vs GM			0.001	0.02	0.10	0.01	0.01
M linear			0.25	0.29	0.96	0.23	0.48
M quadratic			0.03	0.03	0.42	0.28	0.49
X linear			0.09	0.05	0.81	0.79	0.23
X quadratic			0.83	0.75	0.57	0.39	0.32
M×X linear			0.25	0.29	0.96	0.23	0.48
M×X quadratic			0.25	0.29	0.96	0.23	0.48

BWG, body weight gain; FCR, feed conversion ratio (food intake/BW); SEM, standard error of the mean; RTC, ready to cook; SBM, soybean meal; M, mannanase; X, xylanase.

[abcd]Means not sharing common superscript in a column differ significantly ($P<0.05$).

6000 U and xylanase/kg 3250 U or 4875 U/kg were similar to those fed the SBCD. While the weight gain in other groups was significantly higher than those fed the GM basal diets, but lower than the SBCD.

Slaughter variables

Inclusion of the GM or supplementation of graded concentrations of mannanase and xylanase to the GMBD did not influence ($P>0.05$) the relative weights of RTC (Table 4). However, the liver weight increased significantly ($P<0.01$) with inclusion of GM in the diet.

Protein and fat in liver and muscle

The concentration of fat in liver and protein in muscle were not influenced ($P>0.05$) by the inclusion of GM in *Vanaraja* chicken diet without or with enzyme supplementation

Table 5. Effect of feeding guar meal (20%) based diets along with different levels of xylanase (X) and mannanase (M) on liver,muscle and bone parameters in Vanaraja birds (Experiment II)

Diet	M	X	Liver		Muscle		Tibia		
	U/kg diet		Fat	Protein	Fat	protein	Ash	Ca	P
					(g/100 g)				
SBM	Nil	Nil	11.2	70.1[a]	9.08[ab]	79.1	50.0	32.1	17.4
GM	Nil	Nil	12.5	67.6[ab]	9.00[ab]	76.7	50.1	31.4	17.3
GM	2000	1625	11.8	67.4[abc]	9.77[a]	78.1	49.9	31.9	17.1
GM	2000	3250	11.6	67.0[abc]	9.59[a]	76.5	48.7	32.3	17.3
GM	2000	4875	12.7	60.8[c]	8.35[b]	77.6	49.2	32.1	17.1
GM	4000	1625	12.2	61.9[bc]	9.00[ab]	74.9	50.0	32.0	16.9
GM	4000	3250	12.3	70.5[a]	9.06[ab]	77.5	49.6	31.8	17.7
GM	4000	4875	11.8	68.5[ab]	9.67[a]	77.3	49.4	31.4	17.1
GM	6000	1625	11.7	68.8[a]	9.89[a]	77.2	50.1	32.0	16.7
GM	6000	3250	12.3	69.5[a]	9.95[a]	76.8	50.1	32.0	16.9
GM	6000	4875	12.5	69.9[a]	9.61[a]	74.8	49.8	32.0	16.8
SEM			0.18	0.43	0.094	0.30	0.15	0.09	0.09
P values			NS	0.001	0.011	NS	NS	NS	NS
SBM vs GM			0.14	0.05	0.34	0.02	0.52	0.45	0.33
M linear			0.91	0.10	0.96	0.79	0.53	0.22	0.72
M quadratic			0.88	0.01	0.01	0.38	0.17	0.63	0.02
X linear			0.13	0.09	0.40	0.40	0.31	0.80	0.68
X quadratic			0.75	0.02	0.20	0.83	0.70	0.95	0.80
M×X linear			0.91	0.10	0.96	0.79	0.53	0.22	0.72
M×X quadratic			0.91	0.10	0.96	0.79	0.53	0.22	0.72

GM, guar meal; SEM, standard error of the mean; M, mannanase; X, xylanase.

[ab]Means not sharing common superscript in a column differ significantly ($P<0.05$).

(Table 5). However, the liver protein in GMBD supplemented with 2000 U mannanase and 4875 U xylanase or 4000 U mannanase and 1625 U xylanase was significantly lower ($P<0.01$) compared to those fed SBCD. The liver protein in other groups was similar to those fed the SBCD. Further, increasing dietary concentration of mannanase and xylanase quadratically decreased ($P<0.05$) the liver protein.

Bone mineralization

Bone mineral parameters (tibia ash, Ca and P contents in tibia ash) were not ($P>0.05$) influenced due to the dietary variations (Table 5).

DISCUSSION

The nutrient profile of GM used in the present study is in line with the reported values of Lee *et al.* (2004) and Nadeem *et al.* (2005).

The data indicated significant reduction in performance due to incorporation of GM at 20% of the diet in Vanaraja chicken. These results are in accordance with the findings of Gheisari *et al.* (2011), who also observed significant reduction in BWG and feed efficiency in broilers fed diet with 120, 150 and 180 g GM/kg of starter, grower, and finisher diet, respectively. Reduction in performance of *Vanaraja* birds fed GMBD might be due to presence of residual gum in the meal. Guar gum predominantly contains non digestible β-mannans (Whistler and Saarnio, 1957). Mannans increase the viscosity of intestinal content (Lee e*t al.,* 2005) and thereby reduce the nutrient digestion and absorption in the gastrointestinal tract (Blackburn and Johnson, 1981; Rainbird e*t al.,* 1984). Increased intestinal digesta viscosity is also associated with reduced gut motility (Salih e*t al.,* 1991), fat emulsification (Edwards e*t al.,* 1988; Maisonnier e*t al.,* 2003) and digestibility of macro nutrients (Smits e*t al.,* 1997; McNaughton e*t al.,* 1998; Maisonnier e*t al.,* 2002). By feeding guar gum to swine, Rainbird *et al.* (1984) reported a considerable reduction (35%) in absorption of glucose through intestine. Furthermore, the growth depression in GM fed birds may be due to the presence of trypsin inhibitor in the protein source (Couch e*t al.,* 1967). However, Conner (2002) reported that trypsin inhibitor concentrations are not high enough to depress growth in GM fed birds. Though the nutrient retention was not estimated in the present study, Daskiran *et al.* (2004) reported significant reduction in nutrient retention in broilers fed guar gum incorporated diet.

Supplementation of mannanase, xylanase, β-glucanase, cellulase or combinations of enzymes significantly improved the BWG in birds fed 20% GM based diet in experiment I. Mannanase might have hydrolysed β-mannan link of residual gum present in GM and consequently enhanced the nutrient digestion and utilization, and BWG (Zou e*t al.,* 2006). Similar to these findings, β-mannanase supplementation was reported to alleviate the deleterious effects associated with GM feeding in chicken. The improved performance in mannanase supplemented group might be due to hydrolysis of β-mannans and reduced intestinal viscosity (Lee e*t al.,* 2003).

In experiment II, BWG of SBCD and GMBD fed groups was relatively lower compared to the experiment I. The higher (27 to 39°C) ambient temperatures (due to summer) experienced during the experiment II might be the reason for lower performance of birds. The improved BWG and reduced FCR with supplementation of mannanase and xylanase are in agreement with our previous report (Rama Rao e*t al.,* 2014) and the findings of Jackson *et al.* (2004) and Zou *et al.* (2006). Improved performance of birds with supplementation of mannanase and xylanase in birds fed GM based diets suggest that these two enzymes improved the nutritional value of GMBD (Verma and McNab, 1982; Gheisari *et al.,* 2011). Similar to these findings, supplementation of β-mannanase to GMBD was also reported to alleviate the deleterious effects associated with feeding of GM (Lee *et al.,* 2005). Similarly, enzyme supplementation to diets containing highly viscous compounds was reported to improve growth and feed efficiency in chicken (Almirall *et al.,* 1995; Steenfeldt *et al.,* 1998).

Liver weight increased in birds fed the GMBD and enzymes supplementation showed no effect. Similarly, the liver fat was not affected either by the GM feeding or enzyme supplementation. Further, other slaughter variables were not influenced by the dietary treatments. The results of the present study are in agreement with those of Brahma *et al.* (1982) and Gheisari *et al.* (2011), who reported no considerable changes in slaughter parameters in chicks fed 10% raw or up to 16% toasted GM based diet.

CONCLUSIONS

Based on the data of the two experiments, it is concluded that inclusion of GM at 20% significantly reduced body weight gain and increased feed conversion ratio in *Vanaraja* birds. However, supplementation of mannanase (6000 U/kg) and xylanase (3250 or 4875 U/kg) in the GM based diet improved the performance.

REFERENCES

Almirall, M., Francesch, M., Perez-Vendrell, A.M., Brufau J. and Esteve-Garcia, E. 1995. The difference in intestinal viscosity produced by barley and â-glucanase alter digesta enzyme activities and ileal nutrient digestibilities more in broiler chicks than in cocks, *Journal of Nutrition,* 125: 947-955.

AOAC. 1980. *Official Methods of Analysis,* 13th ed. Association of Official Analytical Chemists, Arlington, VA, USA, pp. 125-142.

Blackburn, T.A. and Johnson, I.T. 1981. The effect of guar gum on the viscosity of the gastrointestinal contents and on glucose uptake from the perfused jejunum in the rat, *British Journal of Nutrition,* 46: 239-246.

Brahma, T.C., Siddiqui, S.M. and Reddy, C.V. 1982. A study on the utilization of toasted guar meal with and without supplemental amino acid in broiler rations, *Indian Veterinary Journal,* 59: 960-967.

Conner, S.R. 2002. *Characterization of Guar Meal for Use in Poultry Rations*. PhD Dissertation, Texas A&M University, College Station, TX.

Couch, J.R., Bakshi, Y.K., Ferguson, T.M., Smith, E.B. and Creger, C.R. 1967. The effect of processing on the nutritional value of guar meal for broiler chicks, *British Journal of Poultry Science,* 8: 243-250.

Daskiran, M., Teeter, R.G., Fodge, D. and Hsiao, H.Y. 2004. An evaluation of endo-β-D-mannanase (Hemicell) effects on broiler performance and energy use in diets varying in β-mannan content, *Poultry Science,* 83: 662-668.

Edwards, C.A., Johnson, I.T. and Read, N.W. 1988. Do viscous polysaccharides slow absorption by inhibiting diffusion or convection. *European Journal of Clinical Nutrition,* 42: 306-312.

Gharaei, M.A., Dastar, B., Nameghi, A.H., Tabar, G.H. and Shargh, M.S. 2012. Effects of Guar meal with and without β-mannanas enzyme on performance and immune response of broiler chicks. *International Research Journal Basic Applied Sciences,* 3: 2785-2793.

Gheisari, A., Shavakhi, A., Zavareh, M., Toghyani, M., Bahadoran, R. and Toghyani, M. 2011. Application of incremental program, an effective way to optimize dietary inclusion rate of guar meal in broiler chicks, *Livestock Science,* 140: 117-123.

Jackson, M.E., Geronian, K., Knox, A., Mcnab J. and Mccartney, E. 2004. A dose-response study with the feed enzyme β-mannanase in broilers provided with corn-soybean meal based diets in the absence of antibiotic, *Poultry Science,* 83: 1992-1996.

Lee, J.T., Bailey, C.A. and Cartwright, A.L. 2003. Guar meal germ and hull fractions differently affect growth performance and intestinal viscosity of broiler chickens, *Poultry Science,* 82: 1589-1595.

Lee, J.T., Connor-Appleton, S., Bailey, C.A. and Cartwright, A.L. 2005. Effects of guar meal by-product with and without β-mannanase (Hemicell) on broiler performance, *Poultry Science,* 84: 1261-1267.

Lee, J.T., Connor-Appleton, S., Haq, A.U., Bailey, C.A. and Cartwright, A.L. 2004. Quantitative measurements of negligible trypsin inhibitor activity and nutrient analysis of guar meal fractions. *Journal of Agricultural and Food Chemistry,* 52: 6492-6495.

Llames, C. and Fontaine, Y. 1994. Determination of amino acids in feeds: collaborative study. *Journal of AOAC International,* 77: 1262-1402.

Maisonnier, S., Gomez, J., Bree, A., Berri, C., Baeza, E. and Carre, B. 2003. Effects of microflora status, dietary bile salts and guar gum on lipid digestibility, intestinal bile salts, and histomorphology in broiler chickens, *Poultry Science,* 82: 805-814.

Maisonnier, S., Gomez, J., Gabriel-Crévieu, I. and Carré, B. 2002. Analyses of degradation products from lipid and protein hydrolyses in the small intestine of broiler chickens fed on maize-based diets containing guar gum, or wheat-based diets, *British Journal of Poultry Science,* 43: 78 - 85.

McNaughton, J.L., Hsiao, H., Anderson, D. and Fodge, D.W. 1998. Corn/soy/fat diets for broilers, Beta-Mannanase and improved feed conversion, *Poultry Science,* 77(Suppl. 1):153. (Abstr.)

Nadeem, M.A., Gilani, A.H., Khan, A.G. and Mahr-Un-Nisa. 2005. Amino acids availability of poultry feedstuffs in Pakistan. *International Journal of Agriculture and Biology*, 7: 985-989.

Patel, M.B. and McGinnis, J. 1985. The effect of autoclaving and enzyme supplementation of guar meal on the performance of chicks and laying hens, *Poultry Science,* 64: 1148-1156.

Rainbird, A.L., Low, A.G. and Zebrowska, T. 1984. Effect of guar gum on glucose and water absorption from isolated loops of jejunum in conscious growing pigs, *British Journal of Nutrition,* 52: 489-498.

Rama Rao, S.V., Panda, A.K., Raju, M.V.L.N., Sharma, S.R., Shyam Sunder, G. and Sharma R.P. 2006. Performance of *Vanaraja* chicks fed diets containing different levels of protein, *Indian Journal of Animal Nutrition*, 23: 83-87.

Rama Rao, S.V., Panda, A.K., Raju, M.V.L.N., Sharma, S.R., Shyam Sunder, G., Bhanja, S.K. and Sharma, R.P. 2005. Performance of *Vanaraja* chicken on diets containing different concentrations of metabolizable energy at constant ratio with other essential nutrients during juvenile phase, *Indian Journal of Poultry Science,* 40: 245-248.

Rama Rao, S.V., Prakash, B., Raju, M.V.L.N., Panda, A.K. and Murthy, O.K. 2014. Effect of supplementing non-starch polysaccharide hydrolyzing enzymes in guar meal based diets on performance, carcass variables and bone mineralization in *Vanaraja* chicken, *Animal Feed Science and Technology,* 188: 85-91.

Salih, M.E., Classen, H.L. and Campbell, G.L. 1991. Response of chickens fed on hull-less barley to dietary *â*-glucanase at different ages, *Animal Feed Science and Technology,* 33: 139-149.

Shahbazi, H.R. 2012. Dietary Inclusion of guar meal supplemented by β-mannanase II) evaluation egg quality characteristics and blood parameters of laying hens. Global Veterinaria. 9: 67-72.

Smits, C.H.N., Veldman, A., Verstegen, M.W.A. and Beynen, A.C. 1997. Dietary carboxymethylcellulose with high instead of low viscosity reduces macronutrient digestion in broiler chickens, *Journal of Nutrition*, 127: 483-487.

Steenfeldt, S., Mullertz, A. and Jensen, J. 1998. Enzyme supplementation of wheat-based diets for broilers. 1. Effect on growth performance and intestinal viscosity, *Animal Feed Science and Technology*, 75: 27-43.

Swain, B.K., Naik, P.K., Chakurkar, E.B. and Singh, N.P. 2011. Effect of probiotic and yeast supplementation on performance, egg quality characteristics and economics of production in *Vanaraja* layers, *Indian Journal of Poultry Science,* 46: 313-315.

Verma, S.V.S. and Mc Nab, J.M. 1982. Guar meal in diets for broiler chickens, *British Journal of Poultry Science,* 23: 95-105.

Whistler, R.L. and Saarnio, J. 1957. Galactomannan from soybean hulls. *Journal of the American Chemical Society,* 79: 6055-6057.

Zou, X.T., Qiao, X.J. and Xu, Z.R. 2006. Effect of β-mannanase (Hemicell) on growth performance and immunity of broilers, *Poultry Science,* 85: 2176-2182.

Zuyie, R., Sharma, V.B., Bujarbaruah, K.M. and Vidyarthi, V.K. 2009. Performance of *Vanaraja* birds under extensive system of rearing at different altitudes in Nagaland, *Indian Journal of Poultry Science,* 44: 411-413.