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RESEARCH ARTICLE

Effect of Mannanase Supplementation on Broilers Fed Diets Containing Varying Levels of Guar Korma Meal

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Abstract

Background and Objective: Guar korma meal (GKM), a byproduct of the guar gum industry, has emerged as a potential alternative protein source in poultry nutrition, particularly in the subcontinent. This study evaluated the effects of graded inclusion levels of GKM, with and without mannanase enzyme supplementation, on the growth performance of broiler chickens.

Materials and Methods: A total of 2,000 day-old mixed-sex broiler chicks (Arbor Acre Plus) were allocated to eight dietary treatments in a completely randomized design with a two-way factorial arrangement (4 GKM inclusion levels×2 enzyme levels), with five replicates of 50 birds each. Diets were formulated with GKM inclusion levels of 0, 2.5, 5 and 7.5%, replacing soybean meal, with or without mannanase supplementation at 200 g/t. Growth performance parameters, including feed intake (FI), body weight (BW), feed conversion ratio (FCR) and mortality, were recorded at 14, 28 and 42 days of age.

Results: Across the starter, grower and finisher phases, increasing GKM inclusion up to 7.5% had no significant effect ($p>0.05$) on FI, BW, FCR, or mortality. Mannanase supplementation significantly improved FI and FCR during the starter phase ($p<0.05$) but had no significant effect during the grower or finisher phases. A significant GKM×mannanase interaction ($p = 0.01$) was observed for starter-phase FCR, indicating that the response to enzyme supplementation varied with the level of GKM inclusion.

Conclusion: These findings demonstrate that GKM can effectively replace soybean meal at inclusion levels up to 7.5% without compromising broiler growth performance, with mannanase offering additional benefits during the early growth phase. This supports GKM as a viable, cost-effective alternative protein source for broiler diet formulation, particularly in regions facing soybean meal price volatility and import dependence.

INTRODUCTION

Protein is one of the most critical and costly nutrients in poultry diets, significantly affecting growth rate, feed efficiency and overall production economics. Soybean meal (SBM) is the predominant protein source widely used globally in broiler diets due to its well-balanced amino acid (AA) profile and high digestibility[1]. However, the increasing global demand for SBM, price volatility and reliance on imports in many countries have raised concerns about its long-term sustainability. Consequently, there is growing interest in identifying and evaluating alternative[2], locally available protein sources that can partially or wholly replace SBM without compromising broiler performance[3].

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Guar korma meal (GKM), a coproduct of guar gum extraction, is another alternative protein source with a moderate crude protein content, typically ranging from 40-45%. Despite its potential, GKM contains galactomannans and other soluble non-starch polysaccharides (NSPs), which can increase intestinal viscosity and reduce nutrient absorption in poultry. Inclusion of GKM above species-specific thresholds can depress feed efficiency and growth performance. However, supplementation with specific enzymes, such as β-mannanase and other carbohydrases, has been reported to counteract these antinutritional effects by breaking down galactomannans, reducing gut viscosity and improving energy and nutrient digestibility .

Several studies have demonstrated that moderate inclusion levels of GKM, when supplemented with enzymes, can partially replace SBM without adversely affecting growth performance. For example, incorporating 5-10% GKM with β-mannanase improved feed conversion and body weight gain to levels comparable to those achieved with conventional SBM-based diets[6]. Additionally, enzymatic treatment can facilitate the improved utilization of amino acids and energy, making GKM a viable ingredient in precision nutrition approaches for broilers[7].

Overall, the exploration of guar korma meal as a partial replacement for SBM represents a promising strategy for sustainable poultry production. The use of standardized digestibility measurements combined with targeted enzyme supplementation enables the effective formulation of multi-ingredient diets. This approach addresses both economic and environmental challenges in modern broiler production while maintaining optimal growth performance. The present study aims to evaluate graded inclusion levels of GKM, with and without enzyme supplementation and determine their effects on growth performance, feed utilization and amino acid digestibility in broilers.

MATERIALS AND METHODS

This study was conducted in accordance with the ethical guidelines established by the Ethical Review Committee of PMAS Arid Agriculture University, Rawalpindi, Pakistan. The research protocol was reviewed and approved following standard ethical procedures for animal research.

The experiment was conducted at the Research and Development Center, Sultan Feed Mills, Sargodha, Punjab, Pakistan, in collaboration with PMAS Arid Agriculture University, Rawalpindi, Pakistan. The main ingredient used in this study was guar korma meal (GKM), sourced from the guar gum industry in Sindh, Pakistan.

Bird housing: A total of 2,000 day-old mixed broiler chicks (Arbor Acre Plus) were procured from a commercial hatchery (Sultan Hatchery, Pakistan) and allocated to eight treatment groups according to a completely randomized design with a two-way factorial arrangement. The main factors included four different inclusion levels of GKM, supplemented with or without mannanase enzyme. Each treatment group consisted of five replicates, with 50 birds per replicate.

All chicks were housed and reared under controlled environmental conditions. House temperature was maintained at 33±1°C during the first week and gradually decreased to 23°C by the end of the sixth week. The house environment was controlled using inlet ducts, side fans and cooling pads installed on each side of the house. Fluorescent lighting was provided throughout the experimental period. Fresh water from a reverse osmosis plant was provided to maintain the Total Dissolved Solids (TDS) of the water at an optimum level[8].

Experimental diets: In this experiment, eight test diets containing different inclusion levels of guar korma meal were used to evaluate the effects of the test ingredient on the growth performance of broiler birds from day 1 to 42. For this purpose, diets were formulated with GKM inclusion levels of 0, 2.5, 5 and 7.5%, with or without mannanase supplementation at the recommended dose of 200 g/t. Birds were reared from day 1 to 42 in an environmentally controlled house. Growth performance parameters, including feed intake, body weight, Feed Conversion Ratio (FCR) and mortality percentage, were determined at 14, 28 and 42 days of age. Proximate composition (%) of guar korma meal is presented in Table 1. Whereas Table 2 presents the diet composition at different inclusion levels of guar korma meal.

Data collection: On days 14, 28 and 42, growth performance parameters, including feed intake, body weight, FCR and mortality, were recorded and calculated.

Chemical analyses: The test ingredient and experimental diets were analyzed according to the methods of AOAC for dry matter (Method 930.15), ether extract (Method 920.39), crude fiber (CF; Method 978.10), crude protein (N×6.25; Method 994.13) and ash content (Method 942.05).

Statistical analyses: The data were analyzed using two-way analysis of variance (ANOVA) with the General Linear Model procedure of SPSS. Differences were considered statistically

significant at $p<0.05$. Means and standard deviations of the growth performance parameters were calculated to provide information on the variability of the measured responses.

RESULTS

Guar korma meal

Effect of guar korma meal on growth performance

Starter phase (0-14 days): Feed intake (FI), body weight (BW), feed conversion ratio (FCR) and mortality were not significantly affected ($p>0.05$) by increasing levels of GKM (0-7.5%). FI ranged from 598-604 g/bird, while BW ranged from 515-522 g/bird across treatments. FCR was similar among treatments (1.15-1.16) and mortality remained low (1.0-2.2%). No linear or quadratic effects of GKM were detected during this phase (Table 3).

Grower phase (15-28 days): No significant differences were observed in FI, BW, FCR, or mortality ($p>0.05$) among GKM treatments. FI ranged from 1845-1917 g/bird, BW from 1343-1356 g/bird and FCR from 1.37-1.42. Mortality remained within the range of 1.6-3.0%. Overall, replacing soybean meal with up to 7.5% GKM did not impair grower performance (Table 4).

Table 1: Proximate composition (%) of guar korma meal (As-is basis)

	Starter diets				Grower diets				Finisher diets			
Inclusion	0%	2.50%	5%	7.50%	0%	2.50%	5%	7.50%	0	2.50%	5%	7.50%
DM[1]	89.0	88.4	88.1	88.2	89.1	88.6	88.7	88.2	87.8	88.5	88.3	88.2
CP[2]	20.9	20.1	21.9	22.3	20.9	21.8	21.5	22.5	19.8	20.7	20.2	21.2
EE[3]	3.8	3.9	4.5	3.9	4.5	4.5	4.6	5.3	4.4	5	6.1	7.6
CF[4]	4.9	4.6	4.7	4.9	4.4	4.1	4.1	3.8	3.3	3	3.5	4.0
Ash	5.8	5.5	5.9	5.7	5.6	5.6	5.4	5.3	4.9	5	5.1	5.4

[1]DM: Dry matter, [2]CP: Crude protein, [3]EE: Ether extract and [4]CF: crude fiber

Table 2: Diet composition at different inclusion levels of guar korma meal

	Starter diets				Grower diets				Finisher diets			
Inclusion age (%)	0%	2.50%	5%	7.50%	0%	2.50%	5%	7.50%	0%	2.50%	5%	7.50%
Corn	60.2	59.3	59.5	62.7	65.5	66.7	66.3	64.1	70.0	66.5	66.5	64.5
SBM[1]	16.2	17.6	16.8	14.5	16.3	13.7	13.2	12.0	19.8	13.1	11.0	10.0
GKM[2]	0.00	2.50	5.00	7.50	0.00	2.50	5.00	7.50	0.00	2.50	5.00	7.50
CM[3]	7.00	7.00	7.00	7.00	6.00	6.00	6.00	6.00	0.00	6.00	5.00	5.00
SFM[4]	5.00	2.60	0.80	1.10	2.70	1.50	0.00	0.00	0.00	0.00	0.00	0.00
RSM[5]	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
PFRM[6]	0.00	0.00	0.00	0.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
RP[7]	4.00	4.00	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Poultry fat	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.80	0.30	1.80	2.00	2.70
Limestone	1.10	1.10	1.10	1.10	0.95	0.95	0.95	0.95	0.80	0.80	0.80	0.80
Lysin So_4	0.73	0.67	0.70	0.78	0.62	0.72	0.73	0.76	0.59	0.70	0.78	0.80
DLM	0.31	0.30	0.32	0.32	0.25	0.27	0.28	0.28	0.25	0.24	0.26	0.27
L Threo	0.19	0.18	0.19	0.21	0.15	0.18	0.18	0.19	0.12	0.15	0.17	0.18
L Iso	0.15	0.13	0.13	0.15	0.09	0.12	0.12	0.12	0.06	0.10	0.12	0.12
L arginine	0.15	0.00	0.00	0.00	0.10	0.09	0.03	0.00	0.10	0.10	0.07	0.00
L Valine	0.14	0.11	0.12	0.13	0.07	0.10	0.10	0.10	0.05	0.08	0.10	0.10
L glycine	0.10	0.15	0.17	0.20	0.04	0.10	0.10	0.10	0.00	0.00	0.10	0.10
MCP[8]	0.52	0.52	0.51	0.54	0.35	0.35	0.35	0.35	0.15	0.15	0.15	0.15
Salt	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
NaCo3[9]	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.05	0.05
Choline Ch	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Vitamins[10]	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.05	0.01	0.01
Minerals[11]	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.05	0.01	0.01
Phytase	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Mannanase	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
AGP[12]	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Filler	0.59	0.20	0.09	0.15	0.28	0.11	0.05	0.14	1.00	1.18	1.35	1.17
Total	100.00	100.00	100.0	100.00	100.00	100.00	100.00	100.00	100.0	100.00	100.00	100.00

[1]SBM: Soybean meal, [2]GKM: Gaur korma meal, [3]CM: Canola meal, [4]SFM: Sunflower meal, [5]RSM: Rape seed meal, [6]PFRM: Poultry feather rich meal, [7]RP: Rice polish, [8]MCP: Monocalcium phosphate, [9]$NaCO_3$: Sodium bicarbonate, [10]Vitamins; vitamin premix, [11]Mineral premix, phytase enzyme (1000 FTU per ton of feed), AGP lincomycin (200 g per ton of feed) as antibiotic growth promoter, salinomycine as anticoccidial (500 gram per ton of feed)

Finisher phase (29-42 days): Similarly, FI, BW, FCR and mortality did not differ significantly among treatments (p>0.05). FI ranged from 3713-3748 g/bird, BW from 2309-2336 g/bird and FCR from 1.57-1.59. Although the p-value for FCR approached significance (p = 0.09), no significant treatment differences were observed. Mortality (2.8-4.8%) was unaffected by GKM inclusion (Table 5).

Interaction effects (GKM×mannanase): A significant GKM×mannanase interaction (p = 0.05) for FI was detected during the starter phase. However, no other performance parameter was significantly influenced by the addition of mannanase to diets containing different inclusion levels of GKM during the starter phase (Table 3). No significant GKM×mannanase interactions were detected for any performance variable during the grower or finisher phases.

DISCUSSION

The present study evaluated the effects of graded dietary inclusion of Guar Korma Meal (GKM) at 0, 2.5, 5.0 and 7.5% in

Table 3: Effect of different inclusion levels of guar korma meal on the growth performance of broilers from 0 to 14 days of age

Treatments						
Inclusion		Mannanase	FI (g/b)	BW (g/b)	FCR (Wt/FI)	MOR (%)
0.0%			599	522	1.15	2.2
2.5%			598	515	1.16	1.4
5.0%			604	520	1.16	1.6
7.5%			602	519	1.16	1.0
	SEM		7.5	3.8	0.01	0.8
	p-value		0.94	0.58	0.82	0.75
		Yes	610[a]	520	1.15	1.6
		No	592[b]	518	1.14	1.5
	SEM		5.3	2.7	0.01	0.53
	p-value		0.03	0.63	0.12	0.92
0.0%		Yes	624[a]	520	1.12	1.5
0.0%		No	575[c]	524	1.09	2.8
2.5%		Yes	611[b]	516	1.18	1.6
2.5%		No	585[c]	513	1.14	1.2
5.0%		Yes	607[b]	524	1.2	2.0
5.0%		No	60[b]	515	1.16	1.2
7.5%		Yes	597[bc]	518	1.2	1.2
7.5%		No	608[b]	519	1.17	0.8
	SEM		10.66	5.35	0.018	1.06
	p-value		0.05	0.66	0.11	0.77

[1]FI: Feed intake, [2]BW: Body weight, [3]FCR: Feed conversion ratio, [4]Mor: Mortality, [5]SEM: Standard error mean and [6]p-value; probability value

Table 4: Effect of different inclusion levels of guar korma meal on growth performance of broiler from 15-28 days of age

Treatments						
Inclusion		Mannanase	FI (g/b)	BW (g/b)	FCR (Wt/FI)	MOR (%)
0.0%			1796	1348	1.33	3.25
2.5%			1917	1343	1.42	3.00
5.0%			1911	1356	1.41	1.80
7.5%			1845	1347	1.37	1.60
	SEM		76.1	9.1	0.57	0.80
	p-value		0.63	0.78	0.65	0.41
		Yes	1860	1344	1.38	2.57
		No	1874	1353	1.38	2.25
	SEM		53	6.4	0.04	0.59
	p-value		0.86	0.34	0.95	0.7
0.0%		Yes	1689	1336	1.26	3.50
0.0%		No	1902	1359	1.40	3.00
2.5%		Yes	1926	1324	1.45	2.80
2.5%		No	1909	1362	1.40	3.20
5.0%		Yes	1917	1362	1.41	2.00
5.0%		No	1904	1350	1.41	1.60
7.5%		Yes	1909	1353	1.41	2.00
7.5%		No	1781	1341	1.33	1.20
	SEM		107.6	12.93	0.08	1.18
	p-value		0.46	0.149	0.53	0.96

[1]FI: Feed intake, [2]BW: Body weight, [3]FCR: Feed conversion ratio, [4]Mor: Mortality, [5]SEM: Standard error mean and [6]p-value; probability value

Table 5: Effect of different inclusion levels of guar korma meal on growth performance of broiler from 29-42 days of age

Treatments						
Inclusion		Mannanase	FI (g/b)	BW (g/b)	FCR (Wt/FI)	MOR (%)
0.0%		3733	2334	1.68	3.00	
2.5%		3748	2336	1.57	4.80	
5.0%		3718	2325	1.58	2.80	
7.5%		3713	2309	1.59	3.00	
	SEM	37.2	16.7	0.00	1.07	
	p-value	0.91	0.66	0.09	0.53	
		Yes	3754	2336	1.61	3.88
		No	3702	2316	1.61	2.93
	SEM	26.3	11.8	0.02	0.76	
	p-value	0.18	0.25	0.99	0.39	
0.0%		Yes	3763	2321	1.69	3.50
0.0%		No	3703	2346	1.66	2.50
2.5%		Yes	3793	2352	1.58	5.20
2.5%		No	3702	2320	1.57	4.40
5.0%		Yes	3729	2341	1.57	3.20
5.0%		No	3707	2308	1.59	2.40
7.5%		Yes	3728	2328	1.58	3.60
7.5%		No	3698	2290	1.60	2.40
	SEM	52.6	23.6	0.04	1.50	
	p-value	0.91	0.52	0.92	1.00	

[1]FI: Feed intake, [2]BW: Body weight, [3]FCR: Feed conversion ratio, [4]Mor: Mortality, [5]SEM: Standard error mean, [6]P-value: Probability value

combination with or without β-mannanase on broiler performance from 1 to 42 days of age. The principal finding was that increasing GKM inclusion to 7.5% did not significantly affect feed intake, body weight, feed conversion ratio (FCR), or mortality during the starter, grower, or finisher phases. This finding is broadly consistent with earlier work showing that moderate inclusion of guar meal can be tolerated by broilers, although the magnitude of the response is strongly influenced by the type and quality of guar meal, its residual galactomannan content, the age of the birds and dietary formulation[4,10,11].

The absence of a significant response to GKM inclusion in the present study agrees particularly well with the findings of Lee *et al.*[10], who reported that inclusion of the germ fraction of guar meal up to 7.5% did not depress body weight in broilers, although feed efficiency was adversely affected at the highest inclusion level. Lee *et al.*[11] subsequently reported that 2.5% guar meal could be included without adverse effects on growth to 6 weeks, whereas β-mannanase improved feed efficiency when guar meal fractions were included at 5%. The present results extend these observations by demonstrating that, in the GKM evaluated in the current experiment, inclusion levels as high as 7.5% did not significantly compromise BW or FCR through 42 days. This difference from the more conservative inclusion limits reported by Lee *et al.*[11] may reflect differences in the raw material, processing conditions, residual guar gum/galactomannan concentration, diet composition, bird strain and enzyme program. Guar meal is not a nutritionally uniform ingredient; consequently, an inclusion recommendation based on percentage alone may not be transferable among sources. The recent literature also supports this interpretation. Milczarek *et al.*[12] observed a decline in broiler body weight as guar meal increased from 4 to 12%, with the magnitude of the response becoming more pronounced at higher inclusion levels, whereas a recent study by Rashid *et al.*[13] demonstrated that responses to guar meal were strongly dependent on both inclusion level and age, with greater tolerance during the grower phase than during the starter phase.

The maintenance of performance at 7.5% GKM in the present experiment can plausibly be explained by the relatively moderate inclusion levels used, together with the formulation of diets to provide adequate nutrients. Residual galactomannans are considered an important limitation of guar-derived ingredients because these non-starch polysaccharides can increase digesta viscosity and interfere with nutrient digestion and absorption. Lee *et al.*[10] demonstrated that increasing guar meal fractions could increase intestinal viscosity and impair feed efficiency, while β-mannanase reduced viscosity and alleviated the associated performance depression. Therefore, the lack of an observable performance depression in the present study may be related to the physicochemical characteristics of the GKM used, the dietary inclusion range and the overall nutrient supply, which may have been sufficient to prevent these antinutritional effects from becoming performance-limiting. Importantly,

however, intestinal viscosity and nutrient digestibility were not measured in the present experiment; therefore, the proposed mechanism should be regarded as a biologically plausible explanation rather than a directly demonstrated mechanism. The response to β-mannanase was more limited and phase-specific than the response to GKM inclusion. During the starter phase, β-mannanase supplementation increased feed intake, whereas body weight, FCR and mortality were not significantly affected. The increased feed intake therefore did not translate into a corresponding improvement in body weight or feed efficiency. This partial response is consistent with the recognized mode of action of β-mannanase, which hydrolyses β-mannan-containing non-starch polysaccharides and can reduce the viscosity-related constraints associated with guar-derived ingredients[6,10]. Nevertheless, the magnitude of the response depends on substrate concentration, enzyme dose, enzyme activity under gastrointestinal conditions and the composition and processing history of the guar product. The present study used a single β-mannanase dose (200 g/ton); therefore, the absence of a broader performance response should not be interpreted as evidence that β-mannanase has no nutritional value in GKM-containing diets.

A significant GKM×β-mannanase interaction was detected for starter-phase feed intake ($p = 0.05$), indicating that the effect of the enzyme was not completely independent of GKM inclusion level. In contrast, no significant interaction was observed for body weight, FCR, or mortality during the starter phase and no significant interactions were detected during the grower or finisher phases. The interaction for feed intake should therefore be interpreted cautiously because it was not accompanied by a corresponding interaction in growth or feed efficiency. Nevertheless, the finding is biologically compatible with the concept that enzyme efficacy is substrate-dependent: when dietary GKM supplies more β-mannan substrate, the opportunity for β-mannanase to modify the physicochemical properties of digesta may increase but the actual response will depend on the amount and accessibility of the substrate. Lee *et al.*[6] demonstrated in vitro that β-mannanase reduced feed viscosity in diets containing guar meal fractions, providing mechanistic support for a substrate-dependent enzyme response. More recent work also indicates that the benefits of β-mannanase can vary with guar meal inclusion level and bird age. Rashid *et al.*[13] reported stronger enzyme-related improvements at moderate guar meal inclusion levels, with reduced efficacy at very high inclusion, supporting the view that enzyme response is influenced by the balance between enzyme activity and the antinutritional substrate load.

The lack of significant effects during the grower and finisher phases is also noteworthy. Broilers undergo substantial maturation of the gastrointestinal tract during the first weeks of life and older birds generally have greater digestive and absorptive capacity than very young chicks. Consequently, moderate amounts of soluble non-starch polysaccharides may be tolerated more effectively as birds mature. This interpretation is supported by Rashid *et al.*[13], who found that broilers tolerated up to 8% guar meal during the grower phase, whereas higher inclusion was detrimental, while starter birds were more sensitive to increasing guar meal. The present findings provide a complementary observation, as 7.5% of the tested GKM did not significantly depress growth during the starter phase, with treatment effects remaining nonsignificant during the subsequent phases. The difference in tolerance thresholds between studies emphasizes that bird age alone cannot determine the appropriate inclusion level; characteristics of the guar meal and the complete diet must also be considered.

The present findings also differ from studies in which higher guar meal inclusion reduced performance. Milczarek *et al.*[12] reported progressively lower body weight with 4, 8 and 12% guar meal, with 4% recommended as a practical level under their experimental conditions. Similarly, Lee *et al.*[11] identified relatively conservative upper inclusion levels for guar meal fractions, although enzyme supplementation improved feed efficiency at 5% inclusion. These apparently different findings do not necessarily represent contradictory evidence. Rather, they indicate that the nutritional value of guar meal is source-dependent. Residual guar gum, β-mannan concentration, fiber composition, processing intensity, protein quality and the amino acid and energy balance of the complete diet can all influence the response to inclusion. In the present experiment, the diets were formulated across starter, grower and finisher phases and contained supplemental amino acids and other feed additives, which may have reduced the likelihood that differences in the protein contribution of GKM would translate into differences in growth performance. In addition, the tested inclusion range ended at 7.5%; therefore, the present results should not be extrapolated to substantially higher inclusion levels without further evaluation.

The present study adds to previous research by evaluating a locally sourced GKM under a full 42-day broiler production cycle and by examining both the main effect of GKM inclusion and its interaction with β-mannanase. However, the study does not establish that 7.5% is a universal maximum inclusion level, nor does it demonstrate the mechanism responsible for the apparent tolerance. Future studies should characterize the GKM source for residual galactomannan, soluble and insoluble fiber, trypsin inhibitors, amino acid digestibility and

metabolizable energy, while simultaneously measuring intestinal viscosity and digesta characteristics. Dose-response studies using multiple β-mannanase concentrations would also help establish whether the limited performance response observed here was due to an adequate enzyme supply, a low substrate burden, or both. Such measurements would provide a stronger mechanistic basis for defining source-specific GKM inclusion recommendations.

CONCLUSION

Under the conditions of the present study, dietary inclusion of GKM up to 7.5% did not adversely affect feed intake, body weight, FCR, or mortality of broilers during the 1–42-day production period. β-Mannanase supplementation produced a limited early-life response, primarily reflected in increased feed intake during the starter phase, while its effects on other performance parameters were not significant. The absence of significant GKM × β-mannanase interactions for most performance parameters further indicates that the response to enzyme supplementation was limited under the dietary conditions evaluated. Overall, these findings support GKM as a potentially useful local protein ingredient for partial replacement of soybean meal in broiler diets at inclusion levels up to 7.5%, provided that the ingredient is appropriately characterized and diets are adequately formulated. However, the results should not be interpreted as establishing a universal maximum inclusion level because the nutritional value and antinutritional characteristics of GKM can vary among sources. Further research involving different GKM sources, higher inclusion levels, multiple β-mannanase doses and measurements of nutrient digestibility and intestinal viscosity is warranted to establish source-specific inclusion recommendations and clarify the mechanisms underlying GKM utilization in broilers.

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