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Associative Effect of Non-Starch Polysaccharide Enzymes and Phytase on Performance, Nutrient Utilization and Gut Health of Broilers Fed Sub-Optimal Energy Diets

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Abstract: A total of 150 Cobb broilers were divided into 5 groups. These groups were fed a complete corn-soybean based standard and sub optimal energy diets supplemented with non-starch polysaccharide enzymes alone or in combination with phytase. No significant difference was observed among the broiler chicks fed SD, BD and BD supplemented with NSP enzymes, phytase alone or in combination on body weight gain. The feed intake by chicks fed BD, BD supplemented with NSP enzyme and/or phytase was higher ($p<0.01$) in starter phase while lower in ($p<0.01$) finisher phase compared to SD fed chicks and therefore the overall feed intake from 0-6 weeks was comparable. The FCR improved ($p<0.01$) with supplementation of both NSP enzymes and phytase during starter phase while no effect was observed during finisher and overall period. The addition of NSP enzymes and phytase to BD significantly ($p<0.05$) improved retention of OM, CP, NFE, GE and phosphorus with no effect on DM, CF and EE retentions. Supplementation of NSP enzymes and phytase alone and in combination of improved ($p<0.01$) percent tibia ash content compared to BD. No effect of phytase and NSP enzymes was observed on dressing yield, abdominal fat, weight of visceral organs, intestinal pH and intestinal histology except improvement in ($p<0.05$) breast yield and reduced ($p<0.05$) intestinal viscosity and *E. coli* count. The cost of feeding during various phases of broiler production was significantly ($p<0.05$) lower in BD and supplementation of NSP enzyme and phytase to BD did not increase the feeding cost and was lower than SD. The feed cost per kg live weight gain was lowest ($p<0.05$) when the BD was supplemented with phytase and NSP enzymes followed by phytase and NSP enzyme supplementation alone.

Key words: Non-starch, polysaccharides, phytase, standard diet, basal diet, viscosity, histology

INTRODUCION

The majority of broiler diets used in Indian poultry industry are corn and soybean meal based, both of which are important for meeting the protein and energy requirements of the bird. Dietary additions of feed phosphates not only increase the feed and production cost but may also lead to an increase of soluble P in the excreta (Nahm, 2007). Because the bulk of poultry feed is plant based, up to 70% of the dietary P can be in the form of phytate. Phytate is known to contain bound P that is unavailable to the bird, resulting in an increased requirement for P that is met by the addition of inorganic P sources (NRC, 1994). Phytase was developed to reduce the diffuse phosphorus pollution from intensive agriculture. phytase is now present in over 60% of monogastric feed and possibly even in a higher percentage of poultry diets. Phytase mainly been considered to be a tool to increase phosphorus availability/digestibility from vegetable sources. Combination of different types of enzymes or multi-enzyme complexes are used to increase availability of nutrients and energy especially combinations of different carbohydrases with phytase. Results from the several studies have shown increased phosphorus digestibility and utilization and hence reduced phosphorus excretion into the environment due to phytase addition to poultry diets (Applegate *et al*., 2003; Penn *et al*., 2004).

Therefore, the objective of the present experiment was to study the influence of phytase and non-starch polysaccharide enzymes alone and in combination to corn-soybean based sub-optimal energy diets on performance, gut health, nutrient retention and slaughter attributes in broiler chicken.

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Table 1: Details of experimental diets

Diet No.	Diet
1	Standard Diet (SD)
2	Basal Diet (BD)
3	BD + NSP enzymes
4	BD + phytase
5	BD + NSP enzymes + phytase

Table 2: Ingredient composition of Basal Diet (BD)

Ingredient (g kg^{-1})	Prestarter	Starter	Finisher
Maize	522.80	597.20	657.50
Soybean meal	380.20	342.60	305.00
De oiled rice bran	59.20	23.70	0.00
Oil (veg)	0.00	0.00	3.10
Salt	4.50	4.50	4.50
DL-methionine	2.20	2.10	1.80
Di-calcium phosphate	18.30	17.70	16.50
Shell grit	7.70	7.00	6.80
Trace mineral mixture[1]	1.20	1.20	1.20
Vitamin premix[2]	0.40	0.40	0.40
Choline chloride (50%)	0.60	0.60	0.60
Toxin binder	2.00	2.00	2.00
Antibiotic	0.50	0.50	0.50
Coccidiostat	0.50	0.50	0.50
Total	1000.00	1000.00	1000.00
Nutrient composition (calculated)			
ME (kcal kg^{-1})	2725.00	2825.00	2925.00
Protein (%)	22.50	21.00	19.50
Calcium (%)	0.90	0.85	0.80
Available phosphorus (%)	0.45	0.43	0.40
Lysine (%)	1.23	1.13	1.03
Methionine (%)	0.55	0.52	0.48
Crude fibre (%)	4.37	3.82	3.39

[1]Trace mineral provided per kg diet: Manganese, 120 mg; Zinc, 80 mg; Iron, 25 mg; Copper, 10 mg; Iodine, 1 mg and Selenium, 0.1 mg. [2]Vitamin premix provided per kg diet: vitamin A, 20000 IU; vitamin D3, 3000 IU; vitamin E, 10 mg; vitamin K, 2 mg; Riboflavin, 25 mg; vitamin B1, 1 mg; vitamin B6, 2 mg; vitamin B12, 40 mg and Niacin, 15 mg

MATERIALS AND METHODS

Experimental design and sample collection: About 1500 days old Cobb commercial broiler chicks were weighed, wing banded and randomly distributed in to five experimental groups, six replicates per group and five birds per replicate. The NSP enzymes combination (xylanase 7500 IU kg^{-1}, cellulase 100 IU kg^{-1} and β-D-glucanase 100 IU kg^{-1}) and with phytase (675 IU kg^{-1}) was tested at sub optimal energy concentration (225 kcal kg^{-1}) less ME than standard diet (NRC, 1994). The details of experimental diets and ingredient composition are given in Table 1-3. All replicate groups of chicks were offered the respective diets *ad libitum* for a period of 42 days. Weekly body weights and feed intake were recorded. At the end of experiment, a metabolic trial of 4 day duration was conducted to determine the nutrient utilization and balance of nutrients. The samples of each feed, feed residue and feces pooled during 4 days period were ground and analyzed for proximate principles as per the method by AOAC (2005). After metabolic trial, 30 birds (of 6 birds from each diet by selecting one at random from each replicate) were slaughtered to assess the carcass characteristics.

Table 3: Ingredient composition of standard diets

Ingredient (g kg^{-1})	Pre-starter	Starter	Finisher
Maize	542.00	572.80	603.90
Soybean meal	393.00	353.80	314.80
Oil (veg)	27.00	36.80	46.50
Salt	4.50	4.50	4.50
DL-methionine	2.20	2.10	1.90
Di-calcium phosphate	19.00	18.10	16.50
Shell grit	7.10	6.70	6.70
Trace mineral mixture[1]	1.20	1.20	1.20
Vitamin premix[2]	0.40	0.40	0.40
Choline chloride (50%)	0.60	0.60	0.60
Toxin binder	2.00	2.00	2.00
Antibiotic	0.50	0.50	0.50
Coccidiostat	0.50	0.50	0.50
Total	1000.00	1000.00	1000.00
Nutrient composition (calculated)			
ME (kcal kg^{-1})	2950.00	3050.00	3150.00
Protein (%)	22.50	21.00	19.50
Calcium (%)	0.90	0.85	0.80
Available phosphorus (%)	0.45	0.43	0.40
Lysine (%)	1.24	1.14	1.04
Methionine (%)	0.55	0.52	0.48
Crude fibre (%)	3.69	3.52	3.34

[1]Trace mineral provided per kg diet: Manganese, 120 mg; Zinc, 80 mg; Iron, 25 mg; Copper, 10 mg; Iodine, 1 mg and Selenium, 0.1 mg; [2]vitamin premix provided per kg diet: vitamin A, 20000 IU; vitamin D3, 3000 IU; vitamin E, 10 mg; vitamin K, 2 mg; Riboflavin, 25 mg; vitamin B1, 1 mg; Vitamin B6, 2 mg; vitamin B12, 40 mcg and Niacin, 15 mg

Gut health: To study the effect of various dietary energy concentrations, supplementary effect of NSP enzymes with or without phytase on gut health, the digesta was collected from distal portion of small intestine during slaughter. Approximately 2 g of digesta was taken in sterile eppendorf tubes for enumeration of *Escherichia coli*. Another 2 g of digesta was collected and centrifuged at 5000 rpm for 10 min at 20°C. An aliquot of supernatant (0.5-1 mL) was collected and stored in capped vials for viscosity determination. The digesta collected in centrifuge tubes was utilized for measuring the pH.

Statistical analysis: The data were subjected to appropriate statistical analysis using Statistical Package for Social Sciences (SPSS) 16th version and comparison of means was tested using Duncan's multiple range tests (Duncan, 1955).

RESULTS

Nutrient composition of experimental ration: Nutrient composition (dry matter basis %) of broiler finisher standard and basal diets is presented in Table 4.

Table 4: Nutrient composition (dry matter basis %) of broiler finisher standard and basal diets (analyzed)

Diets	Dry matter	Organic matter	Crude protein	Ether extract	Crude fiber	Nitrogen free extract	Total ash	Gross energy (kcal g^{-1})	Total phosphorus
Standard Diet (SD)	92.15	93.93	19.85	6.22	3.34	64.52	6.07	3.85	0.46
Basal Diet (BD)	89.61	93.41	19.52	3.25	3.39	67.25	6.59	3.43	0.46
BD + NSP enzyme	92.05	93.80	19.62	3.24	3.38	67.56	6.20	3.44	0.46
BD + phytase	91.81	93.40	19.64	3.26	3.39	67.11	6.60	3.32	0.46
BD + NSP enzyme + phytase	89.84	93.33	19.62	3.15	3.36	67.21	6.67	3.36	0.45

Each value is average of duplicate analysis

Table 5: Effect of feeding low calorie diet supplemented with NSP enzymes and Phytase on performance and cost economics of broiler chicken

	Weeks							
	Body weigh (g)		Feed intake (g)		Feed conversion ratio		Feed cost per kg live weight gain (Rs.)	
Diets	0-3	0-6	0-3	0-6	0-3	0-6	0-3	0-6
Standard Diet (SD)	463.200	1494.000	726.000^{b}	3016.000	1.570^{c}	2.020	31.550^{b}	40.500^{a}
Basal Diet (BD)	448.800	1436.000	789.700^{a}	2953.000	1.770^{a}	2.060	34.080^{a}	39.570^{ab}
BD + NSP enzyme	471.300	1496.000	774.500^{a}	2895.000	1.640^{b}	1.940	31.740^{b}	37.220^{bc}
BD + probiotics phytase	462.500	1463.000	769.300^{a}	2933.000	1.660^{b}	2.010	32.120^{b}	38.580^{abc}
BD + NSP enzyme + Phytase	477.000	1526.000	776.000^{a}	2924.000	1.630^{bc}	1.920	31.420^{b}	36.780^{c}
SEM	3.240	15.220	4.930	16.240	0.020	0.020	0.260	0.440
p-value	0.055	0.408	0.001	0.184	0.001	0.156	0.002	0.028

Means with different superscripts in a column differ significantly ($p<0.05$)

Body weight gain (g): The starter and total body weight gain in broiler chicks fed Basal Diet (BD) supplemented with NSP enzymes and or phytase is presented in Table 5. No significant difference was observed among the broiler chicks fed SD, BD, BD supplemented with NSP enzymes, BD supplemented with phytase and BD supplemented with NSP enzymes and phytase during starter phase and total period (1-42 days). The body weight gain during starter and total gain (1-42 days) ranged from 448.8-477.0 and 1436-1526 g, respectively.

Feed intake (g/bird/day): The feed intake by chicks fed standard diet during 4th and 5th week was higher ($p<0.01$) than those fed BD and supplementation of NSP enzymes and phytase to BD had no significant effect on feed intake (Table 5). The feed intake was comparable among the chicks fed BD supplemented with NSP enzymes or phytase alone or in combination to BD. The feed intake by chicks fed BD, BD supplemented with NSP enzymes and phytase alone or in combination was higher ($p<0.01$) in starter phase while lower in ($p<0.01$) finisher phase compared to SD fed chicks and therefore the overall feed intake from 0-6 weeks was comparable and did not differ between SD group and BD group. Supplementation of NSP enzymes to BD had no effect on feed intake during starter and total periods. Similarly, phytase supplementation alone or in combination with NSP enzymes to BD had no influence on feed intake during starter and total periods.

Feed conversion ratio (g intake/g gain): The Feed Conversion Ratio (FCR) during starter phase in birds fed BD supplemented with NSP enzymes and phytase was higher than BD and SD birds (Table 5). BD supplemented with phytase alone or in combination with NSP enzymes improved the FCR significantly compared to BD and SD. No significant effect of NSP enzymes and phytase supplementation was observed on FCR during finisher phase. The FCR of BD fed chicks was higher ($p<0.001$) during starter phase compared to SD and adding phytase or NSP enzymes improved the FCR compared to BD but higher than that of SD. While BD supplemented with combination of NSP enzymes and phytase, the FCR improved and was comparable to SD. The FCR in various experimental groups during finisher and overall period was comparable.

Nutrient retention: The BD supplemented with NSP enzymes and phytase was significant ($p<0.05$) for retention of OM, CP, NFE, GE and phosphorus and the values ranged from 68.87-73.30, 54.75-62.69, 75.46-80.29, 63.81-75.37 and 31.14-36.52 %, respectively (Table 6). The supplementation of NSP enzymes and phytase alone or in combination of both significantly improved ($p<0.05$) the utilization of OM (72.63%) in comparison to BD group. The OM retention was comparable among the groups fed SD, BD and BD supplemented with NSP enzymes or phytase.

The CP retention was significantly lowest ($p<0.05$) in BD (54.75%) fed chicks, followed by BD supplemented with phytase (58.96%). Supplementation of NSP enzymes to BD increased ($p<0.05$) CP retention compared to BD but value was lower than the SD. Adding both phytase and NSP enzymes improved CP retention which was comparable to SD. The NFE retention in chicks fed BD with phytase or combination of NSP enzymes and phytase

Table 6: Nutrient retention, intestinal pH, viscosity, *E. coli* and tibia ash content of broilers fed low calorie diet supplemented with NSP enzymes and Phytase

	Nutrient retention (%)									Gut condition		
Diets	DM	OM	CP	CF	EE	NFE	GE	Phosphorus	pH	Viscosity (cP)	*E. coli* count (cfu mL^{-1})	Tibia ash (%)
Standard Diet (SD)	66.120	73.300^{a}	62.690^{a}	32.100	76.810	75.460^{b}	66.740^{b}	31.140^{b}	6.170	8.120^{a}	4.340^{bc}	46.390^{a}
Basal Diet (BD)	67.200	68.870^{b}	54.750^{b}	29.060	71.290	77.080^{b}	63.810^{b}	31.590^{b}	6.160	7.010^{b}	6.680^{a}	42.740^{b}
BD + NSP enzymes	69.890	72.120^{a}	60.720^{a}	32.180	74.560	79.510^{ab}	70.280^{ab}	32.700^{b}	5.600	4.250^{c}	5.280^{ab}	46.390^{a}
BD + phytase	70.270	72.000^{a}	58.960^{b}	33.600	71.180	84.120^{a}	66.650^{b}	35.890^{a}	6.040	5.240^{c}	5.130^{ab}	47.330^{a}
BD + NSP enzymes + phytase	69.640	72.630^{a}	61.240^{a}	32.450	72.240	80.290^{ab}	75.370^{a}	36.520^{a}	6.190	4.180^{c}	3.440^{c}	47.660^{a}
SEM	0.790	0.530	0.920	0.670	0.790	0.980	1.240	0.650	0.160	0.390	0.320	0.530
p-value	0.393	0.059	0.040	0.291	0.086	0.032	0.014	0.004	0.073	0.001	0.005	0.009

Table 7: Effect on slaughter characteristics of broilers fed low calorie diet supplemented with NSP enzymes and phytase

				Visceral organs (Percentage of body weight)		
Diets	Dressing yield (%)	Breast yield (%)	Abdominal fat (%)	Liver	Heart	Gizzard
Standard Diet (SD)	63.670	18.890^{c}	1.040	2.180	0.600	2.660
Basal Diet (BD)	64.610	19.620^{bc}	0.890	2.100	0.690	2.550
BD + NSP enzymes	64.780	18.390^{c}	1.070	2.250	0.620	2.470
BD + phytase	65.640	20.540^{ab}	0.790	2.050	0.610	2.630
BD + NSP enzymes + phytase	66.120	21.800^{a}	0.880	2.110	0.600	2.520
SEM	0.350	0.330	0.050	0.050	0.010	0.040
p-value	0.197	0.001	0.501	0.739	0.067	0.447

Means with different superscripts in a column differ significantly ($p<0.05$)

was higher ($p<0.05$) than the BD. The NSP enzymes along with phytase improved ($p<0.01$) the retention of GE in comparison to SD and BD. BD supplemented with NSP enzymes or phytase alone improved GE retention but the improvement was comparable to BD or SD.

The DM, CF and EE retentions were not influenced by supplementation of NSP enzymes and phytase to BD and the retentions were comparable to SD and BD. The supplementation of NSP enzymes along with phytase significantly ($p<0.01$) improved phosphorus retention when compared to SD, BD and BD supplemented with NSP enzymes. The phosphorus retention was comparable between SD, BD and BD supplemented with NSP enzymes. Supplementation of BD with NSP enzymes and phytase alone and in combination improved the phosphorus retention.

The tibia ash content in broilers was lower ($p<0.01$) in BD fed chicks compared to other four groups. The tibia ash content in birds fed SD, BD supplemented with NSP enzymes, phytase alone or in combination was comparable among each other (Table 6).

Carcass characteristics: The slaughter attributes in terms of dressing yield, breast yield, abdominal fat and visceral organs viz., liver, heart and gizzard is presented in Table 7.

No significant effect was observed among broilers fed SD, BD and BD supplemented with NSP enzymes, phytase alone or in combination on dressing yield and the value varied between 63.67 and 66.12%. The breast yield in broilers fed BD, SD and BD supplemented with NSP enzymes was comparable among each other (18.39-19.62%) while supplementing BD with phytase or in combination with NSP enzymes was higher than that of SD. BD supplemented with NSP enzymes, phytase alone or in combination had no effect on abdominal fat and the values ranged from 0.79-1.07%. No significant ($p<0.05$) effect of supplementation of BD with NSP enzymes, phytase alone or in combination was observed in weight of liver, heart and gizzard and the values ranged from 2.05-2.25, 0.60-0.69 and 2.47-2.66%, respectively (Table 7).

Gut conditions: No significant ($p<0.05$) effect on intestinal pH was observed among BD, BD supplemented with NSP enzymes and phytase alone or in combination and SD and the pH value recorded was 6.16, 5.60, 7.04, 6.19 and 6.17, respectively (Table 6).

The intestinal viscosity was highest in SD (8.12 cP), followed by BD (7.01 cP) fed chicks. Supplementation of phytase and NSP enzymes singly or in combination reduced the intestinal viscosity compared to BD and SD.

The *E. coli* count (cfu/g) in intestine was highest in BD compared to SD. Supplementing BD with NSP enzymes or phytase reduced ($p<0.005$) the *E. coli* count (cfu/g) but was statistically comparable to BD and SD. Supplementing NSP enzymes and phytase in combination to BD reduced the *E. coli* count significantly ($p<0.005$) in comparison to BD but the count was similar to SD (Table 6).

Cost economics: The cost of production per kg live weight gain is given in Table 5. The production cost per kg live weight gain during starter phase was higher ($p<0.002$) (Rs. 34.08) for BD than SD. The feed cost of production decreased ($p<0.002$) with supplementation of phytase and NSP enzymes alone or in combination to BD and was comparable to SD in starter phase. During finisher phase, cost of production was highest ($p<0.05$) in SD group fed chicks (Rs. 43.96) and comparable with BD and BD supplemented with phytase (Rs. 41.19 and 40.77), respectively. Supplementation of BD with NSP enzymes alone (Rs. 38.97) or along with phytase (Rs. 38.50) reduced ($p<0.05$) the cost of production during finisher phase in comparison to SD. The same trend was reflected in total cost of production per kg live weight gain being lowest ($p<0.05$) when the BD was supplemented with NSP enzymes and phytase (Rs. 36.78), followed by BD supplemented with phytase (Rs. 38.58) and NSP enzymes (Rs. 37.22) alone and highest cost of production was observed in BD group (Rs. 39.57).

DISCUSSION

Body weight gain: The starter and finisher body weight gain in broiler chicks fed basal diet supplemented with NSP enzymes and or phytase had no effect on weight gain (Table 5). NSP and phytase enzymes addition to BD improved overall average total body weight gain by 6.29% compared to BD, indicating a positive synergistic effect of supplementing both these enzymes to BD. The results are in agreement with Lu *et al.* (2009) where negative control diets low in phosphorus and calcium (0.15%) supplemented with xylanase and phytase or both had improved weight gain compared to negative control diet.

Feed intake: The feed intake during starter phase was higher in BD compared to SD while in finisher phase it was lower in BD compared to SD (Table 5). The NSP and phytase enzyme addition to BD had no effect on feed intake. The overall average total feed intake of SD was comparable among all the groups. The results were in line with Lu *et al.* (2009) who reported that broilers fed negative diets (0.15% less phosphorus and calcium) added with xylanase and phytase had significantly lower feed intake than positive control diet. Similarly, Woyengo *et al.* (2010) observed that low phosphorus and calcium (0.46 and 1.1%) diet supplemented with multi carbohydrase and phytase had lower ($p<0.05$) feed intake than positive control diet.

Feed conversion ratio: Significant effect of NSP enzymes and phytase supplementation to BD on Feed Conversion Ratio (FCR) was observed during starter phase but comparable during finisher phase. During the starter phase the FCR was lower ($p<0.05$) in BD compared to SD and adding either NSP enzymes or phytase improved the FCR but was lower than SD. Adding both the additives to BD improved the FCR and was comparable to SD (Table 5) indicative of associative effect of these enzymes.

The results were in agreement with Lu *et al.* (2009) who reported that low calcium and phosphorus diets supplemented with phytase, xylanase or phytase plus xylanase had lower ($p<0.05$) feed per gain over birds fed positive control diet. Similarly, phytase plus multi carbohydrase enzyme supplementation improved ($p<0.05$) feed conversion ratio of negative diet from (low in Ca and P) 1.37-1.32 but phytase alone had no effect on feed efficiency (Woyengo *et al.*, 2010).

Nutrient retention: Except for lower CP and CF retentions on BD the nutrient retention was comparable between BD and SD (Table 6). The nutrient retention in BD group improved with supplementation of NSP enzymes or phytase. No associative effect of NSP and phytase enzyme was observed as the retentions were similar to that of individual enzyme supplementation. Woyengo *et al.* (2010) reported that broiler diets deficient in phosphorous and calcium supplemented with multi carbohydrase and phytase alone or in combination improved ($p<0.05$) DM, GE, nitrogen and phosphorus retentions. Tiwari *et al.* (2010) reported that negative control diets marginal in ME and phosphorus supplemented with cocktail of xylanase, amylase, protease and phytase alone or combination had no effect on DM metabolilisability and ME.

Tibia ash content in phytase, NSP enzymes or combination of both increased compared to BD and reached to the level of SD but no associative effect of NSP and phytase enzyme was observed (Table 6). These results were in agreement with Lu *et al.* (2009) and Woyengo *et al.* (2010) who reported improved bone mineralization of tibia ash with supplementation of multi carbohydrase and phytase alone or in combination.

Carcass characteristics: The dressing yield, accumulation of abdominal fat and visceral organs viz., liver, heart and gizzard were not affected by supplementation of NSP enzymes and phytase alone or in combination compared to SD and BD (Table 7). While breast yield percentage was higher ($p<0.01$) in birds fed BD supplemented with NSP enzymes and phytase compared to both BD and SD. Rao *et al.* (2003) observed that the enzyme supplementation to broiler diet did not improve significantly ($p<0.05$) dressing per cent, abdominal fat and weight of giblet, intestinal length and its weight. While in studies of Rambabu (2009), dressing percent improved with NSP enzymes supplementation while organ weight and abdominal fat were not affected.

Gut conditions: Supplementation of NSP enzymes and phytase had no effect on pH values recorded in the intestinal contents (Table 6). Intestinal viscosity reduced with supplementation of NSP enzymes and phytase alone or in combination. The *E. coli* count was higher in BD compared to SD. Supplementation of either NSP or phytase enzyme though reduced the *E. coli* count, it was not statistically significant. Supplementation of both NSP enzymes and phytase significantly decreased ($p<0.01$) the *E. coli* count and was comparable to SD.

Cost economics: The overall total feed cost per kg live weight gain was significantly ($p<0.01$) reduced by Rs. 3.72 and 2.79 in supplemented groups compared to SD and BD, respectively. The feed cost of production during total period (1-42 days) was significantly ($p<0.05$) lower in BD supplemented with NSP enzymes and phytase compared to BD and SD (Table 5). Similar results were reported by Ramesh and Chandrashekaran (2011) where enzyme supplementation of 0.5 g kg^{-1} diet of standard and low nutrient density diets (5% less energy and protein) reduced cost of production per kg gain by 7.5 and 1%, respectively.

CONCLUSION

It can be concluded that adding non-starch polysaccharide enzymes and phytase alone or combination of both to sub-optimal corn-soybean based energy diets can enhance performance, nutrient retention, modulation of gut health and promoting meat quality of broiler chicken with considerable reduction in overall cost of production.

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