

Research Article

EFFECT OF SUPPLEMENTATION OF CORNSOYA PELLETTED DIETS WITH ENCAPSULATED FEED ENZYMES ON PERFORMANCE OF BROILERS

K. Srinath, V. Ravinder Reddy, *K. Kondal Reddy, Mallikarjuna P. V. R, V. Chinni Preetam and M. R. Reddy

Department of Livestock Products Technology, College of Veterinary Science, S V Veterinary University, Rajendranagar, Hyderabad-500 030, India

**Author for Correspondence*

ABSTRACT

The effect of encapsulated enzymes in corn soya pelleted diets was studied on the performance of broilers by an experimental feeding trail of 42 day duration with day old male commercial broiler chicks. Each group was divided into six replicates, with five chicks per replicate and was raised in electrically heated battery brooders. The control group (T₁) and was fed with basal diet alone. Group 2 (T₂) was fed with uncoated phytase @ 500 FTU/kg diet, Group 3 (T₃) was fed with coated phytase @ 500 FTU/kg diet, Group 4 (T₄) was fed with uncoated xylanase @ 2000 IU/kg, Group 5 (T₅) was fed with coated xylanase @ 2000 IU/kg of diet, Group 6 (T₆) was fed with uncoated phytase @ 500 FTU/kg and xylanase @ 2000 IU/kg of diet, Group 7 (T₇) was fed with coated phytase @ 500 FTU/kg and xylanase @ 2000 IU/kg of diet, Group 8 (T₈) was fed with uncoated cocktail enzymes and Group 9 (T₉) was fed with coated cocktail enzymes (@ 2,000 U of cellulase, 1,000 U of pectinase, 300 U of mannanase, 750 U of xylanase, 450 U of glucanase, 1,875 U of amylase, and 150 U of protease per kilogram of diet). Overall the broilers showed significantly (P<0.05) increased body weight gains on supplementation of uncoated and coated enzymes to corn-soya diet during finisher phase (4-6 weeks) and overall period (0-6 weeks) than the control diet. Coated enzyme supplemented diets yielded significantly (P<0.05) efficient feed to weight gain values over their respective uncoated enzyme supplemented diets during finisher phase (4-6 weeks) and overall period (0-6 weeks).

The release of total sugars (mg/g diet) by invitro digestion of diets supplemented with uncoated and coated enzymes yielded higher values of total sugars (mg/g feed) than control diet in both starter and finisher feed. *In vitro* release of inorganic phosphorous (g/kg diet) from phytase supplemented diets, was higher in coated than uncoated phytase supplemented diets. However, both uncoated and coated phytase supplemented diets yielded higher inorganic phosphorous values than control diet. The returns over feed cost per bird in coated enzyme supplemented diets were Rs 51.58, 55.32, 56.49 and 55.26 and the gain of income per bird was Rs 7.53, 11.27, 10.64 and 11.21 for the treatments T₃, T₅, T₇ and T₉ respectively over control diet. The return over feed cost per bird in uncoated enzyme supplemented diets were Rs 48.43, 48.31, 48.47 and 50.94 and the gain of income per bird was Rs 4.79, 4.26, 4.42 and 6.89 for treatments T₂, T₄, T₆ and T₈ respectively over control.

Key Words: *Encapsulation, Feed Enzymes, Broiler Performance*

INTRODUCTION

Corn and soybean meal (SBM) are widely used in diets for pigs and chickens considering their high nutritional value. Feed ingredients of plant origin contain a number of components that cannot be digested by monogastric species because of the lack of or insufficiency of endogenous enzyme secretions. Fibrolytic enzymes, proteases, lipases and phytases play an important role in efficient utilization of fibre and other nutrients in diet. However, Malathi and Devegowda (2001) reported that the level of Non-Starch Polysaccharide (NSP) is up to 29% in SBM and 9% in corn. It was observed that the negative effects of NSPs could be overcome by dietary modifications including supplementation of diets with suitable exogenous enzyme preparations (Creswell, 1994).

Research Article

Hong *et al.*, (2002) found that the use of an enzyme cocktail that has xylanase, amylase and protease activities improved the digestibility of corn-SBM based diets. Improvement in weight gain, efficiency of feed utilization and reduced sticky droppings in broilers by supplementing the diet with enzymes has been documented (Raghavan, 1990). Poultry feeds are, in most cases, steam pelleted at 65 to 85°C before feeding to improve feed efficiency (Leu and Stahl, 2001). As the conditioning temperature increases, the enzyme becomes gradually more inactivated until at 75°C the residual activity is about 30% of the starting level (Cowan, 1993a). Samarasinghe *et al.*, (2000) reported that the activity of the enzyme cellulase was unaffected at 60 and 75°C, but it was reduced by 73% in feed processed at 90°C. The more obvious hydrophobic method of separating the enzyme from the environment is through use of an encapsulating material coat which has proved successful in enhancing thermo tolerance of enzymes (Klein Holkenborg and Braun, 2001).

Birds fed with coated phytase supplemented diets and pelleted at 80°C and 90°C were heavier ($P < 0.05$) at day 21 and had a better FCR ($P < 0.05$) than birds fed with positive control diet. A new coating material applied to the phytase, achieved thermo stability up to 90°C, while demonstrating similar bioefficacy to the uncoated phytase (Asiedu *et al.*, 2007). Sufficient published work is not available regarding the effect of encapsulation of enzymes on the thermal stability during pelletization and subsequent functional activity in broilers. Thus an experiment was conducted with the following objectives to study the effect of encapsulation of feed enzymes on broiler performance.

MATERIALS AND METHODS

Experimental Design

A feeding trial of 6 weeks duration was conducted on 270 day-old commercial male broiler chicks. Each group was divided into six replicates, with five chicks per replicate and was raised in electrically heated battery brooders. The control group (T_1) was fed with basal diet alone. Group 2 (T_2) was fed with uncoated phytase @ 500 FTU/kg diet, Group 3 (T_3) was fed with coated phytase @ 500 FTU/kg diet, Group 4 (T_4) was fed with uncoated xylanase @ 2000 IU/kg, Group 5 (T_5) was fed with coated xylanase @ 2000 IU/kg of diet, Group 6 (T_6) was fed with uncoated phytase @ 500 FTU/kg and xylanase @ 2000 IU/kg of diet, Group 7 (T_7) was fed with coated phytase @ 500 FTU/kg and xylanase @ 2000 IU/kg of diet, Group 8 (T_8) was fed with uncoated cocktail enzymes and Group 9 (T_9) was fed with coated cocktail enzymes (@ 2,000 U of cellulase, 1,000 U of pectinase, 300 U of mannanase, 750 U of xylanase, 450 U of glucanase, 1,875 U of amylase, and 150 U of protease per kilogram of diet). Feed and water were provided *ad libitum* throughout the experimental period. During the experimental period, birds were immunized against Newcastle Disease (ND) at 7th d (primary) and 28th d (booster) of age with Lasota vaccine and Infectious bursal disease with IBD (Intermediate-Georgia strain) vaccine at 14th d of age.

Procurement of Enzymes and Preparation of Feed

The enzymes phytase and cocktail were obtained from Avitec group, Gurgaon and xylanase enzyme from Kaypees Biotech, Mysore. The experimental diets were formulated by supplementing uncoated or coated enzymes to the maize and soya bean based control diet. The birds were offered pelleted feed, which were formulated according to the NRC, 1994 requirements for both starters and finisher stages. Pelleting was done at 80°C in a steam conditioner of 0.6 MPa for 10 seconds. The feed was prepared in feed mixing plant, Poultry Experimental Station, Dept. of Poultry Science, College of veterinary science, Rajendranagar. The composition of experimental diets starter (0-21d) and finisher (22-42d) are presented in Table 1. Body weight gain was calculated on individual bird basis and feed intake was recorded at weekly intervals. The feed conversion ratio (FCR) was calculated as feed intake per unit bodyweight gain from 0-6 weeks of age at weekly intervals.

Encapsulation of Enzymes (Extrusion Technique)

Enzymes were added into a hydrocolloid solution (alginate) and then the cell suspension was extruded through a syringe needle to form droplets, which free-fall into a hardening solution (CaCl_2) or setting

Research Article

bath. The size and shape of the beads depend on the diameter of the needle and the distance of free-fall. The concentration of alginate used was 1% to form a gel with 0.5M CaCl₂ (Krasaekoopt *et al.*, 2003)

Table 1: Ingredients (parts per ton feed) and nutrient composition of control diet*

Ingredients	Starter Diet (0-3wks)	Finisher Diet (4-6wks)
Maize	578.4	633.1
Soya bean meal	373.6	298.0
Salt	4.5	4.5
Dicalcium phosphate	19.0	16.7
Shell Grit	4.4	6.8
DL-methionine	2.4	1.9
Choline chloride, 50%	0.6	0.6
Toxin Binder	2.0	2.0
Trace mineral mixture ¹	1.2	1.2
AB ₂ D ₃ K ²	0.2	0.2
B complex	0.2	0.2
Coccidiostat	0.5	0.5
L-lysine HCL	0.5	0.0
Antibiotic (Chlortetracycline)	0.5	0.5
Oil (veg)	12.2	33.9
Nutrient Composition (Calculated)		
ME (Kcal/kg)	3050	3150
Crude protein (%)	22.00	19.00
Crude Fiber (%)	3.45	3.25
Calcium (%)	0.80	0.80
Available Phosphorous (%)	0.45	0.38
Lysine (%)	1.25	0.90
Methionine (%)	0.56	0.48

* Pelleting was done at 80°C in a steam conditioner of 0.6 MPA for 10 seconds.

¹ Trace mineral provided per kg diet : Manganese 120 mg, Zinc 80 mg, Iron 25 mg, Copper 10 mg, Iodine 1mg and Selenium 0.1mg Vitamin.

² AB₂D₃K at added per kg feed supplied vitamin A-8250 IU, B₂-5 mg, D₃-1200 IU and vitamin-K-1 mg.

In Vitro Sugar and Phosphorous Release

Estimation of Sugar Release

The *in-vitro* evaluations of treatment diets were subjected to a 2-stage *in-vitro* digestion assay according to Malathi and Devegowda, 2001. Digestibility was assessed by estimating the total sugars released by phenol sulphuric acid carbohydrate assay (Dubois *et al.*, 1956).

Research Article

Phytase Assay

Phytase activity was measured by the method of Shimizu (1992) and Bae *et al.*, (1999) with slight modification. The phytase activity was calculated based on the amount of phosphorus liberated per minute under assay condition (Heinonen and Lahti, 1981). One unit of phytase activity is defined as the amount of enzyme that liberates 1mMol of inorganic phosphorus per minute under assay condition.

Statistical Analysis

The data were subjected to statistical analysis by applying one-way ANOVA using Statistical Package for Social Sciences (SPSS), 15th version. Differences between means were tested using Duncan's (1955) multiple comparison test and significance was set at $P < 0.05$.

RESULTS AND DISCUSSION

The effect of encapsulation of feed enzymes on performance of male broiler chicks in terms of the body weight gain, feed consumption, and feed efficiency are presented in Tables 2-4. The *in vitro* release of total sugars after to a 2-stage *in-vitro* digestion assay and phosphorus release from corn-soybean diets are presented in Table 5 and 6. The cost of feeding broilers, returns over feed cost and the difference of returns on exogenous enzyme supplementation diets over control diet is presented in Table 7.

Body Weight Gain

The weekly body weight gains on supplementation of either uncoated or coated enzymes to corn-soya diet (T_2 - T_4) resulted in significantly ($P < 0.05$) increased body weight gain over control diet (T_1) during 6th week. Similarly, supplementation of coated enzymes to corn-soya diet (T_5 , T_7 and T_9) significantly ($P < 0.05$) increased body weight gain over control diet (T_1) during 3-6th wk except in coated phytase supplemented diet (T_3) which showed significantly ($P < 0.05$) increased body weight gain over control diet (T_1) during 5-6th week. Coated enzyme supplemented diets (T_5 , T_7 and T_9) resulted in significantly ($P < 0.05$) increased body weight gain over their respective uncoated supplemented diets (T_4 , T_6 and T_8) during 3-6th wk except in coated phytase supplemented diet (T_3) which showed significantly ($P < 0.05$) increased body weight gain over uncoated phytase supplemented diet (T_2) during 5-6th wk.

The weekly body weight gains on supplementation of both uncoated and coated enzymes to corn-soya pelleted diet resulted in significantly ($P < 0.05$) increased body weight gain over control diet during 6th week. The result for weight gain is in agreement with the works of Marquard *et al.*, (1994), who reported that enzyme supplementation to cereal based diets significantly ($P < 0.05$) improved broilers performance by increasing the rate of gain. Coated enzyme supplemented diets yielded significantly increased body weight gains over their respective uncoated supplemented diets during starter phase (0-3 weeks), finisher phase (4-6 weeks) and overall period (0-6 weeks) except in coated phytase supplemented diet. This may be attributed to the fact that coating/ encapsulation offers stability against pelletization temperature (Klein Holkenborg and Braun, 2001) and protects the enzyme from denaturation. Asiedu *et al.*, (2010) reported that birds fed on coated phytase supplemented diets and pelleted at 80°C and 90°C were heavier ($P < 0.05$) at day 21 and had a better FCR ($P < 0.05$) than birds fed the positive control diet.

Gracia *et al.*, (2003) and Lazaro *et al.*, (2003) who reported that fungal enzyme preparation significantly improved the weight gain of birds fed on barley, rye, wheat, and corn based diets. They explained that inclusion of cereal grains in broiler diets without enzyme, decreased performance due to increased viscosity of the intestine content of birds. Moreover higher NSP contained in the cereal grains might be responsible for the higher viscosity and consequent depression in productivity, which can be improved by enzyme supplementation. Jozefiak *et al.*, (2010) reported that addition of a combination of coated carbohydrase and coated phytase improved body weight gain in the starter and grower phases of the experiment as well as in overall period. Combination of xylanase and phytase in diets (uncoated and coated form) showed increased body weight gain during 6th week age of broilers. These results are in agreement with Rosen (2004), who reported that the combination of xylanase and phytase in diets improved BWG and FCR. Emiola *et al.*, (2010) reported that Growth performance, tibia ash content, P

Research Article

and Ca digestibilities were not different ($P>0.05$) for coated phytase and uncoated phytase, however better ($P<0.05$) than chicks fed the control diet.

In a similar study using probiotics, Hansen (2005) reported improved feed conversion rate and body weight gain over control upon feeding encapsulated probiotics to broilers. The beneficial results obtained from this encapsulated probiotic strain of *Bacillus subtilis* have appeared to occur due to an effect over the GIT microbiota balance, improving the intestinal health and integrity, that has translated into a better general health and consequently enhanced performance. Lippens *et al.*, (2006) reported that RepaXol, a blend of encapsulated essential oils at 100 g/ton and AciXol which is a blend of encapsulated organic acids and essential oils at 500g/ton in broiler diets resulted in consistent improvement of feed conversion rate and body weight gain than the normal uncoated organic acids and essential oils.

Table 2: Effect of uncoated and coated feed enzymes in pelleted diets on weekly body weight gain of broiler male chicks (1-6 wks age)

Treatment	Weekly Body weight gain (g)/bird					
	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
T1	92.20	189.83 ^a	302.25 ^b	389.62 ^b	521.22 ^c	428.22 ^c
T2	90.42	184.80 ^{ab}	302.23 ^b	394.40 ^b	544.85 ^{bc}	491.18 ^b
T3	92.25	180.75 ^{bc}	309.38 ^b	396.70 ^b	564.23 ^{ab}	512.87 ^{ab}
T4	88.37	185.23 ^{ab}	301.62 ^b	388.28 ^b	530.27 ^c	514.32 ^{ab}
T5	91.02	185.57 ^{ab}	338.57 ^a	429.92 ^a	560.88 ^{ab}	522.88 ^a
T6	92.47	177.95 ^{bc}	302.93 ^b	394.83 ^b	531.08 ^c	526.03 ^a
T7	89.23	186.02 ^{ab}	335.93 ^a	428.17 ^a	563.75 ^{ab}	529.38 ^a
T8	88.27	182.28 ^{abc}	306.92 ^b	398.67 ^b	561.75 ^{ab}	513.78 ^{ab}
T9	91.93	174.72 ^c	327.32 ^a	427.33 ^a	585.83 ^a	529.27 ^a

Source of Variance	Degrees of freedom	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
MSS							
Between treatment	8	17.24	126.76	1414.20	1872.14	2634.80	6149.70
Error	45	21.52	43.51	205.83	208.70	543.67	355.77
SEM		0.62	1.01	2.68	2.91	3.99	4.77
F		0.80	2.91*	6.87*	8.97*	4.84*	17.28*

F=* Significant ($P\leq 0.05$)

Research Article

Table 3: Effect of uncoated and coated feed enzymes in pelleted diets on weekly feed intake of broiler male chicks (1-6 wks age)

Treatment	Weekly feed intake (g)/bird					
	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
T1	121.30	284.20	449.10	708.40	872.17	960.00
T2	119.57	275.17	444.30	697.77	871.27	964.63
T3	117.20	273.10	447.35	690.43	862.67	960.03
T4	123.83	278.27	460.17	703.87	869.40	964.07
T5	118.82	271.93	460.50	697.58	859.73	960.90
T6	125.23	282.52	456.63	708.50	870.80	964.80
T7	123.18	284.00	449.33	695.53	862.93	964.50
T8	119.63	278.23	446.83	704.93	858.12	964.63
T9	122.32	272.73	455.00	699.87	860.87	959.87

Source of Variance	Degrees of freedom	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
MSS							
Between treatment	8	41.390	143.37	219.28	224.36	183.44	31.93
Error	45	48.25	175.44	1005.30	562.41	280.41	346.18
SEM		0.93	1.77	4.05	3.07	2.21	2.35
F		0.86	0.81	0.21	0.40	0.65	0.09

F = * Significant ($P \leq 0.05$)

Research Article

Table 4: Effect of uncoated and coated feed enzymes in pelleted diets on weekly feed efficiency of broiler male chicks (1-6 wks age)

Treatment	Weekly feed efficiency					
	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
T1	1.32	1.50 ^{ab}	1.49 ^{ab}	1.83 ^a	1.68 ^a	2.24 ^a
T2	1.32	1.49 ^{ab}	1.47 ^{ab}	1.77 ^a	1.60 ^{bc}	1.96 ^b
T3	1.27	1.51 ^{ab}	1.45 ^{ab}	1.74 ^{ab}	1.54 ^{cd}	1.88 ^{bc}
T4	1.40	1.50 ^{ab}	1.53 ^a	1.82 ^a	1.64 ^{ab}	1.87 ^{bc}
T5	1.31	1.47 ^b	1.36 ^b	1.62 ^c	1.53 ^{cd}	1.84 ^c
T6	1.36	1.59 ^a	1.52 ^a	1.79 ^a	1.64 ^{ab}	1.83 ^c
T7	1.39	1.52 ^{ab}	1.34 ^b	1.63 ^c	1.53 ^{cd}	1.82 ^c
T8	1.36	1.53 ^{ab}	1.45 ^{ab}	1.77 ^a	1.53 ^{cd}	1.88 ^{bc}
T9	1.33	1.56 ^{ab}	1.39 ^{ab}	1.64 ^{bc}	1.47 ^d	1.81 ^c

Source of Variance	Degrees of freedom	Weeks					
		Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
		MSS					
Between treatment	8	0.010	0.008	0.026	0.041	0.028	0.109
Error	45	0.010	0.007	0.012	0.008	0.004	0.007
SEM		0.013	0.011	0.016	0.015	0.011	0.020
F		1.051	1.142*	2.173 *	4.888*	7.034*	16.077*

F=* Significant ($P \leq 0.05$)

Research Article

Table 5: *In vitro* release of total sugars in different enzyme treated corn-soya pelleted diets

Treatments	Total sugars (mg/gm)*	
	Starter feed	Finisher feed
Control diet (T ₁) Control diet	195.19	201.20
Control diet + uncoated phytase (T ₂)	205.35	212.35
Control diet + coated phytase (T ₃)	217.56	220.56
Control diet + uncoated xylanase (T ₄)	278.02	287.86
Control diet + coated xylanase (T ₅)	295.45	306.67
Control diet + uncoated phytase and xylanase (T ₆)	288.78	297.33
(T ₆)xylanase Control diet + coated phytase and xylanase (T ₇)	306.87	311.56
Control diet + uncoated cocktail (T ₈)	310.32	313.43
Control diet + coated cocktail (T ₉)	330.54	334.23

*Average value of triplicate samples

Table 6: *In vitro* release of inorganic phosphorous in different enzyme treated corn-soya pelleted diets

Treatments	Inorganic phosphorous (g/kg)*	
	Starter feed	Finisher feed
Control diet (T ₁)	1.12	1.07
Control diet + uncoated phytase (T ₂)	1.65	1.58
Control diet + coated phytase (T ₃)	1.78	1.74

*Average value of triplicate samples

Research Article

Table 7: Cost of feeding of broilers, returns over feed cost and the difference of returns on exogenous enzyme supplementation diets over control diet during (4-6wk)

Treatment	Total cost of feed (Rs/kg)	Cum feed intake (g)	Cost of Cum feed intake (Rs)	Body wt gain (g)	Sale amount(Rs)	Returns over feed cost(Rs)	Gain/Loss over control (Rs)
T ₁	18.50	2540	46.99	1339	74.98	27.99	-
T ₂	18.60	2533	47.11	1430	80.08	32.97	4.97
T ₃	18.70	2513	46.99	1473	82.49	35.49	7.50
T ₄	18.60	2537	47.19	1432	80.19	33.00	5.01
T ₅	18.70	2518	47.09	1513	84.73	37.64	9.65
T ₆	18.80	2544	47.83	1452	81.31	33.48	5.49
T ₇	18.90	2522	47.67	1521	85.18	37.51	9.52
T ₈	18.70	2528	47.27	1474	82.54	35.27	7.28
T ₉	18.80	2528	47.53	1542	86.35	38.83	10.83

- The sale price of broilers was taken as 56/- per Kg live weight.
- The cost of phytase was taken as Rs0.12/- per Kg diet.
- The cost of xylanase was taken as Rs0.10/- per Kg diet.
- The cost of cocktail enzyme was taken as Rs0.30/- per Kg diet.
- Additional cost of Rs0.10/- per Kg diet for coated enzymes.

Feed Conversion Ratio

The weekly feed intake (Table 3) of broilers on supplementation of uncoated and coated enzymes to corn-soya diet was comparable to control diet (T₁) during 1-6th week. The feed conversion ratio between the weekly feed intake to weight gain values of broilers on inclusion of uncoated and coated enzymes in pelletized corn-soya diet are presented in Table 4. The weekly feed intake to weight gain values obtained on supplementation of uncoated and coated enzymes to corn-soya diet (T₂-T₉) were significantly (P<0.05) efficient than control (T₁) during 5-6th week. Coated enzyme supplemented diets (T₅, T₇ and T₉) showed significantly (P<0.05) efficient feed to weight gain values over their respective uncoated enzyme supplemented diets (T₂, T₄, T₆ and T₈) and also control diet (T₁) during 4-6th week. Coated enzyme supplemented diets (T₃, T₅, T₇ and T₉) yielded significantly (P<0.05) efficient feed to weight gain values over their respective uncoated enzyme supplemented diets (T₂, T₄, T₆ and T₈) during finisher phase(4-6 weeks) and overall period (0-6 weeks).

Supplementation of uncoated and coated enzymes to corn-soya diet did not influence the feed intake values of broilers during 1-6 week of age when compared to control diet (T₁). Similarly Onu *et al.*, (2011) and Youssef *et al.*, (2011) also reported that the supplementation of enzymes to broilers diet did not

Research Article

influence on feed consumption values. Supplementation of uncoated and coated enzymes to corn-soya diet yielded significantly ($P < 0.05$) efficient FCR values over the control diet during finisher phase (4-6 weeks) and overall period (0-6 weeks). Supplementation of coated xylanase (T_5) and a combination of coated phytase and xylanase enzymes (T_7) yielded significantly ($P < 0.05$) efficient FCR values over all other treatments during starter phase (0-3 weeks), finisher phase (4-6 weeks) and overall period (0-6 weeks). The resulted efficient FCR values in this experiment agree with the findings of Marquard (1994), who reported that enzyme supplementation improved the FCR of birds. Patrick and Schaible (1980) also reported that the beneficial effects of enzyme treatment include improvement in growth, feed utilization and litter conditions of chicks. Alam *et al.*, (2003) found that multi enzyme supplementation to the broiler rations improved FCR.

In the present study all coated enzyme supplemented diets resulted in better FCR than their respective uncoated enzymes and control. These results are in agreement with Jozefiak *et al.*, (2010), who reported that supplementation of coated carbohydrase and coated phytase improved FCR in the starter and grower phases of the experiment as well as for the entire trial. Similarly, Hansen (2005) and Lippens *et al.*, (2006) observed improvement of FCR in broilers supplemented with encapsulated organic acids and essential oils over uncoated organic acids and essential oils.

In Vitro Release of Total Sugars and Phosphorus

In vitro digestion for the release of total sugars (mg/g diet) from uncoated and coated enzymes supplemented diets (Table 5) yielded higher values of total sugars (mg/g feed) (T_2 - T_9) than control diet (T_1) in both starter and finisher feed. Coated enzyme supplemented diets (T_3 , T_5 , T_7 and T_9) yielded higher values of total sugars (mg/gm feed) over their respective uncoated enzyme supplemented diets (T_2 , T_4 , T_6 and T_8) in both starter and finisher feed.

In vitro feed analysis of release of inorganic phosphorous (g/kg diet) (Table 6) from phytase enzyme supplemented corn-soya pelleted diets yielded higher values of inorganic phosphorous release in coated phytase (T_3) supplemented diets than uncoated (T_2). However, both uncoated and coated phytase enzyme supplemented diets yielded higher inorganic phosphorous values than control diet (T_1).

Enzyme supplemented diet yielded more sugars (mg/gm diet) than the unsupplemented diets. These results are in agreement with Malathi and Devegowda (2000) and Bedford (2000) who reported higher sugar release in enzyme treated cereal diets than the control diet. A combination of phytase and xylanase yielded more sugars than the individual supplementation of phytase or xylanase in this study. These results are in agreement with Ravindran *et al.*, (1999), Bedford (2000) and Rosen (2004) who reported that carbohydrases could increase the efficacy of phytase by increasing the accessibility of phytase to phytic acid and absorption of nutrients released by phytase. Coated enzymes supplemented diets released more sugars than their respective uncoated enzymes supplemented diets. This result can be attributed to the fact that most of the enzyme activity was retained by the coated enzyme during pelletization than the uncoated enzyme as reported by Nunes (1993), Eeckhout *et al.*, (1995), Dvorakova *et al.*, (1997) and Samarasinghe *et al.*, (2000). Phytase enzyme supplemented diets yielded more sugars than the control diet in the present experiment. These results are in agreement with Ravindran *et al.*, (1999) who reported that supplementation of phytase enzyme to wheat based diets released significantly ($P < 0.05$) more reducing sugars than the control diet.

Economics (return over feed cost)

The data on various parameters of economics as influenced by different dietary enzyme treatment has been presented in Table 7. The returns over feed cost per bird in coated enzyme supplemented diets were Rs 51.58, 55.32, 56.49 and 55.26 and the gain of income per bird was Rs 7.53, 11.27, 10.64 and 11.21 for the treatments T_3 , T_5 , T_7 and T_9 respectively over control diet. The return over feed cost per bird in uncoated enzyme supplemented diets were Rs 48.43, 48.31, 48.47 and 50.94 and the gain of income per bird was Rs 4.79, 4.26, 4.42 and 6.89 for treatments T_2 , T_4 , T_6 and T_8 respectively over control. Coated enzyme supplemented diets generated higher profits than uncoated enzyme supplemented diets.

Research Article

The economics of broilers feeding at 0-6 week period on enzymes supplementation to corn-soya pelleted diet was encouraging where all enzyme treated groups generated more profit than the control group in the present study. The returns over feed cost per bird in coated enzyme supplemented diets were Rs 51.58, 55.32, 56.49 and 55.26 and the gain of income per bird was Rs 7.53, 11.27, 10.64 and 11.21 for the treatments T₃, T₅, T₇ and T₉ respectively over control diet. The return over feed cost per bird in uncoated enzyme supplemented diets were Rs 48.43, 48.31, 48.47 and 50.94 and the gain of income per bird was Rs 4.79, 4.26, 4.42 and 6.89 for treatments T₂, T₄, T₆ and T₈ respectively over control. Coated enzyme supplemented diets generated higher profits than uncoated enzyme supplemented diets. There is no published literature available for comparing the economics of coated and uncoated enzyme supplemented diets in broilers fed corn-soya pelleted diet. However, Kadam *et al.*, (1991), Khan *et al.*, (2006), Sherif (2009) and Youssef *et al.*, (2011) reported that enzyme supplementation to broiler diets improved returns over the unit feed cost.

ACKNOWLEDGEMENTS

The above research work was supported by the Department of Biotechnology, Govt of India (BT/ PR-9921/ AAQ/01/356/2007).

REFERENCES

- Alam MJ, Howlider MAR, Pramanik MAH and Haque MA (2003). Effect of exogenous enzyme in diet on broiler performance. *International Journal of Poultry Science* 2(2) 168-173.
- Asiedu A, Remus JC, Simmins PH and Croxall R (2007). Effect of a new coating on the thermotolerance and bioefficacy of a phytase product in broilers fed corn-soybean-meal based diets. *Poultry Science* 86(4) 756-761.
- Asiedu AO, Nyachoti CM, Woyengo TA, Emiola A, Guenter W and Simmins PH (2010). Effect of a new coating on the bioefficacy of a phytase product in broilers fed corn-soybean meal based diets. *16th European Symposium on Poultry Nutrition*.
- Bae HD, Yanke LJ, Cheng KJ Selinger LB (1999). A novel staining method for detecting phytase activity. *Journal of Microbiology Methods* 39(1) 17-22.
- Bedford MR (2000). Exogenous enzymes in monogastric nutrition-their current value and future benefits. *Animal Feed Science and Technology* 86(1) 1-13.
- Cowan WD (1993). The stability of enzymes in animal feeds. *Feed International* 22-26.
- Creswell DC (1994). Upgrading the nutritional value of grains with the use of enzymes. Technical bulletin, *American Soybean Association*, 341 Orchard Road No.11-03 Liat towers, Singapore.
- Dubois M, Gilles K, Hamilton JK, Rebers PA and Smith F (1956). A colorimetric method for the determination of sugars. *Nature* 168(4265) 167- 168.
- Duncan DB (1955). Multiple range and multiple R. tests. *Biometrics* 11(1) 1-42.
- Dvorakova J, Volfova O and Kopeck J (1997). Characterization of phytase produced by *Aspergillus niger*. *Folia Microbiology* 42(4) 349-352.
- Eeckhout M, De Schrijver M and Vanderbeke E (1995). The influence of process parameters on the stability of feed enzymes during steam pelleting. *Proceedings of the 2nd European Symposium on Feed Enzymes*. Noordwijkerhout, Netherlands, 163-169.
- Emiola A, Nyachoti CM, Woyengo TA, Asiedu AO, Guenter W and Simmins PH (2010). Performance and nutrient utilization responses in broilers fed phytase-supplemented mash or pelleted corn-soybean meal-based diets. *Journal of Poultry Science* 47(4) 310-315
- Gracia EJ, Brufau A, Perez-Vandell A, Miguel and Duven K (1997). Bioefficiency of enzyme preparations containing beta-glucanase and xylanase activities in broiler diets based on barley or wheat, combination with flavomycin. *Poultry Science* 76(12) 1728-1737.
- Hansen (2005). Prospects for probiotics in broilers. *Feed International* 26(10).

Research Article

Heinonen JK and Lahti RJ (1981). A new and convenient colorimetric determination of inorganic orthophosphate and its application to the assay of inorganic pyrophosphatase. *Analytical Biochemistry* **113**(2) 313-317.

Hong D, Burrows H and Adeola O (2002). Addition of enzymes to starter and grower diets for ducks. *Poultry Science* **81**(12) 1842–1849.

Józefiak DA, Ptak S, Kaczmarek P, Maćkowiak M, Sassek and Slominski BA (2010). Multi-carbohydrase and phytase supplementation improves growth performance and liver insulin receptor sensitivity in broiler chickens fed diets containing full-fat rapeseed. *Poultry Science* **89**(9) 1939-1946.

Kadam AS, Ranade AS, Rajmane BV, Dange SH and Patil SS (1991). Effect of enzyme feed supplement on the performance of broilers. *Poultry Adviser* **24**(11) 1-24.

Khan SH, Sardar R and Siddique B (2006). Influence of enzymes on performance of broilers fed sunflower-corn based diets. *Pakistan veterinary journal* **26**(3) 109-114.

Klein Holkenborg ABM and Braun J (2001). Effect of a hydrophobic coating on phytase granulates on pelleting stability and bio-efficacy in broilers. *13th European Symposium on Poultry Nutrition* **13** 341.

Krasaekoopt W, Bhandari B and Deeth H (2003). Evaluation of encapsulation techniques of probiotics for yoghurt. *International Dairy Journal* **13**(1) 3-13.

Lazaro R, Gracia M, Edel P and Mateas GG (2003). Influence of enzymes on performance and digestive parameters of broilers fed rye – based diets. *Poultry Science* **82**(1) 132-140.

Leu XG and Stahl CH (2001). Biotechnological development of effective phytases for mineral nutrition and environmental protection. *Applied Microbiology and Biotechnology* **57**(4) 474-481.

Lippens M, Huyghebaert G and Scicutella N (2006). The efficacy of micro-encapsulated, gastro-resistant blends of essential oils and/or organic acids in broiler diets. *Proceeding of the XII European Poultry Conference* 10-14 September, Verona, Italia.

Malathi V and Devegowda G (2001). *In vitro* evaluation of nonstarch polysaccharide digestibility of feed ingredients by enzymes. *Poultry Science* **80**(3) 302–305.

Marquard RR, Boros D, Guenter W and Crow G (1994). The nutritive value of barley, rye, wheat and corn for chicks as affected by the use of *Atrichoderma reesei* enzyme preparation. *Animal Feed Science Technology* **45**(3) 363 – 378.

NRC (1994). Nutrient Requirement of Poultry. 9th revised edition. National Research Council, National Academy Press, Washington, D.C.

Nunes S (1993). Evaluation of phytase resistance in swine diets to different pelleting temperatures. In: *Proceedings of 1st Symposium. Enzymes in Animal Nutrition*. Kartause-Ittingen, Switzerland. 269–271.

Onu PN, Madubuike FN, Onu DO and Ekenyem BU (2011). Performance and economic analysis of broiler starter chicks fed enzyme supplemented sheep manure-based diets. *ARPJ Journal of Agricultural and Biological Science* **6** (1) 14-19.

Patrick KH and Schaible PJ (1980). Poultry feeds and nutrition 2nd edition. (Avian Publishing Company Inc. Westport, Connecticut) 23 – 73.

Raghavan V (1990). Enzymes beats sticky droppings. *Poultry Misset* **90**(1) 19-23.

Ravindran V, Selle PH and Bryden WL (1999). Effects of Phytase Supplementation, Individually and in Combination, with Glycanase, on the Nutritive Value of Wheat and Barley. *Poultry science* **78**(11) 1588-1595

Rosen G (2004). Admixture of exogenous phytases and xylanases in broiler nutrition. 6 pages on CD *Proceedings of XXII World's Poultry Congress*, June 2004, Istanbul, Turkey.

Samarasinghe K, Messikommer R and Wenk C (2000). Activity of supplemental enzymes and their effect on nutrient utilization and growth performance of growing chickens as affected by pelleting temperature. *Arch. Tierernahr.* **53**(1) 45-58.

Sherif KE (2009). Effect of using probiotics and enzymes with plant-protein diets in broiler performance. *Journal of Agriculture Science Mansoura University* **34**(5) 4493-4505.

Research Article

Shimizu M (1992). Purification and characterization of phytase from *Bacillus subtilis* (natto) N-77. *Bioscience, Biotechnology and Biochemistry* **56**(8)1266-1269.

Youssef AW, Hassan HMA, Ali HM and Mohammed MA (2011). Performance, Abdominal Fat and Economic Efficiency of Broilers Fed Different Energy Levels Supplemented with Xylanase and Amylase from 14 to 40 Days of Age. *World journal of Agricultural Sciences* **7**(3) 291-297.