INFLUENCE OF MICROBIAL PHYTASE ON NUTRIENT UTILIZATION IN BROILERS

By

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THESIS

Submitted in partial fulfilment of the requirement for the degree of

MASTER OF VETERINARY SCIENCE

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Kerala Agricultural University

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College of Veterinary and Animal Sciences,
Kerala Agricultural University
Mannuthy, Thrissur
Kerala, India

2000

DECLARATION

I hereby declare that the thesis entitled **"INFLUENCE OF MICROBIAL PHYTASE ON NUTRIENT UTILIZATION IN BROILERS"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

Mannuthy,
23-9-2000.

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CERTIFICATE

Certified that the thesis entitled " **INFLUENCE OF MICROBIAL PHYTASE ON NUTRIENT UTILIZATION IN BROILERS** " is a record of research work done independently by **Shri. D. Balasubramanian,** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, associateship or fellowship to him.

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We, the undersigned, members of the Advisory Committee of **Shri. D. Balasubramanian**, a candidate for the degree of **Master of Veterinary Science in Poultry Science,** agree that the thesis entitled **" INFLUENCE OF MICROBIAL PHYTASE ON NUTRIENT UTILIZATION IN BROILERS"** may be submitted by Shri. D. Balasubramanian, in partial fulfilment of the requirement for the degree.

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ACKNOWLEDGEMENTS

I wish to express my profound sense of gratitude and indebtedness to Dr. A. Jalaludeen, Director, Centre for Advanced Studies in Poultry Science for his valuable guidance, critical suggestions and incessant encouragement throughout the period of this study as the Chairman of Advisory Committee.

I am cordially obliged to the members of the Advisory Committee Dr. P.A. Peethambaran, Associate Professor, Centre for Advanced Studies in Poultry Science, Dr. Amritha Viswanath, Associate Professor, Department of Poultry Science and Dr. A.D. Mercy, Associate Professor, Department of Nutrition for their meticulous guidance, valuable advice and timely assistance during the study.

I am very much thankful to Dr. A.K.K. Unni and Dr. G. Reghunathan Nair, Retired Directors, Centre for Advanced Studies in Poultry Science for their precious suggestions, encouragement and timely advice given to me.

I am pleased to express my gratitude to Dr. K. Narayanankutty, Senior Scientist, All India Co-ordinated Research Project on Poultry, Dr. V.K. Elizabeth, Assistant Professor (SG), Department of Poultry Science, Dr. Leo Joseph, Associate Professor, Dr. Padmakumar, Assistant Professor, University Poultry Farm, Dr. P. Anitha , Dr. R. Richard Churchil, Dr. P. Veeramani, Dr. Mammen J. Abraham and Smt. Laly John, Assistant Professor, All India Co-ordinated Research Project on Poultry for their whole-hearted help during the study.

I express my thanks to all other staff members of the Department of Poultry Science, All India Co-ordinated Research Project on Poultry, University

Poultry Farm and Revolving Fund Hatchery for their friendly co-operation and accommodation shown to me.

I owe my thanks to Dean, College of Veterinary and Animal Sciences, Mannuthy for providing facilities needed for the research work.

I am grateful to the staff members of the Department of Statistics for helping me in the analysis of data.

I extend my sincere thanks to the staff members of the Department of Nutrition for their timely help during my study.

I express my gratitude to my Departmental colleagues Dr. B. Anil, Dr. A. Sahiba Mahaboob Kadari, Dr. Deepa Menon, Dr. K.S. Jayasree, Dr. Jomy John and Dr. K.V. Shibu for their remarkable co-operation.

I acknowledge with deep thanks to Dr. S. Ramakrishnan, Dr. A. Varadarajan, Dr. P. kanagaraju, Dr. A. Gopinathan, Dr. S. Balaji, Dr. P. Thirumurugan, Dr. A. Kandasamy, Dr. P. Senthilkumar, Dr. S. Kantharaj and Dr. M. Arumugham for their valuable assistance.

I express my indebtedness to my friends and fellow PGs Dr. N. Baskar, Dr. G. Vasudevan, Dr. P. Vijayakumar, Dr. P. Senthilkumar, Dr. S. Senthil kumar, Dr. E. Venkatesakumar, Dr. A. Thirunavukkarasu, Dr. K.M. Sakthivel, Dr. Shibu K. Jacob and Dr. K. Rajkumar for their help and concern shown to me.

I express my profound gratitude to my beloved parents, friends and relatives for their affection, moral support and encouragement during the study.

I record my thanks to Dr. C.V. Sreeranjitkumar, Research Associate, Department of Microbiology for his assistance in the preparation of this thesis.

I am thankful to the Kerala Agricultural University for awarding me the research fellowship for the period of study.

Lastly, to every one who gave me a helping hand, I express my gratitude.

D. BALASUBRAMANIAN

Dedicated to

My Beloved Parents

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INTRODUCTION

1. INTRODUCTION

During the past two decades there has been a remarkable growth in the poultry sector in India. Despite this progress a wide gap exists between availability and the minimum requirement of egg and poultry meat of the nation. Broiler production which was only four million in 1971 has gone upto 700 million in 1998 (Anon, 2000). The present annual per capita availability of poultry meat is 1 kg in India compared to 15 kg in developed countries. There is immense scope for future development in poultry segment since the ICMR recommendation is 10.8 kg. meat from all sources per annum. Eggs and poultry meat seem to be the only alternatives since these are the cheapest and most readily available source of animal protein today in the country.

The anticipated annual growth of commercial layers and broilers in the coming years is estimated at around 10 and 20 per cent respectively. Currently, around five million tonnes of compound feed is produced for poultry alone. This figure will go up in the near future. Availability of feed ingredients is also critical since there is a competition between human beings and livestock for the same. A feed stuff found suitable as an ingredient for poultry feed rapidly becomes main input for some emerging industries making it non-available for livestock production on cost front. This often necessitates the poultry farmer to look into ways and means for alternate strategies to reduce the cost of feed.

The basic components of poultry feeds are plant derived materials such as cereals and oil seed cakes which are blended together to provide necessary proteins and energy for optimizing production. The plant feed ingredients are rich in phosphorus and is in the form of phytic acid (hexaphosphate inositol). Only about 30 per cent of plant phosphorus can be utilized by poultry and the remaining portion is in a complex form called phytin phosphorus, which due to the absence of enzyme phytase in the digestive tract of poultry cannot be utilized and hence excreted as such. On the other hand, inorganic and animal source of phosphorus can be completely utilized by birds.

Apart from its unavailability, phytin phosphorus may combine with starch, protein and certain inorganic elements such as Calcium, Magnesium, Zinc, Copper, Iron, Manganese and Potassium. Being insoluble these compounds precipitate in the gut, without getting absorbed and finally excreted. Over supplementation of phosphorus as well as other nutrients is also common in the feed industry because of the safety margin for the requirements. This excess supplementation leads to phosphorus excretion through droppings and is responsible for environmental pollution.

The need for inorganic phosphorus in the rations can be reduced considerably if phytin phosphorus can be utilized by poultry. To make phytin phosphorus biologically available it is necessary to hydrolyse them by phytase. The enzyme phytase, a normal constituent of feed ingredients like soybean meal, rape seed meal, corn, wheat etc. help in degrading the phytate to a certain extent, but the activity of vegetable phytase is limited as they act only at a narrow pH range. This necessitates the use of extraneous source of this enzyme.

Though the potential use of phytase as a feed supplement was identified long back (Nelson *et al.*, 1968); there was no interest for its regular use in animal feed since the fermentation technologies in the earlier days resulted in smaller enzyme yields with high cost of production. Continuous development of the production process using genetic engineering together with an application oriented product development has resulted in the production of cheaper commercial enzymes. With this renewed interest, the role of enzymes for improving the nutritive value of feed has to be further explored. Apart from overcoming the ill effects of phytin phosphorus, phytase has been reported to enhance the performance of broiler chicken. In this context, a study was planned with the objective of evaluating the influence of dietary supplementation of microbial phytase on nutrient utilization in broiler chicken.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Enzymes are specialized proteins which control specific reactions in the animal body. Recently, they are being are used in animal feeds either to balance the suboptimal synthesis of endogenous enzymes by animals or for breakdown of compounds which cannot be digested into absorbable nutrients. It is believed that phytase of fungal origin *Aspergillus niger* improves the utilization of phytate phosphorus, calcium and trace minerals along with protein and energy in poultry diets based on ingredients of plant origin. In this chapter, an attempt has been made to provide a review of the available literature allied with inclusion of phytase enzyme on nutrient utilization and subsequent performance in broilers.

2.1 Body weight and weight gain

Schoner *et al.* (1992) conducted feeding experiment in one-day-old male Lohmann broilers for 14 days using different levels of inorganic phosphorus (0.6, 1.2 and 1.8 g / kg) and calcium (6.0, 7.5 and 9.0 g / kg) supplemented with phytase at 125, 250 and 1500 units / kg feed and opined that phytase and phosphorus increased live-weight of birds dose-dependently.

Farrell *et al.* (1993) performed an experiment in broiler chickens from day-old to 18 days on a sorghum - soya diet supplemented with Natuphos^{R}-5000 (phytase) at 750 units / kg and observed significant improvement in growth rate throughout the experiment.

Huyghebaert *et al.* (1993a) stated that broilers fed with low phosphorus sorghum or wheat based diets showed significant improvement in weight gain when supplemented with phytase at 250, 500 and 1000 units / kg. They also stated that higher levels of phytase addition (500 and 1000 units / kg) gave intermediate results and was not better than control diet based on mineral phosphorous (0.35 and 0.47 per cent of non-phytate phosphorus).

Vogt (1993) conducted a trial in Lohmann broilers given a maize / soybean meal diet with phosphorus 5.2, 5.7 and 6.2 g / kg and phytase at 0, 200, 400, 800 and 1600 units / kg for six weeks and reported that decreasing dietary phosphorus lead to decreased growth and it could be improved by phytase supplementation.

To study the effect of different intakes (250-1000 phytase units / kg) of microbial phytase on performance in comparison with the effects of mineral phosphorus addition as dicalcium phosphate, Kiiskinen *et al.* (1994) conducted a trial in broilers from zero to 5.5 weeks of age with soybean meal and grain based diets. They indicated that diets with very low (0.05 per cent) or no mineral phosphorus supplementation weight gain can be increased by adding phytase upto 1000 PU / kg.

Richter (1994) observed that diets containing phosphorus at 0.6, 1.1 and 1.6 g / kg (as monocalcium phosphate) supplemented with phytase at 500 and 1000 units / kg feed gained 5.1 and 2.6 per cent body weight in comparison with unsupplemented diets.

Substitution of calcium phosphate for a preparation of phytase in feed containing rape seed oil meal did not cause significant difference in body weight gain (Zyla and Koreleski, 1994).

Chickens of eight days old fed for 12 days on a zinc deficient soya concentrate diet (Zinc 13 mg / kg) showed increased growth rate by 40 per cent when supplemented with calcitriol at 10 µg / kg or phytase at 1200 units / kg (Biehl *et al.*, 1995).

Diets with high activity phytase at 500, 1000 or 2000 units / kg produced 8.5 per cent higher live weight than with control diets for 55 days trial in cobb broiler chicken (Piva *et al.*, 1995).

Thiel *et al.*(1995) informed that supplemented phytase at 700 units / kg and added zinc to provide total zinc content of 34, 39 or 45 mg / kg in a maize-soybean meal diet containing zinc 30 mg / kg had no influence on final live-weight in 35 days feeding trial.

In order to assess the effects of microbial phytase on performance, broilers were fed on diets containing 60, 80 or 100 per cent of the recommended phosphorus requirement and phytase 0 or 500 FTU for six weeks (Kwon *et al.*, 1996). Broilers fed on diets containing 60 per cent of the required phosphorus has significantly lower live weight gains than those fed on 80 or 100 per cent phosphorus diets when no supplemental phytase was fed. However, when broilers were fed on phytase supplemented diets all groups had similar live-weight gains.

Sebastian *et al.* (1996a) stated that phytase supplementation at 600 units / kg in low available phosphorus (0.33 per cent) maize - soybean diet increased body weight in male and female broiler chickens by 13.2 and 5.8 per cent respectively at 21 days of age.

Adding zinc (5, 10 or 20 mg / kg) as $ZnSO_4$ $7H_2O$ and phytase (150, 300, 450 or 600 units / kg) to the low zinc (20 mg / kg) basal diet linearly increased body weight gain (Yi *et al.*, 1996a).

Yi *et al.* (1996b) reported that supplementation of defluorinated phosphate to provide 0.36, 0.45 or 0.54 per cent non-phytate phosphorus and phytase at 350, 700 or 1050 units / kg increased body weight linearly in broilers from one to 21 days old.

Sohail and Roland (1997) observed a reduction in body weight of chicks when available phosphorus was reduced from 0.325 to 0.225 per cent and that phytase supplementation at 300 PU / kg significantly increased body weight at the low available phosphorus level.

Phytase supplementation at a level of 500 units / kg on control and high available phosphorus maize containing diets increased body weight at 49 days of age in cobb male broilers (Huff *et al.*, 1998).

Kanagaraju (1998) reported that broilers maintained on low available phosphorus (0.40 per cent) diet supplemented with phytase at 750 units / kg feed obtained significantly higher body weight and weight gain both at six and eight weeks of age and was statistically comparable to that of group maintained on standard broiler ration. The body weight recorded for control and phytase supplemented low available phosphorus diet groups was 1480.67 g and 1450.33 g at six weeks and 2042.97 g and 2030.00 g at eight weeks of age, respectively. Like wise, the gain in weight was 1434.44 g and 1404.09 g at sixth week and 1996.54 g and 1983.75 g at eight week of age for control and phytase added low available phsophorus group.

Zanini and Sazzad (1998) observed that supplemental phytase at 500 IU / kg diet had no effect on growth performance in broilers when fed with different metabolizable energy level of 2800 and 3000 kcal ME / kg diet for 21 days from one-day-old age.

Inclusion of 15 per cent rice bran in corn-soybean diet with exogenous phytase enzyme was studied in a factorial experiment with different ratios of calcium : phosphorus (1:2, 1: 2.25, 1: 2.5, 1:3 and 1:4) and three levels of enzyme phytase (0, 500 and 1000 FTU / kg) using broilers from one-day old to six weeks of age. Enzyme supplementation at 500 FTU / kg diet improved weight gain at three weeks of age (ELDeeb *et al.*, 1999).

2.2 Feed consumption and feed conversion ratio.

Schoner *et al.* (1992) reported that supplementation of phytase (125, 250 and 1500 units / kg feed) in different levels of inorganic phosphorus (0.6, 1.2 and 1.8 g / kg feed) increased feed conversion efficiency in broilers.

In order to find the effect of dietary phytase on growth, Perney *et al.* (1993) performed trials on broiler chicks with varying levels of phosphorus, 0.32, 0.38 and 0.44 per cent supplemented with 250, 500 and 750 units of phytase. Results indicated increased feed intake and feed conversion efficiency due to increased dietary available phosphorus but not due to phytase.

Addition of zinc and microbial phytase (700 units / kg) in a maize - soybean meal diet containing zinc 30 mg / kg could not produce any differences in feed : gain ratio in comparison to control diet (Thiel *et al.*, 1993).

Broz *et al.* (1994) stated that increase in intake of supplemental phytase significantly increased feed intake but moderately improved feed conversion efficiency.

Kiiskinen *et al.* (1994) studied the effect of different intakes (250 to 1000 units / kg) of microbial phytase on performance of broiler chicks and reported that phytase addition increased feed intake by 3 to 9 per cent.

In a trial, broilers were given starter and finisher mash diets containing phosphorus 0.6, 1.1 and 1.6 g / kg supplemented with phytase 0, 500 and 1000 units / kg for 35 days (Richter, 1994). Average feed intake across all phosphorus content was 2447, 2531 and 2490 g for phytase 0, 500 and 1000 units / kg, respectively.

Richter and Cyriaci (1994) reported that in a 35 day feeding trial phytase supplementation increased feed intake but had no influence on feed conversion efficiency.

Broilers fed on diets containing 60, 80 or 100 per cent of the recommended phosphorus requirement along with added phytase 0 or 500 FTU / kg, Kwon *et al.* (1996) stated that feed intake and feed : gain ratio were reduced as the phosphorus content of the diet decreased when phytase was not supplemented.

Huyghebaert (1996) opined that feed intake in broilers were affected by dietary calcium and phosphorus concentration, calcium: phosphorus ratio and phytase supplementation.

In an experiment, broiler chickens were fed for three weeks on maize - soybean diets containing 0.46 per cent (control) or 0.33 per cent (low) available phosphorus plus microbial phytase at 600 units / kg diet to assess their performance (Sebastian *et al.* 1996a). Phytase supplementation could overcome the reduction of feed intake noticed in low phosphorus diet, however treatments had no influence on feed : gain ratio.

The supplemented zinc and phytase to the low zinc basal diets, linearly increased feed intake. Whereas, the feed : gain ratio was not changed by adding zinc but it was decreased by the addition of phytase (Yi *et al.*, 1996a).

Supplementation of defluorinated phosphate to provide 0.36, 0.45 or 0.54 per cent non-phytate phosphorus and phytase (350, 700 or 1050 units / kg) in both maize-soybean meal based and soybean meal based diets produced linear increase in feed intake (Yi *et al.*, 1996b).

Broilers fed for first three weeks with diets containing 0.225 per cent available phosphorus and 0.75 per cent calcium with phytase 350 FTU / kg, consumed significantly less feed by 4.16 g / bird / day than birds fed with diets contained 0.425 per cent available phosphorus and 0.85 per cent calcium with out phytase (Sohail and Roland, 1997).

Denbow *et al.*(1998) observed that supplementation of phytase at 400, 800 or 1200 units / kg in a basal diet containing 0.2 per cent non-phytate phosphorus during second and third week linearly increased feed intake in male broilers. The mean values of feed intake from two to three weeks were 616, 686 and 710 g, respectively in the above diets.

Huff *et al.* (1998) opined that supplementation of phytase in a ration containing high available phosphorus maize had no influence on feed conversion efficiency.

In a trial, Kanagaraju (1998) found that broilers offered diets containing phytase consumed significantly ($P<0.01$) more fed (g / bird / day) than their respective unsupplemented group except in the group offered 0.4 per cent available phosphorus. He also noticed significantly low cumulative feed intake with birds fèd diets having 0.3 per cent available phosphorus without phytase. However, he observed increase in cumulative feed consumption by 94.01 g and 127.31 g for six and eight weeks, respectively with addition of phytase. He also reported superior feed efficiency among birds fed diet containing 0.4 per cent available phosphorus with supplemental phytase.

Inclusion of 15 per cent rice bran to broiler corn-soybean diet with exogenous phytase enzyme had no influence on feed intake or feed conversion efficiency (ELDeeb *et al.*, 1999).

An experiment was conducted to determine the effect of phytase supplementation in broiler diets containing 30 per cent barley formulated to contain graded levels of available phosphorus (Harter-Dennis *et al.*, 1999). The results showed that phytase or per cent available phosphorus had no influence on feed : gain ratio.

Mohanna and Nys (1999) observed that the level of zinc and manganese or phytase addition does not produce any adverse effect on feed intake but decreased feed conversion efficiency.

2.3 Retention of nitrogen and energy

Miles and Nelson (1974) performed a trial to study the effect of enzymatic hydrolysis of phytate on the available energy content of feed ingredients for chicks. They reported that the phytate phosphorus and metabolizable energy value for untreated and treated wheat bran were 1.26 per cent, 1.11 kcal / g and 0.02 per cent, 1.66 kcal / g, respectively. The corresponding figures for untreated and treated cotton seed meal were 0.98 per cent, 1.69 kcal / g and 0.1 per cent, 2.03 kcal / g and for untreated and treated soybean meal were 0.44 per cent, 2.74 kcal / g and 0.03 per cent, 2.55 kcal / g, respectively.

Farrell and Martin (1993) stated that feed enzymes especially phytase was beneficial in oat based diets to increase metabolizable energy mainly in younger birds rather than older ones.

The beneficial effects of a microbial feed phytase in diets of broilers was investigated by Farrell *et al.* (1993). Birds were fed on grain sorghum / soybean meal diets supplemented with phosphorus from $CaHPO_4$ and phytase from *Aspergillus niger* (Natuphos^R) at 750 units / kg diet. Nitrogen retention was significantly improved with phytase supplementation.

In Cobb broilers, diet containing high activity phytase at a level of 1000 units / kg for 55 days showed a greater retention of protein than with the control diet (Piva *et al.*, 1995).

Kwon *et al.* (1996) conducted an experiment to study the effects of microbial phytase on performance and nutrient utilization of broiler chicks and reported that addition of phytase at 500 FTU / kg had no influence on nitrogen excretion.

In a trial, day old broiler chicks were fed on a low phosphorus (0.3 per cent) maize - soybean meal diet containing 0.6, 1.0 and 1.25 per cent calcium and phytase 0 and 600 units / kg diet for three weeks and found that retention of nitrogen was increased ($P<0.05$) by phytase supplementation (Sebastian *et al.*, 1996b). Although the maximum retention of nitrogen was obtained with 1.25 per cent calcium, it was not significantly different from the values obtained at 0.6 per cent calcium.

In a factorial experiment, microbial phytase at 0, 200, 400, 600 and 1000 units / kg was added to diets containing 0.62 or 0.79 per cent calcium and 0.59 per cent phosphorus. Nitrogen retention changed proportionally to live weight while nitrogen utilization was not affected by phytase treatment (Windisch and Kirchgessner, 1996a).

Yi *et al.* (1996b) conducted an experiment in broilers fed with maize-soybean meal based diets and reported that phytase supplementation at 350, 700 or 1050 units / kg had an effect of increased apparent nitrogen retention.

In an attempt to reduce nitrogen and phosphorus waste production for broilers through diet manipulation, Ferguson *et al.* (1997) conducted a trial in which male broilers were given with low crude protein and low phosphorus diets for starter and grower periods and found that phytase supplementation at a level of 1g / kg produced considerable savings in nitrogen wastage through droppings.

Piao *et al.* (1998) found considerable reduction in nitrogen excretion in Arbor Acres broilers when fed with maize-soybean meal diets supplemented with 0.05 per cent Kemzyme or 0.1 per cent phytase or 0.1 per cent yeast or combination of these three supplements.

To evaluate the effectiveness of supplemental Natuphos^{R}-5000 phytase on the apparent digestibility, Zanini and Sazzad (1998) performed a 21 day trial with day old broilers. They observed that supplemented phytase at 500 units / kg diet increased apparent retention of nitrogen.

The effect of phytase on apparent metabolizable energy was investigated in a 15 day trial using day old male broilers with diets low in calcium (0.90 per cent for control and 0.79 per cent for phytase treatment) and available phosphorus (0.45 per cent for control and 0.35 per cent for phytase treatment). The phytase activity of crumble diet was 1149 FTU / kg. The results indicated that diets with supplemental phytase had higher apparent metabolizable energy utilization ($P<0.01$) than control diets (Namkung and Leeson, 1999).

2.4 Availability of calcium and phosphorus and phosphorus excretion

In a trial, broiler chicks were used to determine the effects of addition of mold phytase to a diet containing natural phytate phosphorus. Results indicated that total hydrolysis of phytate occurred when 3 g of phytase supplement was used per kg of diet and chicks utilized hydrolysed phytate phosphorus as well as supplemental inorganic phosphorus (Nelson *et al.*, 1971).

Farrell *et al.* (1993) stated that broiler chickens fed on grain sorghum / soybean diets supplemented with phosphorus from $CaHPO_4$ and phytase from *Aspergillus niger* at 750 units / kg feed showed an overall improvement in phosphorus retention of 18 per cent with phytase addition.

Huyghebaert *et al.* (1993b) studied the effect of microbial phytase on the availability of phosphorus and calcium in 10 to 21 days old broiler chickens given a diet poor in phosphorus without or with a preparation of microbial phytase (Natuphos) 250, 500, 750 or 1000 units / kg. Microbial phytase at 500 units / kg increased phosphorus metabolism by 12 to 14 per cent independantly of the amount of calcium in the diet (0.6, 0.74 or 1.0 per cent). Phytase also increased the percentages of calcium utilized in the same proportions. The increase in calcium from 0.74 to 1.0 per cent had a negative effect on the percentage of phosphorus utilized.

The effect of dietary phytase and increasing levels of available phosphorus on phosphorus metabolism was evaluated in broilers (Perney *et al.*, 1993). They noticed increased phosphorus excretion by increasing dietary available phosphorus and which could be decreased by supplemental phytase.

When Lohmann broiler chicks were fed on a basal diet from plant (A) or plant and animal source (B) contained 0.4 to 0.5 per cent total phosphorus and supplemented with phytase at 300 and 700 units / kg, there was reduction in phosphorus excretion by 24 and 10 per cent, respectively in diets A and B (Richter *et al.*, 1993b).

Influence of microbial phytase in the diets of broiler chicken on phosphorus availability was investigated by Simons *et al.* (1993). The results indicated that phytase supplementation of 500 units or 250 units / kg feed was equivalent to phosphorus absorption to monocalcium phosphate phosphorus of 0.5g / kg feed.

In an experiment, Broz *et al.* (1994) reported that supplemental phytase improved apparent availability of phosphorus and reduced its concentration in excreta. They concluded that phytase supplementation in practical broiler diets will allow the reduction or omission of additional dietary inorganic phosphorus.

Pointillart (1995) studied phytate and phytase role in monogastric nutrition and suggested that the availability of phosphorus may be improved by adding microbial phytase to the feed or by using phytase rich cereal diet. He also opined that phytase could minimize the need for added inorganic phosphorus thus markedly reducing the excretion of phosphorus in manure.

Huyghebaert (1996) reported that phosphorus excretion can be reduced greatly by supplementing low phosphorus diets with 500 FTU of phytase per kg diet.

Kornegay *et al.* (1996) observed that phytase addition resulted in a linear increase ($P<0.01$) in apparent retention (per cent of intake) or total amount (g) of retained calcium and phosphorus and a linear decrease ($P<0.01$) in the excretion of phosphorus.

Significant reduction of phosphorus excretion was noticed when birds were fed with diets containing 60 per cent of the required phosphorus plus supplemental phytase at 500 FTU / kg level (Kwon *et al.*, 1996).

Phytase supplementation at 600 units / kg in low available phosphorus (0.33 per cent) diet increased the relative retention of total phosphorus and calcium by 12.5 and 12.2 per cent units, respectively in broiler chickens (Sebastian *et al.*, 1996a).

Windisch and Kirchgessner (1996a) reported that supplemental phytase at a level of 600 units / kg on a maize, wheat and soybean meal diets containing calcium 0.62 or 0.79 per cent and phosphorus 0.59 per cent improved utilization and retention of calcium and phosphorus.

Yi *et al.* (1996b) conducted two experiments to study the effectiveness of Natuphos^R phytase for improving phosphorus availability of soybean meal-based semi-purified diets and maize-soybean meal based diets in broiler chicken. Basal diets were supplemented with defluorinated phosphate to provide 0.36, 0.45 or 0.54 per cent non-phytin phosphorus or with phytase 350, 700 or 1050 units / kg diet. They reported that phytase addition increased apparent retention of phosphorus ($P<0.02$) and calcium ($P<0.005$) and a linear decrease ($P<0.005$) in phosphorus excretion. In comparison to the 0.45 per cent non-phytate phosphorus diet, phosphorus excretion was reduced 42 to 51 per cent by addition of phytase.

Nernberg *et al.*(1997) stated that supplementation of phytase and cholecalciferol improved phytate and calcium digestibility with maximum digestibility of 55.4 per cent (phytate) and 61.2 per cent (calcium) for 0.89 per cent calcium diet. They also stated that phytase addition to low non-phytate phosphorus diets reduced phosphorus excretion by 35 per cent.

Bioavailability of calcium and phosphorus was significantly ($P<0.01$) more in phytase supplemented groups than their corresponding unsupplemented groups. Enzyme supplementation also resulted in a significant reduction in phosphorus excretion (Kanagaraju, 1998).

Zanini and Sazzad (1998) conducted a trial to study the effectiveness of supplemental Natuphos^{R}-5000 phytase on mineral utilization of broilers and observed that phytase addition at 500 units / kg had an effect on reducing phosphorus excretion and on increasing apparent retention of calcium and phosphorus.

2.5 Availability of manganese and zinc

Roberson and Edwards (1994) stated that supplementation of 1,25-dihydroxy cholecalciferol at 5 µg / kg and phytase at 600 units / kg in maize-soybean diet increased zinc retention and zinc content of bone in broilers. They suggested that supplemental zinc may be decreased in a maize-soybean meal diet when phytate phosphorus utilization is improved.

When chickens were fed on a zinc deficient soya-concentrate diet (zinc 13 mg / kg), supplementation of diet with calcitriol or phytase increased growth rate by 40 per cent and tibial zinc content by more than 100 per cent. Adding calcitriol together with phytase increased tibial zinc content by 160 per cent.

Utilization of zinc and manganese contained in the maize-soybean meal diet also was markedly enhanced by supplemental phytase (Biehl *et al.*, 1995)

Piva *et al.* (1995) conducted an experiment in broilers fed with control diets, diets with high activity phytase (500, 1000 or 2000 units / kg) and diets with low activity phytase (500, 1000 or 2000 units / kg) for 55 days and observed greater manganese content in bone of birds fed with low activity phytase at 2000 units / kg diet and greater zinc content in bone of birds fed with low activity phytase at 500 units / kg diet and high activity phytase at 500 and 2000 units / kg diet than with control diet.

In an experiment, Thiel *et al.* (1995) studied zinc retention in male broiler chickens given a maize and soybean meal diet containing zinc 30 mg / kg with no supplement or with microbial phytase 700 units / kg and with no added zinc or with added zinc to provide totals of 34, 39 or 45 mg / kg. They reported that without phytase femur zinc increased significantly with added zinc up to 39 mg / kg diet and with phytase femur zinc increased with no added zinc by more than 20 per cent. On the basis of the increments in femur and whole-body zinc, they concluded that the response to the phytase supplement was equivalent to that for a supplement of zinc 15 mg / kg diet and the per cent zinc retention decreased with each increment in dietary zinc.

Day old broiler chicks fed on a maize-soybean diet containing 0.33 per cent available phosphorus plus phytase 600 units / kg diet had an increased relative retention of zinc by 62.3 per cent in comparison with control diet containing 0.46 per cent available phosphorus without phytase (Sebastian *et al.*, 1996a).

Windisch and Kirchgessner (1996b) conducted a trial in broilers to study the effect of phytase on apparent digestibility and gross utilization of iron, copper, manganese and zinc at different levels of calcium supply in broilers. Birds were fed on diets containing microbial phytase 0, 200, 400, 600 and 1000 units / kg and calcium 0.62 or 0.79 per cent with phosphorus 0.59 per cent. Increasing phytase increased gross utilization of zinc by 8.46 and manganese by 3.8 per cent with high dietary calcium gross utilization changed by –3.4 per cent of zinc and +1.4 per cent of manganese.

The effect of microbial phytase on retention and utilization of zinc was studied by Yi *et al.* (1996a). A maize-soybean isolate basal diet containing zinc 20 mg / kg was fed alone or supplemented with zinc 5, 10 or 20 mg / kg as $ZnSO_4$ $7H_2O$ or with phytase 150, 300, 450 or 600 units / kg diet. The amount of zinc retained by bird was linearly improved by adding zinc and phytase ($P<0.01$). Zinc retained as a percentage of intake was linearly decreased by adding zinc but was linearly increased by adding phytase ($P<0.01$).

To study the effectiveness of supplemental Natuphos^{R}-5000 phytase on mineral utilization, Zanini and Sazzad (1998) performed a 21 day trial in day-old broilers with diets containing metabolizable energy of 2800 and 3000 kcal / kg and phytase at the level of 0 and 500 units / kg. They found improvement in tibial zinc concentration and apparent retention of zinc at 500 units supplementation of phytase.

The supplementation of microbial (800 UP equivalent to 14 mg / kg in a maize-soybean meal diet) and vegetal (to a lower extent) phytases increased zinc availability in broilers (Mohanna and Nys, 1999).

2.6 Tibial ash

Nelson *et al.* (1971) studied the effect of supplemental phytase on the utilization of phytate phosphorus by chicks and reported that supplementation of phytase at the level of 1 to 8 g / kg in corn-soybean meal diets contained 0.18 to 0.24 per cent natural phytate phosphorus caused an increase in per cent bone ash.

Broiler chickens fed on grain sorghum / soybean meal diets supplemented with or without phosphorus from $CaHPO_4$ and phytase from *Aspergillus niger* (Natuphos^{R}) at 750 units / kg showed an increase in tibial ash content (Farrell *et al.*, 1993).

Huyghebaert *et al.* (1993a) reported that bone mineralization (per cent ash in tibia) increased in a curvilinear fashion with increased amounts of microbial phytase in broilers fed with low phosphorus sorghum or wheat diet. A high calcium : phosphorus ratio with 0.51 per cent phosphorus had an unfavourable effect on skeletal mineralization. Chicks given the largest amount of phytase (1000 units / kg) had a lower mineralization than those given the control diet.

Dietary phytase and increased levels of available phosphorus, increased the toe and tibial ash content (Perney *et al.*, 1993). They also reported that tibial bone breaking strength was improved by dietary phytase but not by increased levels of available phosphorus.

To study the effect of supplemental phytase in broiler rations with different phosphorus content Vogt (1993) performed a trial in caged Lohmann broilers. Birds were given a maize / soybean meal diet with phosphorus 5.2, 5.7 and 6.2 g / kg feed and phytase supplement 0, 200, 400, 800 and 1600 units / kg diet for 6 weeks. He found that decreasing dietary phosphorus decreased bone mineralization and it was improved by phytase supplementation.

Broz *et al.* (1994) studied the effects of supplemental phytase on performance and phosphorus utilization in broiler chickens fed a low phosphorus diet without addition of inorganic phosphorus. They found increased tibial ash percentages in broilers received phytase added diets.

Richter and Cyriaci (1994) performed a 35 day trial with Lohmann broilers and opined that there was a positive relation between phytase supplementation and total dietary phosphorus and tibial strength. Phytase supplementation resulted in an increase in crude ash content in tibial bone.

Supplemental phytase at 1200 units / kg diet increased bone ash by at least 65 per cent when added to a maize- soybean meal diets contained 0.43 g of phosphorus / 100 g feed (Biehl *et al.*, 1995).

In a trial, broilers were given low phosphorus diets supplemented with phytase at the rate of 500 FTU / kg diet. The results showed a reduction in bone mineralization which was ameliorated by supplementation of phytase (Huyghebaert, 1996).

Mitchell and Edwards (1996) observed that supplementation of calcitriol at 5 µg / kg diet and phytase at 600 units / kg diet could replace upto 0.1 per cent of inorganic phosphorus for bone ash criteria in maize / soybean meal diets.

In a maize-soybean meal diet, contained 0.6, 1.0 and 1.25 per cent calcium supplemented with phytase at 600 units / kg diet increased the ash content in tibial head and shaft (Sebastian *et al.* 1996b).

In an experiment, Yi *et al.* (1996a) stated that addition of phytase in the feed linearly improved the ash per cent of toe and tibial bone in male broilers.

Kanagaraju (1998) reported that phytase supplementation at 750 units / kg diet had a positive effect on tibial ash in low available phosphorus rations.

2.7 Serum calcium, inorganic phosphorus and alkaline phosphatase

Mc Cuaig *et al.* (1972) stated that dietary phosphate at 0.16 per cent greatly increased the activities of serum alkaline phosphatase.

In an experiment, Perney *et al.* (1993) evaluated the effect of dietary phytase on growth performance and phosphorous utilization of broiler chicks. Birds were given maize-soybean meal diets contained 0.32, 0.38 and 0.44 per cent available phosphorus supplemented with 250, 500 and 750 units of phytase / kg feed. Plasma inorganic phosphorus responded quantitatively to increased dietary phytase.

Broz *et al.* (1994) conducted three experiments on broilers with low phosphorus levels of 4.4, 4.8 and 5.2 g / kg diet plus fungal phytase 0 or 500, 0, 125, 250 or 500 and 0, 125, 250 or 500 PU / kg diet, respectively. They reported elevated plasma concentration of inorganic phsophorus in groups received phytase treated diets.

Roberson and Edwards (1994) reported that maize-soybean meal diet supplemented with 1, 25- dihydroxy cholecalciferol at 5 µg / kg and phytase at 600 units / kg had no effect on plasma alkaline phosphatase activity.

In a trial, male broilers fed with maize-soybean meal diets contained four levels of calcium and phosphorus supplemented with calcitriol at 5µg / kg and phytase at 600 units / kg showed that these levels of phytase and calcitriol could replace upto 0.1 per cent of inorganic phosphorus for plasma phosphorus criteria (Mitchell and Edwards, 1996).

In a three week feeding trial, broiler chickens were given maize - soybean meal diets containing 0.46 per cent (control) or 0.33 per cent (low) available phosphorus supplemented with microbial phytase (Netuphos) at 600 units / kg and found increased plasma phosphorus by 15.7 per cent and reduced calcium concentration by 34 per cent (Sebastian *et al.*, 1996a).

Huff *et al.* (1998) observed reduced serum alkaline phosphatase activity in diets supplemented with phytase at the level of 500 units / kg.

Serum calcium and inorganic phosphorus were significantly ($P<0.01$) higher in enzyme supplemented groups than their respective counterparts at sixth week of age (Kanagaraju, 1998). However no difference could be detected at eight week of age.

2.8 Processing yields

Richter *et al.* (1993a) conducted a 35 day feeding experiment with 720 male and female Lohmann broilers for the evaluation of microbial phytase. Birds were given plant based feeds with inorganic phosphorus at 1350, 675, 338 and 0 mg / kg with phytase at 0, 300 and 700 units / kg feed. Results indicated that when phosphorus was 0, slaughter weight decreased by upto 39 per cent. Medium phosphorus with phytase 300 or 700 units / kg increased slaughter weight by 17 and 23 per cent respectively. Bending and breaking strength of tibia decreased with decreasing phosphorus, but increased with phytase. Incidence of leg disorders was limited by phytase supplementation.

Kanagaraju (1998) reported that the per cent dressed yield and ready-to-cook yield were significantly ($P<0.01$) higher in groups fed a diet having 0.4 per cent available phosphorus plus 750 units of phytase / kg diet than other groups. He also noted that the per cent giblet yield was significantly ($P<0.01$) more in group fed a standard diet supplemented with phytase than other groups.

Breast weight and breast weight as a per cent of live weight and carcass weight were increased ($P<0.05$ to 0.01) as the level of crude protein / amino acid or phytase increased in the diet compared with birds fed the low protein diet (Kornegay *et al.*, 1998).

2.9 Livability

In an experiment with microbial phytase Schoner *et al.* (1992) compared the effectiveness with inorganic phosphate with varying calcium supply. Broiler diets were formulated by adding phytase 125, 250, 1500 units / kg feed, inorganic phosphorus; 0.6, 1.2 and 1.8 and a control without phytase or phosphorus and calcium 6.0, 7.5 and 9.0 g / kg. Control diets with calcium 6.0, 7.5 and 9.0 g / kg had 28, 56 and 58 per cent mortality, which decreased significantly when phosphorus or phytase were supplemented, but larger amounts were required to lower mortality when dietary calcium increased.

Lohmann broilers were given a maize / soybean meal diet with phosphorus 5.2, 5.7 and 6.2 g / kg plus phytase 0, 200, 400, 800 and 1600 units / kg for 6 weeks and observed that increased mortality with decreasing dietary phosphorus could be improved by supplemental phytase (Vogt, 1993).

In a study with Lohmann broilers Richter and Cyriaci (1994) reported that increased losses caused by phosphorus deficiency were lessened by phytase supplementation.

Birds fed with maize - soybean meal diet contained non-phytate phosphorus at 2.0 g / kg without phytase supplementation had above normal mortality than phytase supplemented diets (Kornegay *et al.*, 1996).

Sohail and Roland (1997) opined that phytase at 300 units / kg diet had a much greater influence on livability in broilers fed with 0.225 per cent available phosphorus when compared with diets containing 0.325 per cent available phosphorus.

Huff *et al.* (1998) reported that total phosphorus can be reduced by at least 11 per cent in diets prepared with high available phosphorus maize or in diets supplemented with phytase at 500 units / kg diet without affecting the performance or health of broiler chickens.

The per cent livability of commercial broilers was better with enzyme supplemented groups than with unsupplemented groups (Kanagaraju, 1998).

Yan *et al.* (1998) reported that chicks fed normal corn diets in which non-phytate phosphorus was reduced by 0.15 per cent had higher mortality. However, the effect was alleviated by supplementation of phytase at 1000 FTU / kg diet.

2.10 Economics

Newman (1993) reported that 1 kg of phytase enzyme per tonne of feed can potentially replace 6 to 7 kgs of monocalcium phosphate thus allowed significant reduction in phosphorus supplementation cost.

After conducting an experiment with broilers fed diets containing inorganic phosphorus 0.6, 1.1 and 1.6 g / kg supplemented with phytase 0, 500 and 1000 units / kg diet, Richter *et al.* (1994) stated that phytase was more expensive than inorganic phosphorus.

The cost of production per kg live weight (when feed cost alone was considered) was cheaper in groups fed with 0.4 per cent available phosphorus supplemented with phytase at 750 units / kg diet. The net profit per kg live weight was 13 paise higher in groups maintained on 0.4 per cent available phosphorus diet supplemented with phytase 750 units / kg compared to standard broiler ration (Kanagaraju, 1998).

MATERIALS AND METHODS

3. MATERIALS AND METHODS

A biological trial was conducted in the Department of Poultry Science, College of Veterinary and Animal Sciences, Mannuthy to study the influence of phytase on nutrient utilization and subsequent performance in broiler chicken.

3.1 Experimental materials

3.1.1 Experimental birds

The experimental birds comprised of one hundred and eighty, day-old straight-run commercial broiler chicks (Ven cob) procured from Unique hatcheries, Palakkad.

3.1.2 Experimental rations

Two types of broiler rations, viz, standard broiler ration and low available phosphorus broiler ration were used in this trial. The standard broiler ration (SBR) was formulated as per BIS (1992) specifications. In low available phosphorus broiler rations (LAPBR) the level of available phosphorus was kept at 0.3 per cent as compared to 0.5 per cent in the standard broiler ration. The levels of all other nutrients were similar to that of SBR. Feed ingredients used in the formulation of the experimental rations were yellow maize, rice polish, ground nut cake (expeller), soybean meal and unsalted dried fish. Initially the ration with 0.3 per cent available phosphorus was formulated. By the addition of appropriate levels of dicalcium phosphate (DCP) to this ration, diet with 0.5 per cent available phosphorus was formulated. Experimental birds were fed with broiler starter rations upto six weeks of age and then switched over to broiler finisher rations till the end of the experiment.

The ingredient composition and the chemical composition of the experimental rations are presented in Tables 1 and 2, respectively.

3.1.3 Enzyme

The enzyme used in this trial was 'Natuphos^R- 5000' a product manufactured and marketed by M/s BASF, D - 67056, Ludwigshafen, Germany. It is a phosphatase enzyme of fungal origin (*Aspergillus species*) containing phytase as the only component. The enzyme was added in low available phosphorus broiler ration in three different levels viz, 500, 750 and 1000 units per kg of diet.

3.2 Experimental methods

3.2.1 Housing of birds

The experimental house, feeders, waterers and other equipments were properly cleaned and disinfected prior to housing the chicks. The straight-run day-old-chicks were wing banded, weighed individually and vaccinated against Ranikhet disease.

3.2.2 Experimental design

A total of one hundred and eighty chicks were allotted to five treatment groups, each having three replications of twelve chicks each. The treatment groups were named as T1, T2, T3, T4 and T5. The birds in each treatment were assigned to each of the five rations viz, SBR, LAPBR (0.3%), LAPBR (0.3%) with 500 units enzyme per kg of diet, LAPBR (0.3%) with 750 units enzyme per kg of diet, LAPBR (0.3%) with 1000 units enzyme per kg of diet. The details of treatment particulars are presented in Table 3.

3.2.3 Management

The birds were provided with feed and water *ad libitum* during the experimental period (0 to 8 weeks of age) and were maintained under deep litter system of management. The birds were vaccinated against Infectious Bursal Disease at 14 and 28 days of age. Standard managemental procedures were adopted during the entire experimental period of eight weeks.

3.2.4 Climatic parameters

The wet and dry bulb readings were taken at 8 A.M. and 2 P.M. daily. The maximum and minimum temperatures were recorded at 8 A.M. on all days throughout the experimental period. From these data weekly mean maximum and minimum temperatures and per cent relative humidity were arrived at.

3.2.5 Body weight

The body weight of individual birds were recorded at fortnightly intervals to study the pattern of body weight gain under different feeding regimes.

3.2.6 Feed consumption

Feed intake of the birds was recorded replication wise at fortnightly intervals. From these data, the average feed intake per bird was calculated for various treatment groups.

3.2.7 Feed conversion ratio

Feed conversion ratio (kg of feed consumed/ kg body weight gain) was arrived at based on the data on body weight gain and feed intake.

3.2.8 Metabolism trial

At the end of the experiment, a metabolism trial was carried out utilizing two birds from each replicate selected randomly and housed in individual cages. Water was provided *ad libitum.* Excreta samples were collected over 24 hour period for three days using total collection method as described by Summers *et al.* (1976). The droppings were weighed and samples were taken, dried in the oven at 70°C overnight and ground prior to the estimation of nutrients. The total amount of feed consumed and excreta voided were also recorded.

3.2.9 Chemical analysis

The chemical composition of the experimental rations was determined as per the procedure described by AOAC (1990). Available phosphorus was estimated as per the procedure described by Bureau of Indian Standards (BIS, 1992). The gross energy, nitrogen, calcium, total phosphorus, manganese and zinc content of different rations and excreta were analysed as per the procedure of AOAC (1990).

3.2.10 Tibial ash

At the end of sixth week, two birds from each replicate were randomly selected and sacrificed to collect tibia as per the method described by Kalango and Ademosun (1973). The birds were fasted overnight, slaughtered and dressed. The muscular layers covering the left tibia were removed as closely as possible. The adhering connective and muscular tissues were finally removed by boiling the bone in one per cent solution of sodium hydroxide for about ten minutes. Then the tibia were thoroughly washed, dried in the oven at 100°C overnight. The cooled tibia were weighed and the ash content of the tibia were estimated as per the procedure of AOAC (1990). The weight of the tibial ash was expressed as percentage of the weight of the dried tibia. Tibial ash was also determined at the end of eighth week in birds utilized for slaughter studies.

3.2.11 Serum calcium, inorganic phosphorus and alkaline phosphatase

At the end of sixth and eighth week of age, blood samples were collected from two birds in each replicate by severing the jugular vein for the estimation of serum calcium, inorganic phosphorus and alkaline phosphatase. The serum calcium and inorganic phosphorus was estimated by OCPC and phosphomolybdate methods, respectively utilizing the kits supplied by M/s AGAPPE Diagnostics, F-4, Shailesh Industrial Complex, Valiv post, Vasai (E), Thane, Maharashtra - 401 208, India. The serum alkaline phosphatase was estimated using the kit supplied by M/s E. Merck (India) Limited, Worli, Mumbai - 400 018.

3.2.12 Processing yields

At the end of sixth and eighth week, one male and one female bird from each replicate were randomly selected and sacrificed to study the processing yields. Percentages of dressed yield, giblet yield and ready-to-cook yield were calculated from the data.

3.2.13 Livability

The mortality of birds from different treatment groups were recorded and postmortem examination was conducted in each case to find out the cause of death.

Table 1. Percentage ingredient composition of experimental rations

Sl.No	Ingredients	Standard broiler ration (SBR)		Low available phosphorus broiler ration (LAPBR)	
		Starter	Finisher	Starter	Finisher
1	Yellow maize	48.000	58.000	48.000	58.000
2	Rice polish	7.200	6.200	7.650	7.150
3	Groundnut cake (exp)	18.000	14.500	18.000	14.000
4	Soybean meal	19.000	14.000	19.000	14.000
5	Unsalted dried fish	4.500	4.000	4.500	4.000
6	Shell grit	1.000	1.000	1.600	1.600
7	Dicalcium phosphate	1.250	1.450	0.200	0.400
8	Common salt	0.250	0.250	0.250	0.250
9	Vitamin mixture	0.025	0.025	0.025	0.025
10	Trace mineral mixture	0.130	0.130	0.130	0.130
11	Lysine hydrochloride	0.200	0.160	0.200	0.160
12	D.L. methionine	0.145	0.035	0.145	0.035
13	Choline chloride	0.250	0.200	0.250	0.200
14	Coccidiostat	0.050	0.050	0.050	0.050
	Total	100	100	100	100

Vitamin mixture composition:

Each gram contains: Vitamin A -41250 IU, Vitamin D2 -6000 IU, Vitamin E -20 mg, Vitamin K- 5 mg, Vitamin B1- 2 mg, Vitamin B2- 25 mg,Vitamin B6 -4 mg, Vitamin B12 -20 µg, Niacin -30 mg, Calcium pantothenate- 20 mg.

Trace mineral mixture composition:

Composition / 100 kg of feed: Copper sulphate- 10 gm, Manganese sulphate -30 gm, Zinc oxide- 20 gm, Ferrous sulphate -70 gm, Potassium iodide -100 mg.

Coccidiostat composition:

Each gram contains: Maduramycin ammonium 20 mg.

Table 2. Percentage chemical composition of experimental rations (on dry matter basis).

Sl. No.	Nutrients	Standard broiler ration (SBR)		Low available phosphorus broiler ration (LAPBR)	
		Starter	Finisher	Starter	Finisher
	Analysed values*				
1	Moisture	10.05	9.70	9.32	9.64
2	Crude protein	23.68	20.27	23.53	20.20
3	Ether extract	4.87	4.81	4.86	4.84
4	Crude fibre	5.46	5.23	5.30	5.40
5	NFE	54.90	58.45	55.02	58.28
6	Total ash	11.09	11.24	11.29	11.28
7	Acid insoluble ash	2.88	2.90	2.82	2.88
8	Nitrogen	3.78	3.24	3.76	3.23
9	Gross energy (kcal/kg)	4157	4361	4144	4328
10	Calcium	1.25	1.22	1.27	1.29
11	Total phosphorus	0.82	0.81	0.61	0.61
12	Available phosphorus	0.51	0.52	0.32	0.31
13	Manganese (mg / kg)	96.04	96.30	95.24	95.49
14	Zinc (mg / kg)	64.95	64.60	64.81	64.58
	Calculated values				
15	ME (kcal / kg)	2804	2905	2813	2914
16	Lysine	1.34	1.11	1.34	1.11
17	Methionine	0.54	0.41	0.54	0.41

*- Average of six samples

Table 3. Distribution of the different dietary treatments.

Treatment	Replication	No. of birds	Diet	Level of phytase inclusion (u/kg feed)
T1	R1	12	SBR (0.5%)	0
	R2	12	SBR (0.5%)	0
	R3	12	SBR (0.5%)	0
T2	R1	12	LAPBR (0.3%)	0
	R2	12	LAPBR (0.3%)	0
	R3	12	LAPBR (0.3%)	0
T3	R1	12	LAPBR (0.3%)	500
	R2	12	LAPBR (0.3%)	500
	R3	12	LAPBR (0.3%)	500
T4	R1	12	LAPBR (0.3%)	750
	R2	12	LAPBR (0.3%)	750
	R3	12	LAPBR (0.3%)	750
T5	R1	12	LAPBR (0.3%)	1000
	R2	12	LAPBR (0.3%)	1000
	R3	12	LAPBR (0.3%)	1000

3.2.14 Cost-benefit analysis

Cost of feed, cost of enzyme, live weight of broilers produced and quantity of feed consumed by birds in each treatment groups were considered to carry out the cost-benefit analysis.

3.2.15 Statistical analysis

Data collected on various parameters were statistically analysed as per the methods described by Snedecor and Cochran (1985).

RESULTS

4. RESULTS

The results of an experiment conducted to study the influence of dietary supplementation of microbial phytase on nutrient utilization and subsequent performance in broilers fed diets containing low available phosphorus are presented in this chapter.

4.1 Climatic parameters

The data pertaining to climatic parameters viz., the mean maximum and minimum temperatures and per cent relative humidity during the experimental period from January to March 2000 are given in Table 4. During the experimental period, the mean maximum temperature ranged from 33.57 to 37.29°C and the mean minimum temperature from 23.86 to 25.28°C. The per cent relative humidity varied from 73.43 to 81.43 at 8AM and 50.29 to 55.29 at 2 PM. In general, the variation in climatic profile was very small between different weeks of the experimental period.

4.2 Body weight

The data on mean body weight at fortnightly intervals as influenced by dietary supplementation of phytase is given in Table 5. The mean day-old weight of chicks among the different treatment groups ranged from 43.59 to 45.69 g with a difference of 2.1 g. It is apparent that the difference in day-old weight between different treatments was minimal. The mean body weight at two weeks of age given in Table 5, indicated that chicks offered standard broiler mash put on a

Table 4. Mean weekly meteorological data during the experimental period from January 15 to March 10, 2000.

Period (Weeks)	Temperature (°C)		Relative humidity (per cent)	
	Maximum	Minimum	8 A.M.	2 P.M.
1	34.14	23.86	81.43	50.71
2	33.57	24.29	80.71	53.43
3	34.43	25.28	79.00	55.29
4	35.57	25.00	78.29	53.71
5	36.71	24.29	73.43	50.29
6	36.14	24.71	74.14	50.43
7	36.43	24.57	76.29	52.43
8	37.29	24.29	74.71	50.71
Mean ± SE	35.54± 0.48	24.54± 0.16	77.25± 1.08	52.13± 0.66

maximum weight of 315.69 g (T1). While body weight of the group fed low available phosphorus diet without phytase was the lowest (286.67 g). The second week body weight of the enzyme supplemented groups were intermediary. The mean body weight at fourth week of age was highest for chicks fed low available phosphorus diet supplemented with 1000 units of phytase / kg (T5) and lowest with T2 ie. birds maintained on low available phosphorus diet without phytase.

The mean body weight of treatments T1, T2, T3, T4 and T5 at sixth week of age were 1831.67, 1740.39, 1793.33, 1834.87 and 1817.37 g, respectively (Table 5). Similar to previous weeks, the birds fed on low available phosphorus diet without phytase showed apparently lower weights than all other treatments. It was also evident that birds maintained on low available phosphorus diet supplemented with 750 units of phytase (T4) exhibited numerically higher weight than that of the control diet.

The mean eighth week body weight of groups T1, T2, T3, T4 and T5 were 2532.85, 2373.59, 2447.67, 2511.04 and 2495.93 g, respectively. Eighth week body weight was maximum with standard broiler mash fed birds and lowest with group fed a low available phosphorus diet without added phytase. The difference in body weight among treatments at eighth week of age was 159.26 g.

Statistical analysis of the data on mean body weight at fortnightly intervals presented in Table 6 indicated that dietary supplementation of phytase in

Table 5. Fortnightly mean body weight (g) of broilers as influenced by dietary supplementation of phytase.

Treatments	Age in weeks				
	0	2	4	6	8
T1	43.97 ± 0.24	315.69^{a} ± 5.56	1030.83^{ab} ± 8.39	1831.67^{a} ± 16.08	2532.85^{a} ± 20.07
T2	45.11 ± 0.44	286.67^{d} ± 2.78	983.33^{c} ± 12.29	1740.39^{b} ± 18.80	2373.59^{c} ± 7.24
T3	45.69 ± 0.59	299.44^{c} ± 4.65	1010.28^{bc} ± 13.96	1793.33^{a} ± 7.91	2447.67^{b} ± 6.12
T4	44.17 ± 0.02	299.72^{c} ± 1.39	1026.92^{ab} ± 6.73	1834.87^{a} ± 8.42	2511.04^{a} ± 14.02
T5	43.59 ± 0.16	309.20^{b} ± 1.53	1044.39^{a} ± 9.64	1817.37^{a} ± 13.92	2495.93^{ab} ± 25.73
CD	-	5.580	33.18	43.21	51.80

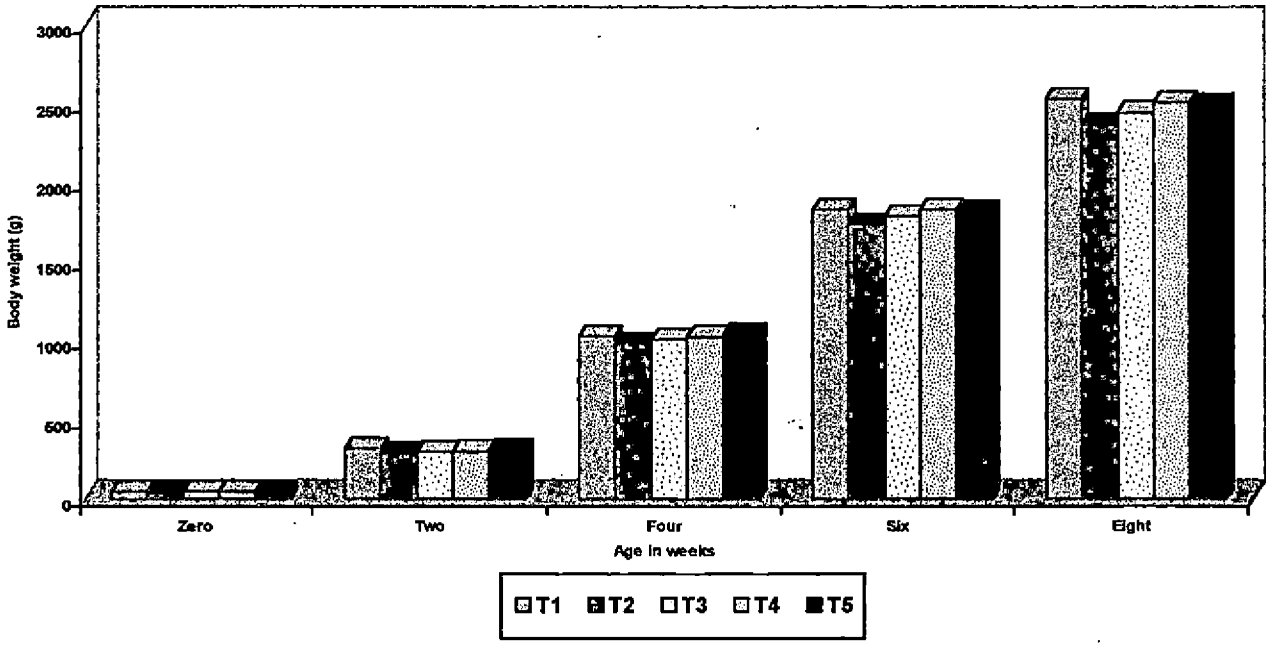
Means bearing the different superscript within the same column differed significantly ($P<0.01$) except at fourth week ($P< 0.05$).

Table 6. Fortnightly mean body weight of broilers as influenced by dietary supplementation of phytase - ANOVA

Age in weeks	Source	d.f.	SS	MSS	F value
0	Treatment	4	6.347	1.587	2.704^{NS}
	Error	10	5.777	0.578	
	Total	14			
2	Treatment	4	1458.407	364.602	9.416**
	Error	10	387.216	38.722	
	Total	14	1845.623		
4	Treatment	4	6586.834	1646.708	4.950*
	Error	10	3326.802	332.680	
	Total	14	9913.635		
6	Treatment	4	18170.311	4542.578	8.052**
	Error	10	5641.281	564.128	
	Total	14	23811.592		
8	Treatment	4	48225.671	12056.418	14.871**
	Error	10	8107.480	810.748	
	Total	14			

**- Significant ($P<0.01$) *- Significant ($P<0.05$)
NS- Not significant

FIG. 1 FORTNIGHTLY MEAN BODY WEIGHT OF BROILERS AS INFLUENCED BY DIETARY SUPPLEMENTATION OF PHYTASE



low available phosphorus diet significantly influenced body weights at second, fourth, sixth and eighth week of age. The mean body weight of day-old chicks was statistically similar among treatment groups.

At second week of age, control group T1 showed significantly ($P<0.01$) higher (315.69 g) body weight than that of all other groups. Among the treatment groups, T2 was the lowest (286.67 g) in body weight in comparison to other groups. Mean body weight of T3 (299.44 g) and T4 (299.72 g) were comparable but significantly lower than T5.

At fourth week of age the group maintained on low available phosphorus diet supplemented with 1000 units of phytase / kg showed significantly ($P<0.05$) higher body weight and was statistically comparable with those fed on low available phosphorus diet supplemented with 750 units of phytase / kg (T4) and standard broiler mash (T1). The body weight of birds maintained on low available phosphorus diet without phytase (T2) was significantly inferior and was statistically comparable with T3. Likewise the body weight of T1, T3 and T4 were also statistically similar.

Sixth week body weight was significantly ($P<0.01$) higher among the birds reared on standard broiler mash as well as low available phosphorus diet supplemented with varying levels of phytase. Birds offered a diet containing 0.3

per cent available phosphorus without phytase exhibited significantly lower body weight.

When the birds attained eight weeks of age, significantly ($P<0.01$) higher body weight was observed with those fed standard broiler mash and was statistically comparable with groups maintained on low available phosphorus diet supplemented with 750 and 1000 units of phytase / kg. Eighth week mean body weight of birds supplemented with 500 and 1000 units of phytase / kg were also statistically comparable. Similar to previous weeks performance, eighth week body weight was statistically lower among the birds fed low available phosphorus diet without phytase.

The fortnightly mean body weight of birds as influenced by dietary supplementation of phytase is depicted in Figure 1.

4.3 Body weight gain

The data on mean body weight gain at fortnightly intervals and the cumulative mean weight gain upto six and eight weeks of age among different treatment groups are given in Table 7.

In general the trend in body weight gain was comparable to that of body weight. The mean body weight gain at two weeks of age was higher in the group fed standard broiler mash (271.72 g) and lower in the group offered low available phosphorus diet without phytase. The body weight gain of phytase supplemented groups were intermediary. However at fourth week of age maximum gain was achieved in the group fed low available phosphorus diet supplemented with 1000 units of enzyme (735.19 g) and lowest gain with the group fed low available phosphorus diet without enzyme (696.67 g). The weight gain values of other treatments were in between these two. At sixth week of age maximum body weight gain was observed with the group T4 (807.95 g) and minimum gain with T2 (757.07 g). The body weight gain values of other treatments were intermediary. Similar to the body weight gain at two weeks of age, maximum and minimum weight gains were noted with T1 and T2, respectively at eighth week of age.

When the cumulative mean body weight gain from zero to six weeks was considered it could be seen that the group T4 ie. birds offered low available phosphorus diet supplemented with 750 units of phytase gained maximum weight. Where as, the group offered low available phosphorus diet without phytase gained the minimum weight. The cumulative mean body weight gain (g) for the treatments T1, T2, T3, T4 and T5 were 1787.69, 1695.29, 1747.64, 1790.71 and 1773.79 g, respectively. The difference between T3 and T4 in mean weight gain on cumulative basis at sixth week of age was 43.07 g.

The cumulative mean body weight gain from zero to eight weeks of age were 2488.88, 2328.48, 2401.97, 2466.87 and 2452.34 g for the treatments T1,

Table 7. Fortnightly and cumulative mean body weight gain (g) of broilers as influenced by dietary supplementation of phytase.

Treatments	Fortnightly mean body weight gain (g)				Cumulative mean body weight gain (g)	
	Age in weeks				Age in weeks	
	2	4	6	8	6	8
T1	271.72[a] ± 5.69	715.14 ± 3.52	800.83[ab] ± 7.95	701.19[a] ± 4.16	1787.69[a] ± 16.18	2488.88[a] ± 20.16
T2	241.55[d] ± 2.67	696.67 ± 12.56	757.07[c] ± 6.90	633.19[c] ± 16.24	1695.29[b] ± 19.25	2328.48[c] ± 7.54
T3	253.75[c] ± 4.56	710.84 ± 10.00	783.05[abc] ± 12.86	654.33[bc] ± 11.92	1747.64[a] ± 7.38	2401.97[b] ± 6.26
T4	255.55[bc] ± 1.44	727.20 ± 5.95	807.95[a] ± 11.77	676.16[ab] ± 5.88	1790.71[a] ± 8.45	2466.87[a] ± 14.01
T5	265.62[ab] ± 1.41	735.19 ± 8.11	772.98[bc] ± 4.41	678.55[ab] ± 11.84	1773.79[a] ± 13.81	2452.34[ab] ± 25.63
CD	11.31	-	29.36	34.45	43.41	51.88

Means bearing the different superscript within the same column differed significantly ($P<0.01$) except sixth and eighth week fortnightly interval ($P<0.05$).

Table 8. Fortnightly and cumulative mean body weight gain (g) of broilers as influenced by dietary supplementation of phytase - ANOVA

Age in weeks	Source	d.f.	SS	MSS	F value
Fortnightly					
2	Treatment	4	1620.422	405.105	10.486**
	Error	10	386.335	38.634	
	Total	14	2006.757		
4	Treatment	4	2669.421	667.355	2.996^{NS}
	Error	10	2227.371	222.737	
	Total	14	4896.792		
6	Treatment	4	5111.909	1277.977	4.908*
	Error	10	2603.869	260.387	
	Total	14	7715.778		
8	Treatment	4	8026.599	2006.650	5.595*
	Error	10	3586.229	358.623	
	Total	14	11612.828		
Cumulative					
6	Treatment	4	18705.834	4676.458	8.213**
	Error	10	5693.813	569.381	
	Total	14	24399.647		
8	Treatment	4	49172.616	12293.154	15.117**
	Error	10	8132.089	813.209	
	Total	14	57304.705		

** - Significant (P<0.01), *- Significant (P<0.05), NS- Not significant

T2, T3, T4 and T5, respectively (Table 7). Maximum gain was noted with control group fed standard broiler mash and minimum gain with birds offered diet having 0.3 per cent available phosphorus without phytase. Enzyme supplemented groups T4 and T5 had comparable weight gains and a difference of 64.9 g was noticed between T3 and T4.

The analysis of variance of the data on mean body weight gain presented in Table 8 revealed that fortnightly weight gain except for the fourth week and cumulative gain for both sixth and eighth week periods were significantly influenced by dietary supplementation of phytase.

The mean weight gain of birds at second week of age given the standard broiler diet T1 (271.72 g) was significantly ($P<0.01$) higher than that of T2 (241.55 g), T3 (253.75 g) and T4 (255.55 g) groups. But it was statistically comparable to that of T5 (265.62 g). The birds offered low available phosphorus diet without phytase (T2) showed the lowest body weight gain. The body weight gain of groups T3 and T4 were statistically comparable. Likewise T4 and T5 were also statistically comparable. However T3 and T5 differed significantly ($P<0.01$).

Perusal of the fourth week mean weight gain, revealed that there was no significant difference between treatment groups, although the gain in group T2 was the lowest.

FIG. 2. FORTNIGHTLY MEAN BODY WEIGHT GAIN OF BROILERS AS INFLUENCED BY DIETARY SUPPLEMENTATION OF PHYTASE

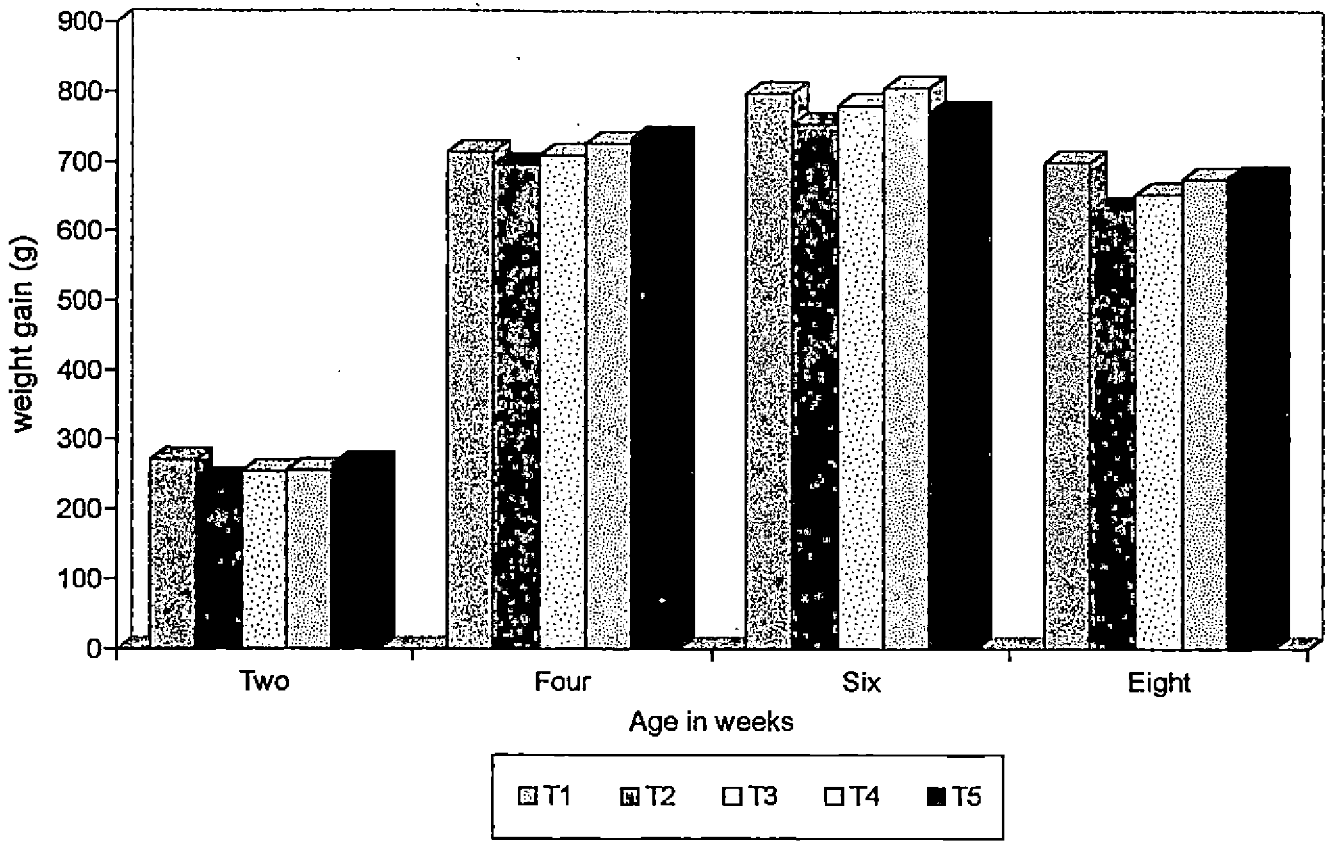
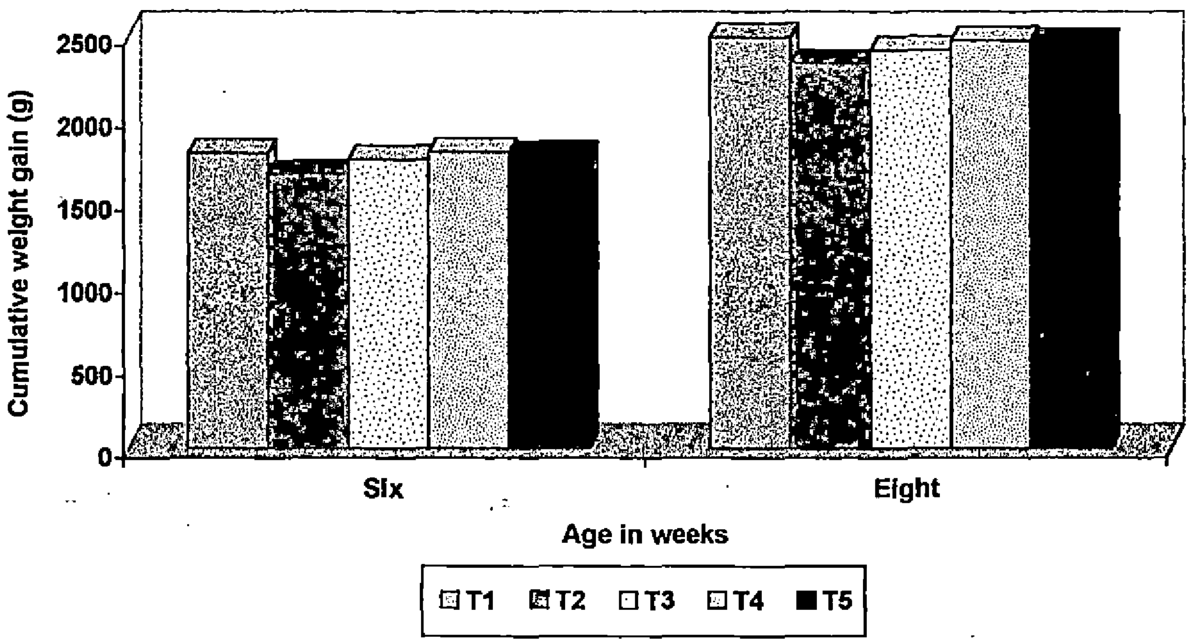


FIG. 3 SIXTH AND EIGHTH WEEK CUMULATIVE MEAN BODY WEIGHT GAIN OF BROILERS AS INFLUENCED BY DIETARY SUPPLEMENTATION OF PHYTASE



At sixth week of age, the gain in group T4 (807.95 g) was significantly ($P<0.05$) higher and was statistically comparable with T1 (800.83 g) and T3 (783.05 g). Low available phosphorus diet group T2 showed significant ($P<0.05$) reduction in weight gain and was statistically comparable with the gain of T3 and T5.

The fortnightly mean body weight gain at eight weeks of age in T1 (701.19 g), T4 (676.16 g) and T5 (678.55 g) were significantly ($P<0.05$) higher than T2 (633.19 g) and T3 (654.33 g). The treatment groups T2 and T3 were statistically comparable.

The cumulative weight gain from zero to six weeks of age was significantly ($P<0.01$) higher in all enzyme supplemented groups as well as standard broiler mash fed birds than T2 which was significantly lower.

An analysis of the cumulative mean body weight gain during zero to eight weeks of age showed that it was significantly ($P<0.01$) higher among standard broiler mash fed birds (T1) and was statistically comparable with T4 and T5. Cumulative weight gain was also comparable between groups T3 and T5. Significantly lower cumulative weight gain at eight weeks of age was observed with the group fed low available phosphorus diet without added enzyme.

The fortnightly and cumulative body weight gain of birds as influenced by dietary supplementation of phytase are shown in Figures 2 and 3, respectively.

4.4 Feed consumption

Mean daily feed intake at fortnightly intervals and cumulative mean feed intake at six and eight weeks of age as influenced by dietary supplementation of phytase are given in Table 9. The mean daily feed intake during the first fortnight ranged from 26.67 to 28.45 g among the treatments. During the second fortnight covering the third and fourth week of age, it ranged from a minimum of 84.64 to a maximum of 89.88 g. During fifth and sixth week of age also much variation in daily feed intake could not be observed between the treatments. A lowest feed intake of 108.57 g was noted with T5 against a maximum daily feed intake of 113.45 g in T4. In the last fortnight covering seventh and eighth week of age a lowest feed intake of 164.29 g was noted with T2 ie. birds fed low available phosphorus diet without added phytase, while a maximum feed intake of 174.52 g among the control birds. In general the difference in daily feed intake among various treatments at fortnightly intervals was only marginal.

When the cumulative mean feed intake upto six weeks was considered, birds in the control group consumed less feed compared to other groups. The feed intake of birds fed low available phosphorus diet supplemented with 750 units of phytase / kg was the highest. Six weeks cumulative feed intake for the treatments T1, T2, T3, T4 and T5 were 3108.33, 3156.67, 3196.67, 3208.33 and 3175.00 g,

Table 9. Daily mean feed intake at fortnightly intervals and cumulative mean feed intake at six and eight weeks of age per bird (g) in broilers as influenced by dietary supplementation of phytase.

Treatments	Daily mean feed intake (g)				Cumulative mean feed intake (g)	
	Age in weeks				Age in weeks	
	2	4	6	8	6	8
T1	28.45 ± 0.66	84.64^{b} ± 1.15	108.93 ± 1.25	174.52^{a} ± 0.86	3108.33 ± 35.86	5551.66^{a} ± 41.26
T2	26.67 ± 0.52	89.64^{a} ± 0.62	109.17 ± 1.46	164.29^{c} ± 2.06	3156.67 ± 26.19	5456.67^{b} ± 10.14
T3	27.50 ± 0.74	89.64^{a} ± 1.69	111.19 ± 1.17	170.71^{ab} ± 1.49	3196.67 ± 20.88	5586.67^{a} ± 26.82
T4	27.02 ± 0.31	88.69^{a} ± 0.69	113.45 ± 2.10	169.76^{b} ± 1.04	3208.33 ± 19.22	5585.00^{a} ± 32.79
T5	28.33 ± 0.33	89.88^{a} ± 1.41	108.57 ± 0.60	170.00^{b} ± 1.09	3175.00 ± 15.00	5555.00^{a} ± 30.14
CD	-	3.90	-	4.62	-	94.67

Means bearing the different superscript within the same column differed significantly ($P<0.05$) except eighth week fortnightly interval ($P<0.01$).

Table 10. Daily mean feed intake at fortnightly intervals and cumulative mean feed intake at six and eight weeks of age per bird in broilers fed the experimental diets- ANOVA

Age in weeks	Source	d.f.	SS	MSS	F value
Daily					
2	Treatment	4	7.399	1.850	1.863 NS
	Error	10	9.927	0.993	
	Total	14	17.326		
4	Treatment	4	58.318	14.580	3.176*
	Error	10	45.908	4.591	
	Total	14	104.224		
6	Treatment	4	50.562	12.641	2.090 NS
	Error	10	60.480	6.048	
	Total	14	111.042		
8	Treatment	4	160.478	40.120	5.967**
	Error	10	67.240	6.724	
	Total	14	227.718		
Cumulative					
6	Treatment	4	18543.333	4635.833	2.573 NS
	Error	10	18016.667	1801.667	
	Total	14	36560.000		
8	Treatment	4	38790.000	9697.500	3.585*
	Error	10	27050.000	2705.000	
	Total	14	65840.000		

** - Significant (P<0.01), *- Significant (P<0.05), NS- Not significant respectively. The corresponding figures for eight weeks were 5551.66, 5456.67, 5586.67, 5585.00 and 5555.00 g, respectively (Table 9). Thus it could be seen that eight weeks cumulative feed intake was less with the group offered low available phosphorus diet without phytase while it was maximum for birds fed low available phosphorus diet supplemented with 500 units of phytase / kg.

The statistical analysis of the data on daily mean feed intake at fortnightly intervals and cumulative mean feed intake at six and eight weeks of age per bird are set out in Table 10.

The mean daily feed consumption upto second week of age was not significantly influenced by different treatment groups whereas, the daily feed consumption during the third and fourth week of age was significantly ($P < 0.05$) lower in T1 (84.64 g) compared to all other groups. Daily feed consumption during this period was statistically similar among all other groups.

The difference in mean daily feed consumption during fifth and sixth week of age among the treatments was only 4.88 g. When the magnitude of difference in mean daily feed consumption during this period was tested statistically no difference could be noticed between treatments.

The mean daily feed intake from seven to eight weeks of age was significantly ($P<0.01$) higher in groups T1 (174.52 g) and T3 (170.71 g) than that

FIG. 4. DAILY MEAN FEED INTAKE OF BROILERS AT FORTNIGHTLY INTERVALS AS INFLUENCED BY DIETARY SUPPLEMENTATION OF PHYTASE

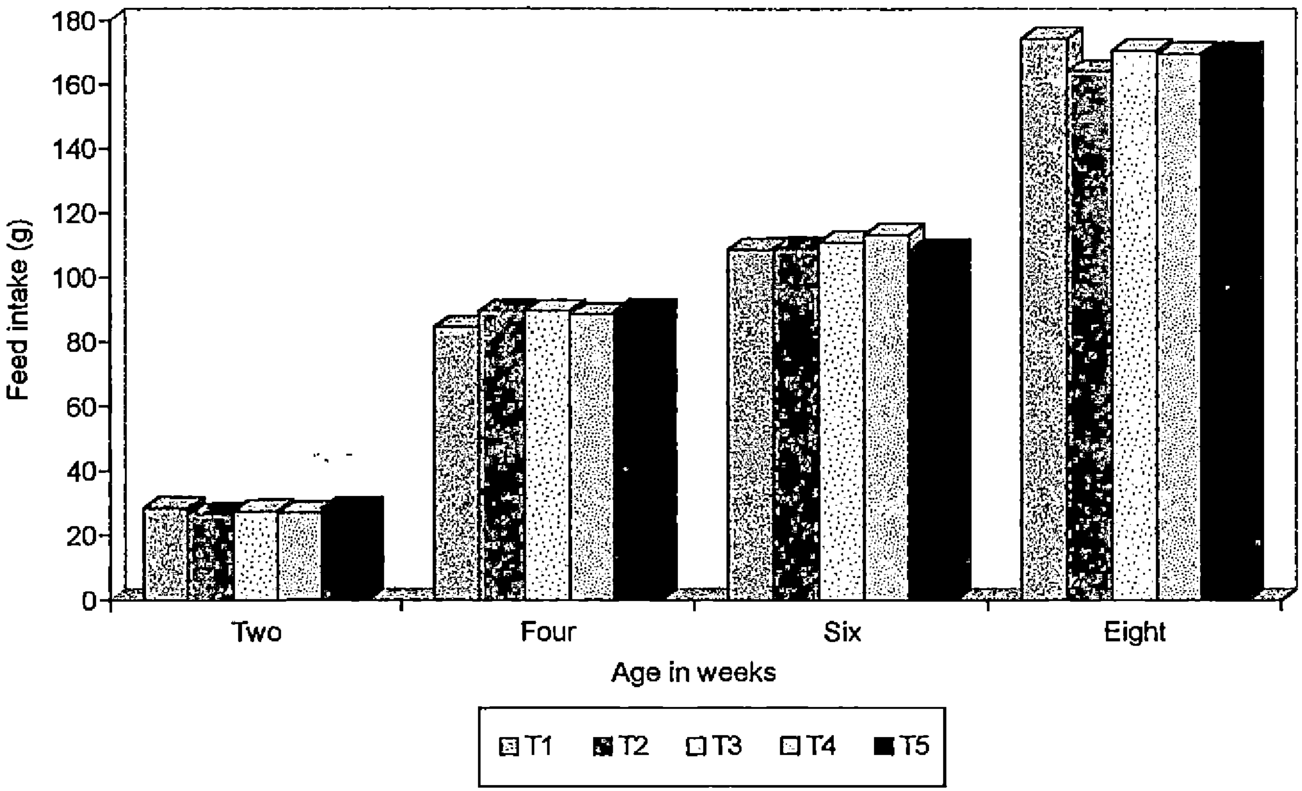
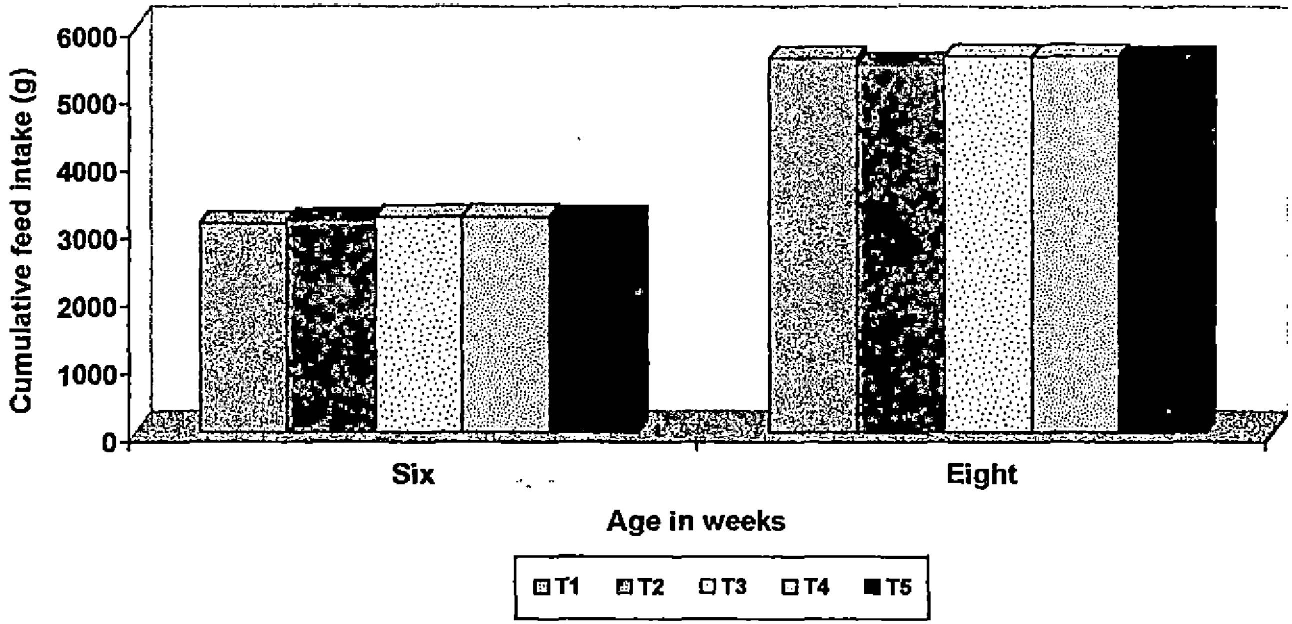


FIG. 5 SIXTH AND EIGHTH WEEK CUMULATIVE MEAN FEED INTAKE AS INFLUENCED BY SUPPLEMENTATION OF PHYTASE



of T2 (164.29 g). Phytase supplemented low available phosphorus diet offered groups T3 (170.71 g), T4 (169.76 g) and T5 (170.00 g) showed statistically comparable feed intake and the mean values were significantly higher than those fed low available phosphorus diet without phytase (T2).

The cumulative mean feed intake till six weeks of age revealed that it was not influenced significantly by different treatment groups.

Statistical analysis of the data on cumulative mean feed intake upto eight weeks of age showed that birds offered low available phosphorus diet without phytase (T2) consumed less feed ($P<0.05$) than all other groups. It was also revealed that eight weeks cumulative mean feed intake was statistically comparable among T1, T3, T4 and T5.

The mean daily feed intake at fortnightly intervals and six and eight weeks mean cumulative feed intake per bird as influenced by dietary supplementation of phytase are depicted in Figures 4 and 5, respectively.

4.5 Feed conversion ratio

The data pertaining to mean feed conversion ratio at fortnightly intervals and cumulative feed conversion ratio upto six and eight weeks of age for different treatment groups are presented in Table 11.

Table 11. Fortnightly and cumulative mean feed conversion ratio (kg of feed consumed / kg body weight gain) of broilers as influenced by dietary supplementation of phytase.

Treatments	Fortnightly mean feed conversion ratio				Cumulative mean feed conversion ratio	
	Age in weeks				Age in weeks	
	2	4	6	8	6	8
T1	1.47 ± 0.02	1.65[d] ± 0.02	1.90[c] ± 0.01	3.48[b] ± 0.02	1.74[d] ± 0.01	2.23[c] ± 0.01
T2	1.50 ± 0.02	1.80[a] ± 0.02	2.02[a] ± 0.01	3.64[a] ± 0.05	1.86[a] ± 0.01	2.34[a] ± 0.01
T3	1.52 ± 0.02	1.77[ab] ± 0.01	1.99[ab] ± 0.03	3.65[a] ± 0.04	1.83[b] ± 0.01	2.33[a] ± 0.02
T4	1.48 ± 0.02	1.70[cd] ± 0.02	1.97[b] ± 0.01	3.51[b] ± 0.02	1.79[c] ± 0.01	2.26[b] ± 0.01
T5	1.49 ± 0.02	1.71[bc] ± 0.01	1.97[b] ± 0.01	3.51[b] ± 0.03	1.79[c] ± 0.01	2.27[b] ± 0.02
CD	-	0.0575	0.0364	0.0983	0.0288	0.0315

Means bearing the different superscript within the same column differed significantly ($P<0.01$) except eighth week fortnightly interval ($P<0.05$).

Table 12. Fortnightly and cumulative mean feed conversion ratio of broilers as influenced by dietary supplementation of phytase - ANOVA

Age in weeks	Source	d.f.	SS	MSS	F value
Fortnightly					
2	Treatment	4	0.012	0.0030	3.000[NS]
	Error	10	0.010	0.0010	
	Total	14	0.022		
4	Treatment	4	0.040	0.0100	12.500**
	Error	10	0.008	0.0008	
	Total	14	0.048		
6	Treatment	4	0.021	0.0053	10.600**
	Error	10	0.005	0.0005	
	Total	14	0.026		
8	Treatment	4	0.075	0.0188	4.947*
	Error	10	0.038	0.0038	
	Total	14	0.113		
Cumulative					
6	Treatment	4	0.025	0.0063	63.000**
	Error	10	0.001	0.0001	
	Total	14	0.026		
8	Treatment	4	0.029	0.0073	24.333**
	Error	10	0.003	0.0003	
	Total	14	0.032		

0** - Significant (P<0.01), *- Significant (P<0.05), NS- Not significant

The mean feed conversion ratio for the first fortnight varied from a lowest value of 1.47 for the control group (T1) to 1.52 noted against T3. The control group continued to show a lowest value of 1.65 as against 1.80 for the treatment T2 during the second fortnight period. The feed conversion values for the other treatments were intermediary.

In the third fortnight covering fifth and sixth week of age, the control group still maintained a lowest feed conversion value of 1.90. The value for T2 was 2.02 which was highest among the treatments. In the last fortnight too the group fed on standard broiler mash (T1) recorded the lowest feed conversion ratio of 3.48 as against 3.65 noted for T3 ie, birds fed low available phosphorus ration supplemented with 500 units of phytase / kg.

A perusal of the cumulative feed conversion ratio from zero to six weeks showed the lowest value of 1.74 for the treatment T1 and the highest value of 1.86 for the group T2. The feed conversion ratio values for the treatments T3, T4 and T5 were 1.83, 1.79 and 1.79, respectively.

The mean cumulative feed conversion ratio calculated for the whole period of eight weeks were 2.23, 2.34, 2.33, 2.26 and 2.27 for the treatments T1, T2, T3, T4 and T5, respectively.

The analysis of variance of the data on feed conversion ratio set out in Table 12 revealed that this trait was not significantly influenced by dietary supplementation of phytase during the first fortnight.

At four weeks of age, the best feed conversion ratio was noticed with group T1 (1.65) that was fed the control diet and was statistically comparable with T4 ($P<0.01$). The feed conversion ratio of T4 and T5 and that of T5 and T3 were also statistically comparable. Likewise, feed conversion ratio of T2 and T4 were also statistically comparable during third and fourth week of age.

The feed conversion ratio at six weeks of age also showed significantly ($P<0.01$) superior value for T1 (1.90) compared to all other groups. The feed conversion ratio of group T2 (2.02) was inferior and was comparable to that of T3 (1.99). The feed conversion ratio in phytase supplemented low available phosphorus diet groups (T3, T4 and T5) were statistically comparable to each other.

The fortnightly feed conversion ratio in treatment groups T1 (3.48), T4 (3.51) and T5 (3.51) were statistically comparable during seven to eight weeks of age. The feed conversion ratio in groups T2 (3.64) and T3 (3.65) were inferior to other groups ($P<0.05$).

FIG. 6. FORTNGHTLY MEAN FEED CONVERSION RATIO OF BROILERS AS INFLUENCED BY DIETARY SUPPLEMENTATION OF PHYTASE

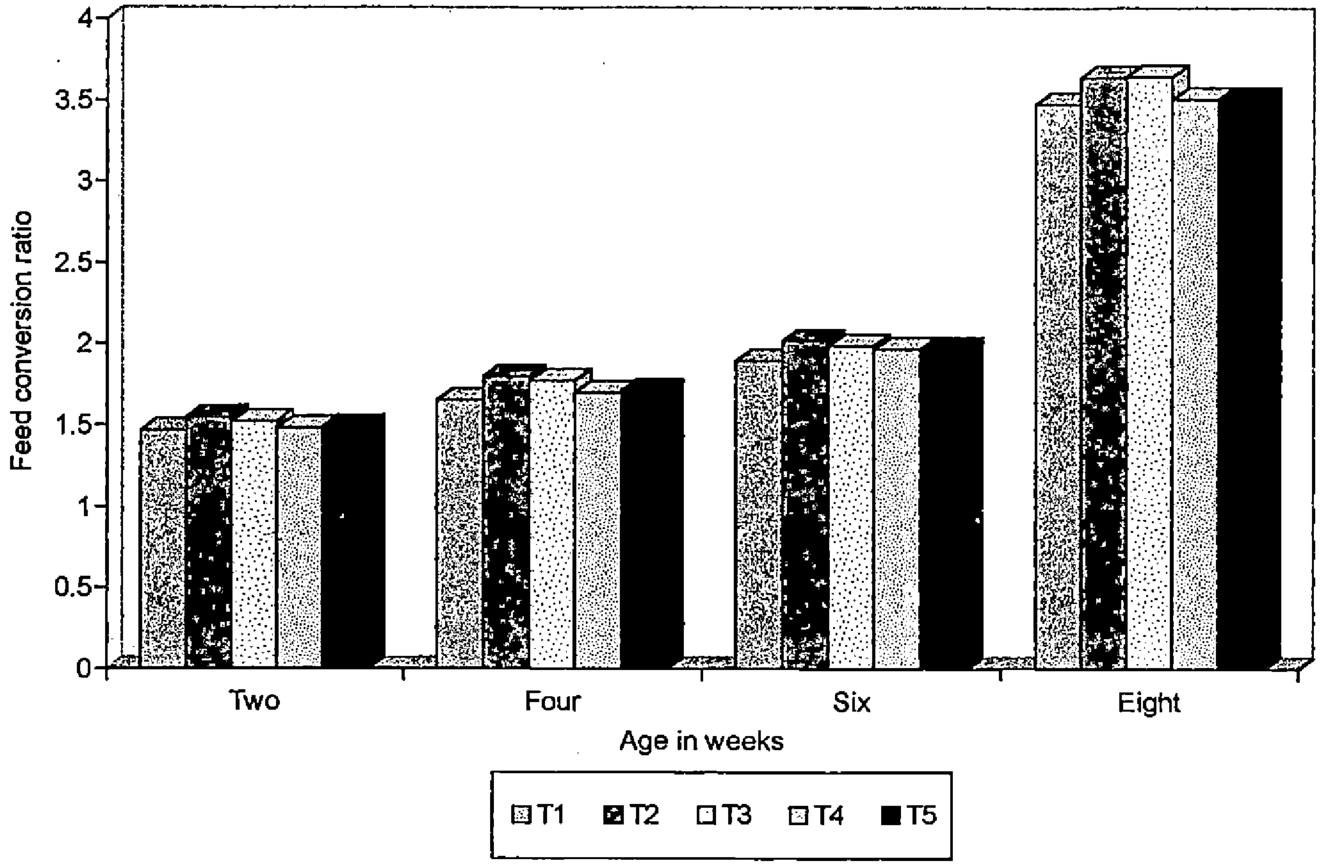
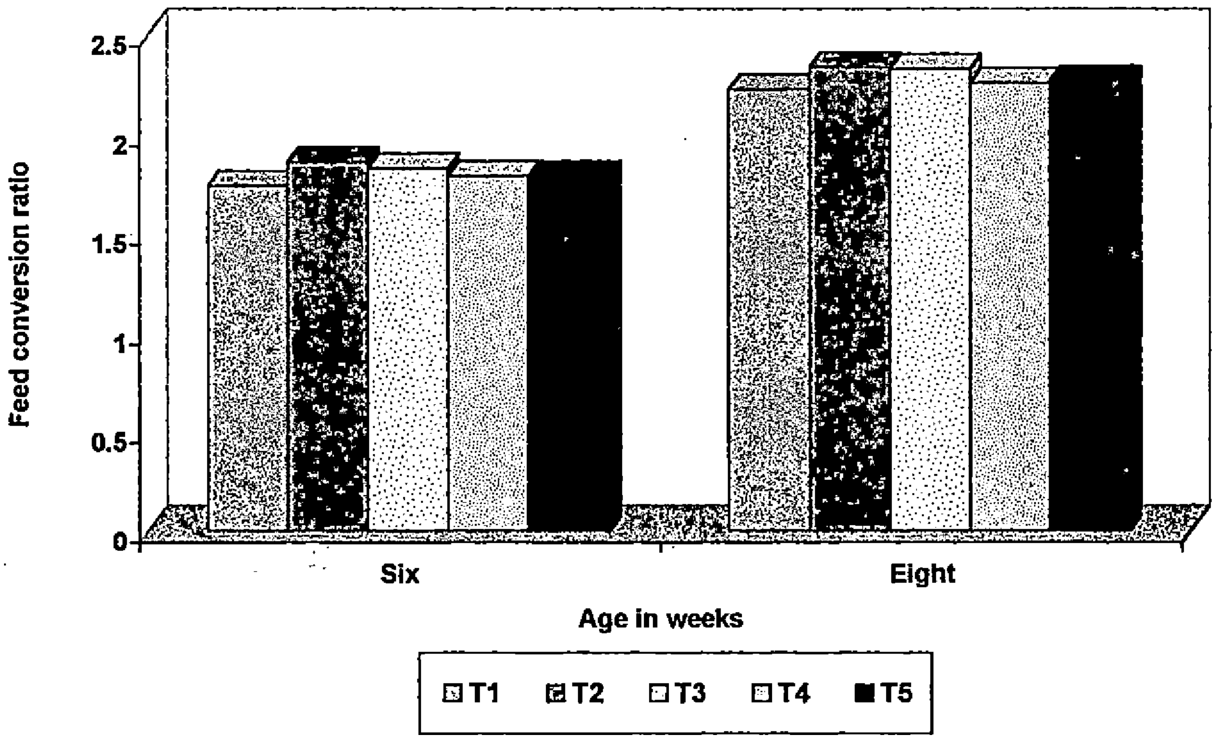


FIG. 7 SIXTH AND EIGHTH WEEK CUMULATIVE FEED CONVERSION RATIO OF BROILERS AS INFLUENCED BY DIETARY SUPPLEMENTATION OF PHYTASE



The sixth week cumulative feed conversion ratio in control group T1 (1.74) was significantly ($P<0.01$) superior in relation to all other groups. Among the low available phosphorus diet groups, T2 (1.86) was inferior in feed conversion ratio. The values improved significantly ($P<0.01$) as the level of phytase supplementation increased. However T4 (1.79) and T5 (1.79) groups were identical in this respect.

The cumulative feed conversion ratio for the eight weeks period was significantly ($P<0.01$) superior in control group T1 (2.23) in comparison to all other groups. A lowest feed conversion ratio of 2.34 was recorded for the group fed low available phosphorus diet without phytase supplementation and was statistically comparable with the group offered low available phosphorus diet supplemented with 500 units of phytase / kg. The feed conversion values of T4 and T5 were statistically comparable and was different from other groups.

The mean fortnightly feed conversion ratio during the eight weeks period and mean cumulative feed conversion ratio at sixth and eighth week of age are depicted in Figures 6 and 7, respectively.

4.6 Retention of nitrogen and energy

4.6.1 Retention of nitrogen

The mean per cent retention of nitrogen registered by different treatment groups viz., T1, T2, T3, T4 and T5 were 67.06, 54.55, 58.17, 60.41 and 63.63, respectively (Table 13).

The retention of nitrogen was more in control group and less in the group fed low available phosphorus diet without phytase. Supplementation of 500, 750 and 1000 units of phytase / kg in low available phosphorus diet improved the nitrogen retention by 6.64, 10.74 and 16.65 per cent, respectively.

When the magnitude of differences in the mean per cent nitrogen retention was tested statistically, it revealed that significant differences existed between treatments (Table 14). Mean per cent nitrogen retention was significantly higher ($P<0.01$) among the birds fed standard broiler diet as compared to other groups and it was significantly low with birds fed low available phosphorus diet without phytase. Dietary supplementation of phytase in low available phosphorus diet significantly improved the retention of nitrogen. In enzyme supplemented group the nitrogen retention was significantly better in group fed 1000 units of phytase / kg followed by 750 and 500 units.

4.6.2 Retention of energy

The data pertaining to per cent energy retention for different treatment groups are shown in Table 13. Mean per cent retention of energy for the treatments T1, T2, T3, T4 and T5 were 69.52, 67.29, 68.15, 71.84 and 70.43, respectively. Higher energy retention was observed among birds maintained on diet containing 0.3 per cent available phosphorus added with 750 units of

Table 13. Mean nitrogen and energy retention (per cent) of broilers as influenced by dietary supplementation of phytase.

Parameters	Treatments					CD
	T1	T2	T3	T4	T5	
Nitrogen	67.06[a] ± 0.55	54.55[e] ± 1.02	58.17[d] ± 0.76	60.41[c] ± 0.72	63.63[b] ± 0.65	2.207
Energy	69.52[b] ± 0.46	67.29[c] ± 0.82	68.15[bc] ± 0.31	71.84[a] ± 0.76	70.43[ab] ± 0.67	1.846

Means bearing the different superscript within the same row differed significantly (P<0.01)

Table 14. Mean nitrogen and energy retention of broilers as influenced by dietary supplementation of phytase - ANOVA

Parameters	Source	d.f.	SS	MSS	F value
Nitrogen	Treatment	4	560.504	140.126	40.667**
	Error	25	86.143	3.446	
	Total	29	646.647		
Energy	Treatment	4	153.674	38.419	15.922**
	Error	25	60.333	2.413	
	Total	29	214.007		

**- Significant (P<0.01)

phytase / kg and it was lower in unsupplemented low available phosphorus diet given birds.

The statistical interpretation (Table 14) showed that the retention of energy was significantly ($P<0.01$) influenced by phytase supplementation. Among the treatment groups, 750 units phytase supplemented low available phosphorus diet (T4) showed significantly ($P<0.01$) higher value for energy retention in comparison to all other groups except the group T5. Low available phosphorus diet T2 noticed lowest energy retention and it was comparable to T3. There were no significant differences between T1 (69.52 per cent), T3 (68.15 per cent) and T5 (70.43 per cent) on energy retention.

The influence of dietary supplementation of phytase on nitrogen and energy retention are shown in Figure 8.

4.7 Availability of calcium and phosphorus

4.7.1 Availability of calcium

The data on mean per cent calcium availability of birds in different treatment groups is given in Table 15.

The per cent calcium availability of birds among the treatment groups T1, T2, T3, T4 and T5 were 63.47, 57.29, 58.89, 60.42 and 61.62, respectively.

The availability of calcium was more with birds fed standard diet and was less in birds with unsupplemented low available phosphorus diet. Phytase supplementation caused an enhancement in the per cent availability of calcium.

Statistical analysis of the data on mean calcium availability (Table 16) indicated that birds offered standard diet had significantly higher ($P<0.01$) per cent calcium availability and was statistically comparable to the group fed low available phosphorus diet supplemented with 1000 units of phytase / kg. Low available phosphorus diets supplemented with phytase at 500 and 750 units / kg were statistically comparable. Among the treatments, T2 recorded significantly inferior values.

4.7.2 Availability of phosphorus

The mean per cent phosphorus availability of birds among different treatment groups are shown in Table 15.

Mean per cent availability of phosphorus registered in different treatment groups viz., T1, T2, T3, T4 and T5 were 53.61, 40.07, 43.05, 48.80 and 49.12, respectively.

Birds maintained on 0.5 per cent available phosphorus diet (T1) registered 33.79 per cent more phosphorus availability than those maintained on 0.3 per cent available phosphorus diet without phytase. The supplementation of phytase

Table 15. Mean calcium, phosphorus, manganese and zinc availability (per cent) and phosphorus excretion (g / kg DM intake) of broilers as influenced by dietary supplementation of phytase.

Parameters	Treatments					CD
	T1	T2	T3	T4	T5	
Calcium	63.47^{a} ± 0.50	57.29^{d} ± 0.70	58.89^{cd} ± 1.11	60.42^{bc} ± 0.78	61.62^{ab} ± 1.27	2.661
Phosphorus	53.61^{a} ± 0.74	40.07^{d} ± 0.91	43.05^{c} ± 1. 05	48.80^{b} ± 0. 74	49.12^{b} ± 1.26	2.569
Manganese	21.70^{d} ± 0.97	25.28^{c} ± 0.85	30.78^{b} ± 0.61	37.72^{a} ± 0.81	35.43^{a} ± 0.73	2.336
Zinc	22.28^{e} ± 0.56	27.95^{d} ± 0.36	30.33^{c} ± 0.50	34.48^{b} ± 0.23	37.78^{a} ± 0.39	1.236
Phosphorus excretion	3.91^{a} ± 0.06	3.78^{a} ± 0.06	3.58^{b} ± 0.06	3.25^{c} ± 0.04	3.21^{c} ± 0.08	0.176

Means bearing the different superscript within the same row differed significantly (P<0.01)

Table 16. Mean calcium, phosphorus, manganese and zinc availability and phosphorus excretion of broilers as influenced by dietary supplementation of phytase - ANOVA

Parameters	Source	d.f.	SS	MSS	F value
Calcium	Treatment	4	136.942	34.236	6.836**
	Error	25	125.195	5.008	
	Total	29	262.137		
Phosphorus	Treatment	4	690.159	172.540	36.970**
	Error	25	116.679	4.667	
	Total	29	806.838		
Manganese	Treatment	4	1083.278	270.819	70.165**
	Error	25	96.493	3.860	
	Total	29	1179.771		
Zinc	Treatment	4	857.228	214.307	198.249**
	Error	25	27.015	1.081	
	Total	29	884.243		
Phosphorus excretion	Treatment	4	2.328	0.582	26.555**
	Error	25	0.548	0.022	
	Total	29	2.876		

**- Significant (P<0.01)

FIG. 8 MEAN NITROGEN AND ENERGY RETENTION OF BROILERS AS INFLUENCED BY DIETARY SUPPLEMENTATION OF PHYTASE

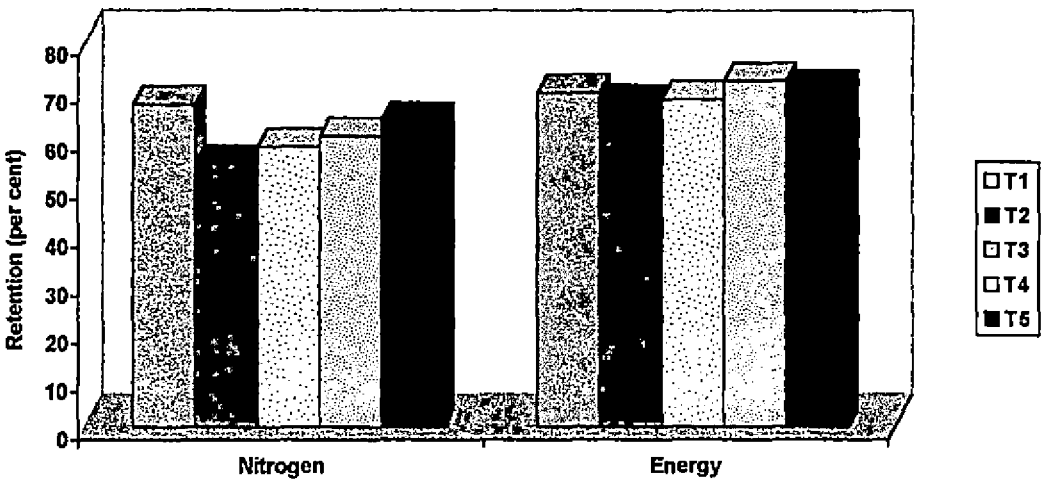


FIG. 9 MEAN CALCIUM AND PHOSPHORUS AVAILABILITY OF BROILERS AS INFLUENCED BY DIETARY SUPPLEMENTATION OF PHYTASE

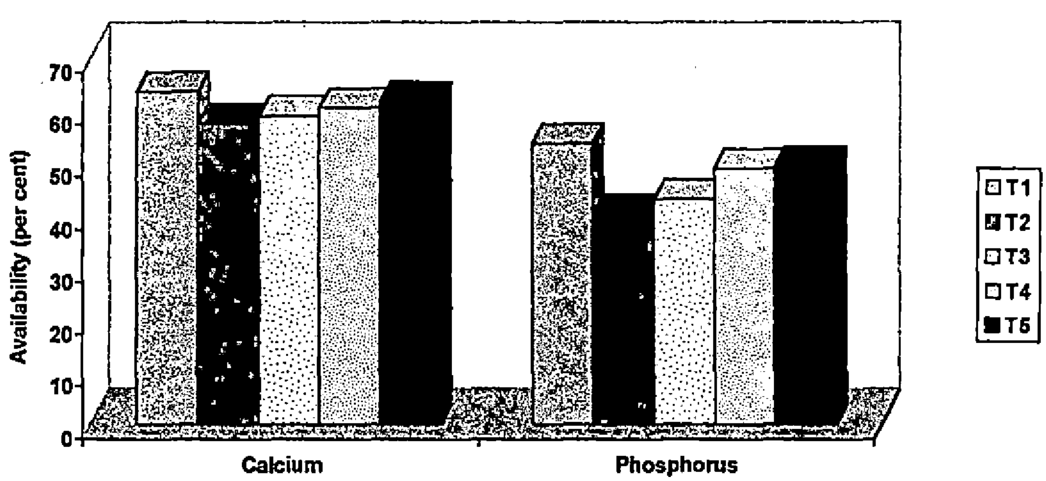


FIG. 10 MEAN PHOSPHORUS EXCRETION OF BROILERS AS INFLUENCED BY DIETARY SUPPLEMENTATION OF PHYTASE

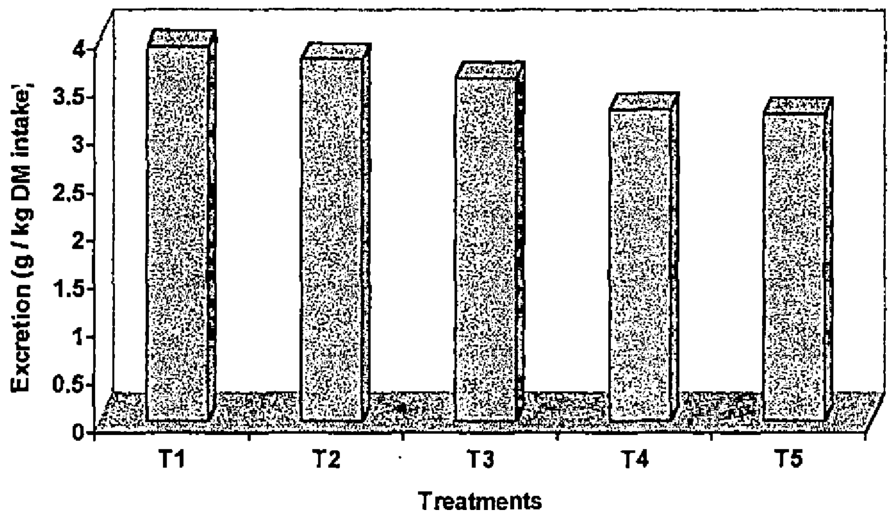
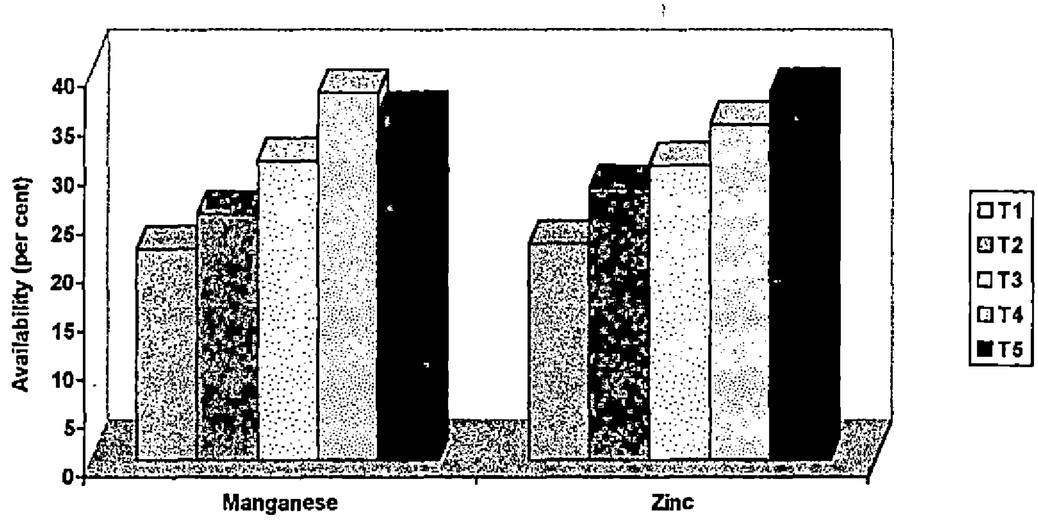


FIG. 11 MEAN MANGANESE AND ZINC AVAILABILITY OF BROILERS AS INFLUENCED BY DIETARY SUPPLEMENTATION OF PHYTASE



improved the availability of phosphorus in birds offered low available phosphorus diets.

The mean phosphorus availability among the varying treatments were analysed statistically (Table 16) and it revealed that the availability was significantly ($P<0.01$) higher in control group compared to all other groups. There was significant reduction in phosphorus availability among birds fed diet containing low available phosphorus without supplemented phytase. The supplementation of phytase linearly improved the availability of phosphorus. The phosphorus availability was statistically comparable between 750 and 1000 units phytase supplemented low available phosphorus diet groups and were statistically superior than those fed low available phosphorus diet supplemented with 500 units of phytase.

4.7.3 Phosphorus excretion

The data obtained on phosphorus excretion of birds among different groups are given in Table 15.

The amount of phosphorus excreted by birds were 3.91, 3.78, 3.58, 3.25 and 3.21 g / kg DM intake for treatment groups T1, T2, T3, T4 and T5, respectively.

Birds fed standard diet excreted more phosphorus in droppings than both phytase supplemented and unsupplemented low available phosphorus diet given birds. The excretion of phosphorus was very low in birds fed low available phosphorus diet supplemented with 1000 units of phytase / kg.

Statistical analysis of the data on mean phosphorus excretion (Table 16) revealed that groups fed diets unsupplemented with phytase (T1 and T2) showed significantly ($P<0.01$) higher phosphorus excretion in droppings and were statistically similar. The supplementation of phytase significantly reduced the excretion of phosphorus at all levels. Among the phytase supplemented groups, the excretion of phosphorus was significantly lower in 750 and 1000 units phytase supplemented groups and were statistically comparable.

The mean calcium and phosphorus availability and phosphorus excretion of birds as influenced by dietary supplementation of phytase are shown in Figures 9 and 10, respectively.

4.8 Availability of manganese and zinc

4.8.1 Availability of manganese

Mean per cent manganese availability as influenced by dietary supplementation of phytase is given in Table 15 and its statistical analysis in Table 16.

The mean per cent manganese availability of birds were 21.70, 25.28, 30.78, 37.72 and 35.43 for the treatments T1, T2, T3, T4 and T5, respectively.

The per cent availability of manganese was lowest with the group offered standard broiler mash and was highest with the group provided low available phosphorus diet supplemented with 750 units of phytase / kg. The supplementation of phytase at 500, 750 and 1000 units / kg showed marked improvement in manganese availability.

The availability of manganese was significantly ($P<0.01$) more with T4 and was statistically comparable with T5. Though T3 also exhibited significantly higher manganese availability the value was lower ($P<0.01$) than that of T4 and T5. When compared to birds fed standard broiler mash manganese availability was better among the birds offered low available phosphorus diet without phytase.

4.8.2 Availability of zinc

Mean per cent zinc availability as influenced by phytase supplementation is presented in Table 15 and its statistical analysis in Table 16.

The per cent availability of zinc for the treatments T1, T2, T3, T4 and T5 were 22.28, 27.95, 30.33, 34.48 and 37.78, respectively.

Similar to manganese availability the birds fed standard broiler mash as well as low available phosphorus diet showed lower zinc availability where as supplementation of phytase did cause an improvement.

Zinc availability was significantly ($P<0.01$) better in T2 as compared to T1. Supplementation of graded levels of phytase in low available phosphorus diet resulted in a linear improvement in zinc availability which was statistically significant.

The influence of phytase supplementation in broilers on the availability of manganese and zinc is shown in Figure 11.

4.9 Tibial ash

Mean per cent tibial ash content as influenced by phytase supplementation is presented in Table 17 and its statistical analysis in Table 18.

The per cent tibial ash content of birds among the treatments viz., T1, T2, T3, T4 and T5 were 44.46, 41.38, 42.97, 43.33 and 43.18 at sixth week of age, respectively. The corresponding values at eighth week were 45.65, 42.11, 43.01. 43.76 and 43.57, respectively.

The mean per cent tibial ash content was highest with birds fed on standard diet and lowest with birds maintained on low available phosphorus diet

Table 17. Sixth and eighth week mean tibial ash (per cent) of broilers as influenced by dietary supplementation of phytase.

Age in weeks	Treatments					CD
	T1	T2	T3	T4	T5	
6	44.46[a] ± 0.31	41.38[c] ± 0.23	42.97[b] ± 0.25	43.33[b] ± 0.12	43.18[b] ± 0.14	0.973
8	45.65[a] ± 0.49	42.11[c] ± 0.60	43.01[bc] ± 0.39	43.76[b] ± 0.36	43.57[b] ± 0.38	1.322

Means bearing the different superscript within the same row differed significantly (P<0.01)

Table 18. Sixth and eighth week mean tibial ash of broilers as influenced by dietary supplementation of phytase - ANOVA

Age in weeks	Source	d.f.	SS	MSS	F value
6	Treatment	4	29.379	7.345	26.139**
	Error	25	7.035	0.281	
	Total	29	36.414		
8	Treatment	4	40.862	10.215	8.263**
	Error	25	30.906	1.236	
	Total	29	71.768		

**- Significant (P≤0.01)

without phytase at sixth and eighth week of age. The tibial ash content of enzyme supplemented groups were intermediary.

The per cent tibial ash was significantly ($P<0.01$) higher among the birds reared on standard broiler mash both at six and eight weeks of age. Birds maintained on low available phosphorus diet without phytase (T2) was inferior ($P<0.01$) at both ages. Irrespective of the age, supplementation of phytase at 500, 750 and 1000 units / kg in low available phosphorus diet had statistically comparable per cent tibial ash content in birds. However, the tibial ash content in T2 and T3 were statistically comparable at eight weeks of age.

The mean tibial ash content at six and eight weeks of age as influenced by dietary supplementation of phytase is shown in Figure 12.

4.10 Serum calcium, inorganic phosphorus and alkaline phosphatase.

The mean serum calcium, inorganic phosphorus and alkaline phosphatase as influenced by dietary supplementation of phytase in broilers is presented in Table 19 and its statistical analysis in Table 20.

The mean serum calcium levels (mg per cent) for the treatments T1, T2, T3, T4 and T5 at six and eight weeks of age were 12.03, 10.81, 11.26, 11.50 and 11.47 and 11.89, 11.08, 11.26, 11.61 and 11.58, respectively. At both ages, apparently higher serum calcium values were recorded with birds fed standard diet (T1) where as, birds fed low available phosphorus ration without phytase showed lower values. Mean serum calcium values for the enzyme supplemented groups were intermediary both at sixth and eighth week of age.

When the mean serum calcium values were tested statistically it revealed that birds fed standard diet showed significantly ($P<0.01$) higher values at sixth and eighth week of age and was statistically higher than all other groups. However at sixth week of age, serum calcium values between T1 and T4 were statistically comparable. Likewise, serum calcium levels for the treatments T3, T4 and T5 and that in T2 and T3 were also statistically comparable at sixth week of age. At eight weeks of age, serum calcium levels in T2 and T3 and that in T4 and T5 were statistically comparable.

Mean serum inorganic phosphorus (mg per cent) for the treatments T1, T2, T3, T4 and T5 were 5.81, 4.93, 5.34, 5.68 and 5.52 at six weeks of age and 6.88, 6.00, 6.46, 6.73 and 6.61 at eight weeks of age, respectively (Table 19). Similar to serum calcium levels, higher serum inorganic phosphorus was noticed with birds fed standard broiler diet (T1) and those offered low available phosphorus without phytase (T2) recorded lower values. Serum inorganic phosphorus values with respect to enzyme supplemented groups were in between these two.

Table 19. Sixth and eighth week mean serum calcium (mg per cent), inorganic phosphorus (mg per cent) and alkaline phosphatase (u/l) of broilers as influenced by dietary supplementation of phytase.

Treatments	Serum calcium (mg per cent)		Serum inorganic phosphorus (mg per cent)		Serum alkaline phosphatase (u/l)	
	Age in weeks		Age in weeks		Age in weeks	
	6	8	6	8	6	8
T1	12.03^{a} ± 0.07	11.89^{a} ± 0.10	5.81^{a} ± 0.05	6.88^{a} ± 0.10	455.83^{b} ± 5.15	420.50^{b} ± 4.71
T2	10.81^{c} ± 0.15	11.08^{c} ± 0.10	4.93^{d} ± 0.06	6.00^{c} ± 0.08	485.67^{a} ± 5.26	468.67^{a} ± 6.48
T3	11.26^{bc} ± 0.12	11.26^{c} ± 0.11	5.34^{c} ± 0.06	6.46^{b} ± 0.12	459.50^{b} ± 5.74	432.50^{b} ± 4.83
T4	11.50^{ab} ± 0.08	11.61^{b} ± 0.06	5.68^{ab} ± 0.07	6.73^{ab} ± 0.12	431.00^{c} ± 4.66	399.83^{c} ± 9.63
T5	11.47^{b} ± 0.30	11.58^{b} ± 0.07	5.52^{bc} ± 0.08	6.61^{ab} ± 0.11	411.17^{d} ± 6.11	385.67^{c} ± 5.96
CD	0.4888	0.2659	0.188	0.3123	15.753	19.14

Means bearing the different superscript within the same column differed significantly (P<0.01).

Table 20. Sixth and eighth weeks mean serum calcium, inorganic phosphorus and alkaline phosphatase (ALP) of broilers as influenced by dietary supplementation of phytase - ANOVA

Observation	Age in weeks	Source	d.f.	SS	MSS	F value
Serum Ca	6	Treatment	4	4.827	1.207	7.149**
		Error	25	4.220	0.169	
		Total	29	9.047		
	8	Treatment	4	2.444	0.611	12.303**
		Error	25	1.241	0.050	
		Total	29	3.685		
Serum inorganic P	6	Treatment	4	2.832	0.708	27.979**
		Error	25	0.633	0.025	
		Total	29	3.464		
	8	Treatment	4	2.738	0.684	9.992**
		Error	25	1.713	0.069	
		Total	29	4.451		
Serum ALP	6	Treatment	4	19536.467	4884.117	27.836**
		Error	25	4386.500	175.460	
		Total	29	23922.967		
	8	Treatment	4	24660. 867	6150.217	23.733**
		Error	25	6478. 500	259.140	
		Total	29	31079.367		

** - Significant (P<0.01)

FIG. 12 SIXTH AND EIGHTH WEEK MEAN TIBIAL BONE ASH OF BROILERS AS INFLUENCED BY DIETARY SUPPLEMENTATION OF PHYTASE

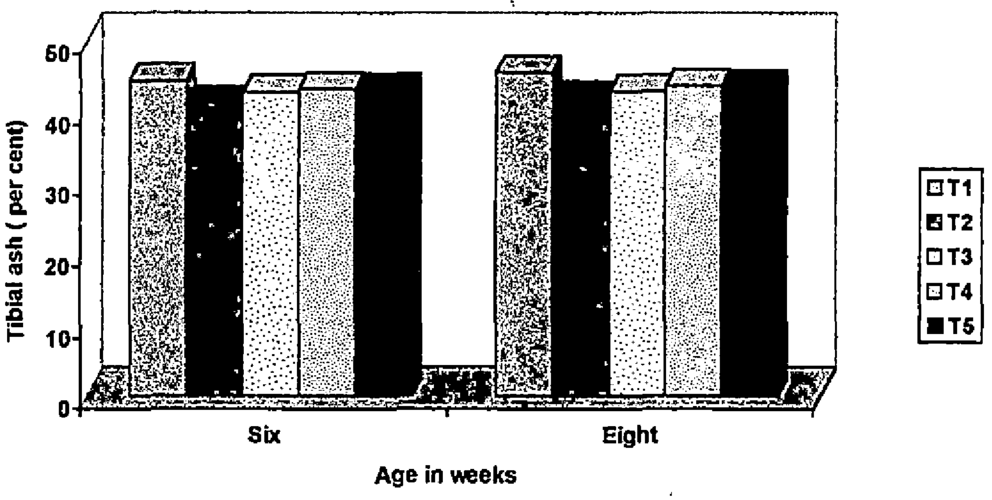
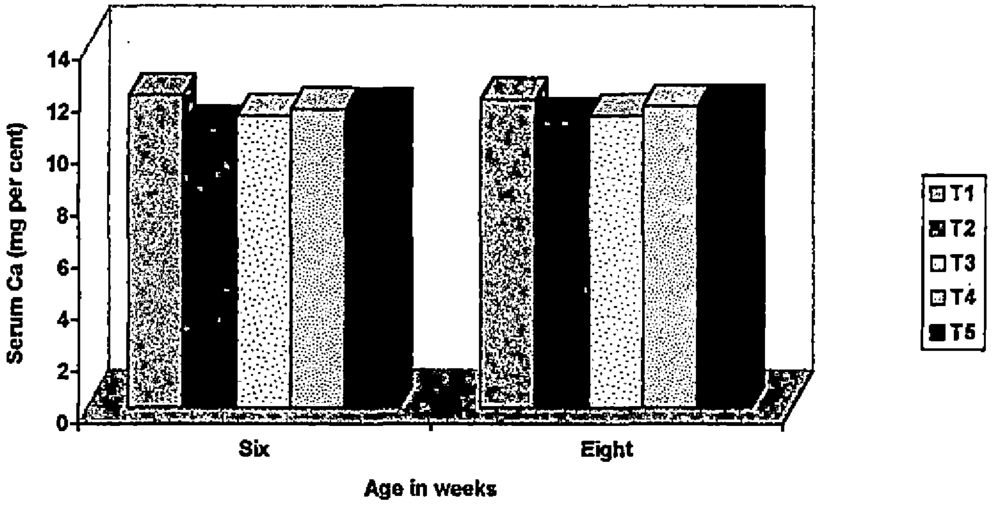


FIG. 13 SIXTH AND EIGHTH WEEK MEAN SERUM CALCIUM OF BROILERS AS INFLUENCED BY DIETARY SUPPLEMENTATION OF PHYTASE



Statistical analysis of the mean serum inorganic phosphorus also confirmed this trend. Birds fed standard broiler mash exhibited significantly ($P<0.01$) higher values, whereas birds in the group T2 recorded lower ($P<0.01$) values. Mean serum inorganic phosphorus values in T4 and T5 and that in T3 and T5 were statistically comparable at sixth week of age. Similarly, the serum inorganic phosphorus values of the groups T3, T4 and T5 were statistically similar at eight weeks of age.

Mean serum alkaline phosphatase (u/l) values estimated at sixth week of age for the treatments T1, T2, T3, T4 and T5 were 455.83, 485.67, 459.50, 431.00 and 411.17, respectively. The corresponding values at eighth week of age were 420.50, 468.67, 432.50, 399.83 and 385.67, respectively. At both ages higher serum alkaline phosphatase values were found with the group offered low available phosphorus diet without added phytase while birds fed low available phosphorus diet supplemented with 1000 units of phytase recorded lower values. In other treatments serum alkaline phosphatase values were medium.

Statistical analysis of the mean serum alkaline phosphatase (Table 20) showed that significant differences existed between treatments both at sixth and eighth week of age. Serum alkaline phosphatase was significantly ($P<0.01$) higher in T2 and was different from all other treatments at both ages. Supplementation of graded levels of phytase resulted in a significantly linear decrease in serum alkaline phosphatase except in T4 and T5 at eight weeks of

FIG. 14 SIXTH AND EIGHTH WEEK MEAN SERUM INORGANIC PHOSPHORUS OF BROILERS AS INFLUENCED BY DIETARY SUPPLEMENTATION OF PHYTASE

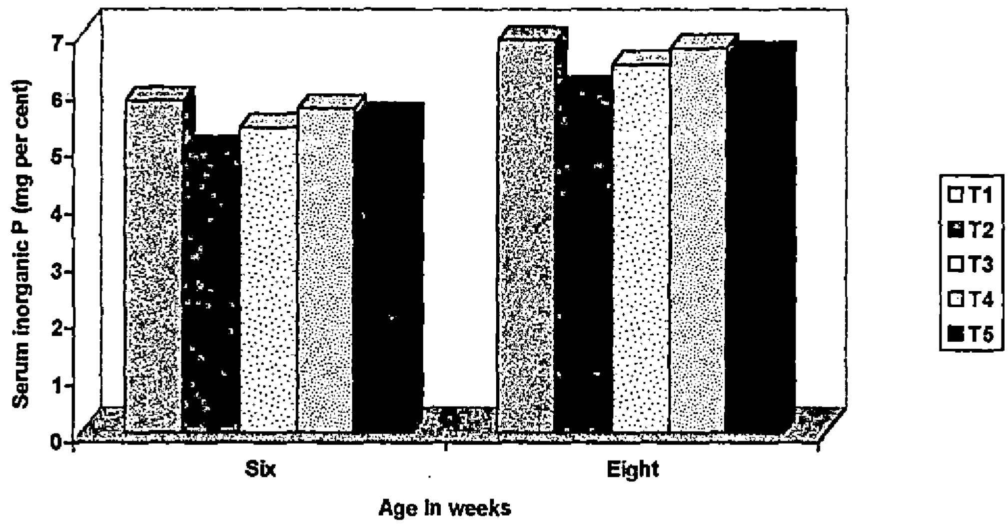
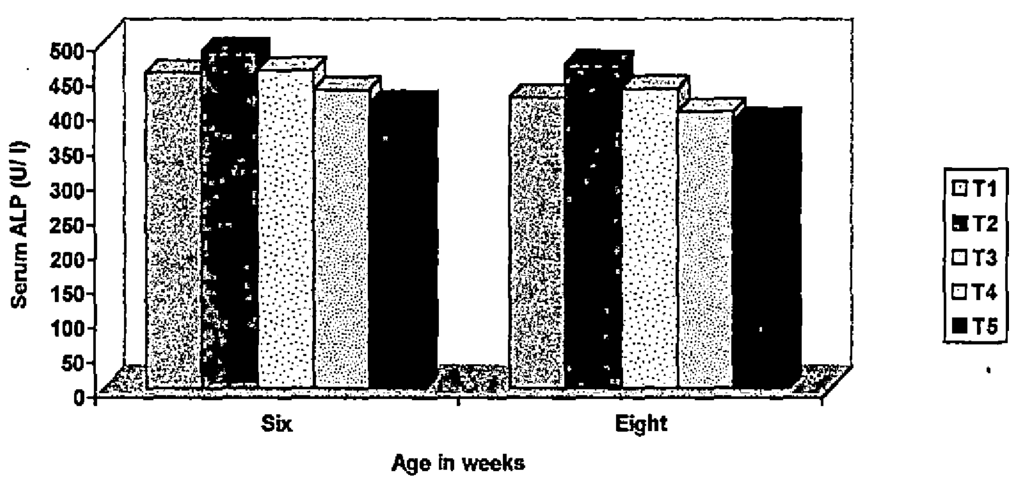


FIG. 15 SIXTH AND EIGHTH WEEK MEAN SERUM ALKALINE PHOSPHATASE OF BROILERS AS INFLUENCED BY DIETARY SUPPLEMENTATION OF PHYTASE



age. The serum alkaline phosphatase values of birds fed standard diet was lower ($P<0.01$) than birds fed low available phosphorus diet without added enzyme.

The variations in mean serum calcium, inorganic phosphorus and alkaline phosphatase levels at six and eight weeks of age as influenced by dietary supplementation of phytase are shown in Figures 13, 14 and 15, respectively.

4.11 Processing yields

Mean per cent dressed yield, ready-to-cook yield and giblet yield as influenced by dietary supplementation of phytase is presented in Table 21 and its statistical analysis in Table 22.

Mean per cent dressed yield ranged from a highest value of 86.58 noted in T3 as against a lowest value of 84.44 in T5 at sixth week of age and a highest value of 86.64 in T3 as against a lowest value of 84.55 in T4 at eight weeks of age. The variations in dressed yield among treatments were 2.14 and 2.09 per cent at sixth and eighth week of age, respectively.

Statistical analysis of the data showed that the difference in mean per cent dressed yield between treatments at both ages were not enough to produce any significant influence.

Table 21. Sixth and eighth week mean dressed yield, ready-to-cook yield and giblet yield (per cent) of broilers as influenced by dietary supplementation of phytase.

Treatments	Dressed yield (per cent)		Ready-to-cook yield (per cent)		Giblet yield (per cent)	
	Age in weeks		Age in weeks		Age in weeks	
	6	8	6	8	6	8
T1	86.01 ± 0.33	86.12 ± 0.77	69.95[ab] ± 0.96	71.10[a] ± 0.93	6.11 ± 0.19	6.30 ± 0.15
T2	85.41 ± 0.87	85.97 ± 0.66	70.19[a] ± 0.47	68.14[b] ± 0.57	6.56 ± 0.24	6.50 ± 0.20
T3	86.58 ± 0.53	86.64 ± 0.44	70.87[a] ± 0.82	69.09[b] ± 0.48	6.05 ± 0.15	6.33 ± 0.20
T4	86.06 ± 0.55	84.55 ± 0.62	67.83[b] ± 0.74	68.36[b] ± 0.75	5.80 ± 0.23	5.99 ± 0.11
T5	84.44 ± 0.87	86.60 ± 0.82	67.85[b] ± 0.64	69.22[ab] ± 0.36	6.36 ± 0.19	6.54 ± 0.14
CD	-	-	2.171	1.894	-	-

Means bearing the different superscript within the same column differed significantly ($P<0.05$).

Table 22. Sixth and eighth week mean dressed yield, ready-to-cook yield and giblet yield of broilers as influenced by dietary supplementation of phytase - ANOVA

Observation	Age in weeks	Source	d.f.	SS	MSS	F value
Dressed yield	6	Treatment	4	16.070	4.017	1.514^{NS}
		Error	25	66.342	2.654	
		Total	29	82.412		
	8	Treatment	4	17.348	4.337	1.583^{NS}
		Error	25	68.506	2.740	
		Total	29	85.854		
Ready-to-cook yield	6	Treatment	4	47.510	11.878	3.564*
		Error	25	83.310	3.332	
		Total	29	130.820		
	8	Treatment	4	32.662	8.165	3.220*
		Error	25	63.388	2.536	
		Total	29	96.050		
Giblet yield	6	Treatment	4	2.064	0.156	2.095^{NS}
		Error	25	6.157	0.246	
		Total	29	8.221		
	8	Treatment	4	1.150	0.287	1.806^{NS}
		Error	25	3.979	0.159	
		Total	29	5.129		

* - Significant (P<0.05), NS- Not significant

FIG. 16 SIXTH AND EIGHTH WEEK MEAN DRESSED YIELD OF BROILERS AS INFLUENCED BY DIETARY SUPPLEMENTATION OF PHYTASE

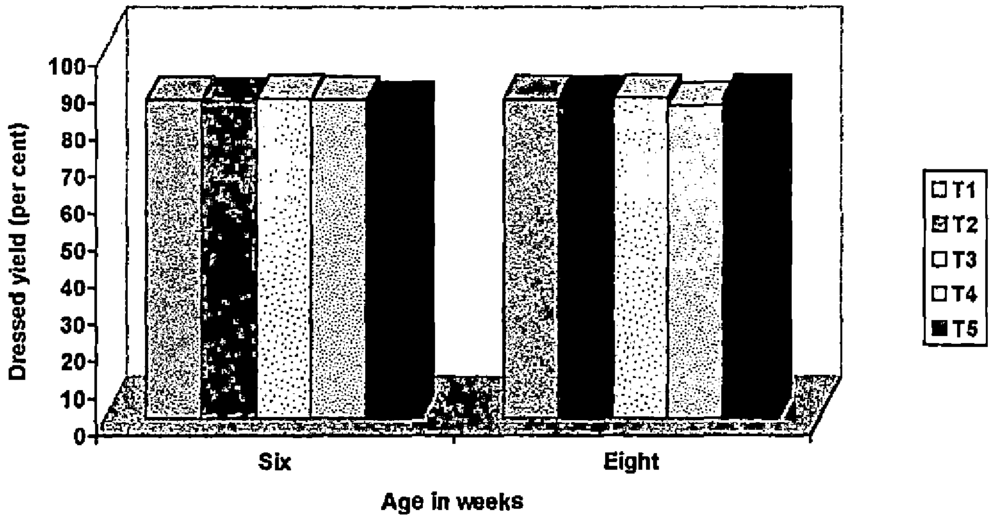


FIG 17. SIXTH AND EIGHTH WEEK MEAN READY-TO-COOK YIELD OF BROILERS AS INFLUENCED BY DIETARY SUPPLEMENTATION OF PHYTASE.

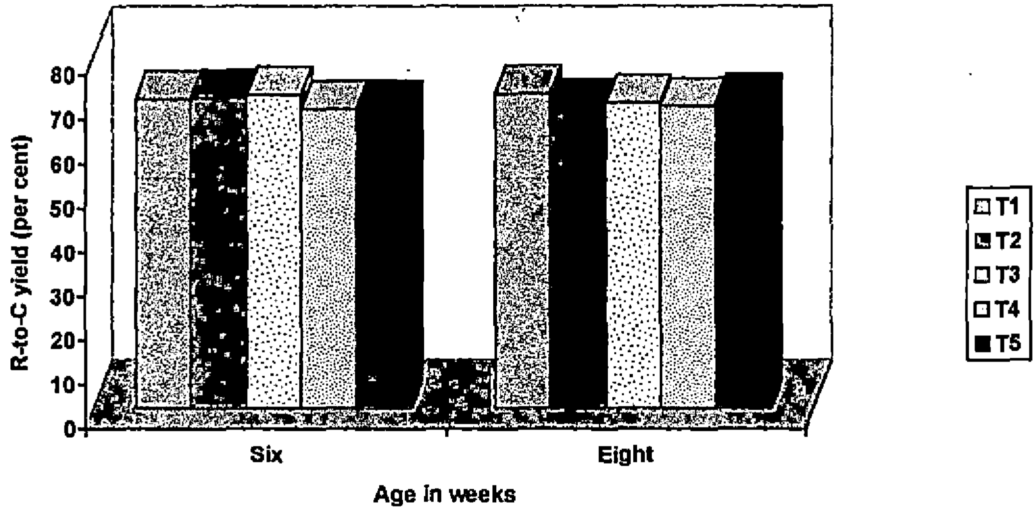
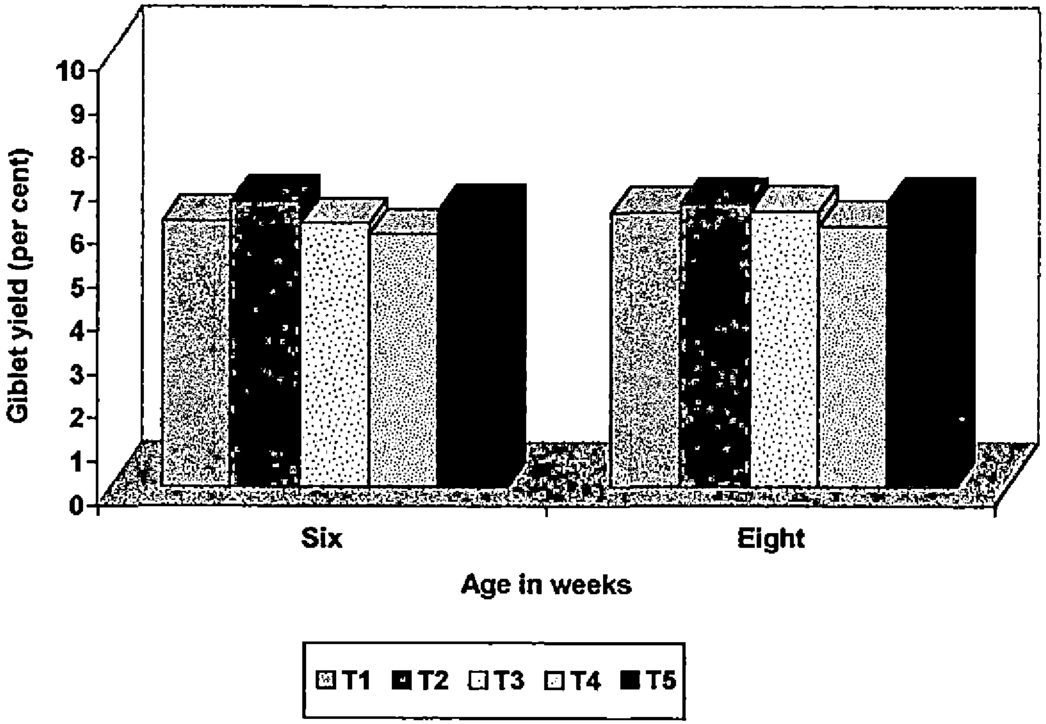


FIG. 18 SIXTH AND EIGHTH WEEK MEAN GIBLET YIELD OF BROILERS AS INFLUENCED BY DIETARY SUPPLEMENTATION OF PHYTASE



The mean per cent ready-to-cook yield for the treatments T1, T2, T3, T4 and T5 were 69.95, 70.19, 70.87, 67.83 and 67.85 and 71.10, 68.14, 69.09, 68.36 and 69.22 at sixth and eighth week of age, respectively. Similar to dressed yield per cent sixth week ready-to-cook yield was highest with T3. On the other hand, eighth week ready-to-cook yield was maximum with control birds (T1). Lowest ready-cook-yield was noted with T4 and T2 at sixth and eighth week of age, respectively. The variation in per cent ready-to-cook yield was 3.07 at six weeks and 2.96 at eight weeks of age.

The statistical analysis of the data on per cent ready-to-cook yield set out in Table 22 showed significant ($P<0.05$) differences between treatment groups.

The per cent ready-to-cook yield in groups T2 (70.19) and T3 (70.87) were significantly ($P<0.05$) higher than that in T4 (67.83) and T5 (67.85) at six weeks of age. However there was no significant difference between T1, T2 and T3 . The per cent ready-to-cook yield was lower in T4 and T5 but was statistically comparable to control group.

At eight weeks of age, the per cent ready-to-cook yield in the group fed standard diet was significantly ($P<0.05$) higher than that of all other groups but was statistically comparable with the group T5. There were no significant difference between groups T2, T3, T4 and T5 on per cent ready-to-cook yield.

The mean per cent giblet yield at sixth week of age was 6.11, 6.56, 6.05, 5.80 and 6.36 for the treatments T1, T2, T3, T4 and T5, respectively. The corresponding values at eight weeks of age were 6.30, 6.50, 6.33, 5.99 and 6.54, respectively. The variation in per cent giblet yield among treatments at six and eight weeks of age were 0.76 and 0.55, respectively. Maximum and minimum giblet yields were noted with T2 and T4 and T5 and T4 at six and eight weeks of age, respectively.

The statistical analysis of the giblet yield data presented in Table 22 revealed that the differences between treatment groups were not significant both at six and eight weeks of age.

The per cent dressed yield, ready-to-cook yield and giblet yield at six and eight weeks of age as influenced by dietary supplementation of phytase are shown in Figures 16, 17 and 18, respectively.

4.12 Livability

Mortality pattern of birds in the different treatment groups is given in Table 23. During the entire experimental period six birds died. The overall livability was 97.2 per cent in groups T1 and T5, while in T2 and T4 it was 94.4 per cent. In the group T3 the livability was 100 per cent. Necropsy of dead birds did not show any signs attributed to treatment effect.

Table 23. Per cent livability of broilers as influenced by dietary supplementation of phytase.

Period in weeks	Mortality				
	T1	T2	T3	T4	T5
1	-	-	-	-	-
2	-	-	-	-	-
3	-	-	-	1	-
4	-	-	-	1	-
5	-	-	-	-	-
6	-	1	-	-	-
7	-	1	-	-	1
8	1	-	-	-	-
Total mortality	1	2	-	2	1
Per cent livability	97.2	94.4	100	94.4	97.2

4.13 Economics

The cost of experimental rations and the cost-benefit analysis for the different dietary treatment groups are set out in Tables 24 and 25, respectively.

The cost of broiler starter rations among the five treatment groups T1, T2, T3, T4 and T5 were Rs. 9.11, 9.00, 9.04, 9.06 and 9.08 and that of finisher rations were Rs. 8.32, 8.22, 8.26, 8.28 and 8.30, respectively. This revealed that the cost of diet T2 containing 0.3 per cent available phosphorus was lower and it increased by two paise for each 250 units of phytase supplementation in both starter and finisher rations. The cost of control diet was higher in comparison to all other diets. The variation between cost of diets T1 and T2 were 11 and 10 paise for broiler starter and finisher rations, respectively. Cost involved for the supplementation of phytase in low available phosphorus diets T3, T4 and T5 were 4, 6 and 8 paise / kg, respectively for both starter and finisher rations.

The cost-benefit analysis revealed that the body weight at six weeks of age was almost similar in birds fed with diets T1 and T4. The overall feed consumption was numerically higher in group T4 and lower in group T1. Birds offered with control diet had low feeding cost (Rs. 28.32) in comparison to all other groups. The return from sale of birds was higher in group T4 followed by T1, T5, T3 and T2 due to the numerical variations in body weight. But the net profit per kg live weight was higher (Rs. 4.71) in control group T1, since the overall feed consumption was low in this group. Among the low available

Table 24. Cost of ingredients in the experimental rations.

Ingredients	Cost/ Kg (Rs.)	Broiler starter ration					Broiler finisher ration				
		T1	T2	T3	T4	T5	T1	T2	T3	T4	T5
Yellow maize	6.27	282.15	282.15	282.15	282.15	282.15	344.85	344.85	344.85	344.85	344.85
Rice polish	4.59	37.64	39.02	39.02	39.02	39.02	37.64	39.02	39.02	39.02	39.02
Groundnutcake (exp.)	10.33	206.60	206.60	206.60	206.60	206.60	154.95	154.95	154.95	154.95	154.95
Soy bean meal	8.87	133.05	133.05	133.05	133.05	133.05	88.70	88.70	88.70	88.70	88.70
Dried fish	10.20	91.80	91.80	91.80	91.80	91.80	91.80	91.80	91.80	91.80	91.80
Shell grit	3.79	1.90	4.74	4.74	4.74	4.74	1.90	4.74	4.74	4.74	4.74
Dicalcium phosphate	14.30	17.88	2.86	2.86	2.86	2.86	20.74	5.72	5.72	5.72	5.72
Common salt	2.00	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Trace mineral mixture	25.15	3.27	3.27	3.27	3.27	3.27	3.27	3.27	3.27	3.27	3.27
Vitamin mixture	600.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00
Lysine hydrochloride	185.00	37.00	37.00	37.00	37.00	37.00	29.60	29.60	29.60	29.60	29.60
D.L. methionine	340.00	49.30	49.30	49.30	49.30	49.30	11.90	11.90	11.90	11.90	11.90
Choline chloride	70.00	17.50	17.50	17.50	17.50	17.50	14.00	14.00	14.00	14.00	14.00
Coccidiostat	350.00	17.50	17.50	17.50	17.50	17.50	17.50	17.50	17.50	17.50	17.50
Enzyme phytase	400.00	-	-	4.00	6.00	8.00	-	-	4.00	6.00	8.00
Total cost / 100 kg		911.09	900.29	904.29	906.29	908.29	832.35	821.55	825.55	827.55	829.55
Cost / kg		9.11	9.00	9.04	9.06	9.08	8.32	8.22	8.26	8.28	8.30

Table 25. Cost-benefit analysis per bird for the different treatment groups in broilers.

Particulars	Six weeks of age					Eight weeks of age				
	T1	T2	T3	T4	T5	T1	T2	T3	T4	T5
Body weight (g)	1831.67	1740.39	1793.33	1834.87	1817.37	2532.85	2373.59	2447.67	2511.04	2495.93
Total feed consumption (g)	3108.33	3156.67	3196.67	3208.33	3175.00	5551.66	5456.67	5586.67	5585.00	5555.00
Total feed cost (Rs.)	28.32	28.41	28.90	29.07	28.83	48.65	47.32	48.64	48.75	48.58
Total cost (Rs.)*	46.32	46.41	46.90	47.07	46.83	66.65	65.32	66.64	66.75	66.58
Returns from sale of bird (Rs.)	54.95	52.21	53.80	55.05	54.52	75.99	71.21	73.43	75.33	74.88
Net profit / bird (Rs.)	8.63	5.80	6.90	7.98	7.69	9.34	5.89	6.79	8.58	8.30
Net profit / kg live weight (Rs)	4.71	3.33	3.85	4.35	4.23	3.69	2.48	2.77	3.42	3.33
Cost benefit ratio	1:1.19	1:1.12	1:1.15	1:1.17	1:1.16	1:1.14	1:1.09	1:1.10	1:1.13	1:1.12

*- Rs. 5 /- per bird was accounted as miscellaneous cost for vaccination and medicines.

phosphorus diets, the phytase supplemented group T4 showed higher net profit per kg live weight (Rs. 4.35) followed by T5 (Rs. 4.23), T3 (Rs. 3.85) and T2 (Rs. 3.33). The cost-benefit ratio was 1: 1.19 in T1 and 1: 1.12 in T2. The enzyme supplemented groups registered intermediary values of 1: 1.15, 1: 1.17 and 1: 1.16 in groups T3, T4 and T5, respectively.

At eight weeks of age body weight was slightly higher in T1 than T4 group, while the feed consumption was lower in T1 than T4 group. So the net profit per kg live weight was higher (Rs. 3.69) in group T1 followed by T4 (Rs. 3.42), T5 (Rs. 3.33), T3 (Rs. 2.77) and T2 (Rs. 2.48). The cost benefit ratio was 1: 1.14 in T1 and 1: 1.09 in T2 group. The enzyme supplemented groups registered intermediary values of 1: 1.10, 1: 1.13 and 1: 1.12 in groups T3, T4 and T5, respectively.

DISCUSSION

5. DISCUSSION

The results obtained in the present study on influence of microbial phytase on nutrient utilization in broilers are discussed in this chapter.

5.1 Climatic parameters

The climatic observations presented in Table 4 revealed that the weekly maximum temperature was the lowest at second week (33.57°C) and the highest during eighth week (37.29°C). Although the magnitude of variations in the maximum temperature between weeks was minimal, it was comparatively higher at the finishing period. The minimum temperature during the study ranged from 23.86 to 25.28°C and was within the comfort zone for broilers. The range in the relative humidity in the forenoon hours during experimental period was from 73.43 to 81.43 per cent. In general the forenoon relative humidity was on the higher side especially during the brooding period. Not much variation was noticed in the after noon relative humidity. These findings indicated that the birds were reared under a hot-humid environment throughout the experiment.

5.2 Body weight

The data on body weight presented in Table 5 showed that the mean body weight of day-old chicks varied from 43.59 to 45.69 g and were comparable statistically between treatment groups.

In the control group, the fortnightly mean body weight at second, fourth, sixth and eighth week of age were 315.69, 1030.83, 1831.67 and 2532.85g, respectively observing the normal pattern of growth in broilers. Whereas, the group fed the low available phosphorus diet (T2) registered lower body weights consistently in all the fortnights in comparison with the standard broiler diet containing 0.5 per cent available phosphorus. Thus, a decrease in the available phosphorus by 0.2 per cent resulted in decline of body weight by 9.2, 4.6, 5.0 and 6.3 per cent at two, four, six and eight weeks, respectively.

Significantly higher body weights at all fortnights were noticed in the control group fed standard broiler diet (T1), while the group fed low available phosphorus diet (T2) showed significantly lower fortnightly body weights. This difference could be due to the variations in nutrient utilization. The higher body weights observed in the control group was highly significant ($P<0.01$) in comparison with the low available phosphorus diet at all the above ages except at fourth week ($P<0.05$). Sohail and Roland (1997) also observed reduction in body weight of chicks when available phosphorus in the diet was reduced from 0.325 to 0.225 per cent.

Supplementation of phytase at levels of 500, 750 and 1000 units / kg in the low available phosphorus diet resulted in a significant improvement in fortnightly body weights right from second week onwards. However, the body weight at two weeks of age in all the enzyme supplemented birds was significantly lower than the control birds.

When the birds attained fourth week of age, the body weight of groups fed 750 and 1000 units of phytase was statistically comparable with the control group. At sixth week of age, the body weight of all enzyme supplemented groups as well as control groups were statistically comparable. This confirms that the available phosphorus content of broiler diets can be reduced to 0.3 per cent provided the feed is supplemented with at least 500 units of phytase.

Higher body weight observed in the control group at eighth week of age was statistically comparable with groups fed low available phosphorus diet supplemented with 750 and 1000 units of phytase / kg. However there was no significant difference between 500 and 1000 units / kg phytase supplemented groups. Phytase addition in low available phosphorus diets at 750 units / kg seems to be optimum as far as body weight is concerned.

The above finding is in partial agreement with Schoner *et al.* (1992) who conducted feeding experiment in broilers using different levels of inorganic phosphorus and calcium and supplemented with phytase at 125, 250 and 1500 units / kg feed and opined that phytase and phosphorus increased live-weight of birds level dependently.

Significant improvement in body weight among broiler chicken fed low available phosphorus diet supplemented with phytase was also reported by Huyghebaert *et al.* (1993a), Vogt (1993), Richter (1994), Piva *et al.* (1995), Sebastian *et al.* (1996a) and Kanagaraju (1998). On the contrary, Zanini and Sazzad (1998) observed that supplemented phytase at 500 units / kg diet had no effect on growth performance in broilers when fed with different metabolizable energy levels of 2800 and 3000 kcal ME / kg diet.

The results in the present study revealed that a reduction of 0.2 per cent available phosphorus in the standard broiler diet was compensated by supplementation of 750 units phytase per kg diet with respect to body weight of commercial broilers. The enzyme supplemented in the feed might have acted upon the bound phytate phosphorus in the feed resulting in release of more inorganic phosphorus and other nutrients for utilization by the bird and subsequently better performance in comparison with low available phosphorus diet.

5.3 Body weight gain

A perusal of the body weight gain data presented in Table 7 revealed that a reduction of 0.2 per cent in the available phosphorus content of standard broiler diet resulted in a significantly lower gain in all fortnights except at the second fortnight covering third and fourth week of age. The gain was significantly higher with birds fed standard broiler diet (T1). In general the addition of phytase at 500, 750 and 1000 units to low available phosphorus diets resulted in apparent improvement in the weight gain at all fortnightly intervals. The fortnightly weight gain was more favourable particularly with 750 and 1000 units of phytase / kg diet.

At second week of age the weight gain in the groups supplemented with phytase at 750 and 1000 units / kg were statistically comparable to each other and the latter was comparable ($P<0.01$) with that of the control diet too. Among the enzyme supplemented groups the one which was fed diet containing 500 units / kg although showed significantly lower gain, it was significantly higher than the group fed diet having low available phosphorus without enzyme. In the second fortnight covering third and fourth week of age, statistically comparable weight gain was attained in all groups. The variation in weight gain exhibited at the initial two weeks could be the reason for a difference in body weight at fourth week of age.

The weight gains at third and fourth fortnightly intervals were significant ($P<0.05$) and the lower gain was in the group fed diet containing 0.3 per cent available phosphorus without phytase. The highest gain at sixth week was observed with the group fed 750 units of enzyme while it was the highest with control group at eight week of age.

Similar to the data on sixth week body weight, the cumulative mean body weight gain at sixth week showed that it was significantly ($P<0.01$) lower with the group fed low available phosphorus diet. The supplementation of different levels of phytase in low available phosphorus diet caused improvement ($P<0.01$) in body weight gain which was statistically comparable with gain of birds offered standard broiler diet. Like wise, the trend in the cumulative weight gain at eighth week was also similar to body weight at eighth week of age.

This finding is in close agreement with Kiiskinen *et al.* (1994) who observed improvement in body weight gain by adding phytase upto 1000 units / kg diet. Huyghebaert *et al.* (1993a) also stated that broilers fed with low available phosphorus diets showed significant improvement in weight gain when supplemented with different levels of microbial phytase. In another study Kwon *et al.* (1996) reported that broilers fed on diets containing 60 per cent of required phosphorus had significantly lower live weight gain than those fed on 80 or 100 per cent phosphorus diet when no supplemental phytase was fed. However, when broilers were fed on phytase supplemented diets all groups had similar live-weight gains. Improvements in weight gain due to phytase supplementation was also reported by Kanagaraju (1998) and ElDeeb *et al.* (1999). Beneficial effects in body weight gain due to phytase addition in feed observed in this trial was mainly due to increased feed intake (Table 9). Moreover, phytase supplementation might have acted upon phytate molecule and resulted in the better utilization of phosphorus and other nutrients. Moreover, in addition to its function in bone formation, phosphorus is also required in the utilization of energy and the resultant better body weight gain.

5.4 Feed intake

The daily mean feed intake at fortnightly intervals of the birds in different groups presented in Table 9 indicated that it differed significantly only in the second and fourth fortnights covering third and fourth and seventh and eighth week, respectively. The difference in feed intake between treatments during the first fortnight was 1.78 and during the third fortnight it was 4.88 g. In the second fortnight statistically lower daily feed intake was noted with the control group fed standard broiler diet. All other groups consumed significantly more feed and were statistically comparable. During the fourth fortnight, the group fed low available phosphorus diet consumed significantly less feed, while the control group (T1) consumed more feed ($P<0.01$) reversing the trend observed in the second fortnight. The daily feed intake in the control group and the group fed diet supplemented with 500 units of phytase / kg were statistically comparable. The daily feed intake of all enzyme supplemented groups were statistically similar during this period.

The cumulative feed intake data given in Table 9 showed that irrespective of enzyme supplementation or lowering of available phosphorus in the diet feed intake from zero to six weeks was statistically similar. When feed intake from zero to eight weeks was considered it could be seen that the group offered diet having 0.3 per cent available phosphorus consumed less ($P<0.05$) while the intake of all other groups were more ($P<0.05$) and were statistically comparable. This was due to significantly lower feed intake registered with 0.3 per cent available phosphorus fed group during the finishing period. It might be due to low phosphorus content in that diet.

Though the cumulative feed intake from zero to six weeks noted in the group fed diet having low available phosphorus is statistically similar with other groups, the body weight at six weeks and cumulative weight gain from zero to six weeks were significantly lower. Kwon *et al.* (1996) stated that feed intake was reduced in broilers as the phosphorus content of the diet decreased. The beneficial effect of supplementation of phytase in low available phosphorus diets should be viewed in this context.

The effect of varied intakes of microbial phytase (250 to 1000 units / kg) on the performance of broiler chicks was studied by Kiiskinen *et al.* (1994) and reported that phytase addition lead to increased feed intake by 3 to 9 per cent. In the present study, 500, 750 and 1000 units of phytase / kg supplemented groups consumed 130, 128.33 and 98.33 g / bird respectively more feed than the group maintained on a low available phosphorus diet from zero to eight weeks of age. Richter and Cyriaci (1994) also reported that phytase supplementation resulted in an increase in feed intake. After conducting an experiment on broilers fed diets containing 0.46 per cent or 0.33 per cent available phosphorus plus microbial phytase at 600 units / kg diet, Sebastian *et al.* (1996a) opined that phytase supplementation could overcome the reduction in feed intake noticed in the low available phosphorus diet. Significant increase in feed intake by supplementation of phytase in low available phosphorus diet obtained in the present trial also agrees with the findings of Denbow *et al.* (1998) and Kanagaraju (1998). Significantly higher feed intake observed in enzyme supplemented groups could be due to increased phytate phosphorus digestibility, since phytic acid may be imposing a restraint on voluntary feed intake.

5.5 Feed conversion ratio

The mean fortnightly feed conversion ratio (FCR) as influenced by dietary supplementation of phytase (Table 11) did not reveal any definite trend among the treatments. It ranged from 1.47 to 1.52 at the first fortnight, 1.65 to 1.80 in the second fortnight, 1.90 to 2.02 in the third fortnight and 3.48 to 3.65 in the fourth fortnight. The analysis of variance of the data on mean feed conversion ratio presented in Table 12 showed that it was significantly influenced from second fortnight onwards. In all fortnightly periods, superior feed conversion ratio was recorded with the group fed standard diet, while it was inferior with the group fed low available phosphorus diet. The FCR registered with low available phosphorus diet was statistically comparable with diet supplemented with 500 units of phytase / kg. Groups fed low available phosphorus diets supplemented with 750 and 1000 units of phytase / kg recorded almost similar FCR and were statistically comparable with that of control group at fourth fortnightly period.

The cumulative feed conversion ratio at six and eight weeks of age were significantly superior in control group and inferior in low available phosphorus diet group. All the enzyme supplemented groups were significantly different from the control as well as the low available phosphorus diet groups at sixth week of age. Where as, at eight weeks of age 500 units phytase supplemented group was statistically similar with low available phosphorus diet group. The cumulative feed conversion ratio obtained at sixth and eighth week of age for groups maintained on low available phosphorus diets supplemented with 750 and 1000 units of phytase / kg were similar.

After conducting studies on broilers fed on diets containing 60, 80 or 100 per cent of the recommended phosphorus requirement along with added phytase, Kwon *et al.* (1996) stated that the feed : gain ratio was reduced as the phosphorus content of the diet decreased when phytase was not supplemented. Huff *et al.* (1998) stated that supplementation of phytase in a ration containing high available phosphorus had no influence on feed conversion ratio.

Sebastian *et al.* (1996a) opined that phytase supplementation at 600 units in 0.33 and 0.46 per cent phosphorus diets did not influence feed : gain ratio in a three week feeding trial. However, in the present trial phytase supplementation did cause a significant improvement in feed conversion ratio. Absence of significant influence on the feed conversion ratio in the above work might be due to application of shorter feeding trial. Kanagaraju (1998) also observed superior feed efficiency among broiler chicks fed diets containing 0.4 per cent available phosphorus with supplemented phytase.

The supplementation of microbial phytase might have acted upon the phytate phosphorus with the result phosphorus could have been released for utilization by the bird which tells upon improved feed conversion ratio in enzyme supplemented groups than the unsupplemented low available phosphorus diet.

5.6 Retention of nitrogen and energy

The influence of phytase supplementation on the retention of nitrogen and energy were determined and the mean values are given in Table 13. Per cent retention of nitrogen was significantly more with the group fed the standard diet. A reduction of 0.2 per cent of the available phosphorus in the diet caused 18.66 per cent less in the nitrogen retention. Though supplementation of graded levels of phytase in the diet resulted in a dose-dependent significant improvement in nitrogen retention, it was not equaled with the control group. Even after the supplementation of 1000 units of phytase, the nitrogen retention was 5.11 per cent less than the control group. The results clearly showed significant improvement in nitrogen retention consequent to the addition of phytase in low available phosphorus diets. Increased availability of protein could be the reason for the improvement in nitrogen retention among phytase supplemented groups.

Several workers have supplemented phytase and reported about the increase in nitrogen retention in broiler chicken (Farrell *et al.*, 1993; Piva *et al.*, 1995; Yi *et al.*, 1996b and Zanini and Sazzad, 1998). Their findings confirm the results of the present study. However, Windisch and Kirchgessner (1996a) could not observe any change in nitrogen retention by supplementing different levels of microbial phytase in broiler chicks fed diets containing 0.62 or 0.79 per cent calcium and 0.59 per cent phosphorus. It could be due to the variation in the source of phosphorus contained in the diet.

On the other hand, per cent retention of energy was significantly higher with the group fed low available phosphorus diet supplemented with 750 units of phytase. However, this value was statistically comparable to that of 1000 units / kg fed groups. The per cent energy retention values recorded in the group fed standard diet and 500 units phytase supplemented low available phosphorus diet were intermediary and were statistically comparable to 1000 units phytase supplemented diet group. The energy retention in the low available phosphorus diet group was comparable to that of group fed with 500 units of phytase. These results clearly indicated that phytase supplementation in low available phosphorus diet has a positive influence on per cent energy retention.

Phytate forms bonds with the amino terminus of protein, there by affecting the digestibility of starch and protein. Therefore supplementation of phytase in low available phosphorus diets might have acted upon the bound phytate phosphorus and resulted in an increase in the availability of nutrients and the resultant improvement in the retention of nitrogen and energy.

The effect of enzymatic hydrolysis of phytase on the available energy content of feed ingredients for chicks was studied by Miles and Nelson (1974) and reported that enzyme treatment caused reduction in the phytate phosphorus content of ingredients while metabolizable energy content improved. The beneficial effects of phytase on increasing the metabolisable energy content of diets was also reported by Farrell and Martin (1993) and Namkung and Leeson (1999).

5.7 Availability of calcium and phosphorus

The per cent availability of calcium and phosphorus as influenced by dietary supplementation of phytase is presented in Table 15. It indicated that the calcium availabilty ranged from 57.29 to 63.47 per cent, highest in the control group fed standard broiler diet while the lowest in the group offered low available phosphorus diet. A perusal of the calcium availability data also showed that 1000 units of phytase supplemented group was statistically comparable with that of control group.

The phosphorus availability ranged from 40.07 to 53.61 per cent. Similar to the trend observed in calcium availability, the per cent phosphorus availability was significantly higher with group fed standard diet and lower in the group fed low available phosphorus diet. Lowering of 0.2 per cent of the available phosphorus resulted in a reduction of 25.26 per cent in the availability of phosphorus. Supplementation of different levels of phytase in low available phosphorus diets significantly improved the availability of phosphorus. When 750 units of phytase / kg was supplemented in a diet containing 0.3 per cent available phosphorus, 21.79 per cent more phosphorus was available for the birds. This could be due to enhanced availability and solubility of calcium and phosphorus in the gut.

The effectiveness of phytase supplementation on the availability and utilization of minerals was studied by Huyghebaert *et al.* (1993b), Kornegay *et al.* (1996), Sebastian *et al.* (1996a), Windisch and Kirchgessner (1996a), Yi *et al.* (1996b), Kanagaraju (1998) and Zanini and Sazzad (1998) and reported marked improvement in the retention and bio availability of calcium and phosphorus.

5.7.1 Phosphorus excretion

Influence of dietary supplementation of phytase on phosphorus excretion is set out in Table 15. The excretion of phosphorus (g / kg DM intake) ranged from 3.21 to 3.91. Significantly higher phosphorus excretion was noted among the control group and was statistically comparable with the group fed low available phosphorus diet. Supplementation of phytase in low available phosphorus diets caused significant reduction in phosphorus excretion. Addition of 500, 750 and 1000 units of phytase / kg in the low available phosphorus diet resulted in a reduction of phosphorus excretion to the tune of 0.33, 0.66 and 0.70 g / kg DM intake, respectively than the control group. The phytase acting on the organically bound phytic acid might have liberated more phosphorus for utilization and ultimately less quantities of phosphorus is excreted in the droppings.

Perney *et al.*(1993) studied the effect of dietary phytase and increasing levels of available phosphorus on phosphorus metabolism. They noticed increased phosphorus excretion by increasing dietary available phosphorus and that it could be decreased by supplemented phytase. Reduction of phosphorus excretion in the droppings by phytase supplementation was also reported by Richter *et al.* (1993b), Broz *et al.* (1994), Huyghebaert (1996), Kornegay *et al.* (1996), Kwon *et al.* (1996), Yi *et al.* (1996b), Kanagaraju (1998) and Zanini and Sazzad (1998).

5.8 Availability of manganese and zinc

The per cent availability of manganese ranged from 21.70 to 37.72. It was significantly more with the group fed low available phosphorus diet supplemented with 750 units of phytase / kg while the control group showed lower values. Supplementation of 500, 750 and 1000 units of phytase / kg in low available phosphorus diets resulted in 21.76, 49.21 and 40.15 per cent increased manganese availability respectively.

The zinc availability ranged from 22.28 to 37.78 per cent, the lowest with control group and the highest in the 1000 units of phytase / kg added group. There was a linear significant increase in the availability of zinc with graded levels of phytase supplementation in low available phosphorus diets.

Improvement in the availability and utilization of manganese and zinc by phytase supplementation was reported by Biehl *et al.* (1995), Piva *et al.* (1995) and Windisch and Kirchgessner (1996b). The effect of microbial phytase on retention and utilization of zinc was also studied by Thiel *et al.* (1995), Sebastian *et al.* (1996a), Yi *et al.* (1996a), Zanini and Sazzad (1998) and Mohanna and Nys (1999) and observed increased zinc availability by phytase supplementation in broilers. The increased availability of manganese and zinc could be due to the effect of phytase on bound phytate complexes and release of bound minerals.

5.9 Tibial ash

Perusal of the per cent tibial ash presented in Table 17 indicated that this trait was significantly influenced by phytase supplementation at sixth and eighth week of age. At both these ages, it was significantly higher in the control group fed standard diet and lower in the group offered low available phosphorus diet. Phytase addition to low available phosphorus diets resulted in significant increase in per cent tibial ash but was lower than the control group. The increase in the tibial ash content due to supplementation of 500, 750 and 1000 units of phytase / kg in the low available phosphorus diets was 3.84, 4.71 and 4.35 per cent at sixth week and 2.14, 3.92 and 3.47 per cent at eighth week of age, respectively.

The differences between phytase supplemented groups were statistically nonsignificant among each other which indicated that the phytase supplementation beyond 500 units did not exhibit marked influence on tibial ash. It also confirm the observation of Farrell *et al.* (1993), Huyghebaert *et al.* (1993a), Perney *et al.* (1993) and Broz *et al.* (1994) who observed increased tibial ash percentages in broilers received phytase added diets. A positive relationship between phytase supplementation and total dietary phosphorus and tibial strength was also established by Richter and Cyriaci (1994), Sebastian *et al.* (1996b), Yi *et al.* (1996a) and Kanagaraju (1998).

5.10 Serum calcium, inorganic phosphorus and alkaline phosphorus

The serum calcium content (mg per cent) of representative birds fed the experimental diets estimated at the end of sixth and eighth week of age is given in Tables 19 and 20, respectively. The data indicated that the serum calcium level was significantly higher in the control group and lower in the treatment group fed low available phosphorus diet at both ages. The serum calcium level of groups fed low available phosphorus diet without enzyme and with 500 units of enzyme were statistically comparable at six and eight weeks of age. Supplementation of 750 and 1000 units of phytase caused significant increase in serum calcium level at these ages.

The data on mean serum inorganic phosphorus (mg per cent) levels of birds under different treatments at sixth and eighth week of age (Tables 19 and 20) indicated that phytase addition did have a significant influence on this trait at both ages. It was significantly higher in the control group fed standard diet, whereas lower values were encountered in the low available phosphorus diet fed group at six and eight weeks of age. Phytase supplementation at different levels in low available phosphorus diets caused significant increase in the serum inorganic phosphorus levels.

Mean serum alkaline phosphatase (u / l) measured at sixth and eighth week of age as influenced by different feeding regimen set out in Tables 19 and 20 showed that similar to serum calcium and inorganic phosphorus levels, this trait was also significantly influenced at both ages. It was significantly more in the group fed low available phosphorus diet and less in the group fed diet supplemented with 1000 units of phytase / kg at six and eight weeks of age. The serum alkaline phosphatase level was decreased linearly with the graded addition of enzyme in low available phosphorus diets. The group maintained on standard mash showed medium values at both ages and significantly varied from low available phosphorus fed group as well as groups supplemented with 750 and 1000 units of phytase / kg level.

While screening the literature on the influence of phytase addition in feeds on serum calcium, inorganic phosphorus and alkaline phosphatase, much work could not be traced. However, Sebastian *et al.* (1995) reported a significant reduction in calcium and increase in plasma phosphorus concentration when broiler chickens were given low phosphorus diets supplemented with phytase. Perney *et al.* (1993) and Broz *et al.* (1994) stated that plasma inorganic phosphorus responded quantitatively to increased dietary phytase. Increased plasma phosphorus in broiler chickens fed diets supplemented with phytase was reported by Sebastian *et al.* (1996) and Munaro *et al.* (1996).

Roberson and Edwards (1994) supplemented vitamin D and 600 units of phytase in the diet of broiler chicken and could not observe any effect on plasma alkaline phosphatase activity. Huff *et al.* (1998) observed reduced serum alkaline phosphatase activity in diets supplemented with phytase at the level of 500 units / kg diet.

In this trial, a significant increase in serum calcium and inorganic phosphorus levels was observed when the birds were fed with low available phosphorus diets supplemented with phytase, which indicates the hydrolysis of bound phytin phosphorus and other bound complexes by the enzyme. On the other hand a lowering of serum alkaline phosphatase associated with the diets supplemented with phytase might reflect the down regulation of this enzyme resulting from the increased availability of phosphorus.

5.11 Processing yields

The per cent dressed yield did not differ significantly among the groups both at six and eight weeks of age (Tables 21 and 22). The range of mean values were 84.44 to 86.58 at sixth week and 84.55 to 86.64 per cent at eighth week.

The per cent ready-to cook yield ranged from 67.83 to 70.87 at sixth week and 68.14 to 71.10 at eighth week. The difference between the lowest and highest value was almost same and narrow at both these ages.

At sixth week of age, the per cent ready-to-cook yield recorded with the control diet was intermediary and was statistically comparable with all other diets. At the same time the yields recorded with low available phosphorus diet (T2) and 500 units phytase supplemented diet (T3) were significantly higher than those recorded with the groups fed diets supplemented with 750 and 1000 units of phytase. Kanagaraju (1998) reported that per cent dressed yield and ready-to-cook yield were significantly higher in groups fed 0.4 per cent available phosphorus with 750 units of phytase.

At eighth week of age, significantly higher R-to-C yield recorded with the control diet was comparable only with the group fed diet supplemented with 1000 units of phytase. Contrary to the findings observed at sixth week, the low available phosphorus diet and all the phytase supplemented diets registered statistically comparable R-to-C yield.

The mean giblet yield at sixth week ranged from 5.80 to 6.56 and from 5.99 to 6.54 per cent at eighth week and it did not differ significantly among each other at both these ages. Significantly higher per cent giblet yield in the control group reported by Kanagaraju (1998) is not in agreement with the present study. It might be due to difference in phosphorus levels in the diets.

5.12 Livability

Livability percentage of birds under the different dietary regimen employed in this trial is presented in Table 23. It revealed that during the course of experiment only six birds died. The livability percentage ranged from 94.4 to 100 per cent. Lowest livability percentage was noted with the group offered low available phosphorus diet without phytase and those supplemented with 750 units of phytase. However, the livability of group fed diet supplemented with 500 units of phytase / kg was 100 per cent. Groups maintained on standard mash as well as low available phosphorus diet supplemented with 1000 units of phytase / kg showed a livability of 97.2 per cent.

Necropsy findings did not reveal any ill effects on the physiological well being of the birds. Improvement in the survivability of birds fed phosphorus deficient diets supplemented with phytase has been reported by Vogt (1993), Richter and Cyriaci (1998), Kornegay *et al.*(1996) and Yan *et al.* (1998). Huff *et al.* (1998) also reported that total phosphorus can be reduced by at least 11 per cent in diets supplemented with phytase at 500 units / kg without affecting the health of broiler chicken. Enhanced availability and better utilization of nutrients could have contributed for the better livability percentage in the above trials.

5.13 Economics

An assessment of the cost of different rations used in this trial, presented in Table 24 indicated that control diet conforming BIS specification was costlier and the ration prepared with 0.3 per cent available phosphorus was cheaper with respect to both starter and finisher. The cost difference between these two rations were 11 and 10 paise for starter and finisher rations, respectively. Supplementation of phytase to low available phosphorus rations enhanced the cost of rations. But even after the addition of 500, 750 and 1000 units of phytase / kg diet the cost were 7, 5 and 3 paise and 6, 4 and 2 paise lesser, respectively than the control diet in starter and finisher rations.

In order to assess the economics of phytase supplementation, cost-benefit analysis was done and the relevant details are set out in Table 25. Net profit per kg live weight was worked out to be Rs. 4.71, 3.33, 3.85, 4.35 and 4.23 at six weeks of age for the treatment T1, T2, T3, T4 and T5 respectively. When the birds were marketed at eight weeks of age the corresponding figures were

Rs. 3.69, 2.48, 2.77, 3.42 and 3.33, respectively. It showed that net profit per bird was higher if the birds were marketed at six weeks of age. At six weeks of age the net profit per kg live weight was 1.38, 0.86, 0.36 and 0.48 rupees less in the low available phosphorus diet and diets supplemented with 500, 750 and 1000 units of phytase / kg than the control birds fed standard diet. The net profit per kg live weight was 1.21, 0.92, 0.27 and 0.36 rupees less, respectively for the above treatments than the control group at eight weeks of age. It shows that the control birds fed diet with BIS specification has got a definite edge over the other treatments. However, the beneficial effects of phytase supplementation by way of minimising the environmental pollution has to be considered before arriving at a final conclusion.

Newman (1993) reported that one kg of phytase enzyme per tonne of feed can replace 6 to 7 kgs of monocalcium phosphate thus allowing a significant reduction in phosphorus supplementation cost. Kanagaraju (1998) reported that the net profit per kg live weight (when feed cost alone was calculated) was 13 paise higher in groups maintained on 0.4 per cent available phosphorus diet supplemented with phytase at 750 units / kg compared to standard broiler ration.

SUMMARY

6. SUMMARY

The influence of dietary supplementation of phytase on nutrient utilization was investigated in the Department of Poultry Science, College of Veterinary and Animal Sciences, Mannuthy using one hundred and eighty day-old commercial broiler chicks (Ven cob). The chicks were allotted to five groups, each having three replications of twelve chicks each. The dietary treatments consisted of a standard broiler ration (T1) and broiler ration with 0.3 per cent available phosphorus (T2). The broiler ration with 0.3 per cent available phosphorus supplemented with 500, 750 and 1000 units of phytase / kg of feed formed the dietary treatment groups T3, T4 and T5, respectively. All the rations were formulated as per BIS specifications except in the level of available phosphorus.

Major feed ingredients used in the formulation of the experimental rations were yellow maize, rice polish, ground nut cake (exp), soybean meal and unsalted dried fish. Chicks in each replicate were housed randomly in individual pens and reared under deep litter system of management. Standard managemental procedures were adopted during the entire experimental period of eight weeks. Feed and water were provided *ad libitum*. Birds were fed with broiler starter ration upto six weeks of age and then switched over to broiler finisher ration till the end of the experiment. The body weight of individual birds were recorded at day-old age followed by fortnightly intervals. Feed consumption of the birds was recorded replication wise at fortnightly intervals. From the above data the body weight gain and the feed conversion ratio were arrived at.

At the end of sixth and eighth week two birds from each replicate were randomly selected, sacrificed and serum calcium, inorganic phosphorus and alkaline phosphatase, tibial ash, dressed yield, ready-to-cook yield and giblet yield were determined.

At the end of eighth week metabolism trial was carried out using two birds from each replicate selected randomly and housed individually in cages. Total collection method was employed for droppings collection. Based on the data obtained from the metabolism trial, retention of nitrogen and energy and the availability of minerals viz., Calcium, Phosphorus, Manganese and Zinc in the gut were estimated. The phosphorus excretion rates were calculated. Per cent livability of the birds was also worked out in each treatment group.

The overall performance of the birds offered different dietary regimes are presented in Table 26. Based on the results obtained in this trial, the following conclusions are made:

1. Sixth week body weight was higher ($P<0.01$) among the birds reared on standard broiler diet as well as low available phosphorus (LAP) diet supplemented with different levels of phytase. Body weight at eight weeks of age was higher ($P<0.01$) with birds fed standard broiler diet and was statistically comparable with groups maintained on LAP diet supplemented

with 750 and 1000 units of phytase / kg. Sixth and eighth week body weight were lower ($P<0.01$) among the birds fed LAP diet without phytase.

2. Six weeks cumulative weight gain in the group offered standard diet and the phytase supplemented groups were statistically comparable. Whereas at eight weeks of age, phytase addition at 750 and 1000 units / kg levels recorded body weight gain comparable to that of control group.

3. The cumulative feed intake at sixth week of age was not influenced by different dietary regimes. The feed intake from zero to eight weeks of age in groups fed standard and phytase supplemented diets were statistically comparable. The group fed LAP diet was significantly ($P<0.05$) lower in cumulative feed intake.

4. The feed conversion ratio for different dietary treatments ranged from 1.74 to 1.86 from zero to six weeks and 2.23 to 2.34 from zero to eight weeks period. Birds maintained on standard broiler diet registered significantly ($P<0.01$) better cumulative feed conversion ratios both at sixth and eighth week of age. Among the low available phosphorus diets, groups fed 750 and 1000 units phytase supplemented diets showed better feed conversion ratios.

5. The retention of nitrogen was significantly ($P<0.01$) higher in the group fed standard diet. The addition of phytase linearly improved the nitrogen

retention in groups fed graded levels of phytase in the low available phosphorus diets. The retention of energy was higher ($P<0.01$) in groups fed 750 and 1000 units of phytase in comparison to control group.

6. The availability of calcium was significantly ($P<0.01$) higher in the control group and it was statistically comparable with the low available phosphorus diet supplemented with 1000 units of phytase / kg. Significantly higher ($P<0.01$) availability of phosphorus was noticed in control group. Supplementation of phytase in low available phosphorus diet linearly improved ($P<0.01$) availability of phosphorus. Phosphorus excretion in the droppings was significantly ($P<0.01$) reduced in the enzyme supplemented groups when compared to control and LAP diet groups.

7. Manganese availability was more ($P<0.01$) with birds fed low available phosphorus diet supplemented with 750 and 1000 units of phytase and lower ($P<0.01$) with birds fed standard diet. The availability of zinc was more ($P<0.01$) with 1000 units of phytase / kg supplemented group. Phytase supplementation resulted in a significantly linear increase in the availability of zinc with higher levels of enzyme.

8. The tibial ash content in the control group was significantly ($P<0.01$) higher at sixth and eighth week of age. The tibial ash content of birds maintained on low available phosphorus diet without phytase was lower at both ages.

Supplementation of phytase at 500, 750 and 1000 units / kg in low available phosphorus diet had significantly higher and comparable per cent tibial ash content at both ages except with T3 at eight weeks of age.

9. The serum calcium level was highest ($P<0.01$) in the control group and lowest in the low available phosphorus diet group. All phytase supplemented groups showed statistically higher and comparable serum calcium levels at sixth week, whereas at eighth week the serum calcium levels in the LAP diet with 500 units of phytase and without phytase were statistically comparable. Serum inorganic phosphorus level at sixth and eighth week was higher ($P<0.01$) in control group and lowest in the group fed LAP diet. Group fed 750 units phytase supplemented LAP diet had comparable values with that of standard diet both at sixth and eighth week. The serum alkaline phosphatase (ALP) level was significantly ($P<0.01$) reduced by the addition of phytase in LAP diets.

10. The per cent dressed yield and giblet yield was not influenced either by available phosphorus level in the diet or by phytase supplementation. However, per cent ready-to-cook yield was significantly ($P<0.05$) more in the LAP diet without phytase and with 500 units of phytase / kg and was statistically comparable with birds fed standard diet at six weeks of age. On the other hand per cent R-to-C yield at eight weeks of age was significantly

($P<0.05$) more with control birds and it was statistically comparable with the group fed LAP diet supplemented with 1000 units of phytase / kg.

11. Lowering of available phosphorus in the diet or supplementation of phytase did not influence livability.
12. The cost of standard broiler mash was higher in comparison to low available phosphorus diet. The cost of 0.3 per cent available phosphorus diet was lower and it increased by two paise for each 250 units of phytase supplementation. The cost of rations ranged from 9.00 to 9.11 rupees for starter and 8.22 to 8.32 rupees for finisher diets. The net profit per kg live weight was the highest in the group fed standard diet followed by 750, 1000 and 500 units of phytase / kg offered groups and the lowest in low available phosphorus diet group both at six and eight weeks of age.

An overall assessment of the different parameters studied indicated that phytase supplementation to low available phosphorus diets is beneficial in broiler chicken. Among the enzyme supplemented groups 750 and 1000 units of phytase / kg given birds were superior in terms of body weight, weight gain as well as retention of protein and energy and availability of manganese and zinc. Moreover, phosphorus excretion was lower in these groups. Considering the overall performance, it can be surmised that supplementation of 750 units of phytase per kg in low available phosphorus diets is advantageous for commercial broiler chicken production.

Table 26. Influence of dietary supplementation of phytase on nutrient utilization and subsequent performance in broilers.

Sl No	Particulars	Dietary treatments				
		T1	T2	T3	T4	T5
1	Live weight (g)					
	a) Sixth week	1831.67^{a}	1740.39^{b}	1793.33^{a}	1834.87^{a}	1817.37^{a}
	b) Eighth week	2532.85^{a}	2373.59^{c}	2447.67^{b}	2511.04^{a}	2495.93^{ab}
2	Body weight gain (g)					
	a) Sixth week	1787.69^{a}	1695.29^{b}	1747.64^{a}	1790.71^{a}	1773.79^{a}
	b) Eighth week	2488.88^{a}	2328.48^{c}	2401.97^{b}	2466.87^{a}	2452.34^{ab}
3	Total feed consumption (g)					
	a) 0 to 6 weeks	3108.33^{a}	3156.67^{a}	3196.67^{a}	3208.33^{a}	3175.00^{a}
	b) 0 to 8 weeks	5551.66^{a}	5456.67^{b}	5586.67^{a}	5585.00^{a}	5555.00^{a}
4	Cumulative FCR					
	a) Sixth week	1.74^{d}	1.86^{a}	1.83^{b}	1.79^{c}	1.79^{c}
	b) Eighth week	2.23^{c}	2.34^{a}	2.33^{a}	2.26^{b}	2.27^{b}
5	Retention (per cent)					
	a) Nitrogen	67.06^{a}	54.55^{e}	58.17^{d}	60.41^{c}	63.63^{b}
	b) Energy	69.52^{b}	67.29^{c}	68.15^{bc}	71.84^{a}	70.43^{ab}
6	Availability (per cent)					
	a) Calcium	63.47^{a}	57.29^{d}	58.89^{cd}	60.42^{bc}	61.62^{ab}
	b) Phosphorus	53.61^{a}	40.07^{d}	43.05^{c}	48.80^{b}	49.12^{b}
	c) Manganese	21.70^{d}	25.28^{c}	30.78^{b}	37.72^{a}	35.43^{a}
	d) Zinc	22.28^{e}	27.95^{d}	30.33^{c}	34.48^{b}	37.78^{a}
	e) P. excretion (g / kg DM intake)	3.91^{a}	3.78^{a}	3.58^{b}	3.25^{c}	3.21^{c}
7	Tibial bone ash (per cent)					
	a) Sixth week	44.46^{a}	41.38^{c}	42.97^{b}	43.33^{b}	43.18^{b}
	b) Eighth week	45.65^{a}	42.11^{c}	43.01^{bc}	43.76^{b}	43.57^{b}
8	Biochemical parameters					
	i) Serum calcium (mg per cent)					
	a) Sixth week	12.03^{a}	10.81^{c}	11.26^{bc}	11.50^{ab}	11.47^{b}
	b) Eighth week	11.89^{a}	11.08^{c}	11.26^{c}	11.61^{b}	11.58^{b}
	ii) Serum inorganic phosphorus (mg per cent)					
	a) Sixth week	5.81^{a}	4.93^{d}	5.34^{c}	5.68^{ab}	5.52^{bc}
	b) Eighth week	6.88^{a}	6.00^{c}	6.46^{b}	6.73^{ab}	6.61^{ab}
	iii) Serum ALP (U/l)					
	a) Sixth week	455.83^{b}	485.67^{a}	459.50^{b}	431.00^{c}	411.17^{d}
	b) Eighth week	420.50^{b}	468.67^{a}	432.50^{b}	399.83^{c}	385.67^{c}

9	Slaughter studies					
	i) Dressed yield (per cent)					
	a) Sixth week	86.01	85.41	86.58	86.06	84.44
	b) Eighth week	86.12	85.97	86.64	84.55	86.60
	ii) Ready-to-cook yield (per cent)					
	a) Sixth week	69.95^{ab}	70.19^{a}	70.87^{a}	67.83^{b}	67.85^{b}
	b) Eighth week	71.10^{a}	68.14^{b}	69.09^{b}	68.36^{b}	69.22^{ab}
	iii) Giblet yield (per cent)					
	a) Sixth week	6.11	6.56	6.05	5.80	6.36
	b) Eighth week	6.30	6.50	6.33	5.99	6.54
10	Livability (per cent)	97.20	94.40	100	94.40	97.20
11	Cost / Kg of feed (Rs.)					
	a) Starter ration	9.11	9.00	9.04	9.06	9.08
	b) Finisher ration	8.32	8.22	8.26	8.28	8.30
12	Net profit / Kg live weight (Rs.)					
	a) Sixth week	3.69	2.48	2.77	3.42	3.33
	b) Eighth week	4.71	3.33	3.85	4.35	4.23

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INFLUENCE OF MICROBIAL PHYTASE ON NUTRIENT UTILIZATION IN BROILERS

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ABSTRACT OF A THESIS

Submitted in partial fulfilment of
the requirement for the degree of

MASTER OF VETERINARY SCIENCE

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An eight week feeding trial using 180 day-old broiler chicks was conducted to study the influence of phytase supplementation (Natuphos^{R}-5000) on nutrient utilization and subsequent performance. Treatments involved a standard broiler diet, a low available phosphorus (LAP) diet and the low available phosphorus diet plus graded levels of phytase at the rate of 500, 750 and 1000 units / kg diet. The groups fed standard broiler diet and low available phosphorus diets supplemented with 750 and 1000 units phytase showed significantly ($P<0.01$) higher body weight and weight gain. The cumulative feed intake was statistically comparable among the experimental diets at sixth week, whereas, at eighth week it was significantly ($P<0.05$) lower in LAP diet without phytase than that of other diets. The feed conversion ratio was significantly ($P<0.01$) improved by the addition of phytase at 750 and 1000 units / kg in comparison to low available phosphorus diet. Graded levels of phytase addition linearly improved nitrogen retention while energy retention was significantly ($P<0.01$) higher in groups fed 750 and 1000 units of phytase / kg. The addition of 750 and 1000 units of phytase / kg diet significantly ($P<0.01$) increased the availability of calcium while phosphorus availability was improved by all levels of enzyme 500, 750 and 1000 units / kg. The excretion of phosphorus was significantly ($P<0.01$) reduced in enzyme supplemented groups. The availability of manganese and zinc was significantly more in enzyme supplemented groups. Tibial ash, serum calcium and serum inorganic phosphorus were significantly ($P<0.01$) increased

by the addition of 750 and 1000 units of dietary phytase / kg both at sixth and eighth week of age. The serum alkaline phosphatase level was significantly ($P<0.01$) decreased in the diets supplemented with phytase. Supplementation of phytase had no effect on per cent dressed yield and giblet yield. The per cent R-to-C yield was significantly ($P<0.05$) higher in groups fed standard diet, LAP diet and 500 units phytase supplemented diet at sixth week. Whereas at eighth week it was significantly ($P<0.05$) higher in groups fed standard diet and 1000 units phytase added diet. The livability was not influenced by dietary phytase and available phosphorus levels. The net profit per kg live weight at eighth week was 29, 94 and 85 paise higher in groups fed 500, 750 and 1000 units of phytase, respectively in comparison to LAP diet. The results suggested that supplementation of 750 units of phytase per kg in low available phosphorus diets is advantageous for commercial broiler chicken production.