CELLULASE SUPPLEMENTATION IN HIGH FIBRE DIET ON THE PERFORMANCE OF LAYER CHICKEN

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled **"CELLULASE SUPPLEMENTATION IN HIGH FIBRE DIET ON THE PERFORMANCE OF LAYER CHICKEN"** 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.

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Certified that this thesis, entitled **"CELLULASE SUPPLEMENTATION IN HIGH FIBRE DIET ON THE PERFORMANCE OF LAYER CHICKEN"** is a record of research work done independently by **Shri. P. Ponnuvel**, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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Dedicated to my beloved mother

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Introduction

INTRODUCTION

India has made major strides in poultry production during the last three decades. It is the fastest growing sector of Indian agriculture. Though India produces over 26,000 million eggs annually, making it the 6th largest egg producer in the world our present level of per capita consumption of egg is only 32 (Anon, 1994). Since egg and meat provide affordable alternative sources of protein in the human diet and poultry farming generates income through employment of the rural people, the growth potential of poultry industry is significant. It is estimated that India currently has an improved layer population of about 159 million birds. The eighth five year plan envisages an annual growth target of seven per cent for, eggs. The Indian poultry industry is poised for substantial growth in terms of quantity as well as quality in the next decade.

The continuous growth of poultry in the country calls for increased feed production for the growing demand. The annual feed requirement for poultry for 1995 was estimated at 7.07 million tonnes. By the turn of the century, the feed requirement to meet the growth of poultry sector will be around 8.91 million tonnes per annum (Sachdev, 1995) The expected rate of growth of poultry feed industry is 5.2 per cent per annum.

One of the major constraints in poultry production in the country is the continued increase in the cost of feed. Coupled with this, the heavy demand for the conventional feed ingredients necessitates to identify newer ingredients that will not compete with the human food. To achieve this, many agricultural by-products and industrial wastes have been tried which would not only relieve the pressure on conventional feed ingredients but also enable formulation of least-cost rations. This has major significance, since feed is the major component in poultry production representing 70-75 per cent of the cost of production of egg or meat.

Use of alternate source of feed ingredients in poultry feed is limited because of high crude fibre content and presence of certain anti-nutritional factors like non-starch polysaccharides (NSPs) and others. In many cereals and their by-products a portion of energy is bound up in the form of NSPs. Undegraded NSPs cause low digestability of nutrients, production of sticky droppings, increase in viscosity of intestinal content and consequently low performance of birds.

Degradation of NSPs by using either naturally derived exogenous enzymes or synthetic enzymes. increases digestion and absorption of organic and inorganic components of feed. Birds do not have enzymatic capability to utilise these NSPs. This necessitates the use of exogenous enzymes derived from biotechnological innovations as feed additive (Devegowda, 1993). Feed enzymes break the structural barrier in the form of cell wall carbohydrate (Chesson, 1993).

Enzyme application to poultry diets can be beneficial in two ways: added enzymes can improve nutrient availability directly by supporting the bird's endogenous enzyme in degrading feed components or by improving sub-optimal intestinal physico-chemical conditions in the gastro-intestinal tract with dietary addition of specific enzymes, resulting in a more efficient digestion and absorption. The former mode of action will stimulate the absorption of a single specific nutrient, while the latter usually stimulates the digestion and absorption of a range of nutrients. Hence, feed enzyme technology holds a major promise for production of low priced, good quality and harmless feed for poultry by exploring poorly digestable alternate feed ingredients. Therefore, it was thought relevant to take up an investigation to find out the beneficial effects, if any, by supplementation of cellulase enzyme in high fibre layer diet.

The objective of the study was to evaluate the influence of cellulase supplementation in high fibre diet on nutrient availability, on layer performance and to ascertain its economic feasibility.

Review of Literature

REVIEW OF LITERATURE

The application of feed enzyme in poultry ration is of recent origin. Addition of enzyme preparations in the feed has been found to enhance the biological availability and utilization of nutrients. Enzymes are highly substrate specific and active at particular temperature and pH. Further, various factors like age of the bird, source of enzymes and its activity, level of inclusion of grains, moisture content, presence of coenzymes and inhibitors etc. have been found to alter the enzyme activity. In the following pages an attempt is made to provide a comprehensive review of research findings available in the literature on the role of feed enzymes on the performance of layer chicken and other related parameters.

Feed intake and feed efficiency

Nelson and Hutto (1958) observed that addition of enzyme to barley based diet fed to Leghorn pullets improved the feed efficiency over the control.

Berg (1959) noticed that corn based diet was superior to barley based diet without enzyme supplementation in terms of feed efficiency in layers and that enzymes improved the feed consumption.

Rexen (1981) stated that addition of either cellulase and/or pectinase or protease showed a significant increase ($P \leq 0.01$) in feed utilization by 6 per cent in chickens. The results also indicated better feed utilization when the birds were fed with enzyme supplemented feed mixture containing less digestible feed ingredients.

Addition of cellulose degrading enzyme (Trichoderma viridae filtrate) in barley based diet fed to chicks improved the feed conversion efficiency to a tune of 8 per cent (White *et al.*, 1981).

Hijikuro and Takemasa (1982) reported that cellulase supplementation significantly increased the feed conversion efficiency ($P<0.01$) in a high barley diet fed to Leghorn chicks.

Baranauskas (1988) observed significant improvement in feed conversion efficiency in laying hens when supplemented with enzymes (MG10x and TsG3x) in a diet containing 8 per cent ground poultry excreta.

Supplementation of a multienzyme preparation, Avizyme, significantly improved feed conversion ratio in barley and oat based diets fed to laying hens (Aimonen and Nasi, 1991).

Brenes *et al.* (1993) conducted three experiments to study the effect of beta-glucanase and Pentosanase enzyme complex (Trichoderma viridae, Roxazyme-G and Cellulase TV) on the performance of Leghorn chicks and laying hens. In the first experiment addition of enzymes (0.2 and 0.4 g/kg feed) to the hullless barley and naked oat based diet fed to chicken improved the feed conversion efficiency. In experiment 2, supplementation of Roxazyme to diets containing hullless barley (0.1 g/kg) and rye (4 g/kg) improved feed intake by 8 and 16 per cent, respectively. In the last trial, replacing all the wheat with hullless barley and naked oat/rye in the diet for young pullets had no effect on over all performance during a 12-week laying trial.

In an attempt to study the influence of enzyme on laying hen performance, Francesh *et al.* (1995) added three concentrations of crude commercial enzyme complex (0, 80 or 160 ppm) to barley based feeds with either high energy (2750 Kcal/kg) or low energy (2479 Kcal/kg) content. They observed that inclusion of commercial enzyme to barley based diet increased the feed efficiency ($P<0.01$) in layers.

In an investigation, Satyamoorthy (1995) revealed that feed efficiency for egg production (egg number) was significantly higher in birds fed standard layer ration with cellulase and protease enzymes than those on the control and less dense rations with enzymes. However, average daily feed intake was not statistically significant.

The influence of compound enzyme preparation (containing acid protease, saccharogenic enzyme, alpha amylase, cellulase and pectate lysase) on layer performance was studied by Zang Su Min *et al.* (1996) and reported that addition of 0.5 per cent compound enzyme to the basal diet significantly ($P<0.01$) decreased the feed intake by 15.11 per cent.

Egg production and egg weight

Nelson and Hutto (1958) reported that inclusion of enzymes to barley based diet improved the egg production and hatchability of eggs.

Berg (1959) observed a positive response on egg production when barley based diet was supplemented with enzymes.

Supplementation of bacterial or fungal enzyme in commercial corn or milo laying ration significantly improved the post-peaking egg production to three to five per cent in terms of total egg output in Single Comb White Leghorn chicken (Ely, 1963).

Gleaves and Dewan (1970) observed that laying hens fed with corn or milo ration supplemented with 0.15 per cent fungal enzyme increased the egg production.

The effect of commercial cellulolytic enzyme (celloviridin G3x) in a complete feed mixture devoid of animal protein was studied by Kvitkin and Tishenkova (1982) observed an improvement of 4.7 per cent in the egg yield of laying hens.

Patel and McGinnis (1985) conducted experiments to find out the effect of autoclaving and enzyme supplementation of guar meal on the performance of chicks and laying hens. Egg production was significantly decreased when raw guar meal was given, but autoclaving retrived it. Enzyme hemicellulase with either raw or autoclaved meal gave insignificant egg production.

Tishenkova and Serikova (1987) observed an increase in egg yield when barley and wheat containing diets were supplemented with the enzyme Tselloviridin G3x (Hemicellulase).

Kenzyme, a multienzyme which contained alpha-amylase, beta-glucanase and protease had been tested in laying hens by Adams (1991). The results showed a 7.2 per cent increase in egg production.

Aimonen and Nasi (1991) observed that good quality oat with multienzyme premix could substitute barley in the diet of laying hens without any negative effect on laying performance.

Kuchta *et al.* (1991) studied the effect of pectinolytic enzyme/and or antibiotic in laying hens. They observed highest egg production in diet containing both enzyme and antibiotic. Persistency of laying was improved in birds fed with diet containing enzyme.

Jayanna and Devegowda (1993) studied the effect of superzyme (cellulolytic enzyme with protease, amylase, pectinase, xylanase and beta-glucanase) on 46 weeks old commercial layers with diets containing 2600, 2500 and 2300

Kcal ME/kg. Egg production was considerably improved in lowest energy group.

Mohandas and Devegowda (1993) evaluated the effect of protease at various energy levels in layers. Favourable result was obtained in egg production at lower energy level (2300 Kcal ME/kg).

Prakash and Devegowda (1993) studied the effect of cellulase and protease enzymes either singly or in combination in the high fibre diet of laying chicken containing fibrous feed stuffs like deoiled sunflower cake and deoiled rice bran. The enzyme cellulase supplementation to high fibre diet with low energy significantly ($P<0.1$) improved the egg production when compared with controls.

Sharma and Katoch (1993) obtained a numerical increase in egg production when Novozyme SP-243, a fibre degrading enzyme was supplemented in the diet of 26 weeks old layers.

Brufau *et al.* (1994) observed that supplementation of fungal enzyme in barley based diet of laying hens improved egg production and egg size ($P<0.034$) in the early periods of lay.

Addition of commercial enzyme preparation (containing beta-glucanase, xylanase and pectinase) to layer diet containing 60 per cent barley and 20 per cent sunflower cake improved the rate of lay (P<0.03) and egg weight (P<0.01) (Francesh *et al*., 1995).

The influence of feed enzymes, viz., cellulase or protease supplemented at the levels of 0.06 or 0.02 per cent respectively, on production performance and nutrient availability was evaluated in a standard layer (18% CP and 2600 Kcal ME/kg) and less dense layer (16% CP and 2500 Kcal/kg) rations using White Leghorn pullets (Satyamoorthy, 1995). A numerical improvement was noticed in per cent hen-housed and hen-day egg production in enzyme treated groups. However, the increase was not statistically significant. He also reported that enzyme supplementation did not have any significant influence on egg weight.

Zang Su Min *et al*. (1996) found that compound enzyme preparation (containing protease, alpha-amylase, cellulase and pectatelysase) supplemented in layer basal diet increased the laying rate (P<0.01) and average egg weight (P<0.01).

Body weight gain and growth

Willingham *et al*. (1958) observed significant improvement in growth of chicks with enzyme supplementation in barley containing diets.

An experiment was conducted to study the effect of adding a bacterial enzyme preparation to a diet containing barley in Single Comb White Leghorn pullets at 0, 8 and 21 weeks of age on rate of growth and subsequent laying performance (Berg, 1961). He opined that the addition of enzyme increased growth rate upto 8 weeks of age and during the period from 8-21 weeks the enzyme did not improve the rate of gain. However, body weight gain improved during the laying period due to enzyme supplementation.

Leong *et al.* (1961) stated that the presence or absence of barley in the chick ration was the main factor for the enzyme effect on growth response rather than the level of crude fibre. They observed that substitution of barley for corn diet depressed chick growth but it was counteracted by fungal enzyme supplementation. However, the same was not true in high fibre diet without barley.

Anderson and Warnick (1964) found increased growth rate of chicks due to enzyme supplementation in the ration containing guar by-products.

In order to assess the influence of enzyme preparations on the growth of pullets, Berezhnova (1979) conducted experiment on White Russian pullets. He used amylolytic and/or proteolytic enzymes in the basal diets. Addition of enzyme preparations resulted in an increase in the rate of growth and betterment in body conformation. Best results were noted with addition of both enzymes together (each enzyme 0.5 kg/tonne) rather than singly (1 kg/tonne).

Addition of either cellulase and/or pectinase or protease in barley based diet resulted a significant ($P<0.05$) improvement in weight gain upto 7 per cent (Rexen, 1981).

Tishenkova and Serikova (1987) studied the effect of multienzyme, Tselloviridin G3x (hemicellulase) on layer diet containing barley and wheat. They obtained an increase in body weight gain when the enzyme was mixed with the feed low in nutrients.

Alisheikhov *et al.* (1988) conducted experiment on egg line chickens to evaluate the effect of multienzyme, Mekcx-1 (containing proteolytic and cellulolytic enzymes) on mixed feed based on maize and wheat. Inclusion of enzyme preparation at 0.02, 0.03 and 0.05 per cent showed mean daily body weight gain of 4.67, 10.39 and 10.61 g respectively.

Kumprecht *et al.* (1990) reported that addition of cellulase enzyme in feed mixture improved the body weight gain of broiler chicken.

Bhatt *et al.* (1991) conducted experiments in broiler chicken fed standard diet with or without addition of different levels of fibre degrading enzyme and found that body weight gains were significantly ($P<0.05$) higher in enzyme fed groups.

Richter *et al.* (1991) recorded improved weight gain in broiler chicks when rye and triticale based diet were supplemented with Bergazym-H (cellulase complex and hemicellulase) at the level of 100 mg/kg.

Brenes *et al.* (1993) noticed that inclusion of feed enzymes (beta-glucanase and pentosanase) at 0.2 and 0.4 g/kg improved the weight gain of chickens fed with hull-less barley and oat based diet but not in wheat diet.

The effect of different concentration of a crude enzyme when added to the diet containing high level of barley, rye, wheat/corn on the performance of growing White Leghorn chicks was studied (Marquardt *et al.*, 1994). They observed an improvement in weight gain ($P<0.05$) in chicks fed with diet containing barley, wheat and rye but not with corn diet.

Purushothaman and Natanam (1995) reported that little millet (Panicum miliare) with enzyme or yeast culture resulted in an improvement of body weight gain in growing chickens.

Enzyme supplementation did not have any significant influence on body weight gain of White Leghorn chickens (Satyamoorthy, 1995).

Nutrients availability

Leong *et al.* (1962) observed that inclusion of fungal enzyme increased the metabolisable energy value of western pearlet barley and regular barley to 23.8 and 14.5 per cent respectively in chick ration.

Potter *et al.* (1965) conducted an experiment on chicks to determine the metabolisable energy values and digestibility co-efficients of western grown barley as influenced by fungal enzyme or water treatment. They found that metabolisable energy was increased by 18 per cent by the presence of fungal enzyme and 22 per cent by water treatment. They also noticed that either presence of enzyme or water treatment of barley improved the digestibility of protein, fat and nitrogen free extract.

The feeding value of rye was determined on chicks by Moran *et al.* (1969). They reported that the metabolisable energy of western and tetrapetkus rye grain was increased by 6.4 and 2.4 per cent respectively when supplemented with a crude fermentation product of Aspergillus species origin.

Dovgan *et al.* (1972) evaluated the commercial enzyme preparation, amylorizin p10x in the diet of hens. They found an increase in total sugar, glucose, aminonitrogen and a reduction in duodenal protein content.

Hersted and McNab (1975) reported that the digestibility and metabolisable energy values of North American variety of six row spring barley were significantly improved by amylase enzyme supplementation in broiler diet.

Using broiler chicks Kuzmicky *et al.* (1978) determined the nitrogen corrected metabolisable energy value of wheat bran treated with a commercial cellulolytic enzyme, Pectinol 41p. The cellulolytic enzyme treatment gave an increase of 32 per cent in metabolisable energy (2132 Kcal/Kg) when compared with untreated bran (1612 Kcal/Kg).

Addition of commercial cellulase enzyme supplement to barley based diet fed to White Leghorn chicks increased the metabolisable energy value of the diet (Hijikuro and Takemasa, 1982).

Nahm and Carlson (1985) noted that addition of 0.008 per cent cellulase enzyme significantly improved the digestibility of cell wall components of wheat bran in broiler diet. The enzyme supplementation also solubilised the calcium, phosphorus, iron, zinc and copper associated with cell wall.

An increase in the bioavailable energy was observed when rye based diets were supplemented with pectinase *(Aspergillus nigar)* or cellulase (*Trichoderma viridae*) enzyme complex in chicken diet (Broz, 1987).

Baranauskas (1988) observed an increase in energy utilization when hens were fed with diet containing poultry excreta (8 per cent by weight) supplemented with commercial enzyme preparations.

Petterson and Aman (1989) conducted an experiment on broiler chickens fed with diets containing rye and wheat in equal proportion with or without increasing level (0.11, 0.22, 0.44, 0.88 g/kg) of a technical enzyme preparation (containing pentosanase and beta-glucanase). They observed that enzyme supplementation generally increased the digestibility of organic matter, crude protein and starch. They also opined that solubilisation and disruption of feed endosperm cell walls by enzyme was probably responsible in increasing digestibility and production performance.

Rotter *et al.* (1990) conducted a feeding trial to determine the influence of enzyme on the bioavailable energy, apparent protein digestibility and different cultivars of barley in the diet of young chicks. They found that nitrogen corrected apparent metabolisable energy (AMEn) was significantly increased due to enzyme supplementation. Different cultivars gave different values of AMEn. The greatest increase in energy was noted with Scout variety (25.3 per cent) and no increase in Bedford barley. When Scout barley was supplemented with tallow or corn oil, AMEn and apparent protein digestibility showed an increase due to enzyme addition irrespective of fat sources.

Friesen *et al.* (1991) reported that addition of cellulase enzyme (*T. viridae*) in 60 per cent rye based broiler diet resulted in an increase in the dietary metabolisable energy by 23 per cent and apparent protein digestibility by 12 per cent when compared with unsupplemented control diet.

Addition of multienzyme, Avizyme, to oat based diet fed to laying hens improved the AME, apparent crude fat digestibility, carbohydrate and hemicellulose digestibility. The effect was more pronounced when the ration contained more than 8 per cent fibre content (Aimonen and Nasi, 1991).

Kuchta *et al.* (1991) conducted two experiments in laying hens using commercial diet (control-17.4 per cent CP) and basal diet (16.8 per cent CP) supplemented with pectinolytic enzyme and/or antibiotic. They observed that nitrogen retention was higher in basal diet with pectinolytic enzyme. However, combination of pectinolytic enzyme and antibiotic resulted in higher nitrogen retention in control diet.

Annison (1992) evaluated the effect of commercial enzyme preparation (containing xylanase and beta-glucanase) on wheat based broiler diet. He noted significantly higher AME, apparent pentosan digestibility, ileal digestibility co-efficient of starch and ileal glucanase activity in enzyme supplemented group when compared with control.

Friesen *et al.* (1992) studied the influence of enzyme supplementation on apparent metabolisable energy corrected for nitrogen retention (AMEn), apparent lipid digestibility (ALD) and apparent protein digestibility (APD) in young chicks fed with diet containing wheat, hulled (or) hull less barley, naked oat and spring rye. The results showed that enzyme supplementation significantly increased AMEn, ALD and APD for all test cereals when compared with their respective controls. The corresponding increase in the AMEn of the enzyme supplemented diet containing 70 per cent HY 320 wheat, Bedford barley, Scout barley, Tetra oat and gazelle rye were 4, 7, 42, 33 and 14 per cent, respectively when compared with their unsupplemented counterparts.

Wantia (1993) conducted experiment using adult broiler cocks given rye and wheat based diet to determine quantitative and qualitative effect of feed enzymes, Roxazyme-G. He found that enzyme preparation increased the True metabolisable energy value by 1.1 and 6.3 per cent in rye and wheat diets respectively.

Flores *et al.* (1994) studied the effect of enzyme supplementation in broiler diet containing wheat and triticale. At inclusion rate of 300-600 g/kg of these cereals, nitrogen corrected true metabolisable energy values improved with enzyme addition. Best results were obtained when low nutritive value cereals added at higher inclusion level in the diet with enzyme.

Marquardt *et al.* (1994) conducted a study to assess the effect of crude enzyme preparation (Xylanase and cellulase) at different concentrations in the diet of Leghorn chicks containing high amount of barley, rye, wheat and corn. They observed improvements in the ME of diets containing barley, rye and wheat by 12, 10 and 4 per cent respectively but not in corn diet.

Swain and Johri (1994) conducted a 4x3 factorial experiment with broilers to assess the influence of enzyme supplements (containing amylase, cellulase, protease and lipase) in four basal diets containing unautoclaved or autoclaved rice bran with low fibre content and high fibre with unautoclaved or autoclaved rice bran, wheat bran and sunflower cake. Three test diets from each of the basal diet were prepared by addition of 0, 1.0 and 1.5 g enzyme/kg diet. They found significant increase in metabolisable energy of various low fibre and high fibre diets due to inclusion of enzyme at 1.0 and 1.5 g/kg. The retention of protein was found to be higher on diet containing 1.5 g enzyme/kg.

Satyamoorthy (1995) opined that enzyme supplementation resulted in an apparent improvement in the digestability of crude protein and energy utilization in laying chicken.

Vranjes and Wenk (1995) studied the effect of extruded and unprocessed barley in the diet on the response of broiler chickens to *Trichoderma viridae* enzyme supplement. Greater enzyme effect with the diets containing extruded barley were found for apparent metabolisable energy, fat and nitrogen utilization and betaglucan degradability.

Excreta moisture and intestinal viscosity

Large scale use of feed ingredients like barley, oat, wheat, rye and triticale in poultry ration is limited because of the presence of certain anti-nutritional factors viz. non-starch polysaccharides (NSP). These NSPs are mixed link beta-glucans in barley and oat and arabinoxylans in wheat, rye and triticale. These factors could not be degraded in the digestive system by the host mechanism alone and could be responsible for reduction in nutrient assimilation, growth rate, feed efficiency, production and increased microbial population in the gut. The soluble fractions of NSPs are mainly responsible for increasing the viscosity of fluid phase of intestinal content and gel formation in the digestive tract which produce sticky droppings. The moisture holding capacity of droppings is also increased by the presence of these factors.

Excreta mositure

Berg (1959) noticed that fungal enzyme supplementation decreased the litter moisture significantly than bacterial enzyme in barley based diet fed to laying hens.

Berg (1961) reported that bacterial enzyme preparation improved the condition of the litter when added to barley diet fed to Leghorn pullets.

Anderson and Warnick (1964) noted that addition of enzyme to guar by-products reduced the sticky dropping problem in chicken.

Campbell *et al.* (1987) opined that the problem of wet droppings associated with feeding of oat to broilers could be overcome by incorporation of enzyme preparations rich in beta-glucanase activity.

Inclusion of endo-beta-xylanase in rye based diet decreased the incidence of sticky droppings and improved the litter quality (Petterson and Aman, 1988).

Nasi (1989) noticed a decreased incidence of dirty eggs from layers fed with barley based diet supplemented with bacterial enzyme preparations.

Rotter *et al*. (1989) observed that enzyme supplementation to barley based diet fed to chicks reduced the vent pasting problem.

Raghavan (1990) conducted an experiment with Energex (Multienzyme) on broilers and observed reduced sticky droppings.

Devegowda and Nagalakshmi (1992) noticed an improved condition of faeces with multienzyme supplementation in broiler diet.

Jayanna and Devegowda (1993) and Mohandas and Devegowda (1993) conducted experiments to evaluate the performance of laying chicken with different enzymes. They observed drier faeces in enzyme added groups.

Francesh *et al*. (1994) reported an increased dry matter content of excreta in broilers fed barley based diet supplemented with multienzyme preparation derived from *Trichoderma viridae*.

Francesh *et al*. (1995) conducted experiments in laying hens fed on barley-sunflower based diet and found that high doses of multienzyme improved the excreta quality and reduced the percentage of dirty eggs.

Cellulase and protease enzyme supplementation in standard and less dense layer rations showed an apparent reduction in moisture content of excreta, the effect being more in less dense layer treatment groups (Satyamoorthy, 1995).

Intestinal viscosity

White *et al.* (1981) reported that barley beta-glucan in a corn based diet increased the viscosity of the chick intestinal contents and supplementation of culture filtrate derived from *Trichoderma viridae* decreased the intestinal viscosity to near control diet.

Hesselman and Aman (1986) observed that addition of beta-glucanase enzyme to a broiler diet containing high viscosity barley variety increased the dry matter content of the small intestine digesta when compared with control.

Bedford *et al.* (1991) conducted an experiment in broilers fed with rye based diet supplemented with pentosanase enzyme and found that viscosity of fore and hind gut was significantly reduced. They also observed a decrease in the concentration of high molecular weight carbohydrate complexes.

In a dose response study, utilizing four levels of rye viz., 0, 20, 40 and 60 per cent substituting wheat and six levels of enzyme xylanase viz., 0, 0.1, 0.2, 0.4, 0.8 and 1.6 per cent indicated that addition of enzyme significantly reduced the intestinal viscosity in each of the levels of rye (Bedford and Classen, 1992a). In another study, Bedford and Classen (1992b) found that addition of beta-glucanase to a barley based diet resulted in a very significant reduction in viscosity of intestinal content.

Bedford (1995) stated that both betaglucans and arabinozylans exerted their negative effects on digestion in poultry by creation of very large entanglements in solution which resulted in elevation of viscosity of small intestinal contents and that the application of relevant enzymes, beta-glucanase or arabinoxylanase could alleviate this problem.

Satyamoorthy (1995) observed a reduction in viscosity of intestinal contents when cellulase and protease enzymes were included in the standard and less dense layer rations.

Vanderklis *et al.* (1995) observed that dietary addition of high viscosity wheat variety in broiler diet resulted in higher intraluminal viscosities of intestine than lower viscosity wheat variety. Addition of endo-xylanase lowered the viscosity of the chyme supernatant to similar levels on all wheat based diets.

Livability

Gleaves and Dewan (1970) conducted a feeding trial in White Leghorn layers fed with practical type corn and milo rations supplemented with fungal enzyme (0.15 per cent). They observed that addition of fungal enzyme increased the livability of hens when compared with unsupplemented control.

Kvitkin and Tishenkova (1982) observed that addition of enzyme, celloviridin G3x in the complete feed mixture devoid of animal protein in laying hen ration increased the survivability of hens by 5 per cent.

Supplementation of enzyme, Bergazym-H (contains cellulolytic and hemicellulolytic enzymes) in rye based broiler diet was studied by Jeroch (1992). He noted 8 per cent mortality in all groups irrespective of enzyme addition.

Marek and Splitek (1992) evaluated the effect of cellulase enzyme derived from *Trichoderma viridae* on the performance of broiler chickens fed with high roughage diet.

They found that per cent mortality was not affected by either enzyme or level of roughage inclusion.

Satyamoorthy (1995) observed that addition of cellulase and protease enzyme in standard layer ration and less dense layer ration revealed no harmful effects on survivability of hens.

Cost-benefit analysis

Baranauskas (1988) reported that laying hens fed with a diet containing ground poultry excreta (8 per cent by weight) supplemented with enzyme preparations significantly reduced the cost of feeds by 3.5 to 5.7 per cent.

Kadam *et al.* (1991) conducted an experiment on broiler chicken fed with commercial starter and finisher diets supplemented with a multienzyme, SELFEED (containing protease, amylase, cellulase, lipase and pectinase). They found that inclusion of feed enzymes was cost effective in broiler rations under tropical conditions.

A large scale feeding trial on broilers given complete feed mixtures with and without an enzyme premix (containing lysosyme, proteolytic and amylolytic principles) was studied by Morkunas *et al.* (1991). They found that addition of enzyme premix reduced the feed cost per kilogram gain by 3 per cent.

Satyamoorthy (1995) studied the cost-benefit analysis of supplementation of cellulase and protease enzymes in standard and less dense layer rations. He found that feed cost per egg was comparatively higher when both enzymes were supplemented. Cellulase supplementation alone in less dense ration reduced the feed cost about 1.2 paise per egg and even 3 paise per egg in peak production when compared with standard control diet.

Materials and Methods

MATERIALS AND METHODS

An experiment was conducted at the University Poultry Farm, Centre for Advanced Studies in Poultry Science, College of Veterinary and Animal Sciences, Mannuthy, to evaluate the effect of cellulase supplementation in high fibre diet on the performance and nutrient availability of layer chicken.

Experimental materials

Experimental birds

One hundred and fifty, 18 weeks old Single Comb White Leghorn Pullets of 'F' strain selected at random formed the experimental subjects.

Experimental diets

Two types of rations viz., standard layer ration and high fibre layer ration were used in this study. The standard layer ration (SLR) was formulated as per BIS (1992) specification for chicken layers. The high fibre layer ration (HFLR) was computed similar to SLR except the level of crude fibre which was enhanced to 12 per cent. The level of all other nutrients were similar to that of SLR. Feed ingredients used for the formulation of the experimental diets were yellow maize, rice polish, deoiled groundnut cake, unsalted dried fish, undecorticated sunflower cake, shell grit and mineral mixture. The inclusion level of undecorticated sunflower cake was enhanced in order to obtain the desired level of crude fibre in the high fibre layer ration. The level of incorporation of ingredients in the two rations and chemical composition of compounded diets are presented in Tables 1 and 2 respectively.

Enzyme

The enzyme used in this study was 'Fiberzyme', a product manufactured and marketed by M/s Jayson Agritech Pvt. Ltd., Mysore. It is a fibre degrading enzyme of fungal origin containing cellulase as its major component. Besides, beta-glucanase, hemicellulase and amylase are also present at lower levels as indicated by the manufacturers.

Experimental methods

The cage house, cages, feeders and waterers were cleaned thoroughly and disinfected. The birds were housed in individual cages at 18th weeks of age.

Experimental design

The pullets were randomly divided into five treatments viz., T_1, T_2, T_3, T_4 and T_5 with three replications in each treatment and each replicate had ten birds. The birds in each treatment were assigned to each of the five rations viz., SLR, HFLR and three different levels of enzymes viz., 0.06, 0.12 and 0.18 per cent in high fibre layer ration. The details of treatment particulars are presented in Table 3.

Management

Feed and water were provided *ad libitum* throughout the experiment. Standard managemental procedures were adapted during the entire experimental period. The duration of the experiment was five, 28-day periods covering 21 to 40 weeks of age.

Climatic parameters

The wet and dry bulb thermometer readings were taken at 8 a.m. and 2 p.m. daily. The maximum and minimum temperatures were recorded at 8 a.m. in all days. From these data, period-wise maximum and minimum temperatures and per cent relative humidity were arrived at.

Body weight

The body weight of individual birds was recorded at the beginning and at the end of the experimental period to study the pattern of body weight maintenance under the different feeding regimes.

Feed intake

Feed intake was recorded replicate-wise at the end of each 28-day period. From this data feed intake per bird per day was calculated for various treatment groups.

Egg production and egg weight

Individual egg production record of all birds was maintained throughout the experimental period. From this data, per cent hen-housed and hen-day egg production were calculated.

Data on egg weight was obtained from the weighment of all eggs collected during the last three consecutive days of each 28-day period.

Feed efficiency

Feed conversion efficiency (feed per dozen eggs) was calculated based on the data of dozen of egg produced and kilogram of feed consumed.

Metabolic trial

At the end of the experimental period a digestibility trial was conducted using six birds, randomly selected from each treatment group. Total collection method was employed. *Ad libitum* supply of water was ensured. The total amount of feed consumed and excreta voided were recorded for each day. The excreta of individual birds was collected in polythene bags, sealed and stored in deep freezer for further analysis.

Chemical analysis

The chemical composition and fibre fractions of the different rations and excreta collected during the digestibility trial were analysed and estimated as per the procedure of AOAC (1990) and Van-Soest and Wine (1967) respectively. Uric acid nitrogen in the droppings was determined (Marquardt, 1983) and nutrients digestibility were calculated.

Metabolisable energy

The gross energy in feed and excreta samples were estimated using adiabatic digital bomb calorimeter. From this data, the apparent metabolisable energy of different dietary treatments were calculated.

Intestinal viscosity

At the end of the experiment, six birds from each treatment were sacrificed to study the intestinal viscosity of different treatment groups. The intestine was ligated at the junction of duodenum and jejunum and at the ileo-caecal junction. The intestinal content from this portion was collected in a test tube and centrifuged at 6000 rpm. The supernatant fluid was used for estimation of viscosity using Ostwald viscosity meter (Oser, 1965).

Livability

The mortality of birds from different treatment groups was recorded and post-mortem examination was done to determine the cause of death.

Cost-benefit analysis

Cost of feed and enzyme, number of egg produced and quantum of feed consumed to produce an egg in each treatment group were calculated. From this data the cost-benefit analysis was worked out.

Statistical analysis

Data collected on various parameters were statistically analysed as per methods of Snedecor and Cochran (1967).

Table 1. Per cent ingredient composition of experimental diet

Ingredients	Standard layer ration (SLR)	High fibre layer ration (HFLR)
Yellow maize	42.00	39.00
Rice polish	15.00	8.00
Deoiled groundnut cake (exp)	15.00	5.00
Unsalted dried fish	6.00	6.00
Undecorticated sunflower cake	15.00	35.00
*Mineral mixture	2.75	2.75
Shell grit	4.00	4.00
Salt	0.25	0.25
**Vitamin premix	0.012	0.012

*Contains: Calcium 32%, Phosphorus 6%, Copper 100 ppm Manganese 2700 ppm, Iodine 100 ppm, Zinc 2600 ppm Iron 0.1% and Magnesium 100 ppm

**Each gram contains: Vitamin A 82,500 IU, B_2 50 mg D_3 12000 IU and K 10 mg

Table 2. Per cent chemical composition of experimental diet

Nutrients	Standard layer ration (SLR)	High fibre layer ration (HFLR)
Moisture	9.30	9.60
Crude protein	18.10	18.30
Crude fibre	8.11	12.10
Ether extract	4.00	4.10
Total ash	16.50	17.00
Acid insoluble ash	4.00	4.10
Calcium	3.20	3.15
Phosphorus	1.00	1.10
NFE	43.99	38.90
NDF	24.05	30.58
ADF	14.00	19.30

Table 3. Treatment particulars

Treatment	Replication	No.of birds	Ration	Enzyme	Level of enzyme in ration (%)
T_1	R_1	10	SLR	-	-
	R_2	10	SLR	-	-
	R_3	10	SLR	-	-
T_2	R_1	10	HFLR	-	-
	R_2	10	HFLR	-	-
	R_3	10	HFLR	-	-
T_3	R_1	10	HFLR	Cellulase	0.06
	R_2	10	HFLR	Cellulase	0.06
	R_3	10	HFLR	Cellulase	0.06
T_4	R_1	10	HFLR	Cellulase	0.12
	R_2	10	HFLR	Cellulase	0.12
	R_3	10	HFLR	Cellulase	0.12
T_5	R_1	10	HFLR	Cellulase	0.18
	R_2	10	HFLR	Cellulase	0.18
	R_3	10	HFLR	Cellulase	0.18

Results

RESULTS

A feeding trial to assess the influence of cellulase supplementation in high fibre diet on the production performance and nutrient availability of egg type chickens was conducted for a period of 20 weeks. The results obtained are presented in this chapter.

Climatic parameters

The mean maximum and minimum temperatures and per cent relative humidity during the different periods in this experiment (from November 1995 to April 1996) are presented in Table 4. During the course of the experiment, the maximum temperature ranged from 31.14 to 36.46°Cand minimum temperature from 23.93 to 27.5°C. The per cent relative humidity in the morning varied from 68 to 80, while in the afternoon it ranged from 55 to 62. Temperature and humidity were found to be in an upward trend from the start of experiment until 4th period, but on 5th period temperature was comparatively lower whereas the per cent relative humidity continued to be at higher level.

Feed intake

Mean daily feed intake per bird in different dietary treatment groups viz., standard layer ration (T_1), high fibre

Table 4. Climatic parameters during the experimental period

Period (weeks)	Temperature (°C)		Relative humidity (%)	
	Maximum	Minimum	8 a.m.	2 p.m.
1 (21-24)	31.14	23.93	68	61
2 (25-28)	32.18	24.54	73	61
3 (29-32)	33.89	24.25	73	61
4 (33-36)	36.46	27.50	78	55
5 (37-40)	34.86	26.96	80	62

layer ration (T_2), high fibre layer ration with 0.06 per cent cellulase (T_3), high fibre layer ration with 0.12 per cent cellulase (T_4) and high fibre layer ration with 0.18 per cent cellulase (T_5) was 104.39, 108.55, 102.45, 103.42 and 102.59 g respectively (Table 5).

It could be seen that the daily feed intake per bird among the enzyme supplemented groups was comparatively lower. Highest daily feed intake was noted in the group fed with high fibre layer ration without enzyme (108.55 g). Daily feed intake of birds fed with standard layer ration was medium (104.39 g).

The period-wise mean daily feed intake per bird varied from 96.37 to 112.24 g. It was lowest in the first 28-day period (21-24 weeks of age) and highest in the 5th period (37-40 weeks of age).

The statistical analysis of the data of feed intake are set out in Table 6. Daily feed intake was significantly higher ($P<0.01$) in birds fed with high fibre diet without cellulase and was different from all other groups. Daily mean feed intake per bird was statistically comparable among the groups fed a high fibre diet with different increments of cellulase supplementation and with standard layer ration fed group.

Table 5. Influence of cellulase supplementation on feed intake per bird per day (g)

Period (weeks)	Dietary treatments						
	T_1	T_2	T_3	T_4	T_5	Mean	SE
1 (21-24)	95.18	99.40	97.50	97.38	92.38	96.37^{a}	1.20
2 (25-28)	106.91	108.75	102.62	106.37	110.42	107.01^{b}	1.31
3 (29-32)	102.08	107.09	97.80	96.85	95.06	99.78^{a}	2.16
4 (33-36)	106.50	109.23	103.93	105.60	104.77	106.01^{b}	0.91
5 (37-40)	111.28	118.28	110.42	110.89	110.32	112.24^{c}	1.52
Mean	104.39^{a}	108.55^{b}	102.45^{a}	103.42^{a}	102.59^{a}		
SE	2.72	3.00	2.36	2.72	3.78		

CD - 3.7 ($P<0.01$)

Means bearing the same superscript do not differ significantly

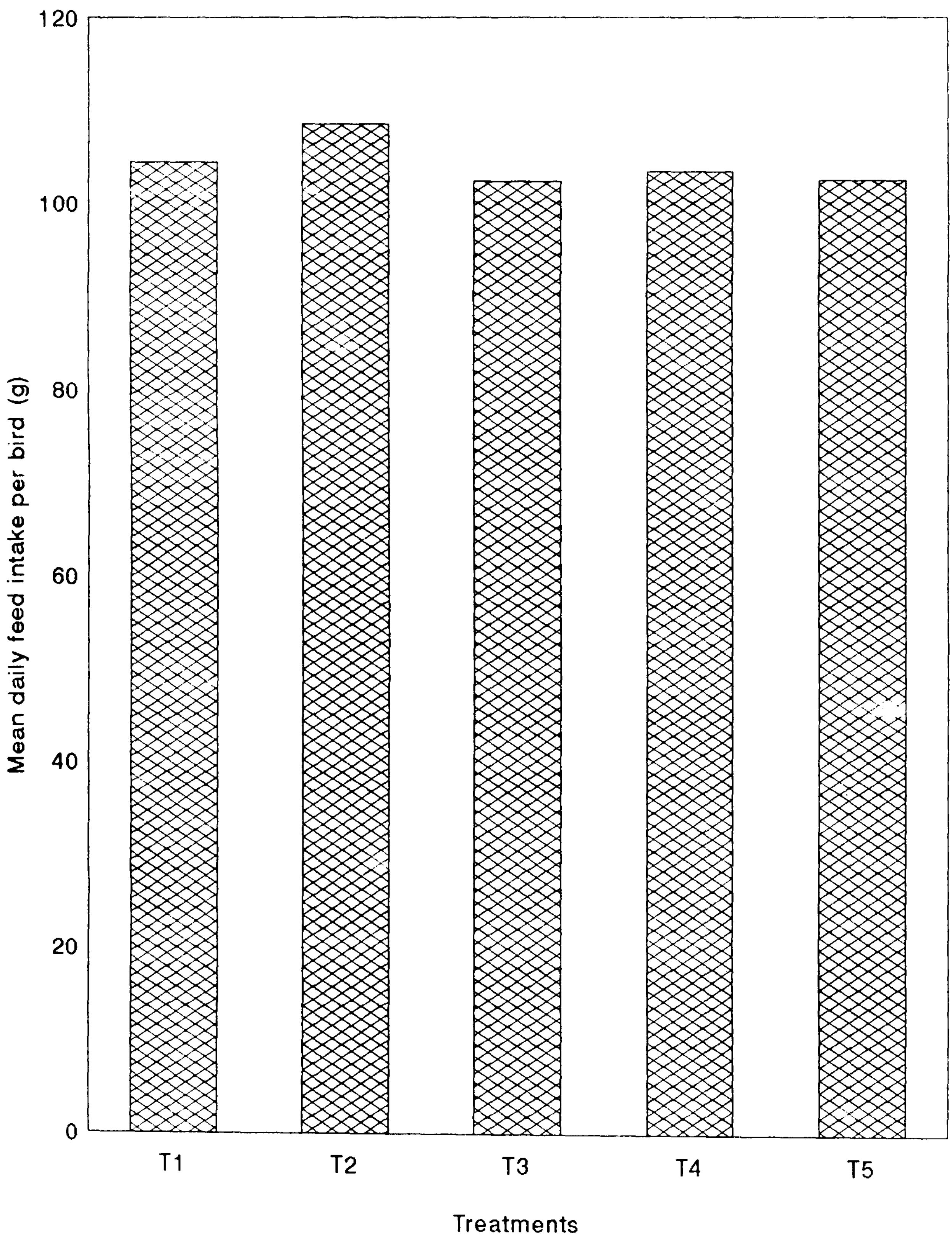
Table 6. Influence of cellulase supplementation on feed intake - ANOVA

Source	df	SS	MSS	F value
Treatment	4	377.838	94.459	6.6155 **
Period	4	2349.158	587.290	41.1309 **
Interaction	16	281.035	17.565	1.2301 NS
Error	50	713.928	14.279	
Total	74	3721.958		

** Significant (P<0.01)

NS - Not significant

Fig.1 MEAN DAILY FEED INTAKE PER BIRD AS INFLUENCED BY CELLULASE SUPPLEMENTATION (g)



Without considering the different treatment groups, daily feed intake showed significant difference among periods. It was significantly ($P<0.01$) lower in the first period and higher with the 5th period and medium with all other periods. However, the differences in feed intake between the periods 1 and 3 and that between 2 and 4 were comparable statistically.

The mean daily feed intake per bird as influenced by cellulase supplementation is presented in Fig.1.

Egg production

The data on per cent hen-housed egg production as influenced by supplementation of cellulase are presented in Table 7. The mean per cent hen-housed egg production was 63.49, 64.05, 68.52, 66.24 and 64.38 for the treatment groups T_1, T_2, T_3, T_4 and T_5 respectively. Highest per cent hen-housed egg production (68.52) was noticed in birds fed with high fibre diet supplemented with 0.06 per cent cellulase and lowest (63.49) in the group fed with standard layer ration. Period-wise mean hen-housed egg production ranged from 30.93 to 76.21 per cent.

Statistical analysis of data (Table 8) showed that the variation in per cent hen-housed egg production among different treatment groups was not statistically significant. However, the differences in hen-housed egg production among

Table 7. Influence of cellulase supplementation on per cent hen-housed egg production

Period (weeks)	Dietary treatments						
	T_1	T_2	T_3	T_4	T_5	Mean	SE
1 (21-24)	24.52	32.74	36.19	30.36	30.83	30.93^a	1.90
2 (25-28)	73.18	67.74	70.24	74.40	73.81	71.87^b	1.25
3 (29-32)	75.24	75.36	72.26	72.38	70.83	73.21^b	0.89
4 (33-36)	71.31	72.74	81.07	80.35	75.59	76.21^b	1.96
5 (37-40)	73.22	71.66	82.86	73.69	70.83	74.45^b	2.16
Mean	63.49	64.05	68.52	66.24	64.38		
SE	9.75	7.91	8.45	9.06	8.42		

CD - 7.98 (P<0.01)

Means bearing the same superscript do not differ significantly

Table 8. Influence of cellulase supplementation on hen-housed egg production - ANOVA

Source	df	SS	MSS	F value
Treatment	4	254.140	63.535	0.9534 NS
Period	4	22351.987	5587.997	83.8540 **
Interaction	16	618.503	38.656	0.5801 NS
Error	50	3331.981	66.640	
Total	74	26556.611		

** Significant (P<0.01)

NS - Not significant

Table 9. Influence of cellulase supplementation on per cent hen-day egg production

Period (weeks)	Dietary treatments						
	T_1	T_2	T_3	T_4	T_5	Mean	SE
1 (21-24)	24.53	32.74	36.19	30.60	30.83	30.93^{a}	1.90
2 (25-28)	73.18	67.74	70.24	74.40	73.81	71.88^{b}	1.25
3 (29-32)	75.24	75.36	72.26	72.38	70.83	73.21^{b}	0.89
4 (33-36)	73.91	72.74	81.07	80.35	78.38	77.29^{b}	1.68
5 (37-40)	76.37	74.28	82.86	76.52	76.12	77.23^{b}	1.46
Mean	64.65	64.57	68.52	66.85	65.99		
SE	10.03	8.05	8.43	9.14	8.86		

CD - 8.30 ($P<0.01$)

Means bearing the same superscript do not differ significantly

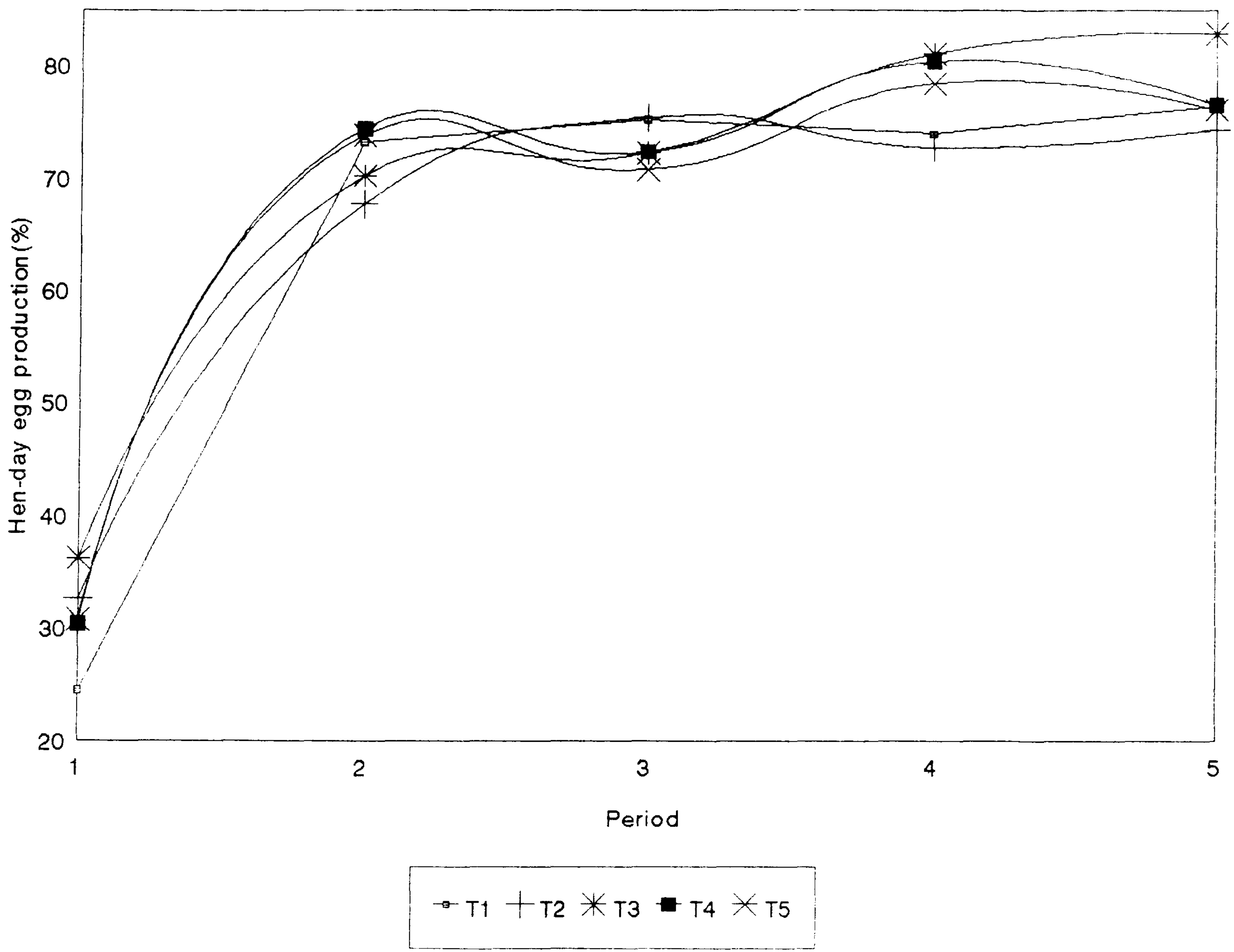
Table 10. Influence of cellulase supplementation on hen-day egg production - ANOVA

Source	df	SS	MSS	F value
Treatment	4	162.470	40.618	0.564 NS
Period	4	23550.669	5887.667	81.739 **
Interaction	16	496.711	31.044	0.431 NS
Error	50	3601.481	72.030	
Total	74			

** Significant (P<0.01)

NS - Not significant

Fig.2 PERCENT HEN-DAY EGG PRODUCTION AS INFLUENCED BY CELLULASE SUPPLEMENTATION



the different experimental periods were highly significant ($P<0.01$).

The data on per cent hen-day egg production (Table 9) showed a similar trend as that of hen-housed egg production. The mean per cent hen-day egg production was 64.65, 64.57, 68.52, 66.85 and 65.99 for the treatment groups T_1, T_2, T_3, T_4 and T_5 respectively. The highest per cent hen-day egg production was noticed in T_3 and the lowest in T_2 groups. Period-wise hen-day egg production varied from 30.93 to 77.29 per cent. When the data were subjected to statistical analysis, the magnitude of differences in percentage hen-day egg production among treatment groups were not significant (Table 10). However, per cent hen-day egg production among different periods was statistically significant ($P<0.01$).

The pattern of per cent hen-day egg production for the various dietary treatment groups are depicted in Fig.2.

Feed efficiency

The data calculated for feed per dozen eggs for the different treatment groups are set out in Table 11. The lowest ratio of 1.97 was observed in the birds fed with high fibre ration containing 0.06 per cent cellulase enzyme while a highest ratio of 2.37 was noted in the groups offered the standard layer diet. The feed per dozen eggs for other groups

Table 11. Influence of cellulase supplementation on feed efficiency (kg feed per dozen eggs)

Period (weeks)	Dietary treatments						
	T_1	T_2	T_3	T_4	T_5	Mean	SE
1 (21-24)	5.06	3.77	3.27	3.96	4.12	4.04^{b}	0.29
2 (25-28)	1.76	1.97	1.77	1.77	1.80	1.81^{a}	0.04
3 (29-32)	1.64	1.71	1.65	1.69	1.61	1.66^{a}	0.02
4 (33-36)	1.67	1.80	1.54	1.59	1.61	1.64^{a}	0.04
5 (37-40)	1.70	1.91	1.60	1.75	1.75	1.74^{a}	0.05
Mean	2.37	2.23	1.97	2.15	2.18		
SE	0.67	0.39	0.33	0.45	0.49		

CD - 0.63 (P<0.01)

Means bearing the same superscript do not differ significantly

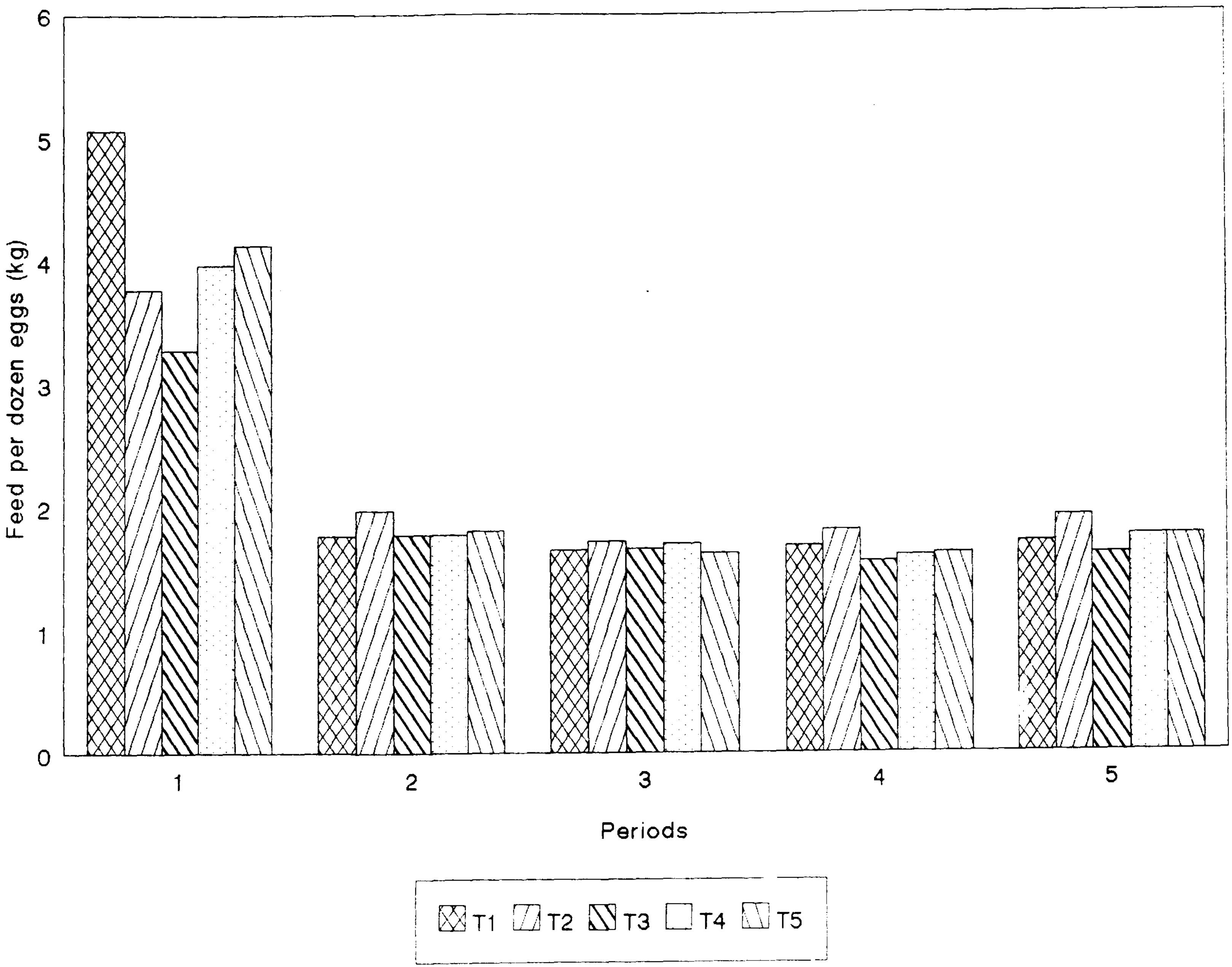
Table 12. Influence of cellulase supplementation on feed efficiency - ANOVA

Source	df	SS	MSS	F value
Treatment	4	1.259	0.315	0.7563 NS
Period	4	65.000	16.250	39.0392 **
Interaction	16	4.314	0.270	0.6477 NS
Error	50	20.812	0.416	
Total	74	91.385		

** Significant (P<0.01)

NS - Not significant

Fig.3 FEED CONVERSION EFFICIENCY AS INFLUENCED BY CELLULASE SUPPLEMENTATION(Kg feed/dozen eggs)



were medium. Comparatively better feed conversion was observed in all groups fed a high fibre diet with varying concentrations of cellulase than standard layer and high fibre control diets. While considering the periods, the highest ratio of 4.04 was found in the first period. Among the periods, superior feed efficiency was noted during the fourth period followed by 3rd, 5th and 2nd periods.

The statistical analysis of data in Table 12 showed no significant differences among various treatment groups with respect to feed per dozen eggs. Whereas, it differed significantly ($P<0.01$) between periods. Superior feed efficiency was noted in the 4th period and it was statistically comparable with 2nd, 3rd and 5th periods. However, feed efficiency in the first period was significantly ($P<0.01$) poorer when compared with all other periods.

The feed efficiency (kg feed per dozen eggs) for different dietary treatment groups in five experimental periods are depicted in Fig.3.

Body weight gain

Individual body weight of birds in the different dietary treatment groups were recorded at the beginning and at the end of the experiment to assess the gain in body weight due to enzyme supplementation. The initial mean body weight ranged

Table 13. Influence of cellulase supplementation on body weight gain (kg)

Replicate	Dietary treatments				
	T_1	T_2	T_3	T_4	T_5
1	0.23	0.17	0.20	0.25	0.21
2	0.18	0.12	0.20	0.23	0.17
3	0.22	0.19	0.25	0.25	0.19
Mean	0.21^{ab}	0.16^{a}	0.22^{ab}	0.24^{b}	0.19^{ab}
SE	0.02	0.02	0.02	0.01	0.01

CD - 0.06 (P<0.05)

Means bearing the same superscript do not differ significantly

Table 14. Influence of cellulase supplementation on body weight gain - ANOVA

Source	df	SS	MSS	F value
Treatment	4	0.012	0.003	4.213*
Error	10	0.007	0.001	
Total	14	0.019		

* Significant (P<0.05)

from 1.300 to 1.340 kg and the final body weight from 1.490 to 1.550 kg. The gain in body weight was calculated and the mean values ranged from 0.16 to 0.24 kg (Table 13). The maximum body weight gain of 0.24 kg was noticed in group fed with high fibre diet with 0.12 per cent cellulase and the lowest gain of 0.16 kg was observed in groups fed with high fibre diet without added enzyme.

The statistical analysis of data presented in Table 14 showed a significant ($P<0.05$) difference in body weight gain among the treatment groups. The gain in body weight of birds fed with high fibre diet without added enzyme was significantly lower than those fed with high fibre diet supplemented with 0.12 per cent cellulase. However, there was no significant difference among birds fed with enzyme supplemented high fibre diets and standard layer ration.

Egg weight

Data on mean egg weight for the different dietary treatment groups as influenced by cellulase supplementation are set out in Table 15. In general, the mean egg weight irrespective of the different feeding regimes was comparatively low. Among the treatment groups, the highest mean egg weight of 48.15 g was noticed in birds fed on a high fibre diet supplemented with 0.12 per cent cellulase and the

Table 15. Influence of cellulase supplementation on egg weight

Period (weeks)	Dietary treatments						
	T_1	T_2	T_3	T_4	T_5	Mean	SE
1 (21-24)	42.85	42.10	43.47	42.25	42.45	42.62^a	0.25
2 (25-28)	47.56	45.88	46.82	47.32	46.63	46.84^b	0.29
3 (29-32)	46.34	49.32	46.76	48.77	47.25	47.69^b	0.58
4 (33-36)	49.87	50.64	50.61	50.39	50.89	50.48^c	0.17
5 (37-40)	51.70	52.12	51.86	52.02	52.16	51.97^d	0.09
Mean	47.66	48.01	47.90	48.15	47.88		
SE	1.52	1.80	1.50	1.67	1.71		

CD - 1.35 ($P<0.01$)

Means bearing the same superscript do not differ significantly

Table 16. Influence of cellulase supplementation on egg weight - ANOVA

Source	df	SS	MSS	F value
Treatment	4	1.953	0.488	0.2557 NS
Period	4	783.472	195.868	102.6038 **
Interaction	16	29.086	1.818	0.9523 NS
Error	50	95.449	1.909	
Total	74	909.959		

** Significant (P<0.01)

NS - Not significant

lowest in the birds which received the standard layer diet (47.66 g). Period-wise mean egg weight data (Table 15) showed that the weight of eggs increased from the first period to fifth period as age advanced. Mean egg weight for the periods 1, 2, 3, 4 and 5 was 42.62, 46.84, 47.69, 50.48 and 51.97 g respectively.

Statistical analysis of data presented in Table 16 showed that the difference in mean egg weight between the different dietary treatment groups was not statistically significant, whereas the magnitude of difference between periods was significant ($P<0.01$). Eggs laid by the birds during the first period was significantly smaller (42.62 g) whereas those laid during the fifth period was significantly heavier (51.97 g). No significant difference in mean egg weight was observed between second and third period. However in all the other periods egg weights were statistically differnt from each other.

Nutrient utilization

Dry matter digestibility

The influence of cellulase supplementation on dry matter digestibility of different rations was determined and are presented in Table 17. The mean dry matter digestibility was 68.13, 70.81, 69.07, 68.99 and 69.64 per cent for treatment

Table 17. Influence of cellulase supplementation on digestibility co-efficient of dry matter

Bird No.	Dietary treatments				
	T_1	T_2	T_3	T_4	T_5
1	70.35	69.88	74.92	68.76	70.06
2	71.75	69.37	68.68	69.50	69.11
3	67.20	69.58	72.82	69.36	68.97
4	72.19	72.79	67.93	64.60	70.92
5	63.97	71.57	65.74	67.74	65.94
6	63.32	71.64	64.31	73.95	72.84
Mean	68.13	70.81	69.07	68.99	69.64
SE	1.59	0.57	1.67	1.24	0.94

Table 18. Influence of cellulase supplementation on per cent dry matter digestibility - ANOVA

Source	df	SS	MSS	F value
Treatment	4	23.400	5.850	0.606 NS
Error	25	241.305	9.652	
Total	29	264.705		

NS - Not significant

groups T_1, T_2, T_3, T_4 and T_5 respectively. The highest dry matter digestibility was recorded in the high fibre control (T_2). Though there were variations in the dry matter digestibility of different rations, statistical analysis of data (Table 18) showed no significant differences among treatments in this trait.

Apparent metabolisable energy

The data on apparent metabolisable energy (AME) content of the rations offered for different treatment groups are presented in Table 19. The highest AME value was noticed in treatment group offered the high fibre diet with 0.18 per cent cellulase, while the lowest value was recorded in birds fed with high fibre diet without enzyme. The mean AME values were 2601.00, 2522.67, 2608.83, 2648.67 and 2664.67 (Kcal/kg) for the treatment groups T_1, T_2, T_3, T_4 and T_5 respectively. With each increment of cellulase supplementation in the high fibre diet, an apparent increase in AME content was observed. When the AME values were subjected to statistical analysis, it revealed significant ($P<0.01$) differences among treatments (Table 20). The high fibre layer ration without enzyme (T_2) had significantly lower AME value than the rations supplemented with 0.12 and 0.18 per cent enzyme. It was also revealed that the AME content of standard layer diet and enzyme supplemented diets were statistically comparable.

Table 19. Influence of cellulase supplementation on apparent metabolisable energy (Kcal/kg)

Bird No.	Dietary treatments				
	T_1	T_2	T_3	T_4	T_5
1	2671.00	2436.00	2424.00	2624.00	2578.00
2	2624.00	2531.00	2577.00	2627.00	2719.00
3	2531.00	2577.00	2625.00	2719.00	2672.00
4	2578.00	2531.00	2531.00	2672.00	2673.00
5	2718.00	2484.00	2671.00	2625.00	2626.00
6	2484.00	2577.00	2625.00	2625.00	2720.00
Mean	2601.00^{ab}	2522.67^{a}	2608.83^{ab}	2648.67^{b}	2664.67^{b}
SE	35.70	22.40	19.74	16.01	22.47

CD - 95.36 (P<0.01)

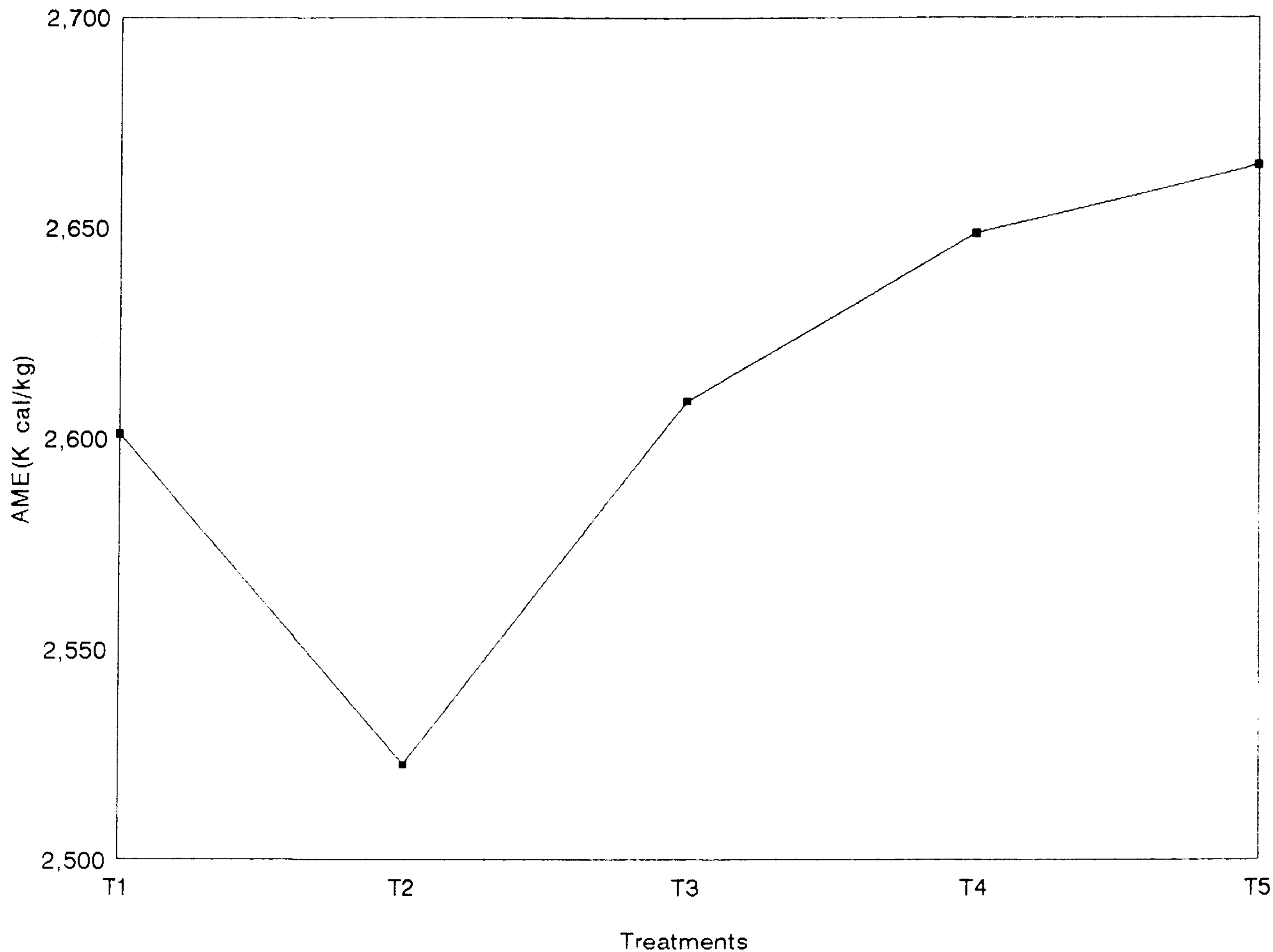
Means bearing the same superscript do not differ significantly

Table 20. Influence of cellulase supplementation on apparent metabolisable energy - ANOVA

Source	df	SS	MSS	F value
Treatment	4	73137.333	18284.333	5.206 **
Error	25	87806.833	3512.273	
Total	29	160944.167		

** Significant (P<0.01)

Fig.4 APPARENT METABOLISABLE ENERGY CONTENT AS INFLUENCED BY CELLULASE SUPPLEMENTATION(K cal ME/Kg)



Apparent metabolisable energy content of different experimental feeds as influenced by cellulase supplementation is presented in Fig.4.

Apparent protein digestibility

The data on apparent protein digestibility of rations fed to birds in the different treatments are presented in Table 21. The mean apparent protein digestibility (APD) was 79.49, 76.29, 79.77, 79.71 and 79.73 per cent for treatments T_1, T_2, T_3, T_4 and T_5 respectively. A highest value of 79.77 was observed in T_3 and the lowest value of 76.29 in T_2.

The statistical analysis of data presented in Table 22 showed significantly ($P<0.01$) lower APD in the high fibre diet without cellulase when compared with standard layer diet and high fibre diets supplemented with graded levels of enzyme.

Ether extract digestibility

The data on ether extract digestibility of the groups fed various rations are set out in Table 23. The mean ether extract digestibility was 71.91, 69.15, 77.04, 75.51 and 76.42 per cent for treatments T_1, T_2, T_3, T_4 and T_5 respectively. The highest value (77.04) was noted in T_3 and the lowest value (69.15) in T_2. When the data were subjected to statistical analysis (Table 24), the magnitude of difference among the treatments was statistically significant ($P<0.01$). Ether

Table 21. Influence of cellulase supplementation on apparent protein digestibility (%)

Bird No.	Dietary treatments				
	T_1	T_2	T_3	T_4	T_5
1	78.28	78.16	77.85	80.46	81.23
2	77.77	73.86	82.95	79.68	79.19
3	79.93	77.77	77.52	79.55	80.88
4	82.43	72.98	79.50	78.41	79.15
5	79.62	75.77	80.20	80.68	79.50
6	78.93	79.19	80.58	79.48	78.41
Mean	79.49^{b}	76.29^{a}	79.77^{b}	79.71^{b}	79.73^{b}
SE	0.67	1.02	0.81	0.33	0.45

CD - 2.77 (P<0.01)

Means bearing the same superscript do not differ significantly

Table 22. Influence of cellulase supplementation on apparent protein digestibility - ANOVA

Source	df	SS	MSS	F value
Treatment	4	55.298	13.825	4.679 **
Error	25	73.862	2.954	
Total	29	129.161		

** Significant (P<0.01)

Table 23. Influence of cellulase supplementation on ether extract digestibility (%)

Bird No.	Dietary treatments				
	T_1	T_2	T_3	T_4	T_5
1	75.25	70.73	74.71	69.84	78.78
2	68.33	72.08	78.86	74.50	80.25
3	71.43	68.14	75.41	79.13	76.10
4	74.53	64.97	77.44	78.97	70.30
5	67.72	70.00	76.10	75.88	76.67
6	74.22	68.96	79.74	74.71	76.42
Mean	71.91^{b}	69.15^{a}	77.04^{b}	75.51^{b}	76.42^{b}
SE	1.34	1.00	0.81	1.40	1.39

CD - 4.74 (P<0.01)

Means bearing the same superscript do not differ significantly

Table 24. Influence of cellulase supplementation on ether extract digestibility - ANOVA

Source	df	SS	MSS	F value
Treatment	4	271.753	67.938	7.689 **
Error	25	220.903	8.836	
Total	29			

** Significant (P<0.01)

extract digestibility was significantly more in the high fibre diet supplemented with 0.06 per cent cellulase and statistically comparable with other enzyme supplemented groups. The high fibre diet (T_2) had a significantly lower ether extract digestablity. No significant difference could be observed between high fibre diet (T_2) and standard layer diet (T_1) in respect of ether extract digestibility.

Digestibility coefficient of fibre fractions

The influence of cellulase supplementation on digestibility of fibre fractions in the rations (Table 25 and 26) was estimated. The digestibility coefficient for acid detergent fibre (ADF) ranged from 22.11 to 28.27 and for neutral detergent fibre (NDF) varied from 28.68 to 36.89. The highest ADF and NDF digestibility values were noted in T_5 while the lowest values were noted in T_2 and T_1 respectively.

The statistical analysis of data presented in Table 27 indicated that the digestibility values of ADF and NDF were not statistically significant among treatments.

Excreta moisture

Per cent moisture content of droppings of different treatment groups as influenced by cellulase supplementation in high fibre diets are presented in Table 28. Moisture content of droppings was highest (82.08%) in birds fed with high

Table 25. Influence of cellulase supplementation on per cent acid detergent fibre digestibility

Bird No.	Dietary treatments				
	T_1	T_2	T_3	T_4	T_5
1	19.36	24.51	24.86	33.70	26.94
2	21.35	20.23	20.27	28.20	27.97
3	23.27	19.50	33.70	16.63	33.16
4	27.58	20.72	24.76	30.37	24.42
5	17.13	20.10	29.38	32.01	21.87
6	27.30	27.60	18.92	27.78	35.23
Mean	22.66	22.11	25.32	28.12	28.27
SE	1.73	1.32	2.26	2.47	2.08

Table 26. Influence of cellulase supplementation on per cent neutral detergent fibre digestibility

Bird No.	Dietary treatments				
	T_1	T_2	T_3	T_4	T_5
1	27.90	33.58	44.46	34.44	39.70
2	35.29	30.56	34.38	35.03	35.94
3	24.95	28.99	40.08	37.03	31.49
4	27.84	34.92	29.42	28.33	38.52
5	23.23	32.95	30.83	32.49	35.22
6	32.98	35.46	26.13	42.88	40.49
Mean	28.68	32.74	34.22	35.03	36.89
SE	1.90	1.03	2.82	1.98	1.37

Table 27. Influence of cellulase supplementation on digestibility co-efficient of fibre fractions - ANOVA

Source	df	SS		MSS		F value	
		ADF	NDF	ADF	NDF	ADF	NDF
Treatment	4	203.01	229.00	50.75	57.25	2.09NS	2.59NS
Error	25	608.68	552.81	24.35	22.11		
Total	29	811.69	781.81				

NS - Not significant

Table 28. Influence of cellulase supplementation on per cent moisture content of droppings

Bird No.	Dietary treatments				
	T_1	T_2	T_3	T_4	T_5
1	77.59	82.98	80.96	73.05	74.22
2	79.95	83.92	75.73	72.50	74.73
3	75.01	80.00	78.50	75.07	72.50
4	79.05	84.08	76.05	70.20	76.00
5	70.04	80.96	70.50	75.00	70.75
6	70.06	80.55	69.95	78.50	77.90
Mean	75.28 [a]	82.08 [b]	75.28 [a]	74.05 [a]	74.35 [a]
SE	1.79	0.73	1.78	1.16	1.03

CD - 5.37 (P<0.01)

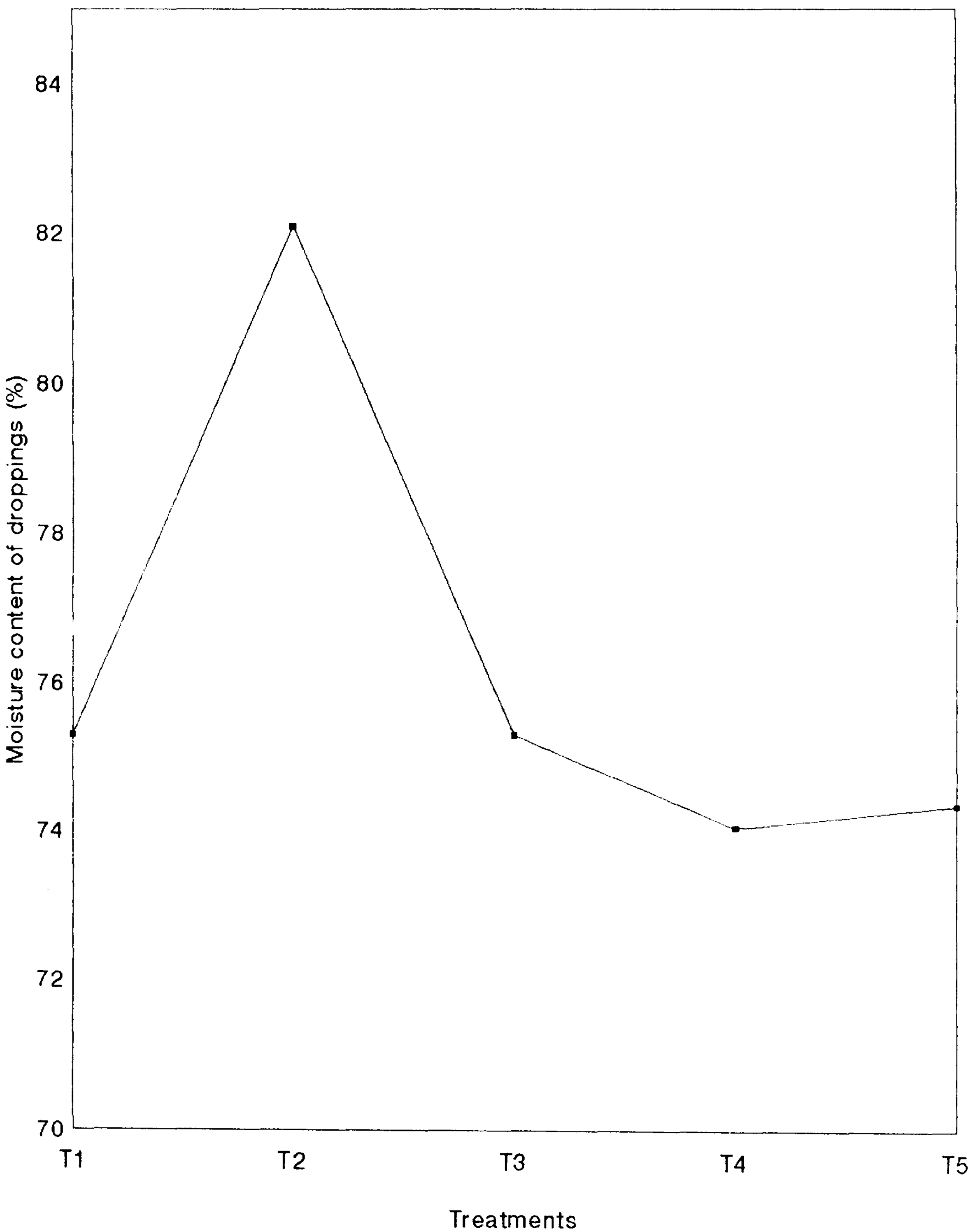
Means bearing the same superscript do not differ significantly

Table 29. Influence of cellulase supplementation on per cent moisture content of dropping - ANOVA

Source	df	SS	MSS	F value
Treatment	4	265.836	66.459	5.960 **
Error	25	278.779	11.151	
Total	29	544.615		

** Significant (P<0.01)

Fig.5 MOISTURE CONTENT OF DROPPINGS AS INFLUENCED BY CELLULASE SUPPLEMENTATION



fibre diet without enzyme (T_2). Addition of varying levels of cellulase in high fibre diets resulted in reduction of excreta moisture to a tune of 7 to 8 per cent. Moisture content of droppings voided by birds fed standard layer mash was more or less similar to that of enzyme fed birds.

The statistical analysis of data (Table 29) showed a significant ($P<0.01$) difference among the treatment groups with respect to excreta moisture content. Significantly higher moisture content of droppings in birds fed with high fibre diet was observed in comparison with all other groups. The T_1, T_3, T_4 and T_5 groups were statistically comparable in respect of moisture content of droppings.

The per cent moisture content of droppings of different treatments as influenced by cellulase supplementation is depicted in Fig.5.

Intestinal viscosity

The effect of cellulase supplementation on the viscosity of intestinal contents was determined and the connected data are presented in Table 30. The mean values for intestinal viscosity were 2.79, 3.08, 1.82, 1.79 and 1.81 for the groups T_1, T_2, T_3, T_4 and T_5 respectively. The results revealed that enzyme addition to feed considerably reduced the intestinal viscosity. Among the enzyme supplemented groups not much variation could be seen in the intestinal viscosity values.

Table 30. Influence of cellulase supplementation on intestinal viscosity

Replicate	Dietary treatments				
	T_1	T_2	T_3	T_4	T_5
1	2.77	3.16	1.73	1.82	1.84
2	2.82	3.18	1.82	1.90	1.73
3	2.77	2.90	1.90	1.64	1.86
Mean	2.79^b	3.08^c	1.82^a	1.79^a	1.81^a
SE	0.02	0.09	0.05	0.08	0.04

CD - 0.27 (P<0.01)

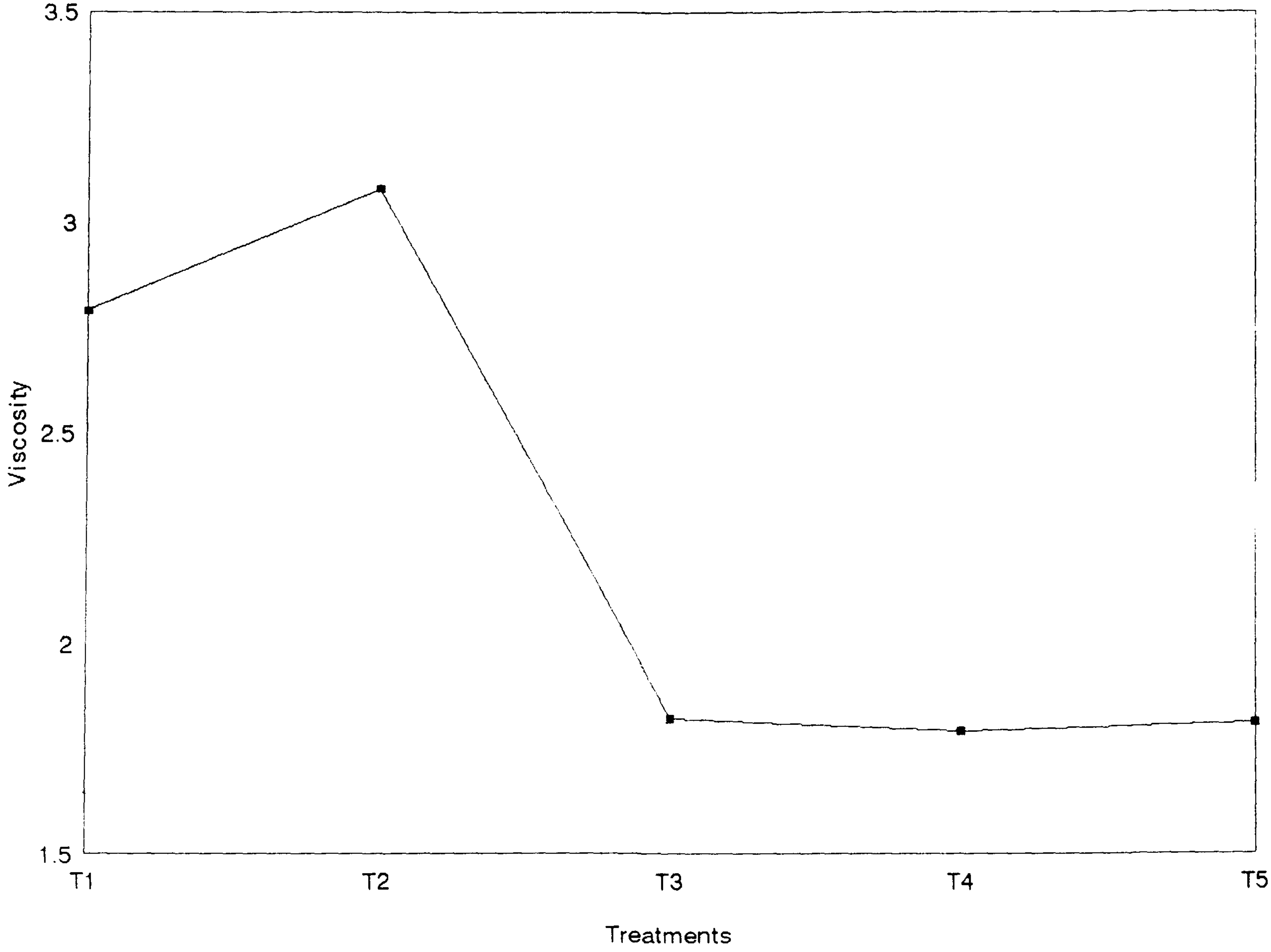
Means bearing the same superscript do not differ significantly

Table 31. Influence of cellulase supplementation on intestinal viscosity - ANOVA

Source	df	SS	MSS	F value
Treatment	4	4.72	1.18	107.04 **
Error	10	0.11	0.01	
Total	14	4.83		

** Significant (P<0.01)

Fig.6 VISCOSITY OF INTESTINAL CONTENTS AS INFLUENCED BY CELLULASE SUPPLEMENTATION



Birds fed with a high fibre diet without enzyme showed the highest viscosity value of 3.08 and a medium value of 2.79 was observed in birds on a standard layer diet.

The statistical analysis of data (Table 31) showed significant differences in intestinal viscosity among treatments. The birds fed on high fibre diet without enzyme and standard layer ration had significantly ($P<0.01$) higher values when compared to enzyme supplemented groups. The intestinal viscosity of standard layer ration fed group was significantly lower than the high fibre fed birds and it was also significantly different from enzyme fed groups. The intestinal viscosity values were statistically comparable among the enzyme supplemented groups.

Viscosity of intestinal contents of different dietary treatments as inflfuenced by cellulase supplementation is presented in Fig.6.

Livability

The influence of cellulase supplementation on survivability of hens was studied based on the mortality pattern observed during the course of experimentation. Mortality of birds occurred in the different treatment groups are shown in Table 32. Altogether five birds died during the course of study. The percentage mortality ranged from a minimum of 3.3 to a maximum of 6.7. There was no mortality in

Table 32. Influence of cellulase supplementation on mortality pattern

Periods	Dietary treatments				
	T_1	T_2	T_3	T_4	T_5
1					
2					
3					
4	1				1
5		1	0	1	1
Total	1	1		1	2
Rate %	3.3	3.3	-	3.3	6.7

the group fed high fibre diet with 0.06 per cent cellulase. Necropsy of dead birds were conducted to detect the causes of death which did not show any signs that are attributable to treatment effect. The overall mortality in the experiment was within the standards prescribed for laying house mortality.

Cost benefit analysis

In order to assess the cost-benefit particulars of supplementation of cellulase enzyme in high fibre diet, the cost of different rations used in the study was calculated based on the actual price of feed ingredients which prevailed at the time of experiment and are presented in Table 33. Cost of rations computed for the different treatments viz., T_1, T_2, T_3, T_4 and T_5 were 5.48, 4.89, 4.97, 5.04 and 5.12 rupees per kg respectively. Among the rations, cost of standard layer diet was the highest (Rs.5.48) and the high fibre diet was the cheapest (Rs.4.89). When graded levels of enzymes were added to the high fibre diet, their costs gradually increased. Even after the addition of different levels of enzyme to the high fibre diets their costs were well below of that of standard layer diet.

The economics of production set out in Table 34 indicated that cost of production of an egg varied from 90.09 to 74.30 paise for the different treatments. Further, it revealed that cost of production of eggs was lower in all enzyme

Table 34. Economics of production

Particulars	Dietary treatments				
	T_1	T_2	T_3	T_4	T_5
Total feed intake (kg)	426.15	452.51	430.30	431.20	421.50
Total number of eggs produced	2592	2690	2878	2782	2704
Feed consumed per egg (g) (21-40 weeks)	164.40	168.20	149.50	155.00	155.90
Cost of feed/kg (Rs.)	5.48	4.89	4.97	5.04	5.12
Cost of feed/egg (Paise)	90.09	82.25	74.30	78.12	79.82

Table 33. Cost of rations without or with enzyme

Ingredients	Cost/kg (Rs.)	Cost of rations per 100 kg				
		T_1 (Rs.)	T_2 (Rs.)	T_3 (Rs.)	T_4 (Rs.)	T_5 (Rs.)
Yellow maize	5.89	247.38	229.71	229.71	229.71	229.71
Rice polish	3.69	55.35	29.52	29.52	29.52	29.50
Deoiled groundnut cake (exp)	7.54	113.10	37.70	37.70	37.70	37.70
Dried fish	8.05	48.30	48.30	48.30	48.30	48.30
Undecorticated sunflower cake	3.00	45.00	105.00	105.00	105.00	105.00
Mineral mixture	6.99	19.22	19.22	19.22	19.22	19.22
Shell grit	3.50	14.00	14.00	14.00	14.00	14.00
Salt	2.25	0.56	0.56	0.56	0.56	0.56
Fiberzyme	125.00	-	-	7.50	15.00	22.50
Vitamins (AB_2D_3K)	437.91	5.25	5.25	5.25	5.25	5.25
Total		548.16	489.26	496.76	504.26	511.76
Cost/kg		5.48	4.89	4.97	5.04	5.12

supplemented groups when compared with standard layer diet and high fibre diet without enzyme addition. The highest cost of production of an egg was noted in groups fed with standard layer ration (90.09 paise) while it was medium in high fibre control group (82.25 paise).

Discussion

DISCUSSION

The results pertaining to the study of cellulase supplementation in high fibre diet on the performance and other related parameters of layer chicken are discussed in this chapter.

Based on the climatic parameters recorded it is evident that the experimental period fall within the normal hot-humid period of Kerala.

Feed intake

The mean daily feed intake per bird in the different dietary treatments ranged from 102.45 to 108.55 g. A perusal of feed intake data presented in Table 5 revealed that birds offered a high fibre diet without enzyme consumed more feed than those fed with a standard layer diet or high fibre layer diets supplemented with different levels of cellulase enzyme. The increase in feed intake in the high fibre layer ration fed birds was to a tune of 4 to 6 g than the other groups. Statistical analysis of feed intake data presented in Table 6 showed that it was significantly more in birds fed with high fibre diet without enzyme than all other groups tested. The lowered feed intake noticed with enzyme supplemented groups has much significance when viewed from the commercial egg production angle.

Since birds consume feed primarily to satisfy their energy requirement, significantly (P<0.01) lesser feed intake noticed in the enzyme supplemented high fibre diets could be due to the availability of more metabolisable energy in these diets when compared with high fibre diet without enzyme addition. However, this has to be adjudged with the AME of high fibre feeds after enzyme addition.

The mean daily feed intake per bird recorded was 96.37, 107.01, 99.78 and 106.00 and 112.24 g for periods, 1, 2, 3, 4 and 5 respectively. Comparatively lower feed intake was noticed during first period (21 to 24 weeks of age) than that recorded for the last period (37-40 weeks of age). Statistical analysis of the data (Table 6) indicated that feed intake in different periods was statistically significant (P<0.01). It was significantly lower during the first period and higher in the fifth period. There was no significant difference in feed intake between first and third period. Likewise, the feed intake between second and fourth period was also comparable. Lowered body weight of pullets during the initial period might have resulted in a lowered feed intake at that time. Apparently lowered egg production during the first period could also have contributed to the lesser feed intake.

Lower feed intake observed in the third period should be corroborated along with egg production and other traits during that period. The present results confirm the observation of Zang Sumin (1996) who reported that addition of 0.5 per cent compound enzyme to the basal diet significantly ($P<0.01$) decreased the feed intake. On the contrary, Satyamoorthy (1995) reported that daily feed intake in birds fed with standard layer and less dense layer diets with cellulase and protease enzymes was not statistically different. On scanning the literature, it could be seen that only limited work has been carried out on the role of feed enzymes on the performance of layer chicken.

Moreover most of the studies reported in the literature are based on compound enzyme preparations rather than single enzyme. Therefore comparison of this trait with other related works become difficult. However, considering the results in the present study and related studies reported by other workers, it is reasonable to presume that cellulase supplementation in high fibre diet reduces the feed intake by improving the availability and utilization of nutrients possibly by acting on the non starch polysaccharides present in the feed.

Egg production

The mean per cent hen-housed and hen-day egg production presented in Tables 7 and 9 respectively revealed that birds maintained on a high fibre diet supplemented with 0.06 per cent cellulase laid numerically more number of eggs than birds on other feeding regimes. Statistical analysis of the data (Table 8 and 10) indicates that the magnitude of differences in hen-housed and hen-day egg production among the various treatments was not substantial to exhibit any statistical difference. Thus it is evident that overall mean egg production among the birds maintained on different types of feeds viz., standard layer ration, high fibre layer ration, high fibre layer rations with 0.06 per cent, 0.12 per cent and 0.18 per cent cellulase was comparable. It was also evident from the tables that the mean hen-housed and hen-day per cent egg production during the first period (21-24 weeks of age) were statistically lower than the subsequent periods (30.93%). Hen-housed egg production during 2nd, 3rd, 4th and 5th period was 71.88, 73.21, 76.21 and 74.45 per cent respectively. The corresponding hen-day egg production was 71.88, 73.21, 77.29 and 77.23 per cent respectively.

Though there were no significant differences in hen-housed and hen-day egg production due to supplementation of cellulase enzyme in high fibre diets, numerical increase in egg production indicates the beneficial response of enzyme addition in layer rations even if the diet contains highly fibrous feed ingredients. The improvement in hen-housed egg production with enzyme supplementation accounts for 4.48, 2.20 and 0.35 per cent in high fibre layer rations with 0.06, 0.12 and 0.18 per cent cellulase respectively. The corresponding improvement in hen-day egg production was 3.95, 2.23 and 1.42 per cent respectively. The results of the present study agrees with Sharma and Katoch (1993) who observed a numerical increase in egg production when a fibre degrading enzyme was supplemented in a diet of 26 weeks old layers. In another study, Satyamoorthy (1995) supplemented cellulase or protease at levels of 0.06 and 0.02 per cent respectively in a standard layer and less dense rations and observed a numerical improvement in per cent hen-day and hen-housed egg production. Similar observations were also made by Gleaves and Dewan (1970), Tishenkova and Serikova (1987), Jayanna and Devegowda (1993) and Mohandas and Devegowda (1993). Significant improvement in egg production with supplementation of sigle or compound enzyme was also reported by Prakash and Devegowda (1993), Brufau *et al.* (1994) and Francesh *et al.* (1995). Thus considering the findings in this study and those reported in literature by others, it can be surmised that beneficial effects in egg production can be achieved by supplementation of cellulase enzyme in layer rations containing high fibre content. It is believed that added enzyme will break the structural barriers in the feed and augument the nutrient utilization which subsequently leads to better performance.

Feed efficiency

The mean feed conversion efficiency (feed per dozen eggs) was 2.37, 2.23, 1.97, 2.15 and 2.18 for the treatment groups T_1, T_2, T_3, T_4 and T_5 respectively (Table 11). The superior feed efficiency among the five treatments was recorded in birds fed with high fibre diet supplemented with 0.06 per cent cellulase (T_3) followed by T_4, T_5, T_2, and T_1. It is apparent from the table that in all the enzyme supplemented groups feed efficiency was better when compared with standard layer diet as well as high fibre diet without enzyme. Further, it was observed that birds fed standard layer ration had numerically inferior feed efficiency. Comparative poor egg production recorded in the first period might have contributed for the lowered feed efficiency observed with the birds maintained on a standard layer diet. However, this trend has to be critically assessed along with the data on other production traits noted in the standard layer diet fed birds.

The statistical analysis of the data on mean feed conversion efficiency (Table 12) revealed that all treatments were statistically comparable in respect of this trait.

However, the numerically superior feed efficiency observed in enzyme supplemented birds points towards the beneficial effects of enzyme addition in feeds containing a high proportion of agricultural by-products which contributes high fibre level and resultant more NSPs.

When the period-wise feed efficiency data was assessed it showed that in the first period the efficiency was poor (4.04). However, in all subsequent four periods, the feed efficiency was more or less comparable and are well within the normal limits for the egg type birds. In all the treatments, most of the birds came to production only during the later part of first period. This could have contributed for the poor feed efficiency observed in the first period. Statistical analysis of period-wise feed efficiency data revealed that this trait was significantly ($P<0.01$) poorer during the first period than other periods. Variations in the feed efficiency values among the subsequent periods were too narrow to exhibit any statistical difference.

Improvement in the feed efficiency due to the addition of single enzyme or the compound enzyme have been reported by many workers (Rexen, 1981; White *et al.*, 1981; Hijikuro and Takemasa, 1982; Baranauskas, 1988; Aimonen and Nasi, 1991; Francesh *et al.*, 1995; Satyamoorthy, 1995).

In the present study also feed efficiency was numerically better with supplementation of different levels of cellulase in high fibre diet. However, the differences observed in feed efficiency among the treatments were small to show any significant difference. Absence of any significant difference in feed efficiency among the cellulase supplemented birds observed in this trial could be due to a very high fibre content in the basal diet (12.1%) or due to the nature of fibre in the diet. Further studies in this direction may throw more information on this aspect.

Body weight gain

The data on body weight gain are set out in Table 13. The mean gain in body weight was 0.21, 0.16, 0.22, 0.24 and 0.19 kg for treatments T_1, T_2, T_3, T_4 and T_5 respectively. Statistical analysis of data on body weight gain (Table 14) revealed that birds fed with a high fibre layer ration supplemented with 0.12 per cent cellulase attained significantly ($P<0.01$) more gain in body weight than those maintained in a high fibre diet without enzyme. It was also apparent that gain in body weight of birds fed on high fibre diet supplemented with different levels of cellulase and those fed with standard layer ration were statistically comparable. Likewise, body weight gain was statistically similar among birds maintained on high fibre layer diet, standard layer diet and high fibre diet with 0.06 and 0.18 per cent added cellulase. Thus it is evident that though enzyme supplementation did have a positive significant influence on gain in body weight, it was not consistent with different levels of enzyme tested. This trend of results has to be corroborated with the findings of other works related with enzyme supplementation in layer diets. Unfortunately, most of the works pertaining to this trait has been carried out in broiler chicks and growing egg type chicks. Satyamoorthy (1995) observed that cellulase and protease supplementation did not have any significant influence on body weight gain of White Leghorn layers. Tishenkova and Serikova (1987) studied the effect of multienzyme on layer diet containing barley and wheat and obtained an increase in body weight gain. It was also evident that enzymes did have a positive response in body weight gain when it is mixed with the feed low in nutrients. Based on this observation, it is apparent that improvement in body weight gain will not only depend upon the type and proportion of the ingredients used in the formulation of diet but also the type of enzymes supplemented.

Egg weight

Egg weight is also a trait which determines profitability and it is related to marketability of eggs. Small and medium sized eggs fetch a relatively lesser price. This factor should be borne in mind while discussing about this trait.

A perusal of the data on egg weight (Table 15) revealed that, irrespective of the treatments, the general egg weight recorded in this study cannot be considered as optimum for egg type birds. The experimental birds used in this investigation belonged to 'F' strain of white Leghorn maintained in the University Poultry Farm, Mannuthy. Keeping the stock without selection over a number of generations in the past could have contributed for the lower egg weight recorded in this trait. Since 'F' strain is being maintained in the farm primarily as the female line in the production of Astrawhite chicks, best suited for backyard rearing, weightage has not been paid in the past for egg weight.

Statistical analysis of egg weight data (Table 16) indicated that this trait was not significantly influenced by enzyme supplementation. The maximum variation observed in egg weights among the various treatments was 0.49 g. It was also apparent from the table that as age advanced, egg weight also increased. Statistical analysis indicated a significant difference in egg weight with respect to periods. It was significantly lower in the first period and was different from all other periods. Egg weights recorded in the 2nd and 3rd period were statistically comparable and was different from other periods. The egg weight observed in the 4th period was significantly higher than the first three periods and was different from 5th period. Significantly highest egg weight was noted in the 5th period. A critical analysis of the mean egg weight data showed that all the eggs laid by birds in the first period (21 to 24 weeks of age) in the different feeding regimes were under the 'small' category (38 to 44.9 g). The results also indicated that in the subsequent four periods birds laid only medium sized eggs (45 to 52.9 g) and not even touched the 'large' eggs mark (53 to 59.9 g). It was also apparent that the transformation of medium to large sized eggs did not occur upto 40 weeks of age.

The results of the present study closely agrees with Satyamoorthy (1995), who opined that cellulase and protease enzymes supplementation at 0.06 and 0.02 per cent respectively in a standard layer and less dense layer diets did not have any significant influence on egg weight. On the other hand. Brufau *et al.* (1994) could observe an improvement in egg size with supplementation of fungal enzyme in barley based diets. Francesh *et al.* (1993) and Zang Sumin *et al.* (1996) also reported that supplementation of compound enzyme preparation in laying hen diets resulted in significant improvements in egg size. The positive results in egg weight observed in the above studies could be due to the application of compound enzyme preparations, since it is common for mixtures of enzymes to produce better results. In the present study the enzyme product used was a compound which contained primarily cellulase.

Nutrient utilization

Chickens being monogastric animals, only small quantity of essential amino acids and vitamins are synthesised in their gastro-intestinal tract, thereby depending mainly on the type of diet being provided to them. All the essential nutrients in adequate amounts and in optimum ratio must be present in an available form to promote maximum growth rate, optimum egg production and reproduction with better feed utilization efficiency. The incorporation of agricultural by-products and other feed stuffs having high fibre content in poultry rations hamper the bio-availability of essential nutrients. Fibres and various non-starch polysaccharides are the most important antinutritional factors in poultry diet. It is well known that insoluble fibre tends to increase transit time and form an insoluble coat which decreases the digestibility of nutrients. The soluble fibres slow down the transit time of feed and their gelling characters retards digestion and absorption of nutrients. In the present context, the role of feed enzymes in improving the feeding value of high fibre low energy feed stuffs should be considered in tune with the above observations.

The digestibility of dry matter, AME, APD, ether extract and ash digestibility and digestibility of fibre fractions namely ADF and NDF of the feed used in different treatments were determined to assess the improvement, if any, in the nutrient availability due to supplementation of cellulase in high fibre layer diet.

The mean dry matter digestibility (Table 17) ranged from 68.13 to 70.81 per cent for the different dietary treatments. The highest dry matter digestibility was noticed in high fibre control diet (T_2) and lowest in standard layer ration (T_1) and it was medium with enzyme supplemented groups. Perusal of the statistical analysis of the data presented in Table 18 revealed no significant differences among treatments with respect to dry matter digestibility.

The mean AME value in Table 19 showed that the lowest value of 2522.67 Kcal/kg was recorded with high fibre control diet (T_2). It was also evident from the table that as the level of cellulase supplementation in high fibre diet increase there were corresponding improvements in AME values. Addition of 0.06, 0.12 and 0.18 per cent cellulase in high fibre diets resulted in an improvement of 86.16, 126.00 and 142.00 Kcal ME per kg respectively as compared with high fibre control diet.

Statistical analysis of AME values (Table 20) revealed significant differences among treatments. Significantly (P<0.01) lower AME value was noticed in high fibre layer ration. Further it was noticed that AME content of standard layer diet and enzyme supplemented high fibre diet were statistically comparable. The findings of this study clearly indicate that addition of cellulase enzyme in high fibre diet results in an improvement in AME value. Significantly lower feed intake noticed in the groups fed with high fibre diet containing various levels of cellulase than the high fibre diet without cellulase confirms this finding.

The crude protein content of standard and high fibre layer rations was 18.10 and 18.30 per cent respectively (Table 2). The mean apparent protein digestibility (APD) for the treatments T_1, T_2, T_3, T_4 and T_5 was 79.49, 76.29, 79.77, 79.71 and 79.73 per cent (Table 21) respectively. It is evident from the table that the APD was lower in high fibre diet without cellulase supplementation than the other diets. The APD values of other diets were almost comparable. The statistical analysis of data (Table 22) confirms this trend. The high fibre diet without cellulase had a significantly (P<0.01) lower APD than the other diets. A similar trend was noticed with respect to ether extract digestibility also (Table 23). It was significantly (P<0.01) more in high fibre diet supplemented with 0.06 per cent cellulase than high fibre control and standard layer diet fed groups. It was statistically comparable among enzyme supplemented groups. However, no significant difference in ether extract digestibility was observed between high fibre and standard layer diets (Table 24).

The digestibility of fibre fractions as influenced by cellulase supplementation was studied by estimating digestibility of ADF and NDF. The mean digestibility of ADF (Table 25) revealed that it ranged from 22.11 to 28.17 per cent. It is apparent from the table that cellulase addition in high fibre diet resulted in an improvement in the digestibility of ADF. However, when the magnitude of differences were tested statistically (Table 27), it was not found to be significant. Though numerical increase in digestibility of NDF was observed due to cellulase supplementation (Table 26), no significant differences could be observed among treatments (Table 27). The trends in the digestibility of fibre fractions namely ADF and NDF due to cellulase supplementation were almost comparable.

An overall assessment of the digestibility co-efficient of nutrients indicated a clear positive response in nutrient availability due to cellulase supplementation in high fibre diets. Enzyme addition significantly ($P<0.01$) improved the

AME value of diet and digestibility co-efficient of crude protein and ether extract. In addition, enzyme supplementation also resulted in an apparent improvement in the digestibility of ADF and NDF. This trend of results is in close agreement with those reported in the literature. Addition of cellulase enzyme to barley or rye based diet resulted in an increase in metabolisable energy values of diets (Hijikuro and Takemasa, 1982 and Broz, 1987). Friesen (1991) observed that addition of cellulase in rye based broiler diets resulted in an increase in the dietary ME by 23 per cent and APD by 12 per cent. Aimonen and Nasi (1991) and Friesen (1992) reported that addition of multienzymes improved the AME value, APD and apparent lipid digestibility of poultry diets. Improvements in nutrient availability due to addition of single or compound enzyme preparations was also reported by Wantia (1993), Flores (1994), Marquardt (1994), Swain and Johri (1994), Satyamoorthy (1995) and Vranjes and Wenk (1995).

In the present study addition of 0.06, 0.12 and 0.18 per cent cellulase in high fibre diets gave an increase of 86.16, 126 and 142 Kcal of AME per kg, 3.34, 3.42 and 3.44 per cent improvement in APD and 7.89, 6.39 and 7.27 per cent improvement in ether extract digestibility respectively, when compared with unsupplemented high fibre control diet. Considering this result, it is reasonable to conclude that bioavailability of nutrients can be improved by supplementation of cellulase enzyme in diets having a high fibre content. Since all plant derived feedstuffs contain some quantity of NSPs derived primarily from the cell wall, supplementation of cellulase enzyme in feed may cause breaking down of these cell walls and thereby increasing the relative concentration of digestible nutrients and consequent improved performance. It is believed that the enzymes will not only improve the digestibility of cereal grains which is the source of antinutrients but also digestibility of other dietary components. However, more elaborate studies with appropriate enzymes are warranted to gather further information on this aspect.

Excreta moisture

The data on per cent moisture content of droppings presented in Table 28 revealed that supplementation of cellulase enzyme reduced 6 to 8 per cent of the moisture content of droppings of birds fed with high fibre diet. The statistical analysis of data (Table 29) showed that the excreta moisture reduction due to enzyme supplementation was significant ($P<0.01$). It was also observed that birds fed with high fibre diet voided droppings of significantly higher moisture content. High fibre content of diet may cause high level of NSPs. These NSPs cannot be utilised by the birds as their digestive secretions do not have relevant enzymes to hydrolyse them, which may hold more water content and void as wet droppings. Addition of enzyme might have probably acted upon these NSPs and increased their digestibility and reduced the moisture holding capacity which resulted in dry faeces.

Reduction in the excreta moisture content with supplementation of single or multienzyme preparations was reported by Campbell *et al.* (1987), Devegowda and Nagalakshmi (1992), Jayanna and Devegowda (1993), Mohandas and Devegowda (1993) and Francesh *et al.* (1994). Francesh *et al.* (1995) found that high doses of multienzyme preparations improved the excreta quality in laying hens. Satyamoorthy (1995) also reported that cellulase and protease enzyme supplementation in standard and less dense layer rations resulted in an apparent reduction in the moisture content of excreta.

Intestinal viscosity

The mean intestinal viscosity values, as influenced by supplementation of cellulase in high fibre diet (Table 30) indicated that it was highest in birds fed with high fibre diet (3.08). It was also revealed that supplementation of cellulase enzyme resulted in a reduction of gut viscosity. Birds fed with standard layer diet had an intestinal viscosity of 2.79. When the data on intestinal viscosity were subjected to statistical analysis (Table 31), significant differences existed among the treatments. It was significantly (P<0.01) lower in birds fed with high fibre diet supplemented with varying levels of cellulase and significantly higher in birds receiving high fibre diet without enzyme. The intestinal viscosity of birds offered a standard layer diet was medium and was significantly different from the other groups. It was also evident that irrespective of different levels of cellulase used, the intestinal viscosity values of enzyme supplemented groups were statistically comparable.

On reviewing the literature, it was seen that the effect of feed enzymes on viscosity of intestinal contents are mostly related to works carried out with broilers and chicks. Hesselman and Aman (1986) and Bedford *et al*. (1991) observed that soluble indigestible polysaccharides in the feed deteriorate digestion and absorption of organic feed components by increasing the viscosity of the fluid phase of the intestinal contents. Bedford and Classen (1992a, 1992b) reported that enzyme xylanase supplementation in wheat based and beta-glucanase in barley based diets significantly reduced the viscosity of intestinal contents.

Bedford (1995) stated that both beta-glucans and arabinoxylans exerted their negative effects on digestion in poultry by increasing the intestinal viscosity and that addition of relevant enzymes could alleviate this condition. Supplementation of cellulase and protease enzymes in standard and less dense layer rations resulted in reduction of viscosity of intestinal contents (Satyamoorthy, 1995).

Reduction in the viscosity of intestinal contents with supplementation of cellulase enzyme observed in the present study is in full agreement with those reported by other workers. As the intestinal viscosity increases with high NSPs in feed, a reduction in digestion of feed occurs and with the result lowered performance of birds are encountered. The NSPs are thought to create viscous solution by aggregating into large networks as a result of entanglements of large polymers (Bedford, 1995). As the dietary concentration of crude fibre increases, the concentration of high molecular weight carbohydrates in the intestine increases which results in increased viscosity and ultimately reduced performance of birds.

Supplementation with the required enzymes may break the large polymers into shorter ones and thereby reducing the viscosity of intestinal contents causing an improvement in the digestion and absorption of nutrients.

Livability

The data on the mortality pattern of birds under the different dietary treatment groups presented in Table 32 revealed that it ranged from 3.3 to 6.7 per cent. During the entire course of the experiment covering 20 weeks only five birds died. No mortality was observed in birds fed with high fibre diet supplemented with 0.06 per cent cellulase. Groups fed with standard layer diet, high fibre diet without enzyme and with 0.12 per cent cellulase recorded mortality of one bird each and two birds in the groups fed with higher fibre diet with 0.18 per cent added enzyme. Necropsy findings revealed that four birds died due to non-specific enteritis and one bird due to heat stroke. Thus it is evident that cellulase supplementation did not have any detrimental effects on the physiological well being of laying hens.

Marek *et al.* (1992) evaluated cellulase supplementation on the performance of broiler chickens fed with high roughage diet and reported that per cent mortality was not affected by either enzyme or level of roughage inclusion.

Satyamoorthy (1995) also could not observe any harmful effects on the survivability of hens when they were fed standard and less dense rations supplemented with cellulase and protease enzyme.

Cost-benefit analysis

The cost of different rations employed in the experiment (Table 33) revealed that standard layer diet formulated as per BIS specification was costlier than others. Incorporation of high fibre ingredient (decorticated sunflower cake) at higher level enhanced the fibre content to 12 per cent in the total ration but reduced the cost of ration by 59 paise per kg. However, supplementation of cellulase enzyme to high fibre diet enhanced the cost of ration in proportion to the level of enzyme addition. But even with higher level of enzyme incorporation (0.18%) the cost was 36 paise per kg lesser than standard ration.

When the cost of egg production based on feed cost alone was calculated (Table 34), it was observed that compared to standard ration all other rations were cheaper, the cheapest being the diet supplemented with 0.06 per cent cellulase enzyme.

The economic analysis points to the fact that enzyme addition can be used as a means of reducing feed cost as well as egg production cost.

Summary

SUMMARY

An investigation was taken up at the University Poultry Farm, Mannuthy, using one hundred and fifty Single Comb White Leghorn pullets of 'F' strain at 21 weeks of age to assess the influence of cellulase supplementation in high fibre diets on production performance and on nutrient availability of laying hens. The pullets were randomly distributed into five dietary treatments with each treatment having three replicates of 10 birds each. The dietary treatments consisted of standard layer ration (T_1), high fibre layer ration containing 12 per cent CF (T_2), high fibre layer rations with 0.06, 0.12 and 0.18 per cent cellulase supplementation (T_3, T_4 and T_5) respectively. All the diets were formulated as per BIS specification except the level of crude fibre in high fibre layer rations.

Feed ingredients used in the formulation of experimental diets were similar. However, the level of undecorticated sunflower cake was enhanced in order to obtain the desired level of crude fibre in high fibre layer rations. The birds were housed in individual cages. Standard managemental procedures were adopted throughout the experimental period. The duration of the experiment was five, 28-day periods covering 21-40 weeks of age. The body weight of individual birds was recorded at the beginning and at the end of the

experiment. Daily feed intake and egg production were recorded. All the eggs collected during the last three consecutive days of each 28-day period were weighed individually to arrive at the mean egg weight. From these data daily feed intake per bird, per cent hen-housed and hen-day egg production, feed conversion efficiency (feed per dozen-eggs), mean egg weight and body weight gain for the different treatments were worked out.

At the end of the experimental period a metabolic trial was conducted using six birds from each treatment. Total collection method was employed. Based on the data obtained from the metabolic trial apparent metabolisable energy and nutrient digestibility viz., dry matter digestibility, apparent protein digestibility, ether extract digestibility and digestibility of fibre fractions were calculated. Six birds from each treatment were sacrificed to study the intestinal viscosity. Mortality of the birds were recorded. Cost-benefit analysis due to cellulase supplementation was worked out by calculating the cost of egg production based on feed cost alone.

The overall performance of the birds fed different dietary regimen are presented in Table 35.

Based on the results of this study following observations were made.

1. The mean daily feed intake per bird in the different dietary treatments ranged from 102.45 to 108.55 g. Daily feed intake per bird was significantly higher ($P<0.01$) in birds fed with high fibre diet without cellulase enzyme than all other groups. Daily mean feed intake per bird was statistically comparable among the groups fed a high fibre diet with different levels of cellulase and with standard layer ration fed group. Daily feed intake showed significant differences among periods.

2. Enzyme supplementation caused a numerical increase in egg production. The improvement in hen-housed egg production with enzyme supplementation accounts to 4.48, 2.20 and 0.35 per cent on high fibre layer rations with 0.06, 0.12 and 0.18 per cent cellulase respectively. The corresponding improvement in hen-day egg production was 3.95, 2.23 and 1.42 per cent respectively. However, cellulase supplementation did not have any significant influence on hen-housed and hen-day egg production. The differences in hen-housed and hen-day egg production per cent among the different experimental periods were statistically significant.

3. There were no significant differences among various treatment groups with respect to feed per dozen eggs, whereas, it differed significantly between periods.

Numerically better feed efficiency was observed with all the enzyme supplemented groups when compared with standard layer diet as well as high fibre diet without enzyme.

4. Birds fed with a high fibre layer ration supplemented with 0.12 per cent cellulase attained significantly ($P<0.05$) more body weight than those maintained on a high fibre diet without enzyme. The gain in body weight of birds fed on high fibre diet supplemented with different levels of cellulase and those fed with standard layer ration was statistically comparable.

5. Cellulase supplementation did not have any significant influence on mean egg weight. The maximum variation observed in egg weights of various treatment was 0.49 g.

6. Though there were variations in the dry matter digestibility of different rations it was not found to be statistically significant.

7. Addition of 0.06, 0.12 and 0.18 per cent cellulase in high fibre diets resulted in an improvement of 86.16, 126.00 and 142.00 Kcal ME per kg respectively as compared with high fibre control diet. The high fibre layer ration without enzyme had significantly ($P<0.01$) lower

AME value than the rations supplemented with 0.12 and 0.18 per cent enzyme.

8. Apparent protein digestibility was significantly (P<0.01) lower in high fibre diet without cellulase supplementation than standard layer diet and high fibre diets supplemented with varying levels of cellulase.

9. Ether extract digestibility was significantly (P<0.01) more in high fibre diet supplemented with 0.06 per cent cellulase than high fibre control and standard layer diet fed groups.

10. Though numerical increase in the digestibility of fibre fractions, viz., ADF and NDF was observed due to cellulase supplementation, differences were not significant among treatments.

11. Supplementation of cellulase enzyme significantly (P<0.01) reduced the moisture content of droppings of birds fed with high fibre diet. Excreta moisture was significantly higher in high fibre fed birds.

12. The viscosity of intestinal contents was significantly (P<0.01) lower in birds fed with high fibre diet supplemented with varying levels of cellulase. It was significantly higher in birds receiving high fibre diet

without enzyme and was medium in birds fed with standard layer diet.

13. The survivability of laying hens was not affected by cellulase addition in their diet.

14. The cost of production of an egg varied from 90.09 to 74.30 paise for the different treatments. Cost of production of eggs was lower in all enzyme supplemented groups when compared with standard layer diet and high fibre diet without enzyme addition. Even with higher level of enzyme incorporation in the high fibre feed the cost of feed was 36 paise per kg lesser than standard ration.

15. Among the different levels of cellulase tested incorporation at 0.06 per cent was found to be optimum.

Based on the results of this study it can be inferred that the fibre level in layer ration using normal dietary ingredients can be raised upto 12 per cent and that incorporation of cellulase will not only enhance the nutrient utilisation in higher fibre diet but also will counteract the high excreta moisture and high intestinal viscosity normally encountered with high fibre diets in poultry. Cellulase supplementation may offer scope for incorporation of higher levels of agro-industrial by-products in poultry ration thereby opening an avenue for lowering feed cost.

Table 35. Influence of cellulase supplementation on overall performance of White Leghorn layer chicken

Parameters	Dietary treatments				
	T_1	T_2	T_3	T_4	T_5
Mean feed intake per bird per day (g)	104.39	108.55	102.45	103.42	102.59
Mean hen-day egg production (%)	64.65	64.57	68.52	66.80	65.99
Mean feed efficiency (kg feed/dozen eggs)	2.37	2.23	1.97	2.15	2.18
Mean egg weight (g)	47.66	48.01	47.90	48.15	47.88
Excreta moisture (%)	75.28	82.08	75.28	74.05	74.35
Intestinal viscosity	2.79	3.08	1.82	1.79	1.81
Mortality rate (%)	3.30	3.30	Nil	3.30	6.70
Cost of feed (Rs./kg)	5.48	4.89	4.97	5.04	5.12
Feed cost per egg (Paise)	90.09	82.25	74.30	78.12	79.82

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CELLULASE SUPPLEMENTATION IN HIGH FIBRE DIET ON THE PERFORMANCE OF LAYER CHICKEN

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ABSTRACT

The effect of three levels of cellulase enzyme viz., 0.06, 0.12 and 0.18 per cent in high fibre layer rations on production performance and on nutrient availability of egg type chicken was evaluated using one hundred and fifty 'F' strain of Single Comb White Leghorn Pullets of 21 week of age for a period of 20 weeks. The birds were divided into five dietary treatment groups viz., standard layer ration (T_1), high fibre layer ration (T_2), high fibre layer ration with 0.06 per cent cellulase (T_3), high fibre layer ration with 0.12 per cent cellulase (T_4) and high fibre layer ration with 0.18 per cent cellulase (T_5). Standard layer ration (SLR) was formulated as per BIS (1992) specification for chicken layers. The high fibre layer ration was similar to SLR except the level of crude fibre which was enhanced to 12 per cent. The inclusion level of undecorticated sunflower cake was enhanced in order to obtain the desired level of crude fibre in the high fibre layer ration. The mean daily feed intake per bird was significantly ($P<0.01$) higher in birds fed high fibre diet without enzyme and was different from all other groups. A numerical improvement in per cent hen-day and hen-housed egg production was noticed among enzyme supplemented groups. However, the increase was not statistically significant.

Numerically superior feed efficiency was observed with all the enzyme supplemented groups when compared with standard layer diet as well as high fibre diet without enzyme. However, the differences among various treatments in feed per dozen eggs were not statistically significant. The gain in body weight of birds fed on high fibre diet with 0.12 per cent cellulase was significantly ($P<0.05$) higher than unsupplemented high fibre diet. Body weight gain was statistically comparable among birds fed on high fibre diet supplemented with different levels of cellulase and those fed with SLR. Cellulase supplementation did not have any significant influence on mean egg weight. Cellulase addition did not improve the dry matter digestibility. The apparent metabolisable energy (AME) values were significantly ($P<0.01$) higher in birds fed with high fibre diet supplemented with 0.12 and 0.18 pre cent cellulase than unsupplemented high fibre control. The AME values of standard layer and enzyme fed groups were statistically comparable. Cellulase supplementation significantly ($P<0.01$) improved the apparent protein digestibility and ether extract digestibility when compared with high fibre control. Though numerical increase in the digestibility of fibre fractions viz., ADF and NDF was observed due to cellulase supplementation, differences were not significant among treatments. Supplementation of cellulase enzyme significantly ($P<0.01$) reduced the moisture content of droppings when compared with unsupplemented high fibre diet. The viscosity of intestinal contents was significantly lower ($P<0.01$) in birds fed with high fibre diet supplemented with varying levels of cellulase. Cost of production of eggs was lower in all enzyme supplemented groups when compared with standard layer diet and high fibre diet without enzyme addition.

Based on the above findings, it can be concluded that cellulase supplementation in high fibre layer ration is beneficial especially when fibrous agricultural by-products are used as alternate feed ingredients in the chicken diet.