INFLUENCE OF CELLULASE SUPPLEMENTATION ON THE PERFORMANCE OF BROILERS FED LOW ENERGY DIET

BY
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THESIS

Submitted in partial fulfilment of the requirement for the degree

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DECLARATION

I hereby declare that the thesis entitled "**INFLUENCE OF CELLULASE SUPPLEMENTATION ON THE PERFORMANCE OF BROILERS FED LOW ENERGY DIET**" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

Mannuthy
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CERTIFICATE

Certified that the thesis, entitled "**INFLUENCE OF CELLULASE SUPPLEMENTATION ON THE PERFORMANCE OF BROILERS FED LOW ENERGY DIET**" is a record of research work done independently by **Shri. S.P. Muthukumar**, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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Dedicated

To My Parents,

whose unfailing love has always inspired me

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Introduction

1. INTRODUCTION

During the last few decades, the Indian poultry industry has shown spectacular growth from backyard production to modern intensive systems. The broiler industry has expanded from a mere 3 million in 1970 to 30 million in 1980 and was projected to 330 million broilers in 1995 (Anon, 1994). Based on this growth rate, production is expected to reach over 1400 million broilers by the turn of this century. The per capita consumption of poultry meat could then increase from the current 520 g per annum to approximately 1500 g per annum by 2000 AD. This stands as a telling statement of the sheer growth potential of the broiler industry. Based on the anticipated growth of the industry in the coming years there will be a definite increase in the export of meat and their byproducts.

We are looking at an industry that will multiply by atleast two to three times over the next 5 to 6 years. Considering this enormous growth potential in poultry production, one can wonder whether the country will be able to supply enough feed. It is needless to say that feed is one of the most important factor in poultry production since it alone constitutes a major part of the total production cost. At present the country has to meet the demand of about 6 million tonnes of feed per annum for the industry. Very often the issue being raised is that poultry compete with human beings in their requirement of feed ingredients. Also any feedstuff which is being initially used as an ingredient for poultry feed, rapidly becomes main input for some emerging industries thereby making it disadvantageous to poultry industry on cost front (Iqballuddin, 1996).

There are large number of unconventional resources not tried or tried with little success in poultry feeding. Since poultry being monogastric, the physiological limitations restrict them from the utilization of fibrous feeds rich in non-starch polysaccharides (NSPs) like cellulose, hemicellulose, beta-glucans etc. and affect metabolisable energy values negatively by "locked-up energy" (Rakshit and Rao, 1994). The non-starch polysaccharides in some cereals have a distinct anti-nutritional effect in chicken. They may also inhibit activity of the endogenous enzymes and resist digestion of some nutrients. Intensive research on this topic introduced an innovative biotechnological tool "feed enzymes" to maximise nutrient availability of alternate feedstuffs. These enzymes in the feed help to release the energy locked up and also other nutrients masked by the structural barrier in the form of cell wall carbohydrates.

The successful use of enzymes in this branch of the poultry industry has stimulated interest in the application of enzymes to a wide range of alternate feed sources for poultry. The enzymes such as cellulase, hemicellulase and beta-glucanase by the partial cleavage of NSPs, remove the anti-nutritive activity in cereal based diets for poultry. The benefits of using enzymes in poultry diets include not only enhanced bird performance and feed conversion, but also less environmental problems due to sticky droppings and reduced output of excreta. Increased accuracy and flexibility in least-cost feed formulation and improved well-being of the birds are other possible benefits of using feed enzymes in poultry diets. Therefore, use of grains and their by-products having high NSPs as energy sources, a more efficient utilization of cereal by-products, industrial wastes and elimination of specific anti-nutritive factors have received increasing attention from the scientists working on this field (Choet, 1997).

Considering the increasing cost of conventional feed ingredients and growing needs from other industries, a number of agricultural by-products and their combinations have been used in poultry ration viz., deoiled rice bran, wheat bran etc., which are available at fairly low prices. In order to improve the availability of nutrients of these low energy, high fibre feed stuffs, several enzyme supplements have been tried. Commercial preparations of cellulolytic enzyme alone or with some of the other enzymes have been found effective in the chemical alteration of low energy high fibre feedstuffs, resulting in the improvement of metabolisable energy and nutrient digestibility to a considerable extent.

In view of this, the present study was undertaken to assess the influence of cellulase supplementation on the performance of broiler chicken fed diet low in metabolisable energy and the economics involved.

Review of Literature

2. REVIEW OF LITERATURE

Enzymes play a vital role in the functioning of biological systems as catalysts for chemical reactions. As such, they can participate in a wide range of reactions under diverse environmental conditions. This is particularly true for enzymes derived from bacteria and fungi because of their importance in the cycling of organic matter in nature. Enzymes used in animal feed are primarily derived from bacterial or fungal action. Successful application of enzyme technology relies on knowledge of the chemical reaction to be affected and the conditions under which the reaction will occur. It is possible to improve the feed utilization by the use of these feed enzymes in poultry diet. Here, an attempt has been made to provide a review of the available literature related with supplementation of cellulase and allied enzyme products on the performance of broiler chicken and other related parameters.

2.1 Body weight

Berg (1961) found that in chicks fed a diet containing barley adding a bacterial enzyme preparation containing cellulase increased growth rate upto 8 weeks of age.

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

Rexen (1981) reported that chicks fed on barley based diets with cellulase and/or pectinase or protease showed a significant ($P<0.05$) increase in weight gain upto 7 per cent.

White *et al.* (1981) added a cellulose degrading enzyme to a barley ration fed to chicks and reported 19 per cent improvement in growth.

Hijikuro and Takemosa (1982) observed that in chicks given a high barley diet with cellulase at 0.1 per cent level significantly increased weight gain.

Isshiki and Nakahiro (1983) demonstrated greater daily weight gain in cockerels fed on diets containing enzymes (including cellulase) than in birds given the conventional stock diet only.

Reese *et al.* (1983) gave meat type chicks normal diet with Driselase-20 from hatching to 42 days and improved gain in body weight was recorded.

Nahm and Carlson (1985) concluded that the addition of cellulase in broilers neither result in a significant growth response nor impair growth.

Tishenkova and Serikova (1987) reported that the addition of multienzyme Tselloviridin-G3x having cellulase and hemicellulase activity, brought an increase in per cent body weight gain in broiler chicks.

Alisheikov *et al.* (1988) stated that inclusion of multi enzyme containing cellulolytic activity in mixed feed based on maize and wheat for egg-line chicks improved daily body weight gain.

Rotter *et al.* (1989) reported that cellulase supplementation to barley diet fed to Leghorn and broiler chicks improved weight gain by 11.1 and 11.2 per cent respectively.

Al-Zubaida *et al.* (1990) conducted an experiment on broiler chicken from 4 to 8 weeks with cellulase and found increase in body weight over unsupplemented controls.

Kumprecht *et al.* (1990) reported an increased body weight in broiler chicken of 3 and 7 weeks old, by supplementing cellulase P-10 enzyme in feed mixtures.

Tishenkova and Selivanova (1990) in an experiment with supplementation of Ekonaza (which hydrolyses cellulose) on a diet based on maize and barley registered increase in average body weight at 7 weeks old.

Arora *et al.* (1991) studied the influence of broiler diets with Novozyme SP-243 and observed that the weight gain was significantly improved in enzyme supplemented group than controls at 8 weeks of age.

Avinash (1991) tested the effect of Selfeed, an enzyme mixture containing cellulase on broiler chick at 0.05 and 0.1 per cent and noticed improved weight gain.

Bhatt *et al.* (1991) evaluated the influence of Novozyme SP-243, a fibre degrading enzyme on broiler chicks and reported that body weight was significantly ($P<0.05$) higher with enzyme supplemented groups.

Brufau *et al.* (1991) added enzyme cellulase in pelleted barley based broiler diets and observed significant improvement in weight gain by 2.7 per cent throughout the experiment.

Friesen *et al.* (1991) concluded that addition of *Trichoderma viridae* cellulase at the rate of 3.2 g/kg feed, yielded increase in weight gain of 193 per cent compared with that of the unsupplemented control diet fed to broilers.

Significant increase ($P<0.05$) was observed for average live weight and weekly weight gain in broilers fed with enzyme Selfeed upto 7 weeks (Kadam *et al.*, 1991).

Devegowda and Nagalakshmi (1992) supplemented a multienzyme (cellulase) preparation in broiler diet and found significant improvement in weight gain.

Jeroch (1992) demonstrated increase in body weight gain in broiler chicks given rye based diets supplemented with Bergazym-H (cellulolytic and hemicellulolytic enzymes) at 0.01 and 0.02 per cent.

Marek and Splitek (1992) studied the effect of *Trichoderma viridae* cellulase on broilers fed on high roughage diet and announced significant improvement in the weight gain.

Ranade and Rajmane (1992) recorded a 4.79 per cent improvement in live weight in broilers when fed on Natuzyme Plus, a feed enzyme containing cellulase at 0.5 g/kg feed.

Birzer *et al.* (1993) through their experiments with male chicks fed on pelleted and mash diets supplemented with Roxazyme-G found improvement in live weight.

Brenes *et al.* (1993 a,b,c and d) through a series of experiments on broiler and Leghorn chicks fed diets containing barley/oat/rye/lupins/peas supplemented with enzyme preparations found improved weight gain.

Kralik *et al.* (1993) recorded increased body weight gain when enzyme preparations containing cellulase was added in diet fed to male chicks.

Ritchner *et al.* (1993) noted feed enzyme, Bergazym-H added in rye and triticale based diets increased live weight gain among broiler chicks.

Zobac *et al.* (1993) opined that enzyme preparations having cellulase are effective supplements in poultry feeds as these significantly increased live weight gain in broilers.

Flores *et al.* (1994) in their experiment on broilers fed wheat and triticale based diets with an enzyme containing fungal cellulase improved ($P<0.05$) the weight gain.

Marquardt *et al.* (1994) recorded that feed enzyme preparations containing cellulase activity considerably improved ($P<0.05$) weight gain in growing chicks when added to diets containing barley, wheat and rye, but not when added to the maize/corn diet.

Rajmane *et al.* (1994) performed a study on broilers for 6 weeks with Selfeed and recorded higher body weight at 0.1 per cent inclusion level.

Schurz *et al.* (1994) in a trial with male broiler chicks fed pelleted diets supplemented with Roxazyme-G showed body weight of 1774 g against the 1742 g in unsupplemented group.

Swain *et al.* (1994a) found addition of an enzyme feed supplement containing cellulase in high fibre diet containing autoclaved rice bran, wheat bran and sunflower cake supported significantly higher growth over the control among broiler chicken maintained from day-old to 7 weeks.

An experiment was conducted on broiler chicks with Luctazyme (multi-enzyme having cellulase) and concluded both heated and non-heated enzymes significantly improved the body weight (Viveros *et al.*, 1994).

Vranjes *et al.* (1994) reported significant improvement in the live weight among broiler chicks fed pelleted and extruded high-energy diets with Roxazyme-G at 0.15 g per kg for 39 days.

The results indicated the addition of Roxazyme-G in diet containing 50 per cent barley given to male hybrid broilers significantly increased the body weight (Mohammed, 1995).

Sathyamoorthy (1995) reported that feed enzyme cellulase and protease supplemented either alone or in combination did not have any significant influence on the body weight gain in White Leghorn pullets of 20 weeks to 40 weeks of age.

Vranjes and Wenk (1995a) found that Roxazyme-G positively influenced the weight gain of broilers fed on diets containing 40 per cent barley.

In response to dietary enzyme *Trichoderma viridae* cellulase inclusion of extruded barley in the diet of broiler chickens potentiated the weight gain (Vranjes and Wenk, 1995b).

Ponnuvel (1996) reported that Single Comb White Leghorn layers 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.

2.2 Feed consumption and feed conversion efficiency

Anderson and Warnick (1964) expressed increased feed efficiency when an enzyme premix containing cellulase was added to rations containing guar or soyabean by-products in chick feed.

White *et al.* (1981) reported improved feed efficiency by 8 per cent, when a culture filterate from *Trichoderma viridae* was added to a barley ration fed to chicks.

Hijikuro and Takemosa (1982) reported significantly increased feed conversion efficiency (P<0.01) in Leghorn chicks received a high barley diet with cellulase supplementation.

Nahm and Carlson (1985) observed reduced feed consumption and improved feed gain ratio in broilers fed with cellulase supplemented diets containing high levels of wheat bran.

Rotter *et al.* (1989) reported improved feed efficiency (8.5 per cent less) in chicks fed on cellulase supplemented hullless barely diet.

Al-Zubaida *et al.* (1990) reported feed gain ratio was 2.38, 2.56 and 2.83 without and 2.22, 2.39 and 2.70 with dietary cellulase supplemented at 80 mg per kg diet containing 0, 7.5 and 15 per cent dried sheep manure fed to broiler chicks.

Kumprecht *et al.* (1990) added Cellulase P-10 in a feed mixture at 4 or 8 units per g for broiler chicken of 3 and 7 weeks old and recorded decreased feed intake.

Rotter *et al*. (1990) reported significant improvement in feed gain ratio in male broiler chicks fed diets containing barley with crude cellulase enzyme preparation.

Tishenkova and Selivanova (1990) in their experiment on broiler chicken supplemented with Ekonaza, an enzyme preparation (which hydrolyses cellulose, hemicellulose and beta-glucan) recorded improvement in feed gain ratio.

Arora *et al*. (1991) reported that addition of Novozyme SP-243 in broiler diets decreased ($P<0.05$) feed intake and feed gain ratio over controls.

Avinash (1991) in his experiment fed broiler chicken with diet containing Selfeed reported improved feed utilization and better efficiency at 0.05 and 0.1 per cent level.

Bhatt *et al*. (1991) reported improved feed utilization when Novozyme SP-243, added in the diet of broiler chicks at 0.02 per cent when compared to 0, 0.025, 0.03 per cent level.

Brufau *et al*. (1991) conducted an experiment on chicks with *Trichoderma viridae* enzyme supplementation in pelleted broiler diet and reported significant improvement in feed gain ratio.

Supplementation of a crude enzyme preparation (*Trichoderma viridae* cellulase) in 60 per cent rye diet fed to young broiler chicks revealed increased feed consumption by 71 per cent and feed gain ratio by 43 per cent compared with that of unsupplemented control (Friesen *et al.*, 1991).

Kadam *et al.* (1991) studied the effect of an enzyme feed supplement Selfeed (having cellulolytic activity) at 0.05 and 0.1 per cent levels on the performance of broilers and noticed less feed consumption and better feed efficiency.

Devegowda and Nagalakshmi (1992) carried out an experiment on broilers supplemented multienzyme (cellulase) with low, moderate and high fibre diets. They reported significant improvement in feed conversion in enzyme supplemented groups.

Enzyme (*Trichoderma viridae* cellulase at 0.04 g/kg diet) treatment improved feed conversion efficiency of broiler chicks fed diet containing cereals like wheat, barley, oat and rye in a 17 days trial from day-old (Friesen *et al.*, 1992).

Roxazyme-G, an enzyme complex having cellulase activity improved feed conversion efficiency in broiler chicks fed on pelleted and expanded diet (Gadient and Broz, 1992).

Jeroch (1992) found that cellulase (Bergazym-H) supplementation at 0, 100 and 200 mg per kg in broiler diet for 42 days could improve the feed efficiency as 2.23, 2.16 and 2.15 respectively.

Ranade and Rajmane (1992) reported an 18.33 per cent less feed consumption and improved feed conversion ratio (0.22 per cent less) when broilers fed an enzyme feed supplement, Natuzyme Plus (multienzyme containing cellulase) at 0.5 g per kg of feed.

Birzer *et al.* (1993) expressed positive influence on feed conversion by supplementation of a commercial enzyme, Roxazyme-G (0.02% inclusion) in day-old male chicks till 30 days fed on pelleted or mash diets based on maize/soyabean meal/soya oil, wheat or barley, or wheat plus rye, wheat bran, rape seed oilmeal or soyabeans.

Brenes *et al.* (1993a,b,c and d) studied the effect of enzyme preparations (including Cellulase-Tv) on broiler diet and published reduced feed consumption and improved feed gain ratio among enzyme supplemented groups.

Kralik *et al.* (1993) registered feed gain ratio of 2.05, 1.96, 1.99 and 1.97 in control and the enzyme (polizym, Polizym G and Polizym BX) supplemented group respectively when chicks fed commercial starter and finisher mixtures for 42 days.

Ritchner *et al.* (1993) in a broiler feeding trial replaced maize with barley/rye/triticale revealed improved feed conversion efficiency when Bergazym-C supplemented in the diet at 0.01 per cent level.

Flores *et al.* (1994) found the enzyme (with cellulolytic activity) supplementation in broiler diets did not modify the feed intake, but improved the feed efficiency at the highest rate of inclusion of triticales.

Francesch *et al.* (1994) recorded decrease in feed intake (88.8 Vs 91.4 g) and improved feed conversion efficiency (1.855 Vs 1.910) in growing chicks fed pelleted barley based diet with *Trichoderma viridae* cellulase from day-old to 42 days in chicks over the unsupplemented controls.

Inborr and Bedford (1994) recorded a positive linear effect of enzyme level on feed efficiency and no influence on feed intake when Avizyme-SX supplemented in a barley based diet for broiler chicken.

Marquardt *et al.* (1994) in their experiment showed that the enzyme (with cellulase and xylanase activities) considerably improved ($P<0.05$) the feed intake in chicks fed barley and rye as 11 and 12 per cent, the feed gain ratio as 6 per cent for barley and 12 per cent for rye and 4 per cent for the wheat based diet.

Mikulec *et al.* (1994) reported favourable improvement in feed conversion efficiency when Fermacto, a crude enzyme prepared from *Aspergillus* meal was added at 0.02 per cent in feed given to fattening chicken under stress.

Rajmane *et al.* (1994) in their experiment on broiler chicken with a multienzyme, Selfeed at 0.1 per cent in conventional feed found the level as optimum and recorded better feed efficiency and less feed consumption than the control diet.

Schurz *et al.* (1994) registered lower feed intake and feed conversion efficiency of 1.798 in Roxazyme-G, enzyme supplemented group when control showed feed conversion efficiency of 1.849 with male broilers kept for 35 days.

Swain *et al.* (1994a) reported better feed conversion efficiency when dietary enzyme including cellulase was added at 1.0 and 1.5 g per kg to high fibre broiler diet.

The adding of the enzyme, Luctazyme (having cellulase) significantly improved the feed gain ratio in broiler chicks fed a barley based diet over 28 day period (Viveros *et al.*, 1994).

The enzyme complex, Roxazyme-B improved feed conversion ratio (1.81 Vs 1.77; $P<0.001$) until the end of growing period

(39 days) when supplemented in a cereal-based broiler diet (Vranjes *et al.*, 1994).

Mohammed (1995) observed significant improvement with regard to feed conversion efficiency at 3 and 7 weeks old when Roxazyme-G at 150 g/ton of feed was added to diets containing 50 per cent barley in male hybrid broilers.

In an investigation, Sathyamoorthy (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 ration without enzymes. However, average daily feed intake was not significantly different.

Vranjes and Wenk (1995a,b) recorded improved feed efficiency in response to dietary enzyme, Roxazyme-G (*Trichoderma viridae* cellulase) supplemented in the broiler diet containing 40 per cent barley irrespective of extrusion.

Ponnuvel (1996) reported that 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. Further he has registered numerically better feed efficiency with all the enzyme supplemented groups when compared with standard layer diet and high fibre without enzyme.

2.3 Nutrient digestibility and availability

Kuzmicky *et al.* (1978) determined nitrogen corrected ME value of wheat bran treated with a commercial cellulolytic enzyme, Pectinol-41P and recorded ME increased by 32 per cent (1612 to 2132 kcal/kg).

Hijikuro and Takemosa (1982) noticed that addition of commercial cellulase enzyme to a 60 per cent of barley based diet significantly increased ME value in male White Leghorn chicks.

Isshiki and Nakahiro (1983) in their experiment on Leghorn cockerels found that the digestibility of nutrients other than crude fibre was increased by increasing the level of supplementation of cellulase + xylanase + pectinase to diets containing ground barley or milo.

Nahm and Carlson (1985) based on their experiment on broilers with cellulase supplementation at 0.008 per cent in a wheat bran based diet concluded that the cellulase supplementation significantly ($P<0.01$) improved the digestibility of cellwall components.

Broz (1987) observed an increase in bio-available energy when rye based diets were supplemented with pectinase

(*Aspergillus niger*) or cellulase (*Trichoderma viridae*) enzyme mixture in chicken diet.

Cellulase-Tv supplemented with rye based diet fed to chicks increased (P<0.05) fat and dry matter retention by 12 and 15 per cent, respectively. But no effect (P<0.05) was noticed when added to a wheat based diet (Fengler *et al.*, 1988).

Al-Zubaida *et al.* (1990) in an experiment on broiler chicken of 4 to 8 weeks age with or without cellulase supplementation on basal diet containing 0, 7.5 and 15 per cent dried sheep manure indicated that dietary cellulase significantly increased the digestibility of organic matter, crude fibre and NFE regardless of the amount of dried sheep manure in the diet.

Rotter *et al.* (1990) found that nitrogen corrected apparent ME (AMEn) and apparent protein digestibility was increased due to cellulase supplementation among broiler chicks fed barley based diet.

Arora *et al.* (1991) through their experiment on broiler chicks fed diets containing Novozyme SP-243 stated that this multienzyme cleaves certain polymers of glucose, arabinose and xylose by releasing extra energy in enzyme supplemented group

Bhatt *et al.* (1991) reported that the digestibility co-efficients of different proximates like dry matter, crude protein, crude fibre, ether extract and nitrogen free extract and AME increased with corresponding increase in the rate of enzyme (Novozyme SP-243) inclusion when broiler chicks were fed on a conventional diet.

Friesen *et al.* (1991) found that addition of crude cellulase enzyme (*Trichoderma viridae*) in rye based broiler diets resulted in an increase in the dietary AMEn by 23 per cent and apparent protein digestibility by 12 per cent when compared with unsupplemented control diet, which were 9.7 and 4.6 per cent respectively.

Annison (1992) recorded a significant raise in the AME value of the wheat from 14.26 MJ to 15.24-15.79 MJ per kg dry matter when a wheat based diet fed to broiler chickens was supplemented with commercial enzyme preparations including cellulase.

Friesen *et al.* (1992) showed that crude cellulase supplementation in broiler chicks fed with diet containing wheat, barley, oat and rye significantly increased AMEn, apparent lipid digestibility and apparent protein digestibility for all test cereals.

Enzymes appeared to increase the apparent protein digestibility but not significantly (P>0.05) in an experiment with broiler chicks fed a diet containing 70 per cent raw lupins (*Lupinus albus*) with adding a combination of three enzymes namely Energex, BioFeed-Pro and Novozyme (Brenes *et al.*, 1993b).

Wantia (1993) found that enzyme preparation increased the true ME value by 1.1 and 6.3 per cent in rye and wheat diets fed to adult broiler cockerels.

Marquardt *et al.* (1994) observed improvements in the ME of chick diets containing barley, rye and wheat but not with corn diet. Apparent protein digestibility (APD) and drymatter digestibility (DMD) were improved by 6 and 9 per cent in diets with barley and rye respectively.

A balance study conducted by Swain *et al.* (1994b) revealed high protein and low fat retention in the broiler diets containing 0.1 and 0.15 per cent crude cellulase preparation.

Two high fibre and two low fibre diets were assayed by *in vitro* digestion test by Swain (1994c) and the results indicated inclusion of enzymes (containing cellulase activity) caused significant increase in average carbohydrate content and acid soluble nitrogen fraction and a significant decrease in NDF and ADF content.

There were no differences in apparent digestibility of fibre fractions but the digestibility coefficient of fat and starch were improved significantly ($P<0.001$) in the birds fed barley based diet of broiler chicks with supplementation of a commercial feed enzyme containing cellulase activity (Viveros *et al.*, 1994).

Vranjes *et al.* (1994) showed that enzyme complex Roxazyme-G added to a commercial diet for broiler chicks containing wheat improved energy metabolisability, fat, nitrogen and fibre utilization but the difference was not significant.

Sathyamoorthy (1995) opined that enzyme cellulase and/or protease supplementation in standard or less dense ration resulted in an apparent improvement in the digestibility of crude protein and energy utilization in laying chicken.

Vranjes and Wenk (1995a and b) recorded greater enzyme (Cellulase-Tv) effect among broiler chicks fed diets containing extruded barley for AME, fat and nitrogen utilization and beta-glucan degradability.

Dhar *et al.* (1996a) in their studies with broilers found no significance (P<0.01) in the per cent utilization of dry matter, fat, protein, calcium and phosphorus but an apparent improvement in the fibre digestibility was recorded when a commercial enzyme mixture (Ventrigold - containing cellulase) was supplemented in the feed.

In another experiment, Dhar *et al.* (1996d) found no significance on per cent utilization of dry matter, fat, protein, calcium and phosphorus by the supplementation of Salfeed (enzyme preparation having cellulolytic activity) in the diet of broilers. An apparent improvement in the fibre digestibility was evidenced by the addition of the digestive enzyme.

Ponnuvel (1996) reported that the AME value, apparent protein digestibility (APD) and ether extract digestibility (EED) were significantly (P<0.01) more in high fibre diet with enzyme supplemented groups than the controls. Numerical increase in the digestibility of fibre fractions i.e., ADF and NDF was also observed due to cellulase supplementation.

2.4 Excreta moisture

Hesselman *et al.* (1982) registered significantly increased (P<0.001) dry matter content of excreta when broiler chicks were given barley based diet with enzyme supplementation.

Hesselman and Aman (1986) recorded increased dry matter content of the digesta on addition of enzyme beta-glucanase to a broiler diet containing high viscosity barley variety.

Rotter *et al*. (1989) observed the crude cellulase enzyme supplementation to barley based diet fed to chicks reduced the vent pasting problem ($P<0.05$).

Brufau *et al*. (1991) recorded higher incidence of sticky droppings among chicks fed on barley diet than those on the enzyme (*Trichoderma viridae*) supplementation.

Devegowda and Nagalakshmi (1992) noticed an improved condition of droppings with multienzyme supplementation in broiler diets of low, moderate and high fibre.

Jeroch (1992) in an experiment with day old broiler chicks reared upto 42 days given diets with 15 per cent rye supplemented with Bergazym-H recorded reduction in the incidence of sticky droppings over controls.

Schutte and Geerse (1992) reported increased dry matter content of droppings of broilers when barley based diets were supplemented with enzyme complex having cellulase activity.

Francesch *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*.

Incidence of vent pasting decreased linearly with enzyme inclusion rates in a barley based diet fed to broiler chicks with a commercial enzyme product, Avizyme-SH at 0.1 and 0.01 per cent level (Inborr and Bedford, 1994).

Marquardt *et al.* (1994) reported reduction of water content in the colon digesta as well as excreta moisture in chicks fed barley/wheat/rye/corn, when diet supplemented with *Trichoderma reesei* crude enzyme preparation having cellulase and xylanase activity.

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 ration fed groups (Sathyamoorthy, 1995).

Ponnuvel (1996) recorded significant reduction in the moisture content of droppings of birds fed high fibre diet with cellulase supplementation. Excreta moisture was high ($P<0.01$) in high fibre fed birds.

2.5 Slaughter studies

Kumprecht *et al*. (1990) reported no effect on the dressed percentage of broilers fed diets supplemented with cellulase P-10 at 4 or 8 units per g inclusion level.

Brenes *et al*. (1993a) showed the relative gizzard weight of White Leghorn chicks fed rye with the enzyme was lower by 18 per cent ($P<0.05$) than that of chicks fed on rye diet alone.

In a broiler experiment a crude cellulase enzyme preparation was added at 100 mg per kg in barley based diet and recorded reduced relative weight of the proventriculus (39%), pancreas (24%), liver (8%), duodenum (16%), jejunum (20%), ileum (18%), colon (29%), crop (15%) and gizzard (17%). The enzyme addition also increased the relative size of the fat pad and the dressing yield of broilers (Brenes *et al*., 1993d).

Wyatt *et al*. (1993) observed higher abdominal fat in enzyme supplemented broilers fed barley based diet suggesting an improvement in fat digestion.

Carcass yield, viscera weight and abdominal fat were not significantly affected by addition of *Trichoderma viridae* cellulase in diet fed to broiler chicks from 0 to 42 days in an experiment by Francesch *et al.* (1994).

Mikulec *et al.* (1994) in their experiment on the effect of enzyme preparation, Fermacto on the production performance in fattening chicken at 2 g per kg in the diet recorded lower abdominal fat than in unsupplemented group.

Schurz *et al.* (1994) registered no significant difference among carcass composition, carcass quality and organoleptic properties among broilers fed diet supplemented with polysaccharide cleaving enzymes. But he recorded significantly higher breast skin proportion and abdominal fat in enzyme supplemented group.

Tyagi *et al.* (1995) reported that female chicks tended to accumulate more abdominal fat than their male counterparts irrespective of diet, when maize was replaced with broken rice (*rice kani*) in part or full.

Vranjes and Wenk (1995a) studied the influence of enzyme complex, Roxazyme-G on the fat retention and carcass yield and found no effect among broilers fed on 40 per cent barley diet.

Dhar *et al.* (1996b) undertook an experiment to examine the response of digestive enzyme supplementation (Ventrigold) in the high fibre diet on the performance of broilers upto seven weeks of age. No significant difference was noticed in carcass quality characteristics like dressing percentage and giblet yield between the treatments.

No significant response was observed in carcass quality characteristics (dressing percentage and giblet yield) when a dietary enzyme mixture Salfeed was added to a high fibre diet fed to broiler chicken (Dhar *et al.*, 1996c).

Benabdeljelil (1997) in his experiment on the influence of an enzyme mixture added to barley based diets on broiler performance found that enzyme supplementation did not improve the percentage of abdominal fat as dietary barley levels were increased.

2.6 Intestinal viscosity

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

Hesselman and Aman (1986) observed that enzyme supplementation to a broiler diet containing high viscosity barley variety reduced the viscosity of the small intestinal digesta when compared with control.

In a broiler experiment with *Bacillus subtilis* enzyme reduction in the viscosity of the digesta was observed and the component responsible for the viscosity of digesta was suggested as beta-glucan content of untreated wild groat (Campbell *et al.*, 1987).

The viscosity of the excreta was dramatically reduced when *Trichoderma viridae* cellulase was added in rye based diets fed to chicks (Fengler *et al.*, 1988).

Bedford and Classen (1992a) indicated that the addition of enzyme in rye based diet fed to broiler chicks significantly reduced the intestinal viscosity.

In another study, Bedford and Classen (1992b) found that addition of enzyme to barley based broiler diet resulted in a significant reduction in the viscosity of intestinal contents.

The digesta viscosity showed significant negative linear response with the inclusion level of enzyme Avizyme-SH to a barley based diet for broiler chicks (Inborr and Bedford, 1994).

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

Ponnuvel (1996) reported that the layers fed with high fibre, standard and enzyme supplemented groups showed significantly ($P<0.01$) higher, medium and lower viscosity of intestinal contents respectively.

2.7 Livability

Tishenkova and Serikova (1987) recorded increased percentage survivability in chicks fed on a feed mixture supplemented with Tselloviridin-G3x having cellulase activity over the unsupplemented birds.

Improved percentage survivability was observed by Tizhenkova and Selivanova (1990) in their experiment on broilers supplemented with Ekonaza enzyme preparation.

Arora *et al*. (1991) reported that the mortality was only one chick and no chick when 208 broiler chicks were distributed into two equal groups and fed diets supplemented with 0 and 0.75 per cent level of a fibre degrading enzyme Novozyme SP-243.

Supplementation of enzyme, Bergazym-H (containing 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 chicken fed with high roughage diet. They found that per cent mortality was not affected by either enzyme or level of roughage inclusion.

Ranade and Rajmane (1992) registered improved survivability when broilers were fed with Natuzyme plus containing cellulase, protease, beta-glucanase and amylase with a mortality percentage of 5.6 less than the control.

Fermacto, from *Aspergillus* sp. meal, when added at 2 g per kg in a commercial feed mixture given to fattening chicks under stress lowered the mortality than did the commercial mixture alone (Mikulec *et al*., 1994).

Significant improvement in survivability was recorded with Roxazyme-G supplemented at 150g per ton in 50 per cent barley diet fed to male hybrid broilers (Mohammed, 1995).

2.8 Cost-benefit analysis

Rexen (1981) suggested that better feed utilisation could be obtained by the use of enzymes i.e., cellulase/protease/ pectinase in feed mixture only if the feed was compounded with less-digestible ingredients. The amount of added enzymes strongly influenced the price of resultant feed and in the experiments showing feed improvement, the break even price is less than 26 Dkr per kg of enzyme.

Bhatt *et al.* (1991) calculated the production cost per kg body weight gain in broilers fed standard diet for 6 weeks with a commercial enzyme preparation, Novozyme SP-243 at 0, 20, 25, 30 g per 100 kg as 9.29, 9.12, 9.36 and 10.02 respectively and further stated that the maximum benefit could only be achieved at the initial stage of life of birds.

Kadam *et al.* (1991) conducted an experiment on broiler chicken fed with commercial starter and finisher diets supplemented with a multienzyme, Selfeed (containing cellulase, protease, amylase, lipase and pectinase). They found that inclusion of feed enzymes was cost effective in broiler rations and under Indian conditions the profit per bird receiving enzyme supplementation at 0.1 per cent in feed was 16.83 per cent higher than the control group.

Ritchner *et al.* (1993) conducted two feeding trials on broiler chicks replacing maize with barley, rye, triticale without or with enzyme preparations. In the first trial Bergazym-C at 350 mg per kg with rye based diet and at 250 mg per kg with barley based diet decreased feed expenditure compared with unsupplemented controls. In next trial, same trend was reported to continue when the enzyme was added at 100 mg per kg in rye and triticale based diet.

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

Ponnuvel (1996) reported the 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 with high fibre diet the cost of feed was 36 paise per kg lesser than standard ration.

Materials and Methods

3. MATERIALS AND METHODS

An experiment was conducted in the Department of Poultry Science, College of Veterinary and Animal Sciences, Mannuthy, to evaluate the effect of cellulase supplementation on the performance and nutrient availability in broiler chicken fed low energy diet.

3.1 Experiment materials

3.1.1 Experimental birds

One hundred and ninety two, one-day old straight-run broiler chicks (Hubchix) procured from a commercial hatchery, formed the experimental subjects.

3.1.2 Experimental rations

Two types of rations viz., standard broiler ration and low energy broiler ration were used in this study. The standard broiler ration (SBR) was formulated as per BIS (1992) specifications. The low energy broiler ration (LBR) was formulated with the level of metabolisable energy 300 kcal/kg less than the standard broiler ration. The level of all other nutrients were similar to that of SBR. Feed ingredients used for the formulation of the experimental diets were yellow maize, groundnut cake (expeller), gingelly oilcake, unsalted dried fish, rice polish, wheat bran and de-oiled rice bran. The wheat bran and deoiled rice bran were included in the low energy ration in order to reduce the metabolisable energy. The ingredient composition and the chemical composition of the above rations are presented in Table 1 and 2 respectively.

3.1.3 Enzyme

The enzyme used in this study was `Fiberzyme', a product manufactured and marketed by M/s Zeus Biotech Pvt. Ltd., Mysore. It is a fibre degrading enzyme of fungal origin (*Aspergillus sp.*) containing cellulase as its major component.

3.2 Experimental methods

3.2.1 Housing of birds

The house, feeders, waterers and other equipments were cleaned thoroughly and disinfected prior to housing the chicks. The chicks were weighed and wing banded.

3.2.2 Experimental design

The chicks were randomly divided into sixteen groups each of twelve chicks. These groups were allotted randomly to four treatments viz., T1, T2, T3 and T4 with four replications in each treatment. The birds in each treatment were assigned to each of the four rations viz., SBR, LBR and two different

Table 1. Percentage ingredient composition of experimental rations

Sl. No.	Ingredients	Standard broiler ration (SBR)		Low-energy broiler ration (LBR)	
		Starter	Finisher	Starter	Finisher
1.	Yellow maize	44.00	53.00	30.00	40.00
2.	Groundnut cake (exp)	32.00	26.00	27.00	23.00
3.	Gingelly oilcake	3.00	0.00	6.00	0.00
4.	Unsalted dried fish	9.00	8.00	10.00	9.00
5.	Rice polish	10.00	11.00	10.00	9.00
6.	Wheat bran	0.00	0.00	10.00	10.00
7.	De-oiled rice bran	0.00	0.00	5.00	7.00
8.	Common salt	0.25	0.25	0.25	0.25
9.	Mineral mixture[1]	1.75	1.75	1.75	1.75
	Total	100.00	100.00	100.00	100.00
Added per 100 kg of feed					
10.	Vitamin mixture (g)[2]	10	10	10	10
11.	Lysine hydrochloride (g)	200	100	200	100
12.	Coccidiostat (g)[3]	50	50	50	50
13.	Manganese sulphate (g)	2	2	2	2

1. Mineral mixture composition:

   Calcium 32%, Phosphorus 6%, Magnesium 1000 ppm, Cobalt 60 ppm, Zinc 2600 ppm, Iron 0.1%, Iodine 100 ppm, Copper 100 ppm, Manganese 2700 ppm.

2. Vitamin mixture composition:

   Each gram contains: Vitamin A 82,500 IU, Vitamin B2 50 mg, Vitamin D3 12,000 IU and Vitamin K 10 mg.

3. Coccidiostat composition:

   Each gram contains: Dinitrotoluamide 250 mg and Ethopabate 16 mg.

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

Sl. No.	Nutrients	Standard broiler ration (SBR)		Low-energy broiler ration (LBR)	
		Starter	Finisher	Starter	Finisher
Analysed values[1]					
1.	Moisture	9.48	9.43	9.62	9.60
2.	Crude protein	23.38	20.26	23.24	20.18
3.	Ether extract	6.32	6.53	6.14	6.08
4.	Crude fibre	4.52	4.43	5.88	5.73
5.	NFE	54.32	57.21	51.27	54.86
6.	Total ash	11.46	11.57	13.47	13.15
7.	Acid insoluble ash	2.11	2.14	2.74	2.68
8.	Calcium	1.43	1.36	1.48	1.41
9.	Phosphorus	0.76	0.69	0.82	0.73
10.	ADF[2]	14.64	15.36	21.17	22.09
11.	NDF[2]	26.30	24.58	34.75	31.83
Calculated values					
12.	ME (kcal/kg)	2810.00	2910.00	2500.00	2610.00
13.	Lysine	1.30	1.05	1.30	1.05
14.	Methionine	0.50	0.45	0.50	0.45
15.	Manganese (mg/kg)	98.00	95.00	116.00	104.00

1. Average of eight samples
2. Percentage to the crude fibre content in the feed

levels of enzyme viz., 0.03 and 0.06 per cent in low energy broiler ration. The details of treatment particulars are presented in Table 3.

3.2.3 Management

Feed and water were provided *ad libitum* throughout the experiment and the birds were maintained under deep litter system. Standard managemental procedures were adopted during the entire experimental period. The duration of the experiment was for a period of 56 days from day-old.

3.2.4 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 throughout the experimental period. From this data, weekly mean maximum and minimum temperatures and per cent relative humidity were arrived at.

3.2.5 Body weight

The body weight of individual birds was recorded at weekly intervals from day-old to study the pattern of body weight gain under different feeding regimes.

Table 3. Distribution of the different dietary treatments

Treat-ment	Repli-cation	No. of birds	Ration	Enzyme treatment	Level of inclusion (%)
T1	R1	12	SBR	-	-
	R2	12	SBR	-	-
	R3	12	SBR	-	-
	R4	12	SBR	-	-
T2	R1	12	LBR	-	-
	R2	12	LBR	-	-
	R3	12	LBR	-	-
	R4	12	LBR	-	-
T3	R1	12	LBR	cellulase	0.03
	R2	12	LBR	cellulase	0.03
	R3	12	LBR	cellulase	0.03
	R4	12	LBR	cellulase	0.03
T4	R1	12	LBR	cellulase	0.06
	R2	12	LBR	cellulase	0.06
	R3	12	LBR	cellulase	0.06
	R4	12	LBR	cellulase	0.06

3.2.6 Feed consumption

Feed intake of the birds was recorded replication-wise at the end of each week. From this data, the average feed intake per bird per day was calculated for various treatment groups.

3.2.7 Feed efficiency

Feed conversion efficiency (kg of feed/kg body weight) was calculated based on the data on body weight and feed intake.

3.2.8 Metabolism trial

At the end of the experimental period metabolism trials were conducted for broiler starter and finisher rations separately using eight birds, randomly selected from each treatment group and housed in individual cages. Total collection method was employed. Water was provided *ad libitum*. The total amount of feed consumed and excreta voided were recorded for each day. The excreta collected for three days from each bird was pooled and stored in deep freezer for further analysis.

3.2.9 Chemical analysis

The chemical composition and fibre fractions of the different rations and excreta collected during the metabolism trial were analysed 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 the nutrient digestibilities were calculated.

3.2.10 **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.

3.2.11 **Slaughter studies**

At the end of the experiment, one male and one female from each replication were randomly selected and sacrificed to study the processing yields and losses as per procedure described by Bureau of Indian Standards (BIS, 1973). Percentages of dressed yield, giblet yield and ready-to-cook yield were calculated from the data.

The abdominal fat was separated and weighed as per the procedure described by Health *et al.* (1980) and the percentages of abdominal fat were derived from it.

3.2.12 **Intestinal viscosity**

During slaughter 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 supernatent fluid was used for estimation of viscosity using Oswald viscosity meter (Oser, 1965).

3.2.13 Livability

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

3.2.14 Cost-benefit analysis

Cost of feed, cost of enzyme, live weight produced and quantity of feed consumed by birds in each treatment groups was calculated. From this data the cost-benefit analysis was worked out.

3.2.15 Statistical analysis

Data collected on various parameters were statistically analysed as per the methods described by Snedecor and Cochran (1980).

Results

4. RESULTS

An experiment was conducted to evaluate the effect of cellulase supplementation on the performance and nutrient availability in broilers fed with low energy diet for a period of eight weeks. The results are presented in this chapter.

4.1 Climatic parameters

The mean maximum and minimum temperatures and per cent relative humidity during different weeks of this experiment (February and March 1997) are presented in Table 4. During the experimental period, the maximum temperature ranged from 32.5°C to 36.4°C and the minimum temperature ranged from 21°C to 24.9°C. The per cent relative humidity in the morning varied from 76 to 91, while in the afternoon it ranged from 21 to 51.

4.2 Body weight

Data on mean body weight at weekly intervals as influenced by different treatments viz., standard broiler ration (T1), low energy broiler ration (T2), low energy broiler ration with 0.03 per cent cellulase (T3) and low energy broiler ration with 0.06 per cent cellulase (T4) are charted out in Table 5.

Table 4. Mean weekly meterological data during the experimental period (February and March 1997)

Period (weeks)	Temperature (°C)		Relative humidity	
	Maximum	Minimum	8 a.m.	2 p.m.
1	32.5	21.0	80	43
2	33.5	21.7	90	45
3	33.9	21.7	76	33
4	34.4	22.7	85	42
5	35.8	22.5	76	21
6	36.4	22.9	80	22
7	34.7	24.3	91	46
8	35.2	24.9	84	51
Mean	34.55	22.71	82.8	37.9
SE	0.42	0.44	1.9	3.7

Table 5. Influence of cellulase supplementation on mean weekly body weight (g)

Treatments		Age in weeks								
		0	1	2	3	4	5	6	7	8
T1	R1	43.25	129.58	282.92	511.67	788.33	1087.50	1391.67	1698.33	2003.33
	R2	43.33	130.00	282.92	512.08	788.75	1087.08	1391.25	1700.00	2003.88
	R3	43.33	130.83	282.92	512.50	789.17	1088.33	1391.67	1702.00	2005.83
	R4	44.00	132.08	285.42	517.50	797.08	1100.00	1409.17	1720.00	2029.17
	Mean	**43.48**^{a}	**130.63**^{a}	**283.54**^{a}	**513.44**^{b}	**790.83**^{c}	**1090.73**^{c}	**1395.94**^{c}	**1704.58**^{c}	**2011.04**^{c}
		±0.18	**±0.55**	**±0.63**	**±1.37**	**±2.09**	**±3.10**	**±4.41**	**±5.16**	**±6.07**
T2	R1	43.25	130.42	272.92	490.83	755.83	1043.33	1336.67	1630.83	1924.17
	R2	43.58	130.42	273.75	491.67	758.33	1045.00	1340.83	1632.50	1924.17
	R3	43.92	131.25	274.58	493.33	761.25	1049.17	1344.17	1640.00	1935.83
	R4	43.67	130.00	273.75	492.92	759.17	1045.00	1340.83	1637.50	1931.67
	Mean	**43.60**^{a}	**130.52**^{a}	**273.75**^{b}	**492.19**^{c}	**758.65**^{d}	**1045.63**^{d}	**1340.63**^{d}	**1635.21**^{d}	**1928.96**^{d}
		±0.14	**±0.26**	**±0.34**	**±0.58**	**±1.12**	**±1.25**	**±1.54**	**±2.14**	**±2.90**
T3	R1	43.25	130.42	283.75	517.92	803.33	1125.42	1462.50	1799.17	2123.33
	R2	43.00	130.00	282.50	512.92	795.00	1112.50	1446.67	1781.67	2102.50
	R3	43.17	129.17	283.33	515.83	799.17	1117.50	1455.00	1790.00	2112.50
	R4	43.25	130.00	284.58	517.92	801.67	1123.33	1458.33	1800.00	2120.00
	Mean	**43.17**^{a}	**129.90**^{a}	**283.54**^{a}	**516.15**^{ab}	**799.79**^{b}	**1119.69**^{b}	**1455.63**^{b}	**1792.71**^{b}	**2114.58**^{b}
		±0.06	**±0.26**	**±0.44**	**±1.19**	**±1.81**	**±2.93**	**±3.36**	**±4.32**	**±4.62**
T4	R1	42.92	130.00	284.17	517.92	807.08	1146.67	1490.83	1851.67	2184.17
	R2	42.92	129.58	284.58	517.50	805.00	1134.17	1488.33	1845.00	2176.67
	R3	43.08	129.58	283.33	517.92	806.25	1128.33	1490.00	1849.17	2182.50
	R4	43.25	130.00	285.00	519.17	812.08	1141.67	1495.83	1856.67	2190.83
	Mean	**43.04**^{a}	**129.79**^{a}	**284.27**^{a}	**518.13**^{a}	**807.60**^{a}	**1137.71**^{a}	**1491.25**^{a}	**1850.63**^{a}	**2183.54**^{a}
		±0.08	**±0.12**	**±0.36**	**±0.36**	**±1.50**	**±1.05**	**±1.62**	**±2.44**	**±2.92**
	CD	-	-	1.956	4.168	7.267	12.978	12.904	16.129	18.717

Means bearing the same superscript within the same column do not differ significantly ($P<0.01$)

The mean body weight recorded with birds of the four treatment groups viz., T1, T2, T3 and T4 were 1395, 1340, 1455 and 1491 g at sixth week and 2011, 1929, 2114 and 2183 g at the end of the experiment (8th week) respectively.

The statistical interpretation as in Table 6 showed no significant (P<0.01) difference among the birds of different treatments with respect to body weight during the first two weeks. But, at the end of third week the chicks fed with low energy ration recorded significantly lower body weight (274g) when compared to other groups, which trend continued till the end of the experiment. At the same time, the significantly highest body weight was recorded in T4 from third to eighth week.

The influence of cellulase supplementation in broilers with respect to mean weekly body weight are shown in Fig.1.

4.3 Body weight gain

The mean weekly body weight gain of chicks during the eight weeks period among different treatment groups are shown in Table 7.

The mean weekly weight gain among the different treatment groups viz., T1, T2, T3 and T4 were 305.21, 295.00, 335.94 and 353.55 g during the sixth week and 306.46, 293,75, 321.88 and 332.92 g during the eighth week respectively.

Table 6. Influence of cellulase supplementation on weekly body weight - ANOVA

Week	Source	df	SS	MSS	F value
0	Treatment	3	0.825	0.275	4.619 NS
	Error	12	0.715	0.060	
	Total	15	1.539		
1	Treatment	3	2.167	0.722	1.587 NS
	Error	12	5.465	0.455	
	Total	15	7.632		
2	Treatment	3	303.515	101.172	123.390 **
	Error	12	9.839	0.820	
	Total	15	313.354		
3	Treatment	3	1731.787	577.262	155.075 **
	Error	12	44.670	3.722	
	Total	15	1776.457		
4	Treatment	3	5548.499	1849.500	163.434 **
	Error	12	135.798	11.316	
	Total	15	5684.297		
5	Treatment	3	19369.992	6456.664	178.888 **
	Error	12	433.120	36.093	
	Total	15	19803.112		
6	Treatment	3	52886.643	17628.881	494.044 **
	Error	12	428.194	35.683	
	Total	15	53314.837		
7	Treatment	3	108475.789	36158.596	648.582 **
	Error	12	669.002	55.750	
	Total	15	109144.791		
8	Treatment	3	151238.706	50412.902	671.519 **
	Error	12	900.875	75.073	
	Total	15	152139.581		

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

Fig.1 WEEKLY BODY WEIGHT AS INFLUENCED BY CELLULASE SUPPLEMENTATION

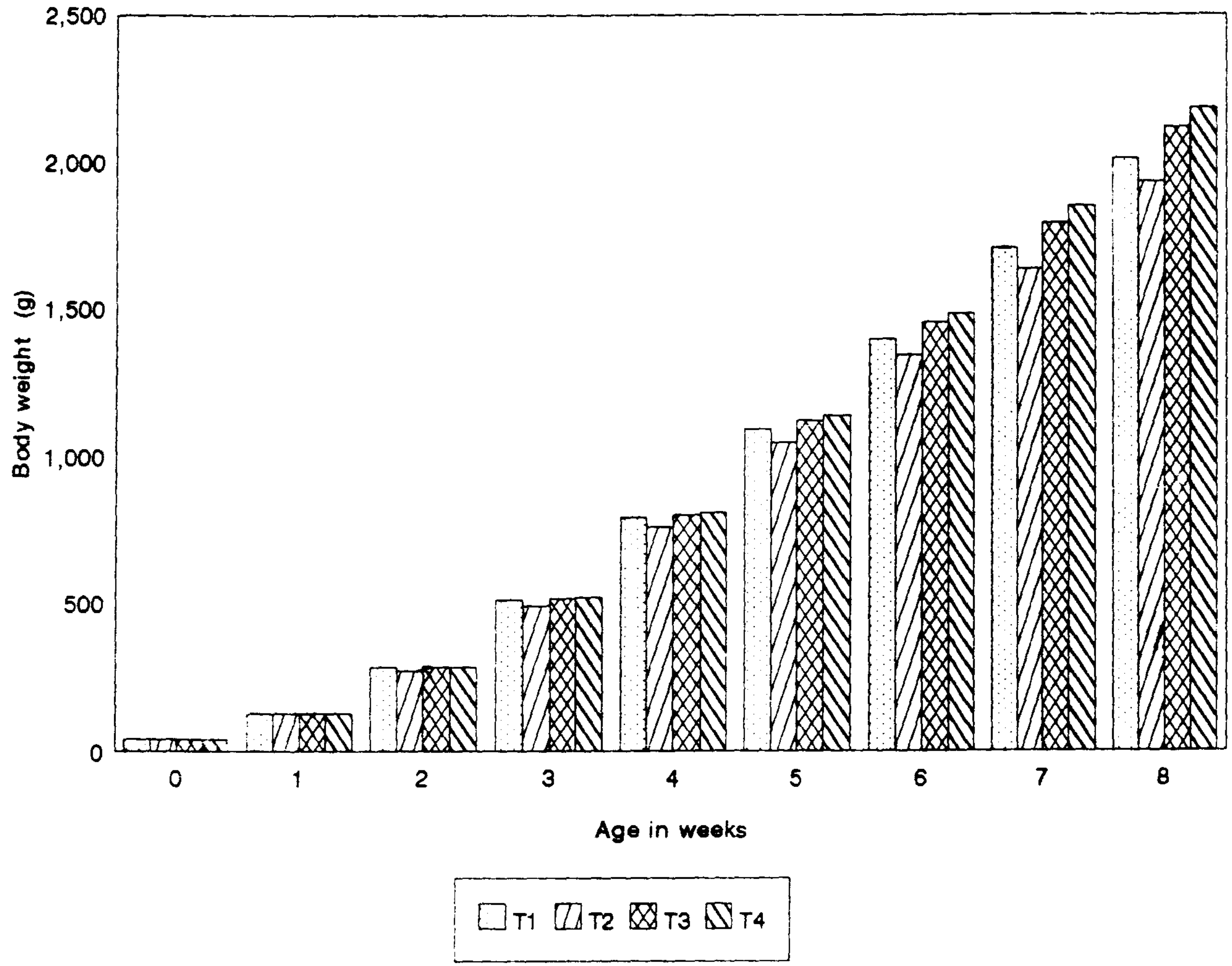


Table 7. Influence of cellulase supplementation on mean weekly body weight gain (g)

Treatments		Age in weeks							
		1	2	3	4	5	6	7	8
T1	R1	86.33	153.33	228.75	276.67	299.17	304.17	306.67	305.00
	R2	86.67	152.92	229.17	276.68	298.33	304.16	308.75	305.83
	R3	87.50	152.08	229.58	276.66	299.16	303.33	308.33	305.84
	R4	88.08	153.32	232.08	279.58	302.92	309.17	310.83	309.17
		a	b	b	c	c	c	c	c
	Mean	**87.15**	**152.92**	**229.90**	**277.40**	**299.90**	**305.21**	**308.65**	**306.46**
		±0.40	**±0.30**	**±0.75**	**±0.73**	**±1.03**	**±1.34**	**±0.86**	**±0.93**
T2	R1	87.17	142.50	217.92	265.00	287.50	293.33	294.17	293.33
	R2	86.83	143.33	217.93	266.67	286.67	293.83	291.68	291.66
	R3	87.33	143.34	218.75	267.92	287.92	295.00	295.82	295.84
	R4	86.33	143.75	219.17	266.25	285.83	295.83	296.67	294.17
		a	c	c	d	d	d	d	d
	Mean	**86.92**	**143.23**	**218.44**	**266.46**	**286.98**	**295.00**	**294.59**	**293.75**
		±0.22	**±0.26**	**±0.31**	**±0.60**	**±0.47**	**±0.59**	**±1.10**	**±0.87**
T3	R1	87.16	153.33	234.17	285.42	322.08	337.08	336.67	324.17
	R2	87.00	152.50	230.42	282.08	317.50	334.17	335.00	320.83
	R3	86.00	154.70	232.50	283.33	318.33	337.50	335.00	322.50
	R4	86.75	154.58	233.33	283.75	321.67	335.00	341.67	320.00
		a	ab	a	b	b	b	b	
	Mean	**86.73**	**153.65**	**232.60**	**283.65**	**319.90**	**335.94**	**337.09**	**321.88**
		±0.26	**±0.46**	**±0.81**	**±0.69**	**±1.16**	**±0.82**	**±1.58**	**±0.93**
T4	R1	87.08	154.17	233.75	289.17	[illegible]	[illegible]	360.83	[illegible]
	R2	86.67	155.00	232.92	287.50	[illegible]	[illegible]	[illegible]	[illegible]
	R3	86.50	153.75	234.58	288.33	322.08	361.67	359.17	333.33
	R4	86.75	155.00	234.17	292.92	329.58	354.17	360.83	334.17
		a	a	a	a	a	a	a	a
	Mean	**86.75**	**154.48**	**233.86**	**289.48**	**330.10**	**353.55**	**359.38**	**332.92**
		±0.12	**±0.31**	**±0.36**	**±1.20**	**±3.60**	**±3.59**	**±0.99**	**±0.54**
	CD	-	1.475	2.582	3.614	8.520	8.550	5.021	3.58[illegible]

Means bearing the same superscript within the same column do not differ significantly (P<0.01)

Analysis of variance on the data pertaining to the mean weekly body weight gain as presented in Table 8, expressed no significant difference among treatment groups at first week but significantly (P<0.01) lower weight gain was observed in chicks fed with low energy diet throughout the experimental period than either standard control or the enzyme supplemented groups. The birds fed on diet supplemented with cellulase gained significantly higher body weight compared to the chicks fed with standard broiler ration from third week to the end of the trial period.

The mean weekly body weight gain of birds for the different treatment groups is pictured in Fig.2.

4.4 Feed intake

The mean daily feed intake per bird during each week among different treatment groups are given in Table 9.

The mean daily feed intake per bird among the four treatment groups, viz., T1, T2, T3 and T4 were 109.76, 113.16, 109.85 and 111.28g during the sixth week and 14[illegible].11, 146.79, 142.59 and 144.29g during the eighth week respectively.

The analysis of variance of the data on feed intake are set out in Table 10. It showed that the daily feed intake was significantly higher (P<0.01) throughout the experimental period except during the second week in the groups fed low

Table 8. Influence of cellulase supplementation on body weight gain - ANOVA

Week	Source	df	SS	MSS	F value
1	Treatment	3	0.443	0.148	0.513 NS
	Error	12	3.454	0.288	
	Total	15	3.897		
2	Treatment	3	332.670	110.890	237.839 **
	Error	12	5.595	0.466	
	Total	15	338.265		
3	Treatment	3	594.075	198.025	138.559 **
	Error	12	17.150	1.429	
	Total	15	611.225		
4	Treatment	3	1163.938	387.979	138.625 **
	Error	12	33.585	2.799	
	Total	15	1197.523		
5	Treatment	3	4526.242	1508.747	96.994 **
	Error	12	186.660	15.555	
	Total	15	4712.902		
6	Treatment	3	8798.669	2932.890	187.223 **
	Error	12	187.983	15.665	
	Total	15	8986.652		
7	Treatment	3	10080.888	3360.296	621.955 **
	Error	12	64.834	5.403	
	Total	15	10145.722		
8	Treatment	3	3546.358	1182.119	429.732 **
	Error	12	33.010	2.751	
	Total	15	3579.368		

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

Fig.2 WEEKLY BODY WEIGHT GAIN AS INFLUENCED BY CELLULASE SUPPLEMENTATION

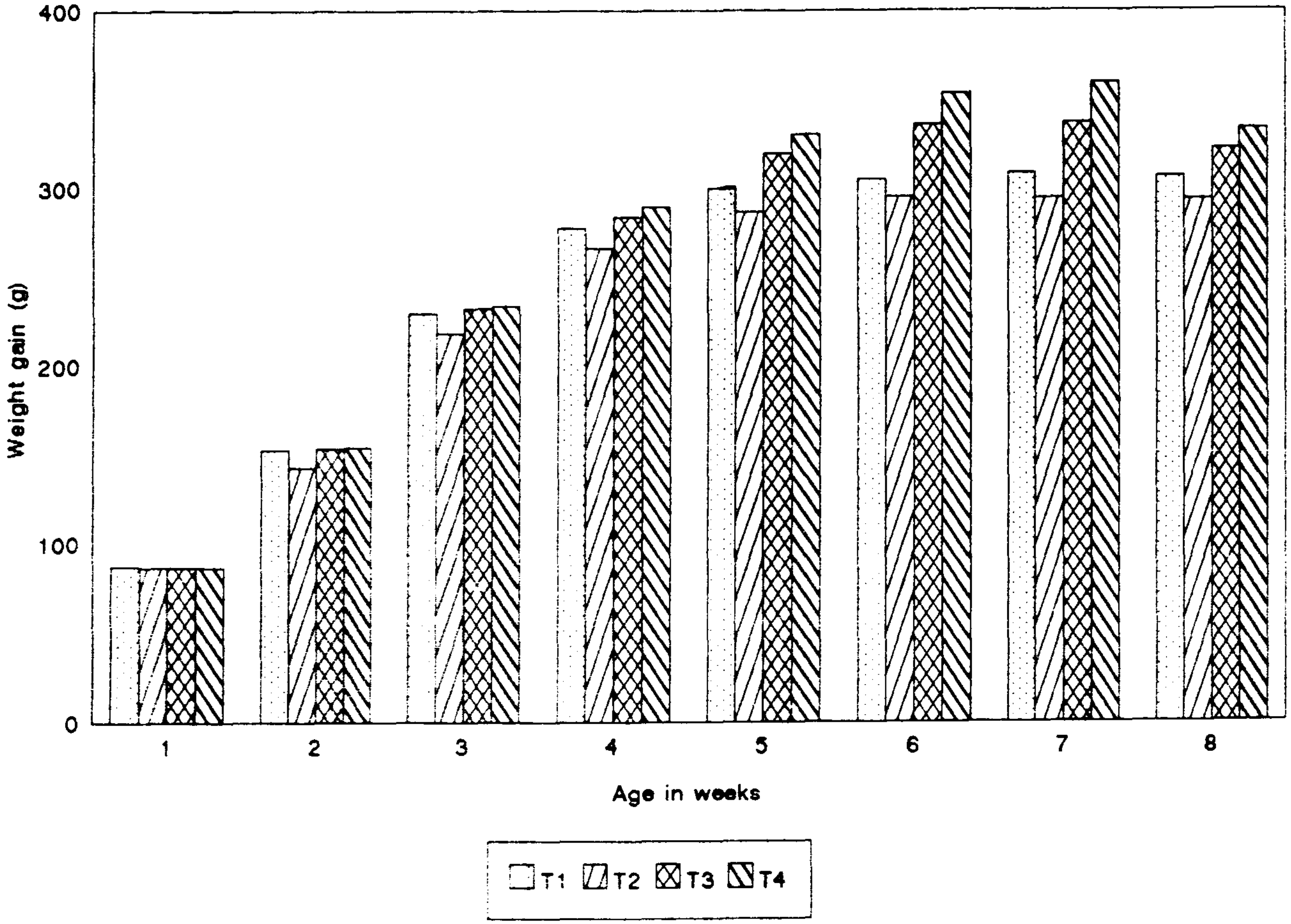


Table 9. Influence of cellulase supplementation on mean daily feed intake per bird (g)

Treatments		Age in weeks							
		1	2	3	4	5	6	7	8
T1	R1	17.14	34.29	53.81	76.43	94.76	109.05	129.76	141.43
	R2	17.26	34.52	54.05	77.02	95.60	109.76	130.71	142.38
	R3	17.50	34.76	54.29	77.62	95.95	110.60	131.67	143.45
	R4	17.38	34.64	54.17	76.90	95.48	109.64	130.60	142.50
		b	a	b	b	b	b	b	b
	Mean	**17.32**	**34.55**	**54.08**	**76.99**	**95.45**	**109.76**	**130.69**	**142.44**
		±0.08	**±0.10**	**±0.10**	**±0.25**	**±0.25**	**±0.32**	**±0.39**	**±0.42**
T2	R1	17.86	35.71	56.07	79.64	98.69	113.57	135.12	147.26
	R2	17.98	35.95	56.43	80.[illegible]	99.40	114.29	136.07	148.21
	R3	17.62	35.24	55.36	78.57	97.38	112.02	133.33	145.36
	R4	17.74	35.48	55.71	79.05	98.10	112.74	134.17	146.31
		a	a	a	a	a	a	a	a
	Mean	**17.80**	**35.60**	**55.89**	**79.35**	**98.39**	**113.16**	**134.67**	**146.79**
		±0.08	**±0.15**	**±0.23**	**±0.34**	**±0.43**	**±0.50**	**±0.59**	**±0.62**
T3	R1	17.38	34.64	54.52	77.38	96.07	110.60	131.55	143.45
	R2	17.38	34.76	54.64	77.50	96.19	110.48	131.79	143.33
	R3	17.14	34.17	53.69	76.19	94.40	108.57	129.29	140.83
	R4	17.50	34.52	54.17	77.02	95.48	109.76	130.48	142.74
		b	a	b	b	b	b	b	b
	Mean	**17.35**	**34.52**	**54.26**	**77.02**	**95.54**	**109.85**	**130.78**	**142.59**
		±0.08	**±0.13**	**±0.22**	**±0.30**	**±0.41**	**±0.47**	**±0.57**	**±0.61**
T4	R1	17.26	31.19	54.40	76.79	97.98	112.98	133.93	146.19
	R2	17.50	34.88	54.52	76.19	97.38	112.02	133.33	145.36
	R3	17.14	34.52	52.98	74.64	95.48	109.76	130.60	142.38
	R4	17.38	34.64	54.64	77.02	96.19	110.36	131.67	143.21
		b	a	b	b	ab	ab	ab	ab
	Mean	**17.32**	**33.81**	**54.14**	**76.16**	**96.76**	**111.28**	**132.38**	**144.29**
		±0.08	**±0.88**	**±0.39**	**±0.54**	**±0.57**	**±0.74**	**±0.74**	**±0.90**
	CD	0.335	-	1.102	1.601	1.851	2.278	2.567	2.826

Means bearing the same superscript within the same column do not differ significantly (P<0.01)

Table 10. Influence of cellulase supplementation on daily feed intake - ANOVA

Week	Source	df	SS	MSS	F value
1	Treatment	3	0.665	0.222	9.354 **
	Error	12	0.284	0.024	
	Total	15	0.949		
2	Treatment	3	6.499	2.166	2.654 NS
	Error	12	9.796	0.816	
	Total	15	16.295		
3	Treatment	3	9.103	3.034	11.684 **
	Error	12	3.116	0.260	
	Total	15	12.219		
4	Treatment	3	22.510	7.503	13.660 **
	Error	12	6.591	0.549	
	Total	15	29.101		
5	Treatment	3	22.730	7.577	10.324 **
	Error	12	8.806	0.734	
	Total	15	31.536		
6	Treatment	3	30.280	10.093	9.076 **
	Error	12	13.345	1.112	
	Total	15	43.625		
7	Treatment	3	41.781	13.927	9.864 **
	Error	12	16.942	1.412	
	Total	15	58.723		
8	Treatment	3	49.055	16.352	9.555 **
	Error	12	20.536	1.711	
	Total	15	69.591		

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

energy diet without cellulase (T2). During the second week there was no significant ($P<0.01$) difference between treatments but numerically higher feed consumption among the birds fed with low energy broiler ration over their counterparts could be observed. The 0.06 per cent enzyme supplemented group showed statistically no difference but numerically higher mean daily feed consumption during the second half (5-8 weeks) of the experiment than standard control and birds fed with 0.03 per cent cellulase.

The mean daily feed intake per bird as influenced by cellulase supplementation is presented in Fig.3.

4.5 Feed conversion efficiency

The data on weekly feed conversion efficiency (FCE) and cumulative feed efficiency among different treatment groups are set out in Table 11 and 13 respectively. The cumulative feed conversion efficiency obtained for different treatment groups viz., T1, T2, T3 and T4 were 1.95, 2.09, 1.87 and 1.83 at sixth week and 2.30, 2.47, 2.19 and 2.14 at the end of the experiment (eighth week) respectively.

The results of statistical analysis of the data are presented in Table 12. The FCE of low energy diet group showed significantly ($P<0.01$) poor feed conversion throughout the experiment starting from the first week. All the

Fig.3 DAILY FEED INTAKE AS INFLUENCED BY CELLULASE SUPPLEMENTATION

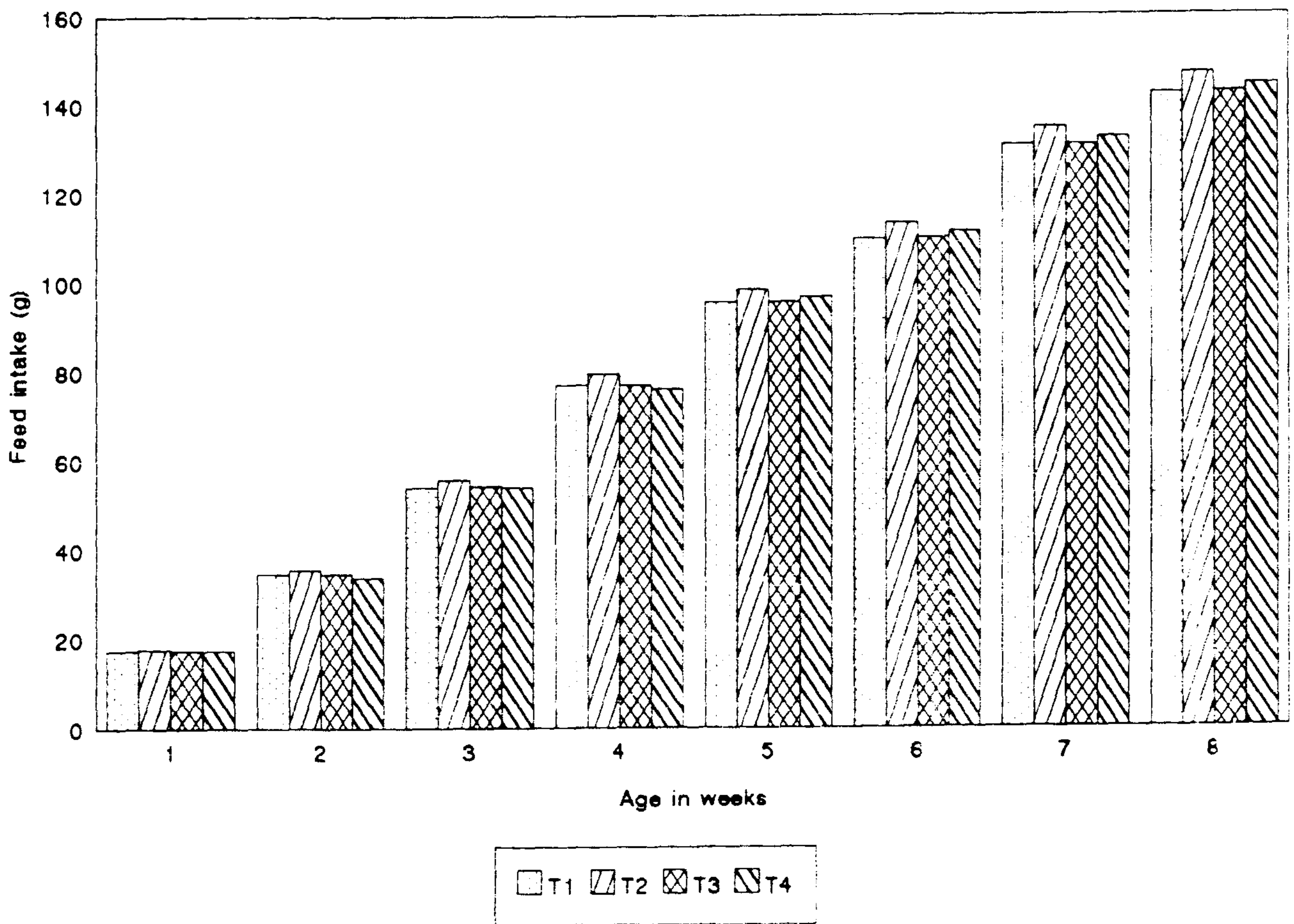


Table 11. Influence of cellulase supplementation on mean weekly feed conversion efficiency

Treatments		Age in weeks							
		1	2	3	4	5	6	7	8
T1	R1	1.39	1.57	1.65	1.93	2.22	2.51	2.96	3.25
	R2	1.39	1.58	1.65	1.95	2.24	2.53	2.96	3.26
	R3	1.40	1.60	1.66	1.96	2.25	2.55	2.99	3.28
	R4	1.38	1.58	1.63	1.93	2.21	2.48	2.94	3.23
		b	b	b	b	b	b	b	b
	Mean	**1.39**	**1.58**	**1.65**	**1.94**	**2.23**	**2.52**	**2.96**	**3.25**
		±0.005	**±0.005**	**±0.005**	**±0.010**	**±0.010**	**±0.015**	**±0.010**	**±0.010**
T2	R1	1.43	1.75	1.80	2.10	2.40	2.71	3.22	3.51
	R2	1.45	1.76	1.81	2.10	2.43	2.70	3.27	3.56
	R3	1.41	1.72	1.77	2.05	2.37	2.66	3.15	3.44
	R4	1.44	1.73	1.78	2.08	2.40	2.67	3.17	3.48
		a	a	a	a	a	a	a	a
	Mean	**1.43**	**1.74**	**1.79**	**2.08**	**2.40**	**2.69**	**3.20**	**3.50**
		±0.010	**±0.010**	**±0.010**	**±0.010**	**±0.010**	**±0.010**	**±0.010**	**±0.025**
T3	R1	1.40	1.58	1.63	1.90	2.09	2.30	2.74	3.10
	R2	1.40	1.60	1.66	1.92	2.12	2.31	2.75	3.13
	R3	1.40	1.55	1.62	1.88	2.08	2.25	2.70	3.06
	R4	1.41	1.56	1.63	1.90	2.08	2.29	2.67	3.12
		b	b	b	b	c	c	c	c
	Mean	**1.40**	**1.57**	**1.63**	**1.90**	**2.09**	**2.29**	**2.72**	**3.10**
		±0.002	**±0.010**	**±0.010**	**±0.010**	**±0.010**	**±0.015**	**±0.020**	**±0.015**
T4	R1	1.39	1.42	1.63	1.86	2.02	2.30	2.60	3.08
	R2	1.41	1.58	1.64	1.86	2.07	2.21	2.62	3.07
	R3	1.39	1.57	1.58	1.81	2.08	2.12	2.55	2.99
	R4	1.40	1.56	1.63	1.84	2.04	2.18	2.55	3.00
		b	b	b	c	c	c	d	d
	Mean	**1.40**	**1.53**	**1.62**	**1.84**	**2.05**	**2.20**	**2.58**	**3.03**
		±0.005	**±0.004**	**±0.015**	**±0.010**	**±0.015**	**±0.040**	**±0.020**	**±0.025**
	CD	0.020	0.088	0.044	0.044	0.048	0.095	0.084	0.086

Means bearing the same superscript within the same column do not differ significantly ($P<0.01$)

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

Week	Source	df	SS	MSS	F value
1	Treatment	3	0.004	0.00133	11.702 **
	Error	12	0.001	0.00008	
	Total	15	0.006		
2	Treatment	3	0.100	0.03333	19.999 **
	Error	12	0.020	0.00167	
	Total	15	0.120		
3	Treatment	3	0.074	0.02467	65.022 **
	Error	12	0.005	0.00042	
	Total	15	0.079		
4	Treatment	3	0.126	0.04200	104.140 **
	Error	12	0.005	0.00042	
	Total	15	0.130		
5	Treatment	3	0.296	0.09867	192.667 **
	Error	12	0.006	0.00050	
	Total	15	0.302		
6	Treatment	3	0.578	0.19267	99.159 **
	Error	12	0.023	0.00192	
	Total	15	0.602		
7	Treatment	3	0.909	0.30300	203.597 **
	Error	12	0.018	0.00150	
	Total	15	0.926		
8	Treatment	3	0.505	0.16833	109.181 **
	Error	12	0.019	0.00158	
	Total	15	0.524		

** Significant (P<0.01)
NS Not significant

Table 13. Influence of cellulase supplementation on production performance at 6 and 8 weeks of age

Treatments		Initial body weight (g)	Upto six weeks			Upto eight weeks		
			Body weight (g)	Total feed consumed (kg)	Cumulative feed efficiency	Body weight (g)	Total feed consumed (kg)	Cumulative feed efficiency
T1	R1	43.25	1391.67	2.698	1.94	2003.31	4.597	2.29
	R2	43.33	1391.25	2.718	1.95	2003.88	4.629	2.31
	R3	43.33	1391.67	2.735	1.97	2005.83	4.661	2.32
	R4	44.00	1409.17	2.718	1.93	2029.17	4.628	2.28
	Mean	**43.48**	**1395.94**	**2.717**	**1.95**	**2011.04**	**4.629**	**2.30**
		±0.18	**±4.41**	**±0.08**	**±0.01**	**±6.07**	**±6.11**	**±0.01**
T2	R1	43.25	1336.67	2.811	2.10	1924.17	4.787	2.49
	R2	43.58	1340.83	2.829	2.11	1924.17	4.819	2.50
	R3	43.92	1344.17	2.773	2.06	1935.83	4.724	2.44
	R4	43.67	1340.83	2.792	2.08	1931.67	4.755	2.46
	Mean	**43.60**	**1340.63**	**2.801**	**2.09**	**1928.96**	**4.771**	**2.47**
		±0.14	**±1.54**	**±0.10**	**±0.01**	**±2.90**	**±0.13**	**±0.02**
T3	R1	43.25	1462.50	2.734	1.87	2123.33	4.659	2.19
	R2	43.00	1446.67	2.737	1.89	2102.50	4.663	2.22
	R3	43.17	1455.00	2.689	1.85	2112.50	4.580	2.17
	R4	43.25	1458.33	5.719	1.86	2120.00	4.632	2.18
	Mean	**43.17**	**1455.63**	**2.720**	**1.87**	**2114.58**	**4.634**	**2.19**
		±0.06	**±3.36**	**±0.10**	**±0.01**	**±4.62**	**±0.13**	**±0.01**
T4	R1	42.92	1490.83	2.734	1.83	2184.17	4.695	2.15
	R2	42.92	1488.33	2.747	1.85	2176.67	4.698	2.16
	R3	43.08	1490.00	2.692	1.81	2182.50	4.603	2.11
	R4	43.25	1495.83	2.732	1.83	2190.83	4.656	2.13
	Mean	**43.04**	**1491.25**	**2.726**	**1.83**	**2183.54**	**4.663**	**2.14**
		±0.08	**±1.62**	**±0.10**	**±0.01**	**±2.92**	**±0.14**	**±0.01**
	Grand mean	43.32	1420.86	2.741	1.93	2059.41	4.674	2.28
		±0.14	±1.90	±0.05	±0.08	±2.47	±0.13	±0.02

remaining three groups did not significantly differ among them till the end of the third week but later, the enzyme supplemented groups showed a significant improvement in FCE than standard control.

The feed efficiency for different dietary treatment groups during the eight weeks period is depicted in Fig.4.

4.6 Nutrient utilization

4.6.1 Dry matter digestibility

The influence of cellulase supplementation on dry matter digestibility of different treatments for broiler starter and finisher ration are presented in Table 14. The mean dry matter digestibility was 70.34, 68.17, 70.25 and 71.19 per cent for broiler starter ration and 69.18, 67.95, 70.14 and 71.06 for broiler finisher ration as influenced by different treatment groups T1, T2, T3 and T4 respectively.

Though there was variation in the dry matter digestibility among different treatment groups for both rations, analysis of variance (Table 15) showed no significant ($P<0.01$) differences among treatments for this parameter.

The dry matter digestibility co-efficient of broiler starter and finisher ration as influenced by cellulase supplementation are pictured in Fig.5 and 6 respectively.

Fig.4 WEEKLY FEED EFFICIENCY AS INFLUENCED BY CELLULASE SUPPLEMENTATION

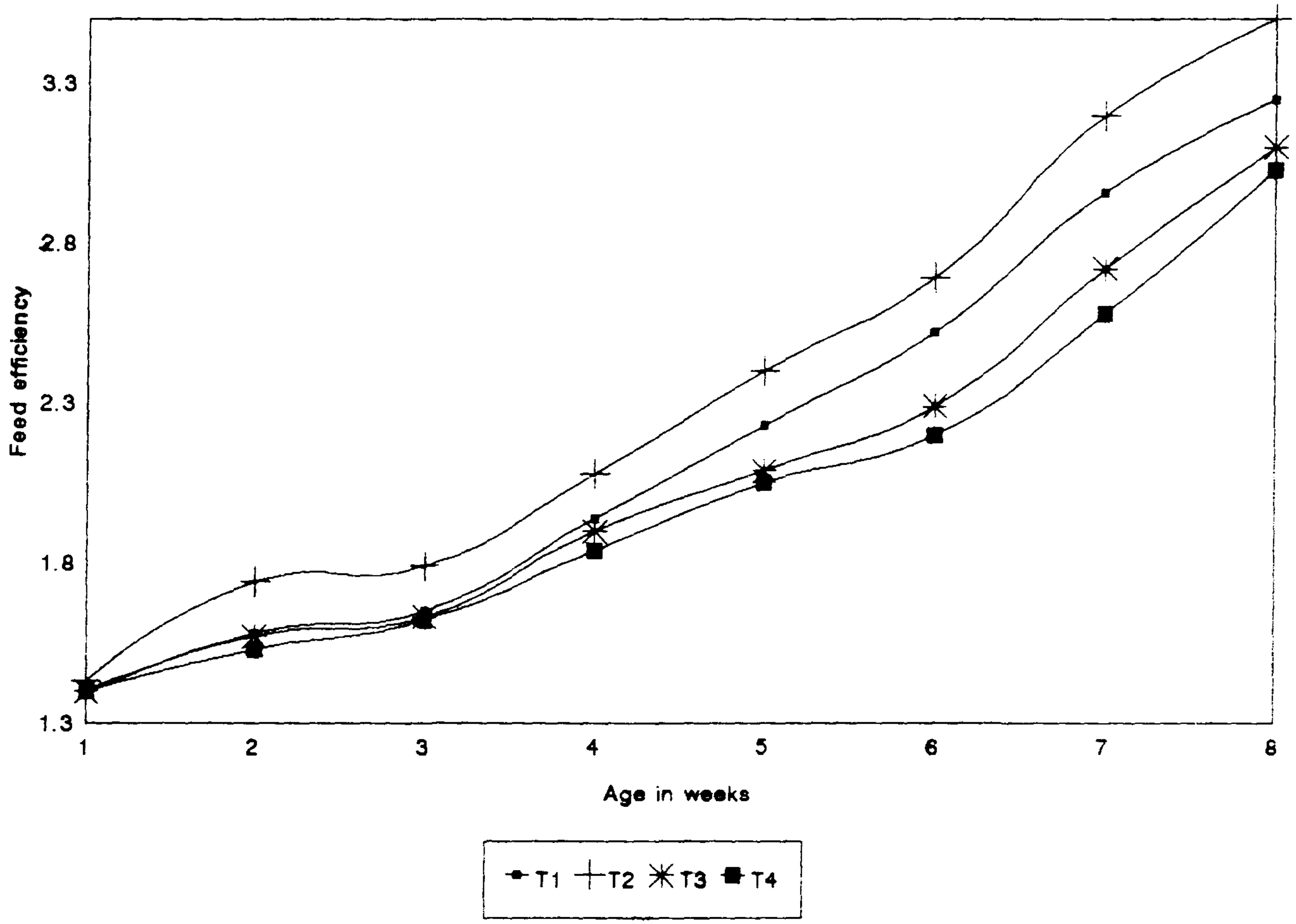


Table 14. Influence of cellulase supplementation on digestibility co-efficient of dry matter (per cent)

Bird No.	Broiler starter ration				Broiler finisher ration			
	T1	T2	T3	T4	T1	T2	T3	T4
1.	68.37	66.34	71.11	70.58	68.21	67.16	66.46	69.71
2.	67.74	64.35	65.53	71.42	66.73	68.88	69.33	68.86
3.	68.99	68.73	73.13	72.22	67.41	68.41	67.49	73.21
4.	72.82	70.02	69.91	69.93	69.89	66.93	73.34	70.54
5.	69.13	65.43	68.42	69.45	70.12	65.54	71.26	71.92
6.	69.51	66.22	71.36	72.21	70.36	69.12	69.68	77.43
7.	74.96	72.17	70.22	72.36	71.22	69.11	68.91	67.89
8.	71.18	72.08	72.28	71.36	69.43	71.42	74.67	68.92
Mean	70.34^a	68.17^a	70.25^a	71.19^a	69.18^a	67.95^a	70.14^a	71.06^a
SE	0.87	1.07	0.84	0.39	0.55	0.72	0.99	1.10

Means bearing the same superscript do not differ significantly ($P<0.01$)

Table 15. Influence of cellulase supplementation on per ent dry matter digestibility - ANOVA

Source	df	SS		MSS		F value	
		BSR	BFR	BSR	BFR	BSR	BFR
Treatment	3	39.602	42.720	13.201	14.240	2.373 NS	2.360 NS
Error	28	155.762	168.980	5.563	6.035		
Total	31	195.364	211.700				

NS Not significant

Fig.5 DIGESTIBILITY OF BROILER STARTER RATION AS INFLUENCED BY CELLULASE SUPPLEMENTATION

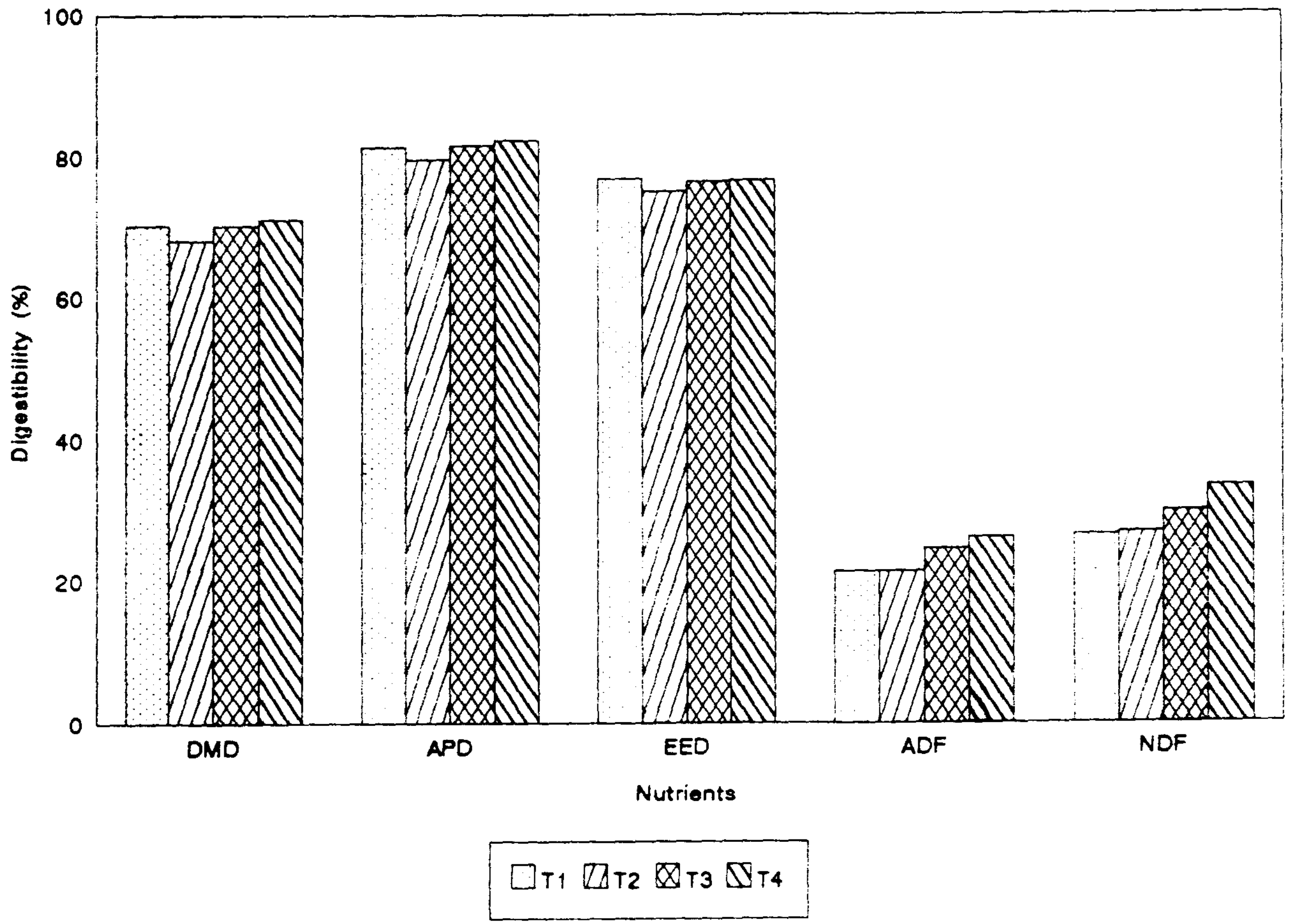
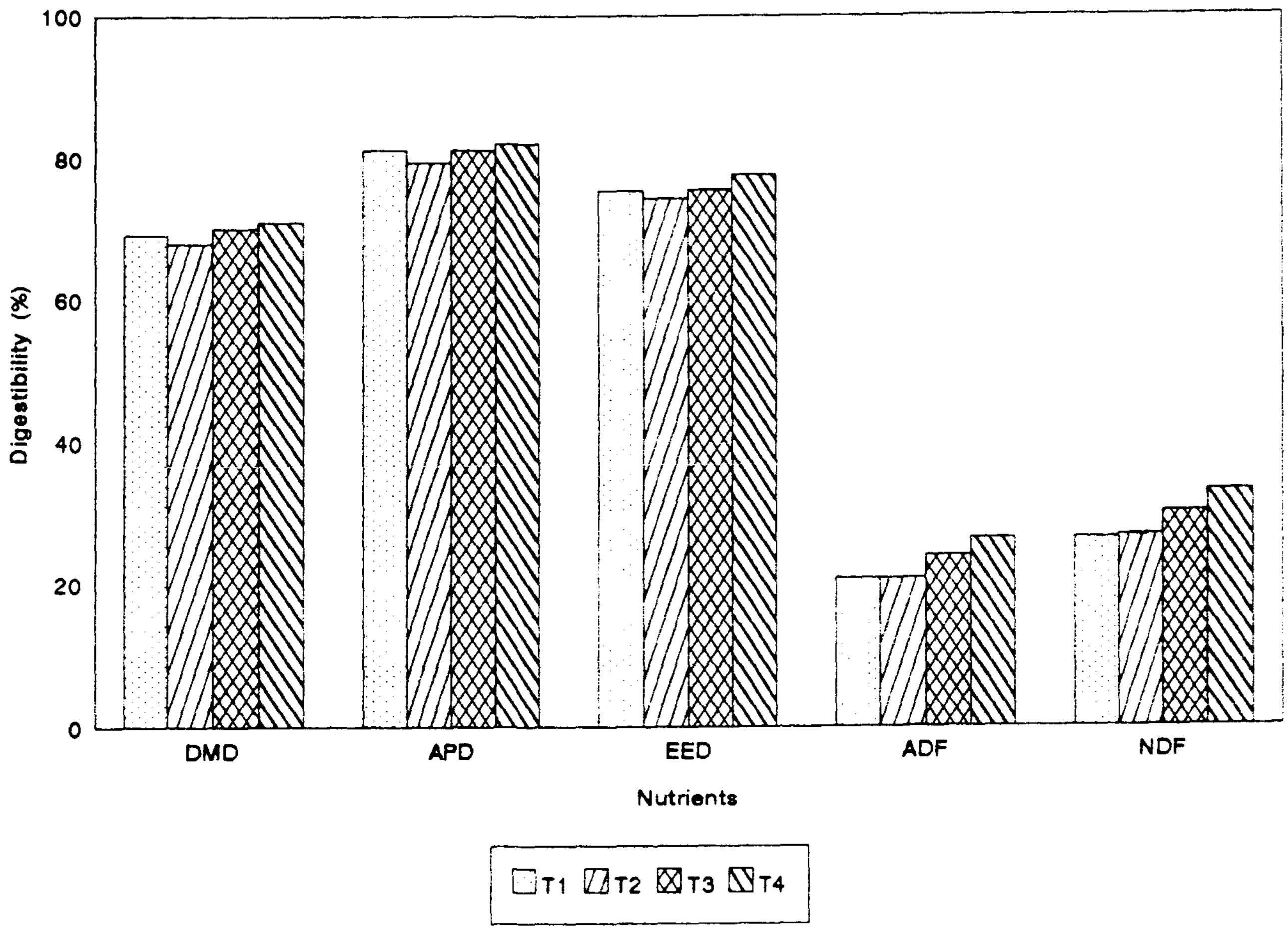


Fig.6 DIGESTIBILITY OF BROILER FINISHER RATION AS INFLUENCED BY CELLULASE SUPPLEMENTATION



4.6.2 Apparent metabolisable energy

The data on apparent metabolisable energy (AME) content of the rations for different treatment groups are presented in Table 16. The AME values were 2788, 2531, 2669 and 2792 kcal/kg feed for broiler starter ration and 2933, 2614, 2789 and 2948 kcal/kg feed for finisher ration among treatment groups T1, T2, T3 and T4 respectively.

When the data were subjected to statistical analysis (Table 17), it revealed significant ($P<0.01$) difference among treatments. The low energy diet without enzyme (T2) had significantly lower AME value than the rations supplemented with 0.03 and 0.06 per cent cellulase as well as standard control. Between the enzyme supplemented groups, T4 showed significantly higher AME than T3. Similar trend was observed with these treatment groups for both starter and finisher ration.

The AME content of different treatment groups for both starter and finisher rations are compared in Fig.7.

4.6.3 Apparent protein digestibility

Data pertaining to apparent protein digestibility (APD) of broiler starter and finisher ration fed to birds in different treatment groups are presented in Table 18. The mean apparent protein digestibility was 81.32, 79.58, 81.59

Table 16. Influence of cellulase supplementation on apparent metabolisable energy (kcal/kg)

Bird No.	Broiler starter ration				Broiler finisher ration			
	T1	T2	T3	T4	T1	T2	T3	T4
1.	2811	2532	2662	2789	2906	2628	2766	2931
2.	2789	2508	2674	2814	2954	2603	2742	2954
3.	2765	2532	2662	2766	2904	2650	2825	2931
4.	2789	2554	2686	2742	2954	2603	2787	2953
5.	2789	2532	2650	2813	2930	2603	2814	2954
6.	2788	2508	2662	2766	2931	2626	2742	2966
7.	2811	2554	2686	2814	2953	2579	2825	2966
8.	2765	2531	2674	2836	2930	2626	2814	2930
	a	c	b	a	a	c	b	a
Mean	2788	2531	2669	2792	2933	2614	2789	2948
SE	6.15	6.15	4.50	11.34	7.02	7.75	12.53	5.42
	CD - 29.28				CD - 33.60			

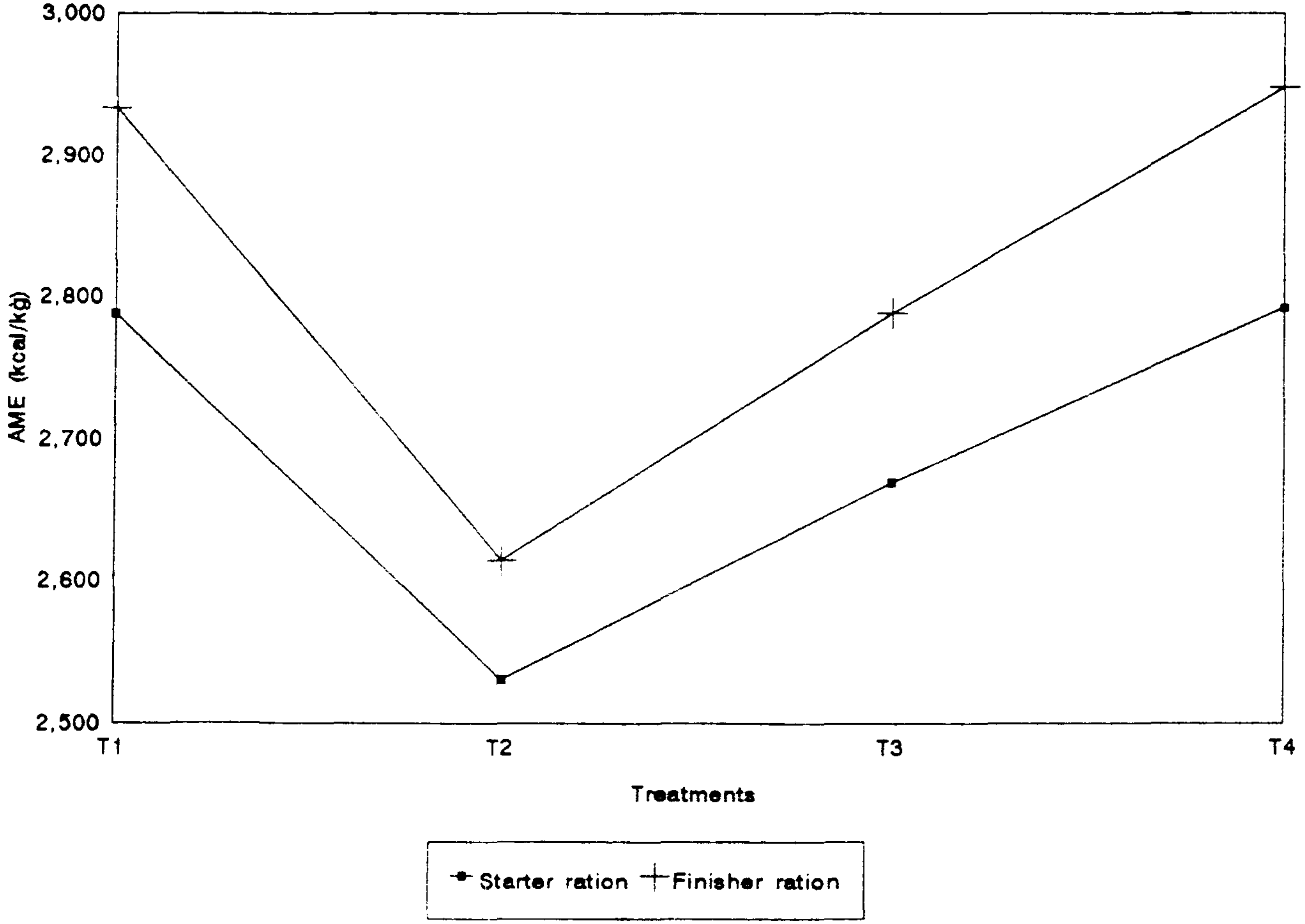
Means bearing the same superscript do not differ significantly (P<0.01)

Table 17. Influence of cellulase supplementation on apparent metabolisable energy - ANOVA

Source	df	SS		MSS		F value	
		BSR	BFR	BSR	BFR	BSR	BFR
Treatment	3	365182.125	577948.625	121727.375	192649.542	271.070**	325.652**
Error	28	12573.750	16564.250	449.063	591.580		
Total	31	377755.875	594512.875				

** Significant (P<0.01)
NS Not significant

Fig.7 APPARENT METABOLISABLE ENERGY AS INFLUENCED BY CELLULASE SUPPLEMENTATION



and 82.20 per cent for broiler starter and 81.21, 79.42, 81.12 and 82.06 per cent for broiler finisher ration with respect to treatments T1, T2, T3 and T4.

Although, there were variations in percentage apparent protein digestibility among different treatments in both the rations, when the data were subjected to statistical analysis (Table 19), it revealed no significant difference among treatments.

The per cent protein digestibility as influenced by various dietary treatments for broiler starter and finisher ration are depicted in Fig.5 and 6 respectively.

4.6.4 Apparent ether extract digestibility

The data on apparent ether extract digestibility (EED) of both broiler starter and finisher ration fed to birds in the different treatment groups are presented in Table 20. The mean apparent ether extract digestibility was 76.87, 74.97, 76.52 and 76.69 per cent for broiler starter and 75.41, 74.36, 75.52 and 77.62 per cent for broiler finisher ration with respect to treatments T1, T2, T3 and T4.

Though numerical deferences could be observed, the analysis of variance (Table 21) showed that they were not significantly different among treatments for both broiler starter and finisher ration.

Table 18. Influence of cellulase supplementation on apparent protein digestibility (per cent)

Bird No.	Broiler starter ration				Broiler finisher ration			
	T1	T2	T3	T4	T1	T2	T3	T4
1.	80.42	77.92	83.41	82.45	78.89	79.51	82.22	78.42
2.	78.59	78.69	84.32	79.35	79.91	76.09	81.98	80.68
3.	81.32	82.56	78.48	83.91	81.65	77.42	79.33	82.95
4.	82.31	80.32	79.97	84.29	79.11	82.95	82.64	82.43
5.	79.45	76.98	85.45	77.04	81.67	78.21	84.23	79.48
6.	77.63	79.13	78.37	83.89	78.42	77.65	79.35	77.77
7.	84.47	81.22	81.07	82.56	85.06	79.58	80.31	86.32
8.	86.34	82.79	81.63	84.12	84.93	83.98	78.89	88.42
Mean	81.32^{a}	79.58^{a}	81.59^{a}	82.20^{a}	81.21^{a}	79.42^{a}	81.12^{a}	82.06^{a}
SE	1.05	0.92	0.93	0.93	0.91	0.97	0.68	1.33

Means bearing the same superscript do not differ significantly (P<0.01)

Table 19. Influence of cellulase supplementation on apparent protein digestibility - ANOVA

Source	df	SS		MSS		F value	
		BSR	BFR	BSR	BFR	BSR	BFR
Treatment	3	30.332	29.218	10.111	9.739	1.372 NS	1.202 NS
Error	28	206.299	226.945	7.368	8.105		
Total	31	236.631	256.163				

NS Not significant

Table 20. Influence of cellulase supplementation on apparent ether extract digestibility (per cent)

Bird No.	Broiler starter ration				Broiler finisher ration			
	T1	T2	T3	T4	T1	T2	T3	T4
1.	75.83	74.55	76.11	75.42	74.23	75.59	74.71	74.51
2.	77.89	72.63	78.86	72.22	76.32	77.36	74.88	75.05
3.	79.45	72.74	75.41	76.93	75.05	71.91	79.23	79.45
4.	74.21	80.06	79.84	75.54	81.11	73.95	69.13	78.31
5.	78.98	74.51	72.08	77.23	79.36	77.23	78.15	76.11
6.	78.08	73.94	78.97	76.86	69.38	74.44	76.11	81.98
7.	78.31	76.81	74.22	77.36	72.27	71.26	75.05	79.23
8.	72.23	74.48	76.67	79.94	75.54	73.11	76.81	76.32
Mean	76.87^a	74.97^a	76.52^a	76.69^a	75.41^a	74.36^a	75.52^a	77.62^a
SE	0.90	0.86	0.93	0.83	1.32	0.80	1.08	0.90

Means bearing the same superscript do not differ significantly ($P<0.01$)

Table 21. Influence of cellulase supplementation on ether extract digestibility - ANOVA

Source	df	SS		MSS		F value	
		BSR	BFR	BSR	BFR	BSR	BFR
Treatment	3	18.420	44.855	6.140	14.952	0.984 NS	1.717 NS
Error	28	174.717	243.801	6.240	8.707		
Total	31	193.137	288.655				

NS Not significant

The apparent ether extract digestibility among different treatment groups for starter and finisher ration are depicted in Fig.5 and 6 respectively.

4.6.5 Digestibility co-efficient of fibre fractions

The digestibility of fibre fractions in the rations of different treatment groups are presented in Table 22 and 24 with statistical interpretation. The digestibility coefficient for acid detergent fibre (ADF) ranged from 21.32 to 26.09 for starter and 20.81 to 26.46 for finisher ration. The digestibility coefficient for neutral detergent fibre (NDF) ranged from 26.34 to 33.21 for starter and 26.46 to 33.14 for finisher ration.

The analysis of variance of the data (Table 23 and 25) showed that the ADF and NDF digestibility were significantly ($P<0.01$) higher in the T4 and T3 when compared to T1 and T2 irrespective of type of ration.

The percentage ADF and NDF digestibility for broiler starter are shown in Fig.5 and that for finisher ration in Fig.6.

4.7 Excreta moisture

The mean percentage moisture content of droppings of different treatment groups as influenced by cellulase

Table 22. Influence of cellulase supplementation on per cent acid detergent fibre digestibility

Bird No.	Broiler starter ration				Broiler finisher ration			
	T1	T2	T3	T4	T1	T2	T3	T4
1.	19.42	20.47	22.14	28.43	18.21	19.45	20.34	29.27
2.	23.50	22.35	25.45	24.76	20.34	20.94	27.47	28.93
3.	21.08	24.22	23.32	24.80	21.46	18.85	23.49	29.43
4.	21.98	18.96	24.23	29.21	21.11	20.03	25.50	21.11
5.	20.73	23.33	26.75	26.34	20.50	22.96	23.68	25.50
6.	21.11	21.18	23.72	24.89	19.21	23.87	26.23	26.34
7.	22.78	19.67	25.95	23.55	22.23	19.24	23.42	21.87
8.	20.46	20.41	23.89	26.73	23.42	21.42	22.11	23.22
Mean	21.38[b]	21.32[b]	24.43[a]	26.09[a]	20.81[b]	20.82[b]	24.03[a]	26.46[a]
SE	0.46	0.60	0.53	0.69	0.58	0.64	0.81	0.99

CD = 2.313 CD = 3.031

Means bearing the same superscript do not differ significantly (P<0.01)

Table 23. Influence of cellulase supplementation on acid detergent fibre digestibility - ANOVA

Source	df	SS		MSS		F value	
		BSR	BFR	BSR	BFR	BSR	BFR
Treatment	3	133.112	179.670	44.371	59.890	15.824 **	12.443 **
Error	28	78.513	134.773	2.804	4.813		
Total	31	211.625	314.444				

** Significant (P<0.01)

Table 24. Influence of cellulase supplementation on per cent neutral detergent fibre digestibility

Bird No.	Broiler starter ration				Broiler finisher ration			
	T1	T2	T3	T4	T1	T2	T3	T4
1.	21.33	23.44	30.73	34.79	23.28	26.58	32.27	33.80
2.	25.86	29.68	26.87	33.70	26.11	25.54	28.90	32.98
3.	27.50	24.95	28.22	29.86	28.90	25.07	28.47	34.56
4.	25.49	28.43	26.34	36.22	22.22	24.56	25.49	38.31
5.	28.88	29.41	34.98	36.50	26.34	27.44	33.11	34.57
6.	25.07	28.88	33.89	31.67	28.47	29.10	31.42	32.22
7.	26.78	27.03	29.11	32.25	26.58	26.78	32.27	30.85
8.	29.81	22.98	27.33	30.70	29.77	28.47	29.67	27.81
Mean	26.34[c]	26.85[c]	29.68[b]	33.21[a]	26.46[b]	26.69[b]	30.20[a]	33.14[a]
SE	0.92	0.96	1.15	0.88	0.94	0.57	0.90	1.08

CD - 3.141 CD - 3.490

Means bearing the same superscript do not differ significantly (P<0.01)

Table 25. Influence of cellulase supplementation on neutral detergent fibre digestibility - ANOVA

Source	df	SS		MSS		F value	
		BSR	BFR	BSR	BFR	BSR	BFR
Treatment	3	239.188	242.254	79.729	80.751	10.311 **	12.656 **
Error	28	216.508	178.659	7.732	6.381		
Total	31	455.696	420.913				

** Significant (P<0.01)

supplementation are presented in Table 26. Moisture percentage of droppings was highest (82.27 and 82.01 per cent) in birds fed with low energy diet and lowest (74.88 and 74.50 per cent) in 0.06 per cent enzyme supplemented group for broiler starter and finisher ration respectively.

The statistical analysis of data showed a significant ($P<0.01$) difference among the treatment groups with respect to excreta moisture content (Table 27). Significantly higher excreta moisture in birds fed with low energy broiler ration was observed in comparison with the other groups. There was no significant difference in the moisture content of droppings between birds fed with standard control and enzyme supplemented ration.

The percentage moisture content of droppings of different treatments for both rations as influenced by cellulase supplementation are depicted in Fig.8.

4.8 Slaughter studies

The data on dressing yield and ready-to-cook yield are presented in Table 28. The mean percentage dressed yield was 91.21, 91.18, 91.19 and 91.17 in females and 91.17, 91.19, 91.15 and 91.18 in males and the ready-to-cook yield was 71.18, 71.06, 71.14 and 71.16 in females and 71.15, 71.02, 71.19 and 71.12 in males among treatment groups viz., T1, T2,

Table 26. Influence of cellulase supplementation on moisture content of droppings (per cent)

Bird No.	Broiler starter ration				Broiler finisher ration			
	T1	T2	T3	T4	T1	T2	T3	T4
1.	73.89	83.11	74.18	72.28	76.32	83.31	78.32	75.67
2.	82.43	84.92	80.35	75.67	75.23	84.33	79.56	75.36
3.	72.90	83.66	75.34	73.98	74.38	79.78	74.55	77.43
4.	78.42	79.67	76.30	77.34	75.36	83.11	78.90	72.23
5.	76.32	84.39	72.89	76.80	81.38	81.42	72.43	77.11
6.	77.43	80.45	77.75	73.51	75.27	81.23	72.89	70.42
7.	73.47	82.73	75.34	74.77	72.54	80.21	75.05	74.38
8.	75.68	81.22	76.78	74.68	77.80	81.67	73.35	75.36
Mean	76.32 b	82.27 a	76.12 b	74.88 b	76.04 b	82.01 a	76.26 b	74.50 b
SE	1.11	0.68	0.81	0.59	0.93	0.56	0.92	0.77
	CD - 3.214				CD - 3.167			

Means bearing the same superscript do not differ significantly ($P<0.01$)

Table 27. Influence of cellulase supplementation on per cent moisture content of droppings - ANOVA

Source	df	SS		MSS		F value	
		BSR	BFR	BSR	BFR	BSR	BFR
Treatment	3	263.049	261.416	87.683	87.139	16.197 **	16.587 **
Error	28	151.581	147.100	5.414	5.254		
Total	31	414.630	408.515				

** Significant ($P<0.01$)

Fig.8 MOISTURE CONTENT OF DROPPINGS AS INFLUENCED BY CELLULASE SUPPLEMENTATION

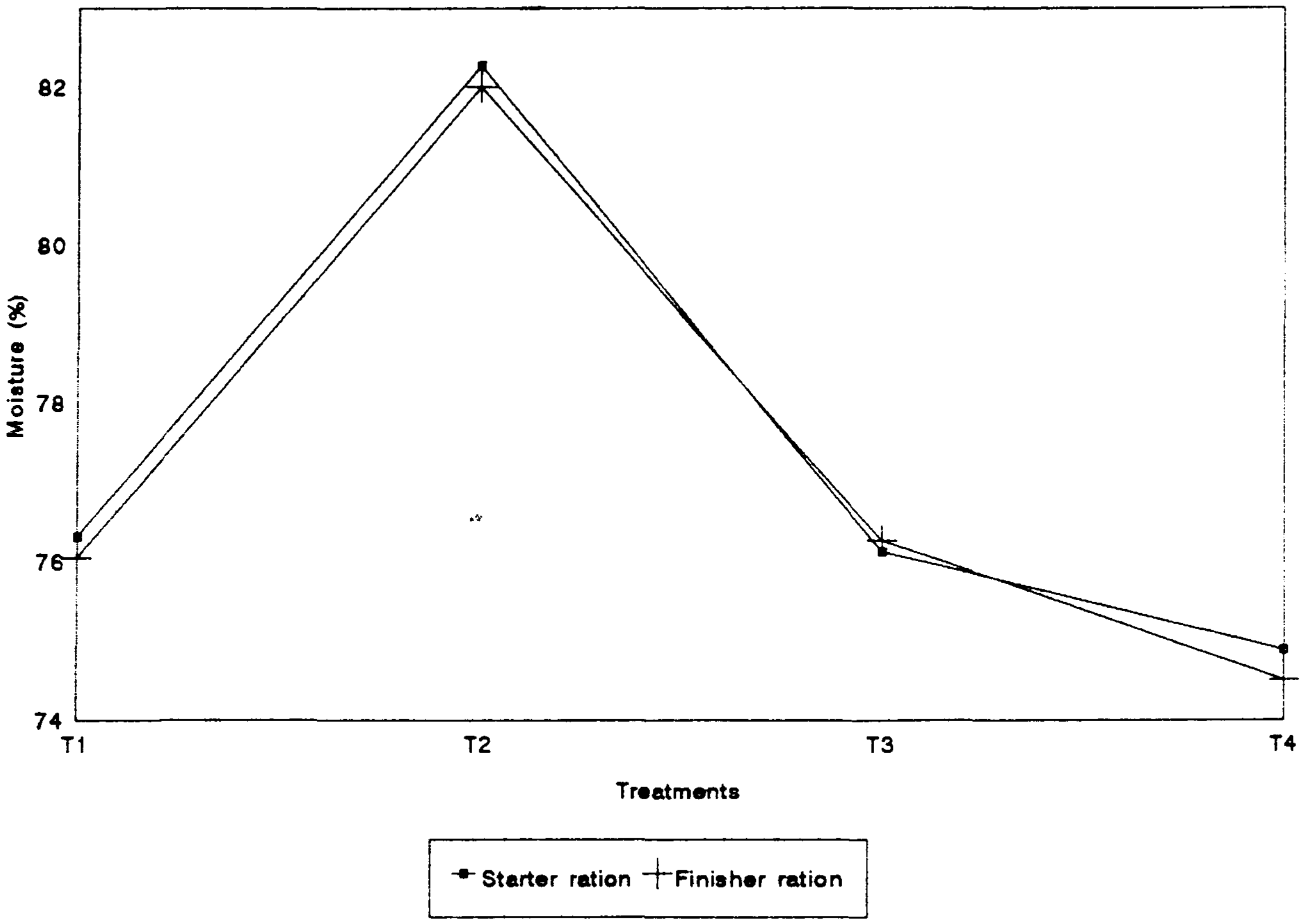


Table 28. Influence of cellulase supplementation on dressed yield and ready-to-cook yield (per cent)

Bird No.	Dressed yield (DRY)				Ready-to-cook yield (RTC)			
	T1	T2	T3	T4	T1	T2	T3	T4
Female								
1.	91.20	91.47	91.18	91.08	71.46	70.51	71.36	70.82
2.	91.31	91.26	91.11	91.25	70.92	71.28	70.81	71.36
3.	91.18	91.06	91.26	91.22	71.23	71.35	71.12	71.12
4.	91.14	90.92	91.21	91.11	71.12	71.09	71.28	71.32
	a	a	a	a	a	a	a	a
Mean	91.21	91.18	91.19	91.17	71.18	71.06	71.14	71.16
SE	0.03	0.10	0.03	0.04	0.10	0.17	0.11	0.11
Male								
1.	91.36	91.08	91.20	91.22	71.03	71.08	71.05	71.04
2.	90.86	91.11	91.10	91.14	71.30	70.68	71.41	71.42
3.	91.44	91.28	91.26	91.17	71.01	70.96	71.18	71.03
4.	91.02	91.30	91.05	91.20	71.26	71.36	71.12	70.99
	a	a	a	a	a	a	a	a
Mean	91.17	91.19	91.15	91.18	71.15	71.02	71.19	71.12
SE	0.12	0.05	0.04	0.02	0.07	0.12	0.07	0.09
Grand	a	a	a	a	a	a	a	a
mean	91.19	91.19	91.17	91.17	71.17	71.04	71.17	71.14
SE	0.06	0.06	0.03	0.02	0.06	0.10	0.06	0.07

Means bearing the same superscript do not differ significantly (P<0.01)

Table 29. Influence of cellulase supplementation on dressed yield and ready-to-cook yield - ANOVA

Source	df	SS		MSS		F value	
		DRY	RTC	DRY	RTC	DRY	RTC
Treatment	3	0.002	0.088	0.001	0.029	0.0268 NS	0.4848 NS
Sex	1	0.001	0.002	0.001	0.002	0.0419 NS	0.0274 NS
Interaction	3	0.006	0.010	0.002	0.003	0.0894 NS	0.0565 NS
Error	24	0.518	1.449	0.022	0.660		
Total	31	0.526	1.549				

NS Not significant

T3 and T4 respectively. Statistical analysis of the data (Table 29) did not reveal any significant ($P<0.01$) difference either between treatments or sex for both the parameters. But a numerical improvement for ready-to-cook yield could be observed in enzyme supplemented birds and standard control over the low energy diet group.

The mean percentage giblet yield and abdominal fat values are presented in Table 30. The percentage giblet yield was 4.69, 4.74, 4.71 and 4.70 in females and 4.70, 4.71, 4.62 and 4.67 in males and the abdominal fat yield was 4.06, 4.01, 4.04 and 4.03 in females and 3.94, 3.92, 3.94 and 3.95 in males among treatment groups viz., T1, T2, T3 and T4 respectively. The data were subjected to statistical analysis and is presented in Table 31. It revealed no significant difference between treatments in both percentage giblet yield and abdominal fat. The sex also had no significant influence on giblet yield. But the females had significantly ($P<0.01$) higher percentage abdominal fat than males.

The percentage dressing yield, ready-to-cook yield, giblet yield and abdominal fat as influenced by cellulase supplementation among different dietary treatments are depicted in Fig.9, 10, 11 and 12 respectively.

Table 30. Influence of cellulase supplementation on giblet yield and abdominal fat (per cent)

Bird No.	Giblet yield (GIB)				Abdominal fat yield (ABF)			
	T1	T2	T3	T4	T1	T2	T3	T4
Female								
1.	4.63	4.69	4.77	4.82	4.00	3.98	3.96	4.07
2.	4.74	4.97	4.62	4.62	3.87	4.17	4.05	4.00
3.	4.75	4.51	4.70	4.74	4.36	3.94	4.10	4.04
4.	4.63	4.77	4.74	4.60	3.99	3.94	4.03	4.04
	a	a	a	a	a	a	a	a
Mean	4.69	4.74	4.71	4.70	4.06	4.01	4.04	4.03
SE	0.03	0.08	0.03	0.04	0.09	0.05	0.03	0.01
Male								
1.	4.64	4.72	4.49	4.70	3.80	3.92	3.91	4.01
2.	4.75	4.69	4.57	4.71	4.02	3.94	3.90	3.95
3.	4.69	4.63	4.75	4.80	3.80	3.85	3.93	3.90
4.	4.71	4.80	4.65	4.45	4.14	3.98	4.00	3.92
	a	a	a	a	b	b	b	b
Mean	4.70	7.71	4.62	4.67	3.94	3.92	3.94	3.95
SE	0.02	0.03	0.05	0.07	0.07	0.02	0.02	0.02
Grand	a	a	a	a	a	a	a	a
mean	4.69	4.72	4.66	4.68	4.00	3.97	3.99	3.99
SE	0.02	0.04	0.03	0.04	0.06	0.03	0.02	0.02

Means bearing the same superscript do not differ significantly ($P<0.05$)

Table 31. Influence of cellulase supplementation on giblet yield and abdominal fat - ANOVA

Source	df	SS		MSS		F value	
		GIB	ABF	GIB	ABF	GIB	ABF
Treatment	3	0.015	0.005	0.005	0.002	0.4171 NS	0.1309 NS
Sex	1	0.009	0.077	0.009	0.077	0.7434 NS	6.3567 *
Interaction	3	0.010	0.001	0.003	0.001	0.2811 NS	0.0271 NS
Error	24	0.294	0.291	0.012	0.012		
Total	31	0.329	0.374				

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

Fig.9 DRESSED YIELD AS INFLUENCED BY CELLULASE SUPPLEMENTATION

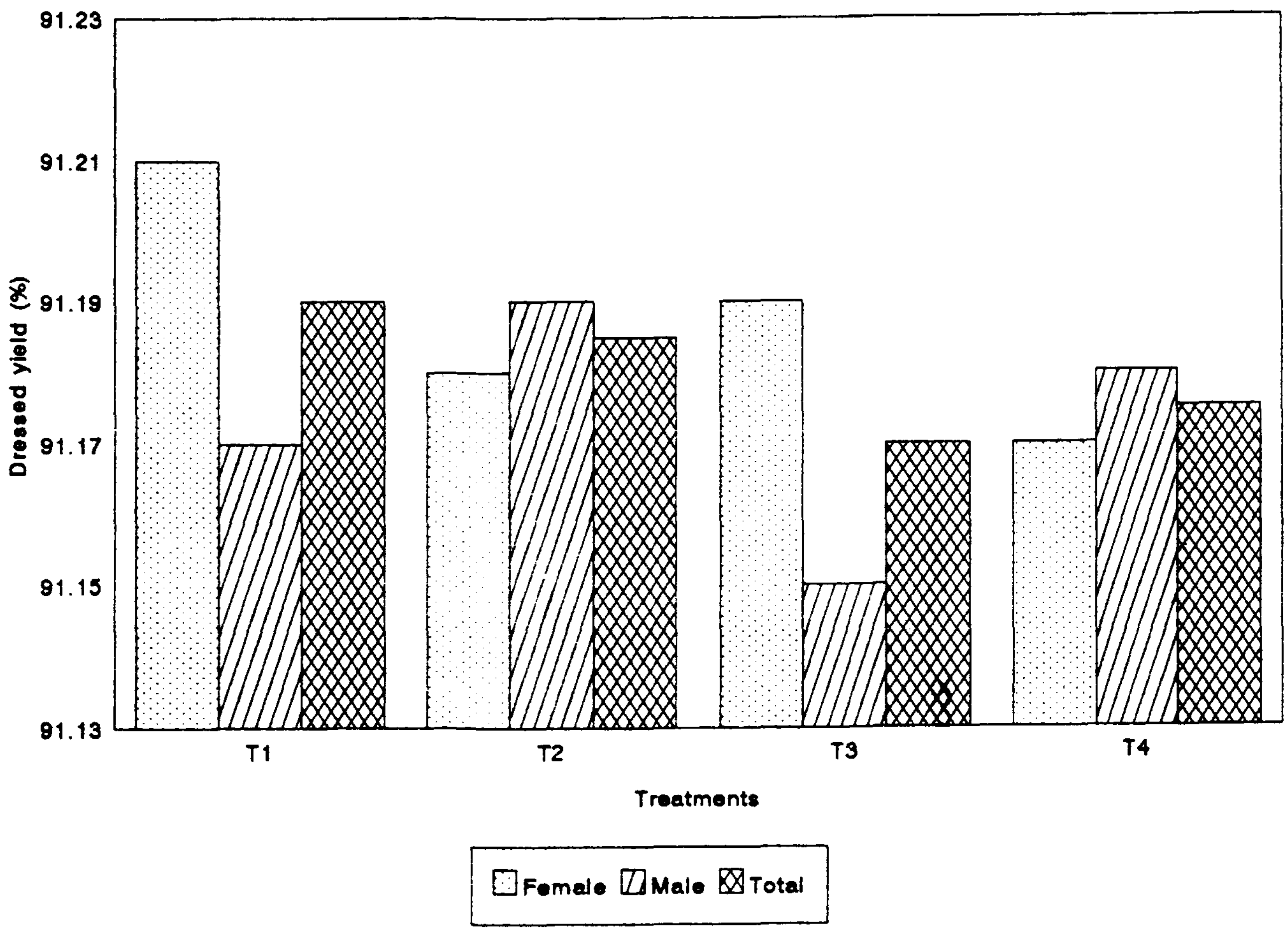


Fig.10 READY-TO-COOK YIELD AS INFLUENCED BY CELLULASE SUPPLEMENTATION

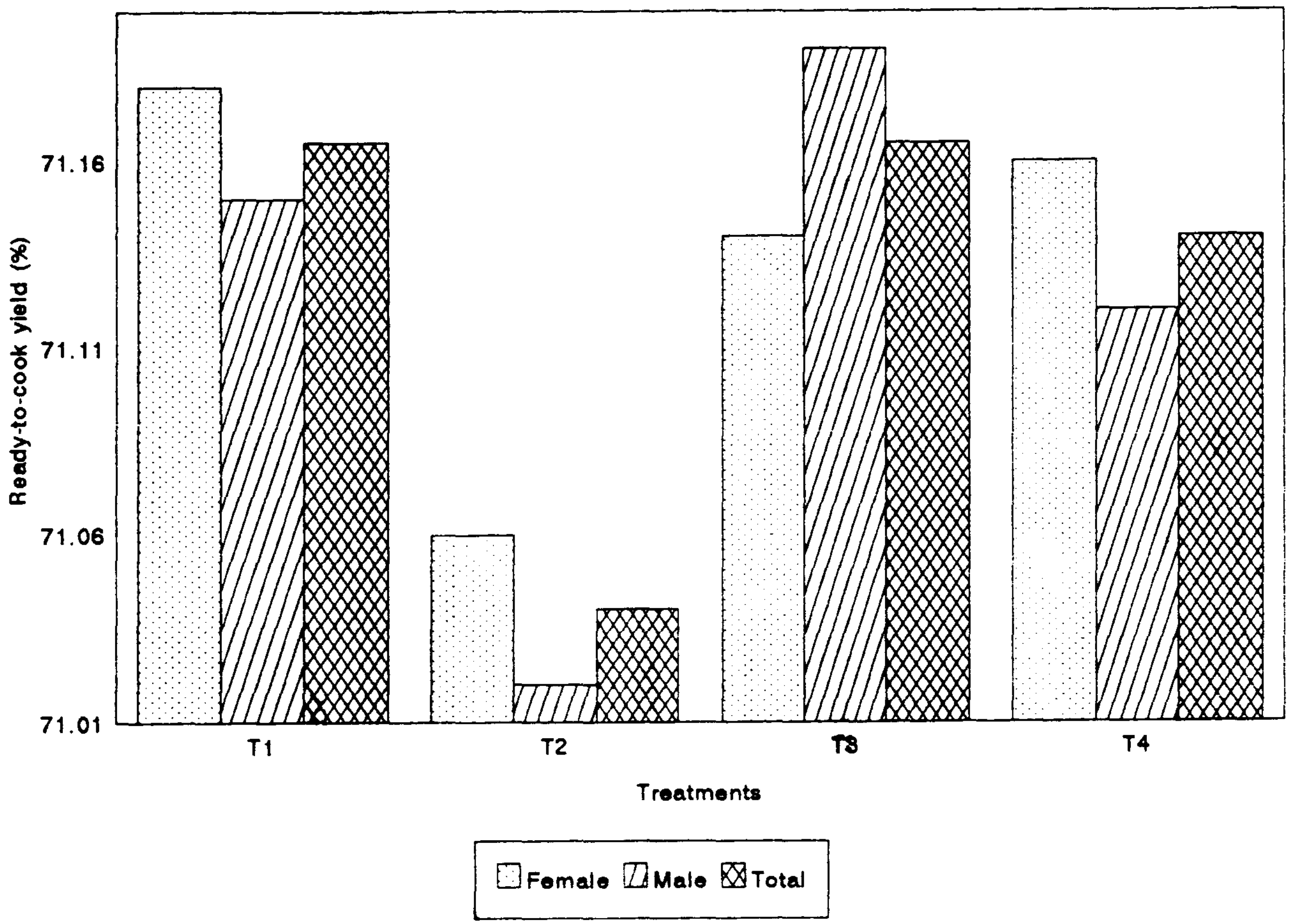


Fig.11 GIBLET YIELD AS INFLUENCED BY CELLULASE SUPPLEMENTATION

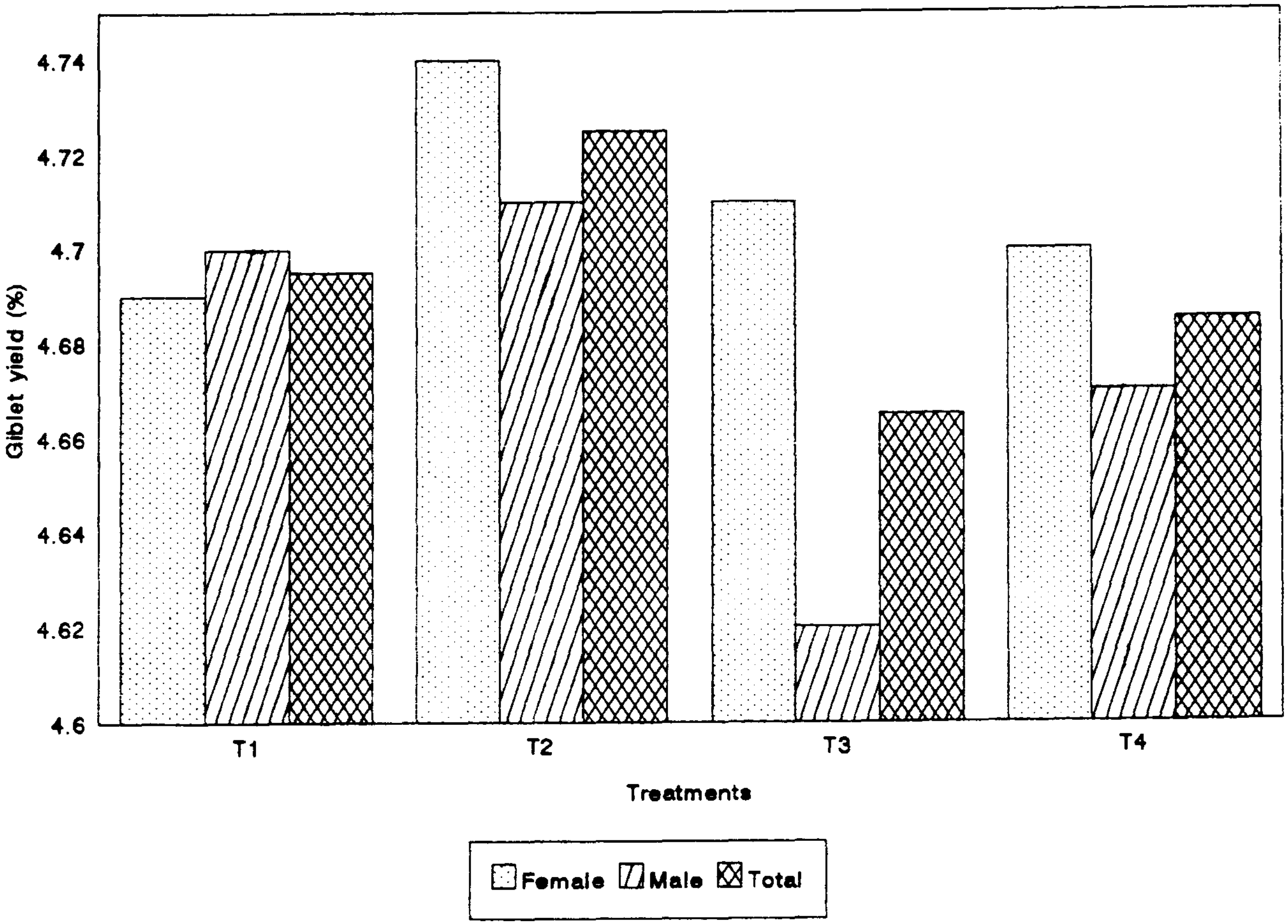
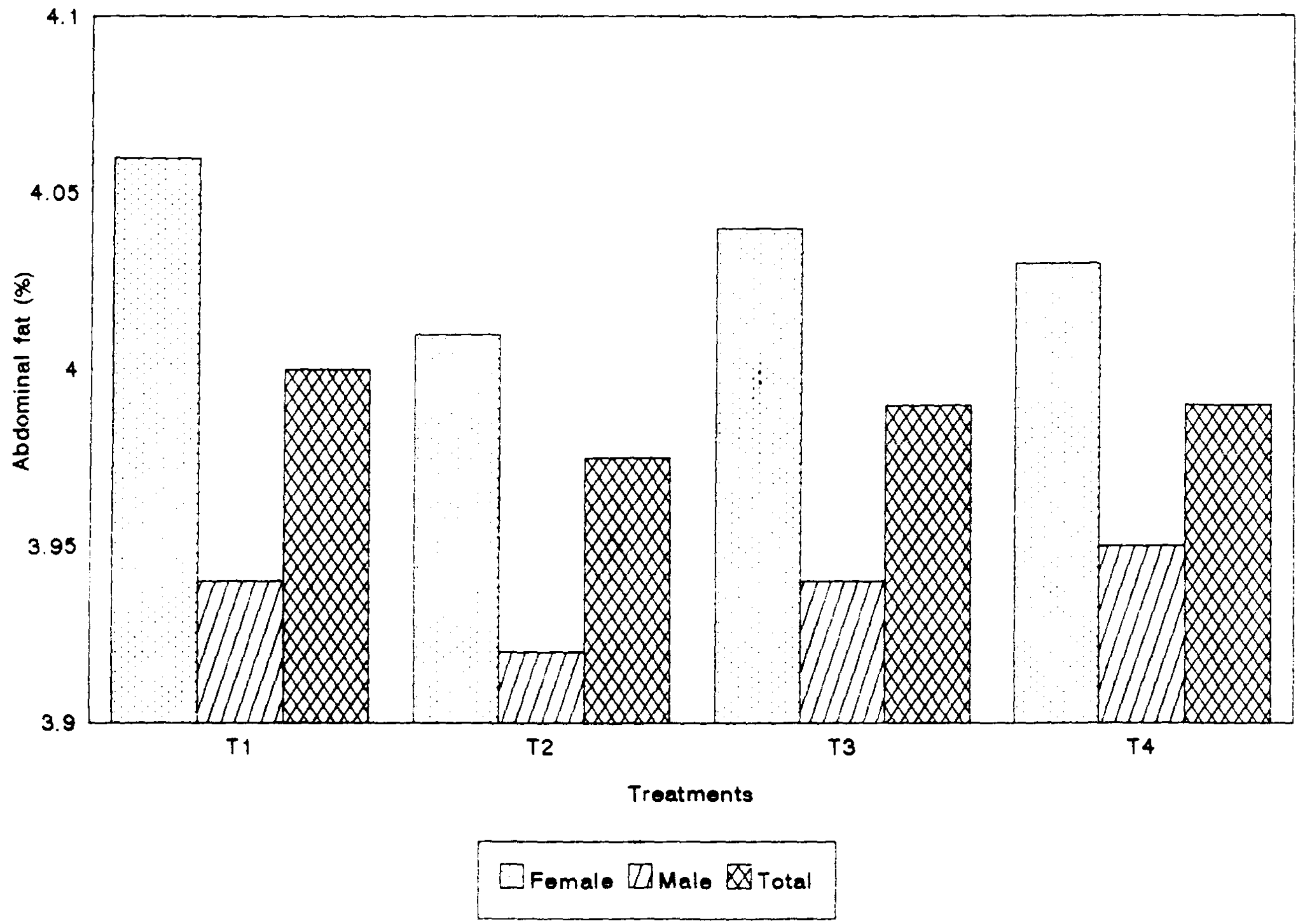


Fig.12 PERCENTAGE OF ABDOMINAL FAT AS INFLUENCED BY CELLULASE SUPPLEMENTATION



4.9 Intestinal viscosity

The effect of cellulase supplementation on the viscosity of intestinal contents are presented in Table 32. The mean values for intestinal viscosity were 2.44, 2.83, 2.02 and 1.96 sec/sec for the groups T1, T2, T3 and T4 respectively.

The statistical analysis of data showed significant differences in intestinal viscosity among treatments as in Table 33. The birds fed on low energy 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 low energy diet fed birds. The intestinal viscosity values were statistically comparable among the enzyme supplemented groups.

Viscosity of intestinal contents of different dietary treatments as influenced by cellulase supplementation is presented in Fig.13.

4.10 Livability

Mortality pattern of birds in the different treatment groups are shown in Table 34. Altogether eight birds died during the course of study. The percentage mortality ranged from a minimum of 2.1 to a maximum of 6.3. There was less

Table 32. Influence of cellulase supplementation on the viscosity of intestinal contents (sec/sec)

Bird No.	T1	T2	T3	T4
1.	2.45	3.09	2.00	1.92
2.	2.45	2.82	2.09	1.82
3.	2.36	2.73	2.09	2.09
4.	2.55	2.82	2.18	1.91
5.	2.45	2.73	1.82	2.00
6.	2.36	2.91	1.91	1.82
7.	2.45	2.82	2.00	2.09
8.	2.45	2.73	2.09	2.00
Mean	2.44^{b}	2.83^{a}	2.02^{c}	1.96^{c}
SE	0.02	0.04	0.04	0.04

CD - 0.145

Means bearing the same superscript do not differ significantly (P<0.01)

Table 33. Influence of cellulase supplementation on intestinal viscosity - ANOVA

Source	df	SS	MSS	F value
Treatment	3	3.971	1.324	122.308 **
Error	28	0.303	0.011	
Total	31	4.274		

** Significant (P<0.01)

Fig.13 VISCOSITY OF INTESTINAL CONTENTS AS INFLUENCED BY CELLULASE SUPPLEMENTATATION

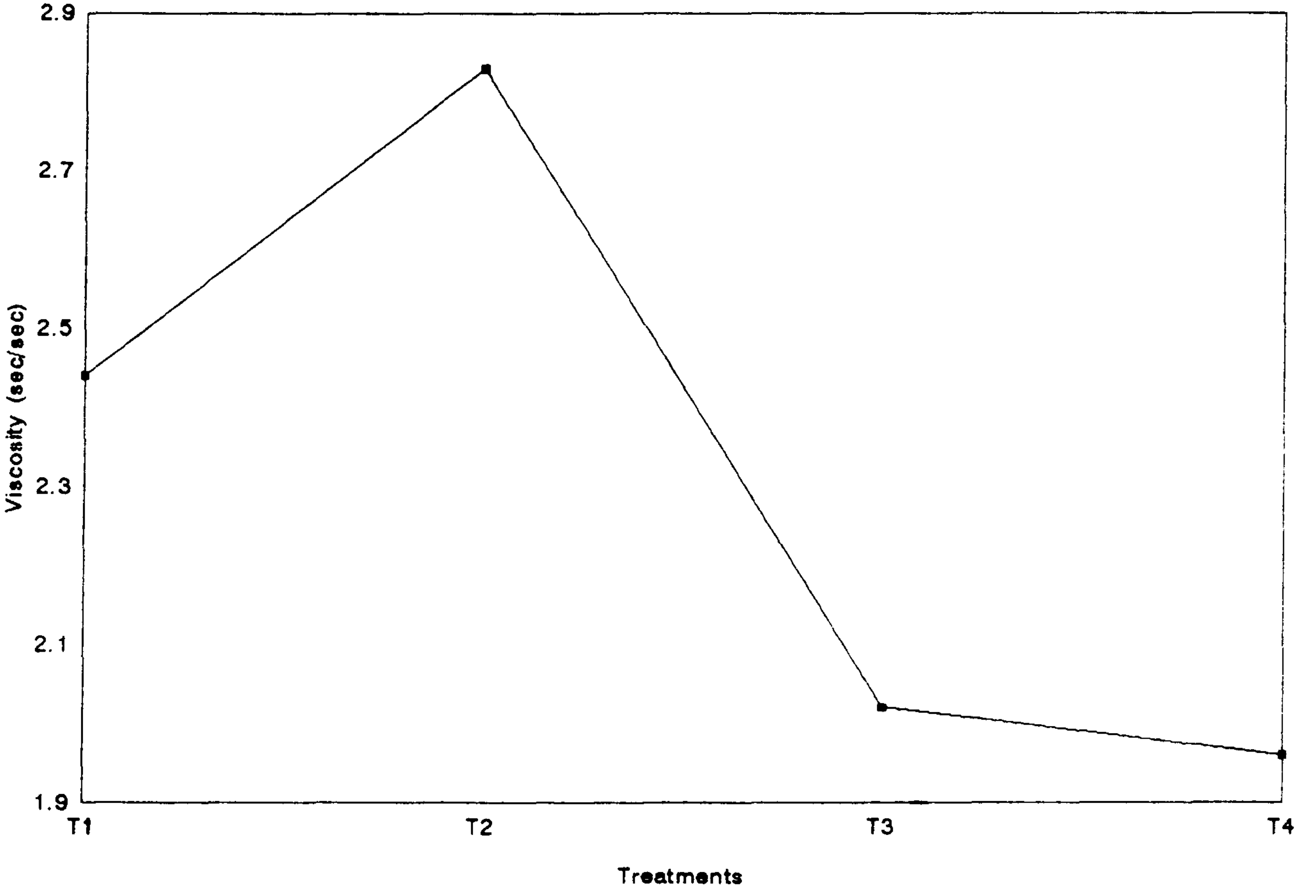


Table 34. Mortality pattern among different treatments

Period (weeks)	T1	T2	T3	T4
1.	-	-	-	-
2.	-	1	1	1
3.	1	-	-	-
4.	-	-	-	-
5.	-	-	-	-
6.	1	-	-	-
7.	-	1	-	1
8.	-	1	-	-
Total	2	3	1	2
Rate (%)	4.2	6.3	2.1	4.2

mortality in the group fed with 0.03 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 broiler housed mortality.

4.11 Cost benefit analysis

In order to assess the cost-benefit particulars of supplementation of cellulase enzyme in low energy 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 35. Cost of rations computed for different treatments viz., T1, T2, T3 and T4 were 8.34, 7.94, 7.96, 7.99 rupees per kg starter and 7.67, 7.24, 7.26, 7.29 rupees per kg finisher feed respectively.

The cost benefit analysis for different dietary treatments set out in Table 36 indicated that feed cost for production of one kg live weight was Rs.18.56, 18.92, 16.81 and 16.44 for different treatments viz., T1, T2, T3 and T4 respectively. This revealed that the cost was lower in both the enzyme supplemented groups when compared with the other two treatment groups.

Table 35. Cost of experimental rations

Ingredients	Cost/ kg* (Rs.)	Broiler starter ration				Broiler finisher ration			
		T1	T2	T3	T4	T1	T2	T3	T4
Yellow maize	5.67	249.48	170.10	170.10	170.10	300.51	226.80	226.80	226.80
Groundnut cake (exp)	11.50	368.00	310.50	310.50	310.50	299.00	264.50	264.50	264.50
Gingelly oilcake	9.24	27.72	55.44	55.44	55.44	-	-	-	-
Unsalted dried fish	8.70	78.30	87.00	87.00	87.00	69.60	78.30	78.30	78.30
Rice polish	4.79	47.90	47.90	47.90	47.90	52.69	43.11	43.11	43.11
Wheat bran	4.69	-	46.90	46.90	46.90	-	46.90	46.90	46.90
De-oiled rice bran	2.70	-	13.50	13.50	13.50	-	18.90	18.90	18.90
Common salt	1.51	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38
Mineral mixture	6.99	12.23	12.23	12.23	12.23	12.23	12.23	12.23	12.23
Vitamin mixture	477.84	4.78	4.78	4.78	4.78	4.78	4.78	4.78	4.78
Lysine hcl	169.41	33.88	33.88	33.88	33.88	16.94	16.94	16.94	16.94
Coccidiostat	216.19	10.81	10.81	10.81	10.81	10.81	10.81	10.81	10.81
Manganese sulphate	173.80	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33
Enzyme cellulase	80.00	-	-	2.40	4.80	-	-	2.40	4.80
Total cost (100 kg)		833.81	793.75	796.15	798.55	767.27	723.98	726.38	728.78
Cost (kg)		8.34	7.94	7.96	7.99	7.67	7.24	7.26	7.29

* The rate contract approved by the University was taken as cost of feed ingredients

Table 36. Cost benefit analysis per bird for the different treatment groups

Sl. No.	Particulars	T1	T2	T3	T4
1.	Live body weight (g)	2011	1929	2115	2184
2.	Total feed consumption (g)	4629	4771	4634	4663
	a. Starter ration (g)	2717	2801	2720	2726
	b. Finisher ration (g)	1912	1970	1914	1937
3.	Feed cost (Rs.)	37.32	36.50	35.55	35.90
4.	Feed ± chick cost (Rs.)	50.57	49.75	48.80	49.15
5.	Total cost (Rs.)*	55.57	54.75	53.80	54.15
6.	Returns from sale of broiler (Rs.)	70.39	67.52	74.03	76.44
7.	Profit over feed cost (Rs.)	33.06	31.01	38.48	40.54
8.	Profit over feed + chick cost (Rs.)	19.82	17.77	25.23	27.29
9.	Net profit per bird (Rs.)	14.82	12.77	20.23	22.29
10.	Feed cost per kg body weight (Rs.)	18.56	18.92	16.81	16.44
11.	Total cost per kg body weight (Rs.)	27.64	28.38	25.44	24.79
12.	Profit over feed cost per kg body weight (Rs.)	16.44	16.08	18.19	18.56
13.	Net profit per kg body weight (Rs.)	7.36	6.62	9.52	10.21

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

Discussion

5. DISCUSSION

The results obtained from the study of cellulase supplementation in low energy diet on the performance of broilers and other related parameters are discussed in this chapter.

5.1 Climatic parameters

The overall mean maximum and minimum temperature recorded inside the experimental shed during the trial period of eight weeks was 34.55°C and 22.71°C, respectively. The mean relative humidity was 82.8 per cent in the morning and 37.9 per cent in afternoons. Based on these climatic observation it was evident that the experimental period fell within the normal summer season of Kerala.

5.2 Body weight

Among the different treatments studied, the low energy group with enzyme supplemented at 0.06 per cent level obtained maximum body weight during sixth week and eighth week. The low energy group with enzyme supplemented at 0.03 per cent showed second best body weight during sixth and eighth week.

The above findings were in line with the reports published by Al-Zubaida *et al.* (1990), Kumprecht *et al.*

(1990), Bhatt *et al.* (1991), Birzer *et al.* (1993), Vranjes *et al.* (1994) and Mohammed (1995). They reported significant improvement in mean weekly body weight among broiler chicken fed diet supplemented with enzyme mixtures having cellulolytic activity. Nahm and Carlson (1985) observed neither significant improvement in growth nor impairment of growth when cellulase was supplemented in broiler diet. The positive results obtained in body weight indicate that the enzyme preparation improved the ability to utilize the nutrients in the less digestible feed ingredients and produced better results than the standard ration. It further revealed that a reduction of about 300 kcal ME per kg was compensated by the addition of different levels of enzyme cellulase and a better performance could be obtained than the control ration by the utilization of cheaper ingredients like deoiled rice bran and wheat bran in the ration.

5.3 Body weight gain

The data on mean body weight gain showed that the level of cellulase has a linear response as evidenced by significantly higher body weight gain from 2 to 8 weeks of age than the standard and low energy diet. It was found that in all groups except the low energy group the peak weight gain was during seventh week whereas the later showed the same during sixth week. From the significantly higher body weight gain in the enzyme supplemented groups it is evident that inclusion of cellulase in low energy diet positively influenced the body weight gain in broilers by the digestion of NSPs and release of locked-up nutrients.

This trend of results when compared with the findings of other workers, Tishenkova and Serikova (1987), Rotter *et al.* (1989), Brufau *et al.* (1991), Friesen *et al.* (1991), Jeroch (1992), Marek and Splitek (1992) and Flores *et al.* (1994) reported that the enzyme mixtures containing cellulase in the diet of broiler chicken significantly improved the body weight gain, but Nahm and Carlson (1985) found that the addition of cellulase in broiler diet neither resulted in a significant growth response nor impaired growth. Based on this observation, it is clear to conclude that improvement in body weight in birds fed with low energy diet is possible and it depends upon the type and proportion of the ingredients used in the formulation of the diet.

5.4 Feed intake

The feed consumption (g/bird/day) of the birds in different dietary treatments revealed that birds offered low energy broiler ration without cellulase supplementation consumed more feed than those fed with a standard broiler ration or low energy diet supplemented with different levels of enzyme. The increase in feed intake in low energy group was to a tune of 0.5 g/day/bird during the first week, which steadily increased and reached 4g in other groups except T4 in which case it was only 2g at the end of the experiment. Thus it contributed to a reduced feed consumption of about 142g in standard control and 137 and 108g in enzyme supplemented groups (T3 and T4) at the end of the trial when compared to the low energy diet without enzyme (T2). Statistical analysis showed that it was significantly ($P<0.01$) more in birds fed with low energy diet without enzyme than all other groups tested. The feed intake among the other groups showed no significant difference except during the later part (5 to 8 weeks), the 0.06 per cent cellulase supplemented group showed a significant difference. In overall, enzyme supplemented group had favourable results when viewed from the commercial angle.

Since birds consume primarily to satisfy their energy requirement, significantly ($P<0.01$) lower feed intake noticed in the enzyme supplemented low energy diets could be due to the availability of more ME in these diets when compared to low energy diet without cellulase supplementation. However, this has to be adjudged with apparent metabolisable energy of low energy diet after enzyme addition. Further, the increased feed intake in 0.06 per cent cellulase supplemented group than 0.03 per cent group might be due to the increased body weight gain in the former eventhough the apparent metabolisable energy was higher.

The present results confirm the observation of Arora *et al.* (1991), Kadam *et al.* (1991), Francesch *et al.* (1994), Marquardt *et al.* (1994), Rajmane *et al.* (1994) and Schurz *et al.* (1994), who reported that addition of enzyme preparations containing cellulase in the broiler diet had significantly decreased the feed intake. On the contrary. Friesen *et al.* (1991) reported that supplementation of a crude cellulase preparation in rye based diet fed to young broilers increased the feed consumption when compared to unsupplemented control. Flores *et al.* (1994) and Inborr and Bedford (1994) recorded no influence on feed intake when enzyme mixtures with cellulolytic activity was supplemented in broiler diet.

Considering the results in the present study and related studies by other workers, it is reasonable to presume that cellulase supplementation in low energy diet reduces the feed intake by improving the availability of nutrients especially the metabolisable energy possibly by acting on the non-starch polysaccharides present in the feed.

5.5 Feed efficiency

The cumulative feed efficiency at the end of the experiment was 2.30, 2.47, 2.19 and 2.14 for the treatment groups T1, T2, T3 and T4 respectively. The superior feed efficiency among the four treatments was recorded in birds fed with low energy diet supplemented with 0.06 per cent cellulase (T4) followed by T3, T1 and T2. It is quite clear from the data that in all enzyme supplemented groups feed efficiency was better when compared to standard broiler diet as well as low energy diet without enzyme. Comparatively lower body weight gain and higher feed consumption in low energy diet group over others contributed to poor feed efficiency. The significantly better feed efficiency in 0.06 per cent cellulase supplemented group than the standard ration indicated the increased availability of the nutrients eventhough the ME content was lower than the standard group.

Improvement in the feed efficiency due to the addition of either cellulase alone or with other enzymes in broiler diet have been reported by many workers (Bhatt *et al.* (1991), Brufau *et al.* (1991), Friesen *et al.* (1992), Gadient and Broz (1992), Ritchner *et al.* (1993), Mikulec *et al.* (1994), Vranjes *et al.* (1994) and Mohammed (1995). From the available literature no report could be traced which contradicts the present findings in feed gain ratio as influenced by enzyme supplementation.

In the present study also the feed efficiency was significantly (P<0.01) better with supplementation of different levels of cellulase in low energy ration. Comparatively less feed intake and increased body weight gain among the enzyme supplemented groups led to favourable improvement in feed efficiency. This could be attributed to availability of more ME and nutrients in these groups when compared with low energy diet without enzyme addition which subsequently decreased the feed intake and increased the weekly weight gain.

5.6 Nutrient utilization and availability

Chicken being a monogastric animal, only limited quantity of essential aminoacids and vitamins are synthesised in their gastro-intestinal tract, thereby depends 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 meat production with better feed utilization efficiency. The incorporation of agricultural by-products and other feed stuffs having low energy and high fibre content in poultry rations hamper the bio-availability of ME and other 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 gel forming characters retard 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 observations.

The DMD, AME, APD, digestibility of ether extract and the fibre fractions namely ADF, NDF of the feed used in different treatments were determined to assess the improvement, if any, in the nutrient availability due to cellulase supplementation in low energy broiler diet.

5.6.1 Dry matter digestibility

In broiler starter and finisher rations higher dry matter digestibility was recorded with enzyme supplemented birds followed by standard control when compared to the low energy diet group without cellulase. But the statistical analysis of the data revealed no significant difference among treatments for both the broiler starter and finisher ration.

Isshiki and Nakahiro (1983) in their experiment on Leghorn cockerels found that digestibility of nutrients was increased by increasing levels of cellulase to diet containing ground barley. Al-Zubaida *et al.* (1990) and Marquardt *et al.* recorded an increased digestibility of organic matter by cellulase addition in broiler diet. Also the reports of

Fengler *et al.* (1988) and Bhatt *et al.* (1991) supported an apparent improvement with no significance ($P<0.01$) in the per cent utilization of dry matter, when broilers were fed diet supplemented with enzyme mixtures containing cellulase.

5.6.2 Apparent metabolisable energy

The mean AME value showed the lowest value of 2531 and 2614 kcal/kg with low energy diet group when fed with broiler starter and finisher ration respectively. It was also evident from the data that as the level of cellulase supplementation in low energy diet increased there was corresponding improvements in AME values. Addition of 0.03 and 0.06 per cent cellulase in low energy diets resulted in an improvement of 138 and 261 kcal/kg in broiler starter ration and 175 and 334 kcal/kg in broiler finisher ration as compared with low energy control group. Statistical analysis of AME values revealed significant ($P<0.01$) differences among the treatments. Significantly lower AME value was noticed in low energy diet for broiler starter and finisher. Further, no significant difference was noticed among 0.06 per cent cellulase supplemented group and standard control.

The findings of this study clearly indicated that addition of enzyme in low energy diet resulted in significant improvement in AME value. Significantly lower feed intake reported in the groups fed with low energy diet containing various levels of cellulase than the unsupplemented control confirms this finding. A same trend has been reported by Rotter *et al.* (1990), Bhatt *et al.* (1991), Friesen *et al.* (1991 and 1992), Wantia (1993), Vranjes *et al.* (1994) and Vranjes and Wenk (1995a and b).

5.6.3 Apparent protein digestibility

The crude protein content of standard and low energy rations was 23.38 and 23.24 in broiler starter and 20.26 and 20.18 in broiler finisher respectively. The mean apparent protein digestibility (APD) among different treatments for both rations revealed lower APD in low energy diet without cellulase supplementation than the other diets. But statistical analysis of the data showed no significant difference among the treatments.

From the data non-significant numerical improvement in the APD with the increasing levels of cellulase supplementation could be observed. This confirms the observations of Rotter *et al.* (1990), Bhatt *et al.* (1991), Friesen *et al.* (1991 and 1992), Marquardt *et al.* (1994) and Swain *et al.* (1994b), who reported that supplementation of enzyme mixtures containing cellulase improved the apparent protein digestibility in broiler or chick diet.

Table 22. Influence of cellulase supplementation on per cent acid detergent fibre digestibility

Bird No.	Broiler starter ration				Broiler finisher ration			
	T1	T2	T3	T4	T1	T2	T3	T4
1.	19.42	20.47	22.14	28.43	18.21	19.45	20.34	29.27
2.	23.50	22.35	25.45	24.76	20.34	20.94	27.47	28.93
3.	21.08	24.22	23.32	24.80	21.46	18.85	23.49	29.43
4.	21.98	18.96	24.23	29.21	21.11	20.03	25.50	21.11
5.	20.73	23.33	26.75	26.34	20.50	22.96	23.68	25.50
6.	21.11	21.18	23.72	24.89	19.21	23.87	26.23	26.34
7.	22.78	19.67	25.95	23.55	22.23	19.24	23.42	21.87
8.	20.46	20.41	23.89	26.73	23.42	21.42	22.11	23.22
Mean	21.38^{b}	21.32^{b}	24.43^{a}	26.09^{a}	20.81^{b}	20.82^{b}	24.03^{a}	26.46^{a}
SE	0.46	0.60	0.53	0.69	0.58	0.64	0.81	0.99

CD = 2.313 CD = 3.031

Means bearing the same superscript do not differ significantly (P<0.01)

Table 23. Influence of cellulase supplementation on acid detergent fibre digestibility - ANOVA

Source	df	SS		MSS		F value	
		BSR	BFR	BSR	BFR	BSR	BFR
Treatment	3	133.112	179.670	44.371	59.890	15.824 **	12.443 **
Error	28	78.513	134.773	2.804	4.813		
Total	31	211.625	314.444				

** Significant (P<0.01)

5.6.4 Apparent ether extract digestibility

The data pertaining to apparent ether extract digestibility (EED) of both broiler starter and finisher rations fed to birds of different treatment groups showed no significant difference among the treatments for both the rations. But a numerical improvement in the percentage EED could be observed among enzyme supplemented groups over low energy diet group without cellulase. The standard control showed apparently similar EED with that of cellulase supplemented groups.

The findings of the present study supports the reports of Fengler *et al.* (1988), Bhatt *et al.* (1991), Viveros *et al.* (1994), Vranjes *et al.* (1994) and Vranjes and Wenk (1995a and b) but Swain *et al.* (1994b) and Dhar *et al.* (1996a and d) who did not notice any favourable effect on EED in broilers fed on diet supplemented with cellulase enzyme mixtures.

5.6.5 Digestibility of fibre fractions

Statistical analysis of the data revealed significantly (P<0.01) lower ADF and NDF digestibility for both standard control and low energy diet fed groups when compared with cellulase supplemented groups. It could be established that cellulase addition in low energy diet resulted in significant improvement in the digestibility of ADF and NDF for starter and finisher rations. A significant linear response could be observed with the inclusion level of cellulase in the broiler diet on the per cent ADF and NDF digestibility. This trend was also supported by the reports of Isshiki and Nakahiro (1984), Al-Zubaida *et al.* (1990), Bhatt *et al.* (1991), Vranjes *et al.* (1994) and Dhar *et al.* (1996a and d).

An overall assessment on the digestibility co-efficient of nutrients indicated a clear response in nutrient availability due to the cellulase supplementation in low energy diets. Enzyme addition significantly (P<0.01) improved the AME value of diet and digestibility of fibre fractions like ADF and NDF. In addition, enzyme supplementation also resulted in an apparent improvement in the digestibility of dry matter, protein and ether extract. This trend of results is in close agreement with those reported in the literature. Considering this, it is reasonable to conclude that bioavailability of nutrients can be improved by supplementation of cellulase enzyme in diets having low AME value. Since all plant derived feed stuffs contain some quantity of NSPs (mainly cellulase) derived primarily from the cell wall, supplementation of cellulase enzyme in feed may cause break 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 products which are 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.

5.7 Excreta moisture

The data on per cent moisture content of droppings for both broiler starter and finisher rations revealed that cellulase supplementation reduced about 6 to 8 per cent of excreta moisture in birds fed with low energy diet. The statistical analysis of data showed that the excreta moisture reduction due to the enzyme addition was significant ($P<0.01$) in broiler starter and finisher diets. It was also observed that birds fed with low energy diet voided droppings with significantly higher moisture content and the cause may be due to high level of NSPs in the diet. These NSPs cannot be utilised by the birds as their digestive system does not have relevant enzymes to hydrolyse them, which may hold more water content and void as watery droppings. Addition of cellulase might have acted upon these NSPs and increased their digestibility and reduced the moisture holding capacity which resulted in less moisture droppings.

Reduction in the excreta moisture content with supplementation of cellulase as single or multienzyme preparations was reported by Hesselman *et al.* (1982), Hesselman and Aman (1986), Schutte and Geerse (1992), Franscesch *et al.* (1994) and Marquardt *et al.* (1994).

5.8 Slaughter studies

The dressed yield and ready-to-cook yield were significantly neither influenced by the dietary treatments nor sex. The dressed yield among the treatments showed no difference between them but the ready-to-cook yield in the cellulase supplemented groups and standard control were numerically higher than the birds fed on low energy diet alone. These findings were in close agreement with Kumprecht *et al.* (1990), Francesch *et al.* (1994) and Vranjes and Wenk (1995a). But in contrast, Brenes *et al.* (1993d) observed that dressed yield of broilers could be increased by addition of crude cellulase in their diet.

The data on percentage giblet yield showed no significant influence by either treatment or sex, but a numerically higher value could be observed among the low energy diet group over the other. This indicated that the birds fed on standard ration and enzyme supplemented low energy diet might have reduced the activity of the visceral organs because of the better availability of nutrients. From the literature reviewed it was found that Brenes *et al.* (1993a and d) reported relatively lower weight of liver, gizzard and a few visceral organs when broiler and egg type chicks were fed on rye and barley diet with enzyme supplementation.

The data pertaining to percentage abdominal fat revealed no significant difference among treatments. However, a numerical improvement could be noted among cellulase supplemented birds over the unsupplemented control. These observations found to be closely related to findings of Brenes *et al*. (1993d), Wyatt *et al*. (1993), Mikulec *et al*. (1994) and Schurz *et al*. (1994). Further, it was found that a significantly ($P<0.05$) higher percentage abdominal fat yield among female birds than males irrespective of treatment. The same trend of result was reported by Tyagi *et al*. (1995) and Benabdeljelil (1997).

5.9 Intestinal viscosity

The mean intestinal viscosity values indicated that it was highest in birds fed with low energy diet (2.83). It also revealed that enzyme supplementation could bring a reduction in the gut viscosity. Birds fed with standard broiler diet had a mean viscosity of 2.44. When the data on intestinal viscosity were subjected to statistical analysis significant differences existed among the treatments. The viscosity was significantly ($P<0.01$) higher in birds fed with low energy diet without cellulase and it could be significantly lowered by enzyme supplementation. The intestinal viscosity of birds offered by standard broiler diet was medium and was significantly different from the rest. Further, it was noticed that irrespective of level of cellulase used, the gut viscosity values of enzyme supplemented groups were statistically comparable.

On a perusal of the literature related to works carried out with broilers and egg-type chicks, it was noted that the feed enzymes containing cellulase gave positive response by reduction in intestinal viscosity (White *et al.* (1981), Hesselman and Aman (1986), Campbell (1987), Fengler *et al.* (1988), Bedford and Classen (1992a and b) and Inborr and Bedford (1994)).

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 is 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.

5.10 Livability

The data on the mortality pattern of birds under different dietary treatment groups revealed that it ranged from 2.1 to 6.3 per cent. During the entire course of the experiment covering 8 weeks only eight birds died. Low mortality was observed in the group fed with low energy diet with 0.03 per cent cellulase followed by standard control and 0.06 per cent cellulase supplemented group. Higher mortality was recorded with birds fed low energy diet without enzyme. Necropsy findings revealed that the birds died due to non-specific reasons. Thus it is evident that cellulase supplementation did not have any detrimental effects on the physiological well being of broiler birds.

In the same line, Jeroch (1992) and Marek and Splitek (1992) reported that the per cent mortality was not affected by the enzyme addition. But, several workers (Tishenkova and

Serikova (1987), Tishenkova and Selivanova (1990), Arora *et al.* (1991), Ranade and Rajmane (1992), Mikulec *et al.* (1994) and Mohammed (1995)) reported improvement in survivability of birds fed diet supplemented with enzyme mixtures having cellulolytic activity.

5.11 Cost benefit analysis

The cost of different rations employed in the experiment revealed that the standard broiler diet for both starter and finisher period formulated as per BIS specification was costlier than others. Incorporation of high fibre low energy ingredients like wheat bran and deoiled rice bran enhanced the fibre content by 1.5 per cent and reduced about 300 kcal/kg in starter and finisher rations. This contributed to reduction in the cost of broiler starter and finisher ration by 40 and 43 paise per kg feed than standard diet respectively. However, supplementation of cellulase enzyme to low energy diet enhanced the cost of ration in proportion to the level of enzyme addition. But even with higher level of cellulase supplementation (0.06%) the cost was 35 and 38 paise lesser than standard broiler starter and finisher ration respectively.

When the cost of production per kg live weight on feed cost alone was calculated, it was observed that compared to low energy ration all other rations were cheaper, the cheapest being the diet supplemented with 0.06 per cent cellulase enzyme. The net profit per bird over the standard ration was Rs.5.42 and Rs.7.48 in the 0.03 and 0.06 per cent cellulase supplemented groups respectively whereas the low energy diet without enzyme showed a loss of Rs.2.05 per bird over the standard ration.

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

Summary

6. SUMMARY

An investigation was carried out in the Department of Poultry Science, College of Veterinary and Animal Sciences, Mannuthy, using one hundred and ninety two one-day old commercial broiler chicks to assess the influence of cellulase supplementation in low energy diet on production performance of broilers and nutrient availability for them. The chicks were randomly distributed into four dietary treatments with each having four replicates of 12 birds each. The dietary treatments consisted of standard broiler ration (T1), low energy broiler ration (T2) and low energy ration with 0.03 and 0.06 per cent cellulase (T3) and T4 respectively). All the diets were formulated as per BIS specifications except the level of ME in low energy broiler ration.

Feed ingredients like yellow maize, GNC (exp), GOC, unsalted dried fish, rice polish, wheat bran and deoiled rice bran were used for the formulation of experimental diets. The birds were housed at random in individual pens and reared under deep litter system. Standard managemental procedures were adopted throughout the experimental period. The duration of the experiment was eight weeks. The body weight of individual birds were recorded at the beginning of the experiment followed by every week end till the end of the experiment. Replicationwise weekly feed consumption was

recorded. From the above data, the feed conversion efficiency and the body weight gain for different treatments were worked out.

At the end of the experimental period, two metabolism trials were conducted using eight birds from each treatment. Total collection method was employed. Based on the data obtained from the metabolism trials apparent metabolisable energy and nutrient digestibility viz., DMD, APD, EED and digestibility of fibre fractions were calculated. The excreta moisture was also estimated. One male and one female from each replication i.e., four males and four females per treatment were sacrificed to study the processing yields like dressed yield, ready-to-cook yield and giblet yield. Abdominal fat and intestinal viscosity were also studied. Mortality of the birds were recorded. Cost benefit analysis due to cellulase supplementation was worked out by calculating the cost of production.

The overall performance of the birds fed different dietary regimen are presented in lable 37.

Based on the results obtained in this study, the following conclusions were made:

1. The mean body weight of the birds for different treatment groups, ranged from 1341 g to 1496 g at six weeks and

1929 g to 2184 g at eight weeks of age. The 0.06 per cent cellulase supplemented group recorded significantly ($P<0.01$) higher body weight over all other groups. The low energy diet group showed significantly lower weekly body weight throughout the experimental period except during the first week.

2. Birds fed with low energy diet supplemented with 0.06 per cent cellulase showed significantly ($P<0.01$) more body weight gain followed by 0.03 per cent cellulase when compared to either standard control or low energy diet group without enzyme. The gain in body weight was lower in birds fed on low energy diet without enzyme when compared to other treatment groups.

3. The mean total feed intake per bird under different dietary treatments ranged from 2.717 to 2.801 kg upto six weeks and 4.629 to 4.771 kg upto 8 weeks. The daily feed intake per bird was significantly ($P<0.01$) higher in birds fed with low energy diet without cellulase enzyme than all other groups. The feed consumption per bird per day was statistically comparable among the groups fed low energy diet with 0.03 and 0.06 per cent cellulase and with standard broiler ration fed group.

4. Significant ($P<0.01$) difference was found among different treatment groups with respect to feed efficiency (FE).

The low energy diet group showed significantly poor feed conversion throughout the experimental period. The enzyme supplemented groups showed a significant improvement in FE over standard control. A linear response could be noted in FE when graded levels of cellulase were added to low energy diet.

5. Though the cellulase supplemented birds with low energy diet showed higher percentage dry matter digestibility for both broiler starter and finisher rations than standard control and low energy group without enzyme, they were not found to be statistically different.

6. Addition of 0.03 and 0.06 per cent cellulase in low energy diet resulted in significant ($P<0.01$) improvement in apparent metabolisable energy by about 138 and 261 kcal/kg in broiler starter ration and 175 and 334 kcal/kg in finisher ration respectively when compared with low energy control diet fed birds. The low energy ration without enzyme had significantly lower mean AME value than the enzyme supplemented groups.

7. Apparent protein digestibility was not influenced significantly by any of the dietary treatments in both the rations. But a numerical increase in per cent protein digestibility could be observed in cellulase fed

birds over standard control and low energy diet without enzyme irrespective of type of ration.

8. No significant difference could be observed among the treatment groups for ether extract digestibility of broiler starter and finisher rations but an apparently higher percentage could be observed in enzyme supplemented groups and lower value among birds fed low energy diet without cellulase.

9. Digestibility of fibre fractions viz., ADF and NDF for both the rations among different treatment groups showed significantly ($P<0.01$) higher digestibility percentage in low energy diet with 0.06 per cent cellulase followed by 0.03 per cent group. The per cent ADF and NDF digestibility of standard control and low energy diet group were lower for both the rations and showed no statistical significant difference between them.

10. Supplementation of cellulase enzyme significantly ($P<0.01$) reduced the moisture content of droppings of birds fed with low energy broiler starter and finisher diet. The excreta moisture was significantly higher in birds offered low energy diet without cellulase.

11. Data on slaughter studies viz., dressed yield, ready-to-cook yield, giblet yield and abdominal fat did not reveal

any significant differences between treatments, but a numerically higher ready-to-cook yield, higher per cent abdominal fat and less giblet yield were observed in cellulase supplemented birds. The percentage abdominal fat in female birds were found to be significantly ($P<0.05$) higher than males irrespective of the treatments.

12. The viscosity of intestinal contents was significantly ($P<0.01$) lower in birds fed with low energy diet supplemented with 0.03 and 0.06 per cent cellulase. The viscosity was significantly higher in birds which received low energy diet without enzyme and medium with birds fed on standard control diet.

13. The survivability of broiler chicken was not affected by cellulase supplementation in their diet.

14. The feed cost per kg live weight varied from Rs.16.44 to Rs.18.92 for the different treatment groups. Cost of production of broilers was lower in both enzyme supplemented groups when compared to standard control and low energy diet without enzyme. Even with higher level of enzyme incorporation in low energy feed, the cost of the feed was 35 and 38 paise per kg lower than standard broiler starter and finisher ration, respectively.

15. Among the different treatment groups, the performance parameters of birds fed with low energy diet with 0.06 per cent cellulase was found to be the best.

Based on the results of this study it could be inferred that by the addition of cellulase enzyme, the energy level in broiler ration using normal dietary ingredients with some feasible cereal by-products like wheat bran and rice bran can be reduced upto 300 kcal/kg of feed. The supplementation of cellulase will not only enhance the nutrient utilization of low energy diet but also will counteract the high intestinal viscosity and higher excreta moisture that are normally encountered with less digestible low energy diets in poultry. Cellulase supplementation may offer scope for incorporation of higher levels of agro-industrial by-products in poultry rations thereby opening an avenue for lowering the feed cost and increasing the profit margin.

Table 37. Influence of cellulase supplementation on the performance and nutrient availability in broiler chicken

Sl. No.	Parameters	Dietary treatments			
		T1	T2	T3	T4
1.	Live body weight (g)	2011	1929	2115	2184
2.	Body weight gain (g)	1968	1885	2072	2141
3.	Total feed consumed (g)	4629	4771	4634	4463
4.	Cumulative feed efficiency	2.30	2.47	2.19	2.14
5.	Nutrient digestibility				
	(i) Starter ration				
	a. Dry matter (%)	70.34	68.17	70.25	71.19
	b. AME (kcal/kg)	2788	2531	2669	2792
	c. Protein (%)	81.32	79.58	81.59	82.20
	d. Ether extract (%)	76.87	74.97	76.52	76.69
	e. ADF (%)	21.38	21.32	24.43	26.09
	f. NDF (%)	26.34	26.85	29.68	33.21
	g. Excreta moisture (%)	76.32	82.27	76.12	74.88
	(ii) Finisher ration				
	a. Dry matter (%)	69.18	67.95	70.14	71.06
	b. AME (kcal/kg)	2933	2614	2789	2948
	c. Protein (%)	81.21	79.42	81.12	82.06
	d. Ether extract (%)	75.41	74.36	75.52	77.62
	e. ADF (%)	20.81	20.84	24.03	26.46
	f. NDF (%)	26.46	26.69	30.20	33.14
	g. Excreta moisture (%)	76.04	82.01	76.26	74.50
6.	Slaughter studies				
	(i) Female				
	a. Dressed yield (%)	91.21	91.18	91.19	91.17
	b. Ready-to-cook yield (%)	71.18	71.06	71.14	71.16
	c. Giblet yield (%)	4.69	4.74	4.71	4.70
	d. Abdominal fat (%)	4.06	4.01	4.04	4.03
	(ii) Male				
	a. Dressed yield (%)	91.17	91.19	91.15	91.18
	b. Ready-to-cook yield (%)	71.15	71.02	71.19	71.12
	c. Giblet yield (%)	4.70	4.71	4.62	4.67
	d. Abdominal fat (%)	3.94	3.92	3.94	3.95
7.	Intestinal viscosity	2.44	2.83	2.02	1.96
8.	Mortality (%)	4.20	6.30	2.10	4.20
9.	Cost per kg of feed (Rs.)				
	a. Starter ration	8.34	7.94	7.96	7.99
	b. Finisher ration	7.67	7.24	7.26	7.29
10.	Feed cost per kg live weight production (Rs.)	18.56	18.92	16.81	16.44

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INFLUENCE OF CELLULASE SUPPLEMENTATION ON THE PERFORMANCE OF BROILERS FED LOW ENERGY DIET

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ABSTRACT OF A THESIS

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ABSTRACT

The effects of different levels of cellulase supplementation viz., 0.03 and 0.06 per cent in low energy broiler ration on production performance and nutrient availability in broiler chicken were evaluated using one hundred and ninety two commercial one-day old broiler chicks for a period of eight weeks. The birds were divided into four dietary treatment groups viz., standard broiler ration (T1), low energy ration (T2), low energy ration with 0.03 per cent cellulase (T3) and low energy ration with 0.06 per cent cellulase (T4). Standard broiler ration was formulated as per BIS (1992) specification for broiler chicken feed. Inclusion of wheat bran and deoiled rice bran was made to formulate the low energy ration. The enzyme supplemented groups showed a significantly higher body weight than the standard and low energy diet without enzyme. The feed intake was significantly higher in the low energy ration without enzyme. A positive response was observed in feed efficiency by enzyme addition which was statistically significant. The feed efficiency was best when the level of enzyme was 0.06 per cent. A non-significant improvement was noticed in digestibility of dry matter, protein and ether extract due to enzyme supplementation. A significantly higher metabolisable energy and crude fibre digestibility was observed in enzyme added groups. The enzyme treatment significantly reduced the

moisture content of the excreta. The processing yields and abdominal fat percentage did not show any significant difference among treatments. The intestinal viscosity was significantly lower in birds fed enzyme supplemented diets. Cost of production of broilers in both the cellulase supplemented groups was lower when compared with other groups fed standard control and low energy ration without enzyme.

Based on the above findings, it can be concluded that cellulase supplementation in low energy diet is beneficial especially when low energy, less digestible agricultural by-products are used as feed ingredients in the chicken diet.