EVALUATION OF SILK WORM PUPAE MEAL ON GROWTH PERFORMANCE IN LARGE WHITE YORKSHIRE PIGS

By

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THESIS

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DECLARATION

I hereby declare that the thesis entitled "**EVALUATION OF SILK WORM PUPAE MEAL ON GROWTH PERFORMANCE IN LARGE WHITE YORKSHIRE PIGS**" 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
14.07.1999

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CERTIFICATE

Certified that the thesis entitled "**EVALUATION OF SILK WORM PUPAE MEAL ON GROWTH PERFORMANCE IN LARGE WHITE YORKSHIRE PIGS**" is a record of research work done independently by **Sri. S. Ramamoorthi**, 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 Beloved Chithi & Chithappa

and

Guide

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Introduction

1. INTRODUCTION

Providing a balanced diet to the population of 930 million people in the country having different dietary habits is a difficult task. Though India has achieved a level of self-sufficiency in its cereal production, the availability of animal protein with high biological value and compositional similarity with human body with regard to the profile and content of amino acids to an average Indian seems to be low as the per capita consumption of meat is less than 5 kg/year as compared to the world's average of 14 kg/year (Shanmugasundaram, 1997).

In order to bridge the gap between the high requirements and low availability of animal protein, it is essential to improve all meat producing animals in the country. The improvement in the production of beef, mutton and chevon may not be sufficient to meet the demand of the people because the ruminants in general have a low rate of weight gain apart from a longer generation interval. The increased demand for meat can be met through pig and poultry because of their rapid rate of growth, economic feed conversion efficiency, high prolificacy and short generation interval.

Hazel (1963) has stated that pigs are extremely versatile animals, able to adapt to a wide variety of circumstances imposed by man and yet retain their own individual peculiarities. They thrive from artic to tropical temperatures on highly concentrated and bulky feed and produce high percentage of meat and fat. Pigs are considered to be supreme amongst meat producing livestock and are efficient converters of feed to valuable animal protein.

In India, pig farming has a special significance as it can play an important role in improving the socio-economic status of a sizeable section of the rural community. The proper development of pig industry on scientific and profitable lines as in other progressive countries of the world, will not only help to solve the country's food problem to a great extent but also to improve the nutritional standards of our growing population.

There are about 410 million pigs in Asia out of which 9 million are in India contributing about 157 million kilogram of pork and 0.5 million kilogram of bristles valued at Rs.244 and Rs.15 million respectively (Ranjhan, 1993).

Pigs are considered "mortgage lifter" by farmers because pig industry gives high returns with low investment.

Profitable raising of pigs depends largely on carefully planned and efficient feeding programme. Since more than 70 to 75 per cent of the cost of swine production is accounted for by feeds, economic formulation of swine rations assumes paramount importance.

Being monogastric, pigs compete with human beings for feed. One of the major constraints that beset the commercial pig rearing in India is the non-availability of suitable feeds. The feeding of swine for the production of pork, bacon or any other product has to be so designed that the requirement of the consumer is met. This is another side of the challenge which the pig nutritionist has to face besides the selection of feedstuffs.

Pigs, because of their monogastric nature must be provided with an animal protein supplement in order to balance the essential amino acid make up of the diet. Unsalted dried fish/fish meal is usually used for this purpose but due to its escalating price and non availability of good quality material it has become necessary that alternative sources are to be looked into. Use of unconventional animal protein sources like silk worm pupae meal will help to reduce the cost of production to a great extent.

Silk worm pupae meal, a byproduct obtained from sericulture, is available in large quantities. It is higher in protein (60-70%) and lower in ash (4.88%) when compared to unsalted dried fish. It is also higher in antinutritional factors such as phenol (2.04%) and uric acid (4.4%) than fish meal (Thangamani, 1995).

Several studies have been conducted in broiler chicken incorporating silk worm pupae meal in different proportions replacing unsalted dried fish. However, reports on the effect of incorporation of silk worm pupae meal in swine rations are scanty. Hence the present experiment was planned to determine the effect of replacing unsalted dried fish with silk worm pupae meal in the diets of growing pigs.

Review of Literature

2. REVIEW OF LITERATURE

The literature available on the different aspects of the study are arranged under separate heads.

2.1 Nutrient requirements of pigs

2.1.1 Protein requirements

Aunan *et al.* (1961) observed that there was no significant difference in the average daily gain and efficiency of feed utilisation when growing pigs were fed on diets containing 18 and 14 per cent of crude protein. Similar results were recorded by Dinusson et *al.* (1961) and Feng *et al.* (1985).

Klay (1964) found that as the level of dietary protein increased from 10.61 to 26.36 per cent in the rations of pig, total intake of both protein and lysine increased while feed consumption and efficiency of protein and lysine utilisation showed linear decrease. It was also observed that the level of protein significantly affected the true nitrogen digestibility and retention of dietary nitrogen per unit of body weight. Similarly, lower weight gain and poor gain:feed ratio were observed by Meade et *al.* (1969) in starter pigs weighing between 5.9 and 23.5 kg, when fed 12 and 15 per cent protein diets. Baird *et al.* (1975) also observed greater efficiency of protein conversion on low protein diets for Poland China pigs.

The growth rate and feed efficiency are positively correlated with the level of dietary protein during the growing period (Cunningham *et al.*, 1973). Improved growth rate and feed efficiency were reported by Fetuga *et al.* (1975) as the protein levels were increased from 16 to 20 per cent in the diets of Landrace and Large White pigs. Similarly, Davey (1976) observed reduced growth rate in Duroc and Yorkshire pigs when fed 11 per cent protein diets. According to Christian *et al.* (1980) ration with 16 per cent protein resulted in improved growth rate and feed efficiency of pigs when compared to 12 per cent protein diet. Similar results were reported by Campbell *et al.* (1984).

Shields and Mahan (1980) studied the effect of varying protein levels on performance and carcass characteristics of growing-finishing swine. Animals were divided into three groups and one group received 16, 14.5 and 13 per cent protein levels at 22, 36 and 59 kg body weight, respectively. The second group was fed 16 per cent protein diet from 22 to 54.4 kg, followed by 13 per cent protein diet to market weight and the third group received 14.5 per cent protein diet throughout the growing-finishing phase. They found that feed intake, gains and feed conversion for the overall period from 22 to 95 kg were similar for pigs on all three protein treatments and suggested that temporary moderate protein restrictions will not adversely affect overall gains or carcass quality.

According to Skoryatina and Korop (1981), the optimum level of protein in a concentrate based diet was 18 per cent for weaners, 16 per cent upto 6 months of age and 14 per cent from 6 to 8 months on dry matter basis. Indian Council of Agricultural Research (ICAR, 1985) recommended the crude protein levels as 18, 16 and 14 per cent for pigs weighing from 5 to 10, 10 to 40 and 40 to 60 kg, respectively. National Research Council (NRC, 1988) recommendation of protein for pigs of 1 to 5, 5 to 10, 10 to 20, 20 to 50 and 50 to 110 kg body weights were 24, 20, 18, 15 and 13 per cent, respectively.

The Landrace male pigs required about 20.1 per cent crude protein (Donzele *et al.*, 1993a) while Landrace female pigs required 19.74 per cent of crude protein (Donzele *et al.*, 1993b) for maximum performance during the growing phase. Latimier and Dourmad (1993) studied the effect of three protein feeding strategies for grower and finisher pigs and found that growth rate and feed conversion efficiency were similar in all groups, while the dressing percentage decreased with increased dietary protein. Martin (1993) and Jost *et al.*

(1995) observed that grower diet containing 16 per cent or less protein resulted in unprofitable performance. They reported that satisfactory growth was obtained with 17 per cent dietary crude protein and 13.9 MJ digestible energy, provided the feed was supplemented with the limiting amino acids lysine, methionine or cystine, threonine and tryptophan. The diets for fattening pigs which contained 17 and 15 per cent crude protein, respectively, during the growing and finishing period increased average daily gain and improved feed:gain ratio (Barac *et al.*, 1995). According to Hata *et al.* (1995) the digestible energy intake and daily gain of castrated male pigs offered a low protein (120 and 104 g/kg) diet was lower than those pigs fed high protein (185, 169, 153 and 136 g/kg) diets. Moita *et al.* (1996) stated that 12 to 28 days old piglets required 23.42 to 23.13 per cent crude protein in their ration.

Oldenberg and Heinrichs (1996) reported that finisher pig diets which contained 17 per cent and 13.5 per cent crude protein had no effect on finishing and slaughter performance. Wu *et al.* (1996) found that average daily gain and feed:gain ratio increased during the starter, grower and finisher periods when the ideal protein intakes were 130, 319 and 375 g/day, respectively.

2.1.2 Amino acid requirements

Klay (1964) observed that decreased absorption of lysine was the major cause for the increase in lysine requirement with increased dietary protein levels. He also stated that feed intake tended to decrease as level of protein increased, so that animals consumed nearly equal amounts of dietary lysine at all levels of dietary protein. Meade *et al.* (1966) found that the addition of lysine alone or in combination with methionine to 12 and 14 per cent protein diets of growing pigs did not affect rate of gain and efficiency of feed utilisation. However, Easter and Baker (1980) reported that the lysine requirement could be reduced when crude protein levels were reduced by replacing soyabean meal with synthetic lysine.

Boomgaardt and Baker (1973) are of opinion that it is preferable to express the amino acid requirements of growing pigs as per cent of total dietary crude protein than as a percentage of the total diet. They also recorded the minimal level of tryptophan requirements of growing pigs for maximal weight gain as 0.71, 0.67 and 0.66 per cent of the protein, respectively, at 10, 14 and 18 per cent dietary protein levels. Batterham *et al.* (1985) studied the feed intake, daily gain and feed conversion ratio of pigs fed varying dietary lysine levels. They found that maximum daily gain was obtained by feeding at least 10 g lysine per kg body weight when pigs were fed *ad libitum*.

Taylor *et al*. (1984) demonstrated the interaction between leucine and isoleucine, as increased dietary leucine resulted in a deficiency of isoleucine in growing pigs. Three or four times the basal level of lysine lowered both weight gain and feed intake of young pigs with no commensurate reduction in feed efficiency in studies conducted by Edmonds and Baker (1987) who concluded that lysine appeared to reduce growth via amino acid imbalance rather than antagonism.

Parsini *et al*. (1991) suggested that dietary protein could be decreased in finisher pig rations if lysine supplements were used. Similarly in growing pigs, supplementation of lysine, methionine, threonine and tryptophan reduced the dietary crude protein requirement by about 2 per cent (Schutte *et al*., 1993). Valaja *et al*. (1993) observed that the crude protein content of the diet of growing pig could be reduced upto 20 per cent, provided, the concentrations of lysine and methionine were maintained. Zollitsch *et al*. (1994) also concluded that supplementation of lysine, methionine and tryptophan could decrease the dietary crude protein of finisher pigs without affecting finishing and slaughter performance. Kuhn and Burgstaller (1995) also found that low protein diets did not influence average daily gain, feed conversion efficiency, carcass yield and meat quality of finishing pigs when supplemented with lysine at 5 g/100 g crude protein.

Nam et *al.* (1995) suggested that pigs were unable to control their protein and lysine intakes to meet their requirements for growth when given a choice of two isoenergetic diets which differed in protein and lysine contents. When diets were supplemented with lysine or methionine and lysine, a 16 per cent crude protein was sufficient to meet the requirement of piglets weaned at 28 days (Trindade *et al.*, 1995).

2.1.3 Energy requirements

Xie *et al.* (1994) showed that energy is a predominant factor affecting production performance followed by protein and trace elements.

Iliescu *et al.* (1982) observed the net efficiency of utilisation of metabolizable energy as 73.8 per cent in young pigs of 10 to 50 kg body weight. They also found that for maintenance, the pigs required 103.4 kcal metabolizable energy/$W_{kg}^{0.75}$ or 76.3 kcal net energy/$W_{kg}^{0.75}$ for 24 hours. Indian Council of Agricultural Research (ICAR, 1985) recommended the digestible energy contents of 3100 and 3000 kcal/kg feed for pigs weighing 5 to 10 and 10 to 60 kg respectively. The National Research Council (NRC, 1988) specification for energy was shown to be 3220, 3240, 3250, 3260 and 3275 kcal metabolizable energy/kg feed for pigs of 1 to 5, 5 to 10, 10 to 20, 20 to 50 and 50 to 110 kg body weight, respectively.

Schiemann *et al.* (1989) from their experiment with barrows concluded that metabolizable energy requirement for maintenance was 955 KJ/$W_{kg}^{0.62}$ and increasing dietary protein did not increase the energy requirement for maintenance. Xie *et al.* (1994) stated the optimum requirement of digestible energy as 13.81 MJ/kg feed for pigs weighing from 20 to 90 kg. They also reported the crude protein and trace element requirements as 16 and 0.5 per cent, 14 and 0.5 per cent and 12.27 and 0.4 per cent, respectively, for pigs weighing 20 to 35 kg, 35 to 60 kg and 60 to 90 kg.

Hogs fed corn made significantly faster gain and required less feed than those fed barley, milo and half corn half oats (Handlin, 1961). Fibre level in the diet of pigs had no effect on rate of gain, efficiency of gain or carcass leanness at constant energy level (Baird *et al.*, 1970; Baird *et al.*, 1975) while increased energy level (15%) in the diet resulted in increased gains and back fat thickness and reduced per cent of lean cuts (Baird *et al.*, 1970).

Varel *et al.* (1984) stated that pigs fed on high fibre diet gained less and had increased feed to gain ratios than those on low fibre diet. Stanogias and Pearce (1985) found that both the amount and the type of dietary fibre influenced the apparent digestibility of dietary dry matter, nitrogen and energy. Frank *et al.* (1983) observed that average daily feed intake increased linearly, but average daily digestible energy intake tended to decrease with increased dietary fibre level. They also found that digestibilities of nitrogen, dry matter, energy, neutral detergent fibre and acid detergent fibre decreased with increased level of dietary fibre.

Ranjhan *et al.* (1972) observed that restriction of energy after 50 kg body weight reduced the growth rate and feed efficiency of pigs. Metz *et al.* (1980) also reported that restriction of the daily energy by 20 per cent caused 15 per cent lower live weight gain and 12 per cent lower nitrogen retention.

Digestibility of organic matter and nitrogen free extract were unaffected whereas digestibility of protein was increased by decreasing energy (Kairis and Ginkyavichyus, 1983). Thomas and Singh (1984) observed that reduction in the digestible energy content of grower pig ration by 15 per cent from National Research Council standards reduced average daily gain and digestibilities of dry matter, organic matter, ether extract, crude carbohydrate and crude protein.

Makhaev (1982) found that the level of energy in the diet of fattening pigs influenced the average daily body weight gain, efficiency of feed utilisation and quantity and quality of product. Campbell *et al.* (1985) observed that average daily gain increased quadratically with increase in energy intake. Akita *et al.* (1991) stated that mean daily gain was increased when total digestible nutrient intake was increased. Kyriazakis and Emmans (1992) also found that increased intake of energy increased the live weight, empty body weight and protein and lipid gains of pigs. Average daily gain of pigs increased linearly with metabolisable energy intake whereas feed conversion ratio was not affected by energy intake (Quiniou *et al.*, 1995).

Hata *et al.* (1993) observed that energy retention was not affected by stage of growth but was changed with feeding level. The energy retention decreased by 0.2 units with an increase in metabolisable energy intake of 1 $MJ/kg^{0.75}$ daily. Utilisation of calories for growth was estimated to be equal for low and high energy diets during cool season, whereas high energy diets were most efficient in warm season (Seerley *et al.*, 1978).

2.1.4 Calorie protein ratio (Energy-protein interrelationship)

Clawson et *al.* (1962) emphasized the need for a higher dietary protein level with increased energy content and observed that daily feed consumption and growth rate of pigs during the first 28 days were significantly influenced by energy-protein ratio.

Baird *et al.* (1975) stated that efficiency of protein conversion was greater on the low protein-high energy diets of pigs indicating that use of protein was more efficient at lower level of intake and high energy diets have a protein saving effect by improving protein efficiency. Simecek and Prokop (1983) observed that a low protein-high energy diet decreased the protein content in the carcass while a low energy diet did not influence the protein content but decreased the fat content of carcass.

Campbell *et al.* (1985) showed that the relationship between energy intake and the rate of protein deposition was linear with maximal protein deposition occurring at about 33 MJ digestible energy per day. According to Feng *et al.* (1985) there was no significant difference in daily gain, feed conversion efficiency and dressing percentage of carcass among pigs given diets with high or intermediate energy and protein. Sivaraman and Mercy (1986) stated that there were no significant differences in average daily gain, feed efficiency and carcass characteristics of pigs fed rations containing different energy protein ratios. They further observed that the animals maintained on 20 per cent crude protein and 3.3 Mcal of digestible energy/kg feed had the lowest cost of production per kilogram live weight.

The different levels of energy had a greater effect on growth than the gradations in protein supply in pigs (Oslage *et al.*, 1987). Kyriazakis and Emmans (1992) showed that efficiency of protein utilization increased with an increase in starch (energy) intake. Kulisiewicz *et al.* (1995) found that raising dietary levels of protein and energy increased the feed conversion efficiency in pigs.

2.2 Feed efficiency

Magee (1962) observed that average daily feed consumption was positively correlated with average daily gain. She also concluded that pigs which consumed more tended to be the least efficient. According to Biswas *et al.* (1966) selection for daily gain would probably result in improvement in feed efficiency. The decrease in feed efficiency with an increase in body weight was found to be due to increased maintenance costs and not due to increased fat deposition (Robison, 1976).

Sebastian (1972) and Devi (1981) recorded the feed conversion efficiency as 4.2 and 3.6, respectively, when varying levels of tapioca starch waste and dried tapioca chips were incorporated in the swine ration. Mohan (1991) recorded the feed conversion efficiency of pigs as 4.8 when fed diets containing 5 per cent unsalted dried fish plus 6.6 per cent prawn waste, 5.2 for the diets containing 13.5 per cent prawn waste, and 4.05 and 4.13 for the diets containing 10 and 5 per cent unsalted dried fish respectively. Sinthiya (1998) reported the feed conversion efficiency as 4.36, 4.35, 4.48 and 4.56 for the pigs fed diets containing 12 per cent unsalted dried fish, 12 per cent carcass meal, 18 per cent carcass meal, and 6 per cent unsalted dried fish plus 6 per cent carcass meal respectively. According to Subramanian (1998), the feed conversion efficiency of pigs ranged from 3.91 to 4.15.

2.3 Digestibility coefficient of nutrients

Pond *et al.* (1962) reported a significant reduction in apparent digestibility of dry matter, nitrogen-free extract and crude protein by the addition of fibre to the low protein ration. Similarly, Eggum *et al.* (1982) found that growth rate and digestibility of dry matter, organic matter, nitrogen, nitrogen free extract, crude fat, crude fibre, gross energy and metabolisable energy: gross energy ratio were decreased on high fibre diet.

Yen *et al.* (1983) stated that contemporary, lean and obese genotype had no effect on coefficients of digestibility of nitrogen and energy.

Saitoh and Takahashi (1985) observed that the digestibilities of dry matter, gross energy, crude protein and crude fibre were decreased with increased feed intake while nutrient digestibilities increased with increasing body weight. However, the variations in nutrient digestibilities were least in pigs weighing 30 to 70 kg and when fed at 3 to 4 per cent of body weight. Fernandez *et al.* (1986) conducted digestibility experiments with 26 feedstuffs and diets in growing pigs and reported a wide variation in the digestibility coefficients of nutrients.

Devi (1981) recorded digestibility coefficients of 79.6 to 82.4, 73.0 to 80.3, 66.9 to 69.9, 37.1 to 40.0 and 86.3 to 90.1, respectively, for dry matter, crude protein, ether extract, crude fibre and nitrogen free extract when different levels of dried tapioca chips were incorporated in swine ration, whereas Mohan (1991) reported digestibility coefficients of dry matter, crude protein, ether extract, curde fibre and nitrogen free extract as 48.9 to 61.8, 55.9 to

65.3, 52.9 to 68.2, 20.6 to 27.4 and 61.8 to 76.1, respectively, for rations containing varying levels of prawn waste.

2.3.1 Digestibility measurements by indicator method

Jongbloed *et al.* (1991) used HCl-insoluble ash at the level of 0.5 g/kg feed and chromic oxide at 0.5 or 10.0 g/kg feed for the estimation of nutrient digestibility in pigs. They observed that coefficient of variation in the concentration of chromic oxide was halved in both feeds and faeces when it was added at 0.5 g/kg whereas the coefficient of variation for HCl-insoluble ash marker was twice in feeds and lower in faeces.

Kohler *et al.* (1990) used chromic oxide and titanium oxide as solid phase markers and Co-EDTA as liquid phase marker in pigs. The recovery rate of markers depended on fibre content of diets and marker recoveries were lowered in the pectin-rich and fibre-rich diets. The most appropriate inert marker for the determination of ileal and faecal apparent digestibility in pigs was titanium dioxide added at the level of 1 g/kg feed (Jagger *et al.*, 1992).

Moughan *et al.* (1991) added chromic oxide and acid insoluble ash as faecal markers in young growing pigs in theirdigestibility study. They observed that total faecal collection gave higher apparent digestibility coefficients than those calculated by reference to chromic oxide for dry matter, organic matter and gross energy, but there were no differences in nutrient digestibilities determined by total collection and by using acid insoluble ash as marker. Based on the correlation between organic matter digestibility estimated with reference to the chromium content of cumulatively bulked daily grab samples of faeces, it was considered necessary to collect daily grab samples of faeces for at least five consecutive days to form a suitable composite grab sample. Schiavon *et al.* (1996) compared total collection and chromic oxide techniques for the evaluation of apparent digestibility in pigs fed different diets and with different adaptation and collection periods. Chemical composition of grab samples showed a lower crude protein and higher acid detergent fibre than that of the total collection samples. They suggested that seven days adaptation and four days collection were sufficient to obtain constant digestibility coefficients for organic nutrients.

Saha and Gilbreath . (1991) determined the analytical recovery of chromium from diet and faeces by colorimetry and atomic absorption spectrophotometry and they reported that the analytical recovery factors should be considered when estimating faecal recovery of marker chromium or digestibility of nutrients. Saha and Gilbreath . (1993) developed a modified chromic oxide indicator ratio technique for accurate determination of nutrient digestibility. The method considered analytical chromium recovery in diets and faeces and faecal recovery of dietary chromium when used as a marker. Kemme *et al.* (1996) calculated apparent total tract digestibility of phosphorus and calcium by using chromic oxide as the marker. They concluded that there were only small differences in the apparent total tract digestibility of phosphorus and calcium between the marker method and quantitative collection method. The average chromium recovery was 101.7 per cent.

Imbeah *et al.* (1995) compared the single dose and withdrawal method for measuring the rate of passage of chromic oxide and dysprosium (a rare earth element) markers in digesta collected from the distal ileum and faeces in growing pigs. The rate of chromic oxide passage, determined using rate constants, for digesta collected from the distal ileum were similar for the withdrawal and single dose methods whereas the rate of dysprosium passage in digesta measured with the withdrawal method was higher than that with the single dose method. The rate of passage of both markers, measured in faeces were similar with the two methods.

The indicator most commonly added to feed to determine the digestibility coefficients of nutrients was chromium in the form of chromic oxide as cited by McDonald *et al.* (1995).

Leeuwen *et al.* (1996) evaluated chromic oxide and HCl insoluble ash as markers for the determination of apparent ileal dry matter and crude protein digestibility of rations fed to pigs and reported that chromic oxide was more suitable as a marker than HCl-insoluble ash.

2.4 Body weight and body measurements

Berge and Indrebo (1959) investigated the regression of gain on age and on heart girth in Norwegian Landrace pigs from birth to over 250 kg. They reported that increases were not uniform throughout the period as at times body length increased to a greater extent than did heart girth. The six month body weight of both male and female pigs were significantly correlated with body length, height at withers and heart girth (Gruev and Machev, 1970). According to Mickwitz and Bobeth (1972) the body measurement most highly correlated with body weight was chest circumference. Deo and Raina (1983) observed that the genetic correlations of body weights with each of the linear body measurements at most of the ages from birth to 32 weeks were positive. According to Sahaayaruban *et al.* (1984) the simple correlations between body weight and body measurements such as length, chest girth, height at shoulder and hip width were found to be highly positive.

Mohan (1991) reported the total body weight gain of pigs as 41.68, 35.30, 61.60 and 60.90 kg, respectively, when pigs were fed diets containing 6.6 per cent prawn waste plus 5 per cent unsalted dried fish, 13.5 per cent prawn waste, 10 per cent unsalted dried fish and 5 per cent unsalted dried fish. The results indicated that diets containing prawn waste promoted significantly lower growth rate when compared to the diets containing unsalted dried fish as an animal protein source, whereas Sinthiya (1998) recorded the total weight gain of pigs receiving 12 per cent unsalted dried fish, 12 per cent carcass meal, 18 per cent carcass meal and 6 per cent unsalted dried fish plus 6 per cent carcass meal as 53.7, 53.9, 53.3 and 51.4 kg respectively. The results suggested that carcass meal could be effectively included in the grower and finisher diets without affecting either growth performance or the carcass characteristics. The body weights of pigs at sixth month of age ranged from 55.0 to 57.6 kg when varying levels of tapioca starch waste was added in swine ration (Sebastian, 1972). Almost similar body weights were reported by Subramnian (1998) while studying the effect of modified environment during summer on the performance of pigs.

Devi (1981) recorded the body measurements such as length, girth and height which ranged from 104.3 to 107.0, 84.2 to 87.2 and 52.0 to 56.2 cm, respectively, for pigs maintained on rations containing different levels of dried tapioca chips. According to Mohan (1991) the length and girth of pigs ranged from 80.4 to 84.0 and 76.5 to 98.0 cm, respectively, when varying levels of prawn waste was incorporated in pig feed. The length, girth and height of pigs maintained on diets containing varying proportions of carcass meal ranged from 76.8 to 82.0, 86 to 88.5, and 54.3 to 57.3 cm, respectively (Sinthiya, 1998). Almost similar values were reported by Subramanian (1998).

2.5 Silk worm pupae meal

2.5.1 Chemical composition

Panda (1968) analysed silk worm pupae and found that it contained 55 per cent crude protein, 25 per cent ether extract and 3 per cent crude fibre. Chopra *et al.* (1971) reported that deoiled silk worm pupae meal contained about 76 per cent crude protein and 5.36 per cent lysine. According to Purushothaman and Thirumalai (1995) silk worm pupae meal had 60.83 per cent of crude protein, 3.90 per cent of crude fibre, 2.41 per cent of ether extract, 8.63 per cent of total ash, 0.31 per cent of calcium and 0.54 per cent of phosphorus on dry matter basis. Studies carried out by Thangamani (1995) showed that deoiled silk worm pupae meal contained 8.20 per cent moisture, 62.60 per cent crude protein, 2.46 per cent crude fibre, 4.40 per cent ether extract, 4.88 per cent total ash, 0.26 per cent calcium, 0.95 per cent phosphorus, 3.12 per cent lysine and

4.61 per cent methionine. The material was found to have 2.04 per cent phenol and 4.40 per cent uric acid. The metabolizable energy value of silk worm pupae meal was 3379 kcal/kg.

2.5.2 Silk worm pupae meal in poultry ration

Joshi *et al.* (1979) studied the effect of feeding deoiled silk worm pupae meal on the performance of broiler chicks. They replaced fish meal with silk worm pupae meal at 25, 50, 75 and 100 per cent levels and found that incorporation at levels above 25 per cent caused depression in growth rate and feed efficiency. Similar results were obtained by Virk *et al.* (1980a) when deoiled silk worm pupae meal was substituted for fish meal in the diets of White Leghorn layers. The efficiency of protein and energy utilisation was reduced without affecting egg production in birds fed silk worm pupae meal. Fagoonee (1983) incorporated silk worm pupae meal at 5 and 10 per cent levels in the diets of growing chicken and found marked depression in performance of birds fed silk worm pupae meal at 10 per cent level.

The effects of water and acid treated deoiled silk worm pupae meal on the performance of broiler chicks were studied by Virk *et al.* (1980b). They found that the untreated material was better than the treated meal and also confirmed that untreated silk worm pupae meal could replace fish meal at 50 and 75 per cent levels in broiler starter and finisher ration, respectively. Reddy *et al.* (1991) found that depression in growth rate due to silk worm pupae meal intake could partly be overcome by supplementing with 0.25 per cent common salt or 1 per cent mineral mixture additionally or both. But according to Purushothaman and Thirumalai (1995) fish meal could be replaced upto 50 per cent level with silk worm pupae meal in chicken ration upto eight weeks of age without calcium and phosphorus supplementation.

2.5.3 Silk worm pupae meal in pig ration

Cool *et al.* (1992) studied the use of chrysalis meal of silk worm (*Bombyx mori*) as a protein source replacing soyabean meal in the rations of growing and finishing pigs and found that the mean daily gain and feed conversion efficiency were not affected by inclusion of silk worm pupae meal.

Materials and Methods

3. MATERIALS AND METHODS

3.1 Animals

Twenty seven weaned Large White Yorkshire female piglets with an average body weight of 16 kg, belonging to the University Pig Breeding Farm were used as the experimental animals. The piglets were divided into three groups of nine piglets each, as uniformly as possible with regard to their age and body weight. The piglets of each group were then randomly allotted to three pens to form three replicates per treatment. All the animals were dewormed before the commencement of the experiment. The three groups of piglets were randomly allotted to three dietary treatments (T_1, T_2 and T_3). All the animals were maintained under identical managemental conditions during the experimental period of 90 days.

3.2 Experimental diets

The experimental rations were so formulated that they were isonitrogenous and isocaloric and contained 16 per cent crude protein and 3000 kcal/kg of digestible energy (ICAR, 1985).

The piglets of the three groups were randomly allotted to the following dietary treatments.

T_1 - Control diet in which unsalted dried fish was incorporated at a level of 10 per cent as the animal protein source

T_2 - 50 per cent of protein from unsalted dried fish was replaced with silk worm pupae meal

T_3 - 100 per cent of protein from unsalted dried fish was replaced with silk worm pupae meal

The ingredient composition and the chemical composition of the experimental diets are given in Table 1 and 2, respectively.

The piglets of each pen were group fed. Restricted feeding was followed throughout the experimental period. They were fed in the morning (10.00 AM) and evening (3.00 PM) everyday and were allowed to consume as much feed as they could, within a period of one hour. Clean drinking water was provided *ad libitum* in all the pens throughout the experimental period.

Experimental feeds were mixed every fortnight and samples were taken after each mixing for analysis.

Table 1. Percent ingredient composition of grower diets

Ingredients	T_1	T_2	T_3
Yellow maize	47	47	47
Groundnut cake (expellar)	8	7	6.3
Rice polish	9	8.6	8
Wheat bran	25	28	31
Unsalted dried fish	10	5	-
Silk worm pupae meal (deoiled)	-	3.4	6.7
Mineral mixture*	1	1	1
CP% (calculated)	16.07	16.02	16.07
DE kcal/kg (calculated)	3021	3027	3022

Common salt and Indomix[R] vitamin supplement were added at the rate of 500 g and 10 g respectively per 100 kg of the feed

* Keyes Mineral mixture contained Calcium - 24%, Phosphorus - 12%, Magnesium - 6.5%, Sulphur - 0.5%, Iron - 0.5%, Zinc - 0.38%, Manganese - 0.15%, Copper - 0.15%, Iodine - 0.03%, Cobalt - 0.02% and Fluorine - 0.04% Manufactured by KSE Ltd., Irinjalakuda.

Indomix(R) vitamin supplement contained Vitamin A - 82, 500 IU, Vitamin D_3 - 12,000 IU, Vitamin B_2 - 50 mg and Vitamin K - 10 mg per gram

Manufactured by Nicholas Piramal India Ltd., Mumbai.

Table 2. Percent chemical composition of grower diets*

Chemical composition	T_1	T_2	T_3
Dry matter	88.3	88.9	88.5
Crude protein (N x 6.25)	16.3	16.3	16.2
Ether extract	5.0	5.1	5.3
Crude fibre	6.8	6.9	7.1
Nitrogen free extract	61.7	63.1	65.0
Total ash	10.2	8.6	6.4
Acid insoluble ash	5.7	4.3	2.8
Calcium	1.06	0.82	0.63
Phosphorus	0.78	0.61	0.54

*On dry matter basis

3.3 Feeding trial

The piglets of the three groups were fed the experimental diets for 90 days. The quantity fed was increased according to their requirements. Records of daily feed intake, fortnightly body weights and body measurements were maintained throughout the experimental period. Body measurements such as length, girth and height were recorded as described below.

3.4 Body length

An imaginary line was projected from the anterior border of the shoulder joint of one side to the same border of the other side and the point of bisection of this line in the mid-dorsal line was taken as the anterior land mark. Similarly an imaginary line was projected from the mid point of the external aspect of the hock joint of one side to the same point of the other side and the point of bisection of this line in the mid-dorsal line was taken as the posterior land mark. The distance in centimetres between these two land marks was taken as the body length.

3.5 Body girth

The circumference of the body barrel just behind the forelimb was taken in centimetres as the body length.

3.6 Body height

Height of the animal was measured in centimetres at the dorsal border of the scapula.

3.7 Digestibility trial

Digestibility trial was conducted at the end of the experiment to determine the digestibility coefficients of nutrients of the experimental diets. Chromic oxide (Cr_2O_3) was added at 0.05 per cent to each experimental diet as an external indicator for measuring the digestibility coefficients of nutrients. Chromic oxide was mixed first with small quantity of feed and then with the already mixed feed in a vertical mixer for 10 minutes to ensure proper mixing.

For the digestibility trial, the experimental animals were fed chromic oxide mixed rations for a period of four days. Faeces was collected for three days from the second day onwards.

Faecal grab samples, uncontaminated with urine, were collected from different places of each pen at 09.00, 13.00 and 17.00 hours, during the collection period of three days. The samples of faeces from each pen taken each day were pooled accordingly and were placed in double lined polythene bags and kept in the deep freezer for analysis.

The feed and faecal samples collected daily for three days during the digestibility trial were pooled and subsamples were taken for proximate analysis. Samples were analysed for proximate composition as per standard methods (AOAC, 1990).

The chromium content of the feed and faecal matter was determined using Atomic Absorption Spectrophotometer. Four grams of wet faecal samples or 1 g of feed samples were subjected to wet digestion as per Sandel (1959). The digestibility coefficient of dry matter and nutrients were calculated using appropriate formulae (Maynard *et al.*, 1979).

Economics of gain, when silk worm pupae meal replaced unsalted dried fish in the ration of pigs, was calculated taking the feed cost as 75 per cent of the total cost of production (Krider and Carroll, 1971).

3.8 Statistical analysis

Statistical analysis of the data was carried out by the Completely Randomized Design (CRD) method as described by Snedecor and Cochran (1981). The effect of the initial body weight on their final body weight was tested by covariance.

Results

4. RESULTS

4.1 Proximate composition of silk worm pupae meal

Chemical composition of silk worm pupae meal utilized for the experiment was estimated and presented in Table 3.

4.2 Live weight gain, body measurements and feed conversion efficiency

The results on the mean values of body weight, body length, body girth and body height of pigs of treatments T_1, T_2 and T_3, recorded at fortnightly intervals, are presented in Tables 4, 5, 6 and 7 respectively. Fortnightly average daily gain, fortnightly feed conversion efficiency,and the cumulative average daily gain and feed conversion efficiency of animals of the three dietary treatments are presented in Tables 8, 9 and 10 and graphically represented in Fig.1, 2, 3 and 4 respectively.

4.3 Digestibility coefficients of nutrients

Data on digestibility coefficients of nutrients of the three experimental diets T_1, T_2 and T_3 are presented in Table 11 and represented in Fig.5.

4.4 Economics of gain

Data on the cost of production (Rs.) per kg live weight gain of pigs maintained on the three dietary treatments T_1, T_2 and T_3 are presented in Table 12 and represented in Fig.6.

Table 3. Percent chemical composition of silk worm pupae meal[a]

Component	Average with S.E.[b]
Dry matter	92.0 ± 0.17
Crude protein	64.5 ± 0.25
Ether extract	4.3 ± 0.06
Crude fibre	2.7 ± 0.05
Nitrogen free extract	24.0 ± 0.28
Total ash	4.5 ± 0.02
Acid insoluble ash	1.4 ± 0.12
Calcium	0.3 ± 0.02
Phosphorus	1.0 ± 0.08

a. On dry matter basis
b. Average of six values

Table 4. Fortnightly body weights (kg) of pigs maintained on the three dietary treatments (Mean ± SE)

Treatments	Fortnights						
	0	1	2	3	4	5	6
T_1	15.8 ± 0.82	21.1 ± 1.36	26.6 ± 1.83	32.9 ± 2.09	38.8 ± 2.26	47.9 ± 2.38	59.1 ± 2.70
T_2	16.0 ± 0.79	21.1 ± 1.13	27.7 ± 1.58	33.4 ± 1.74	41.2 ± 1.95	50.3 ± 2.41	61.9 ± 2.89
T_3	15.8 ± 0.79	20.6 ± 1.03	27.6 ± 1.47	32.8 ± 1.50	40.6 ± 1.74	48.5 ± 1.84	60.4 ± 2.36
F (NS)	0.025	0.053	0.125	0.029	0.341	0.277	0.253

NS Not significant (P>0.05)

Table 5. Fortnightly body length (cm) of pigs maintained on the three dietary treatments (Mean ± SE)

Treatments	Fortnights					
	1	2	3	4	5	6
T_1	55.7 ± 1.63	61.8 ± 1.89	67.6 ± 2.15	73.0 ± 1.39	73.7 ± 1.49	76.4 ± 1.52
T_2	56.4 ± 1.38	58.1 ± 1.61	65.6 ± 1.39	71.1 ± 0.76	75.2 ± 1.06	76.1 ± 1.13
T_3	56.4 ± 1.57	59.8 ± 1.35	68.3 ± 1.31	70.9 ± 0.94	74.8 ± 1.06	78.6 ± 1.36
F (NS)	0.117	1.123	0.664	1.062	0.382	0.864

NS Not significant (P>0.05)

Table 6. Fortnightly body girth (cm) of pigs maintained on the three dietary treatments (Mean ± SE)

Treatments	Fortnights					
	1	2	3	4	5	6
T_1	61.0 ± 1.21	66.2 ± 1.49	71.1 ± 1.49	76.3 ± 1.17	79.9 ± 1.22	85.3 ± 1.27
T_2	61.2 ± 1.25	67.7 ± 1.51	70.3 ± 1.07	78.1 ± 1.49	82.6 ± 1.69	87.2 ± 1.66
T_3	61.1 ± 1.36	65.6 ± 1.44	71.1 ± 0.88	74.4 ± 1.01	79.0 ± 1.25	83.0 ± 1.22
F (NS)	0.007	0.473	0.130	1.946	1.550	2.040

NS Not significant (P>0.05)

Table 7. Fortnightly body height (cm) of pigs maintained on the three dietary treatments (Mean ± SE)

Treatments	Fortnights					
	1	2	3	4	5	6
T_1	39.1 ± 0.76	42.9 ± 0.85	43.0 ± 0.80	44.8 ± 0.68	46.6 ± 0.69	47.6 ± 0.76
T_2	38.4 ± 0.72	41.7 ± 0.94	42.2 ± 0.89	44.2 ± 0.94	46.6 ± 0.80	47.8 ± 0.94
T_3	35.7 ± 1.43	40.4 ± 0.72	42.2 ± 0.38	44.6 ± 0.63	47.2 ± 0.84	48.0 ± 0.74
F (NS)	2.826	1.864	0.343	0.119	0.216	0.066

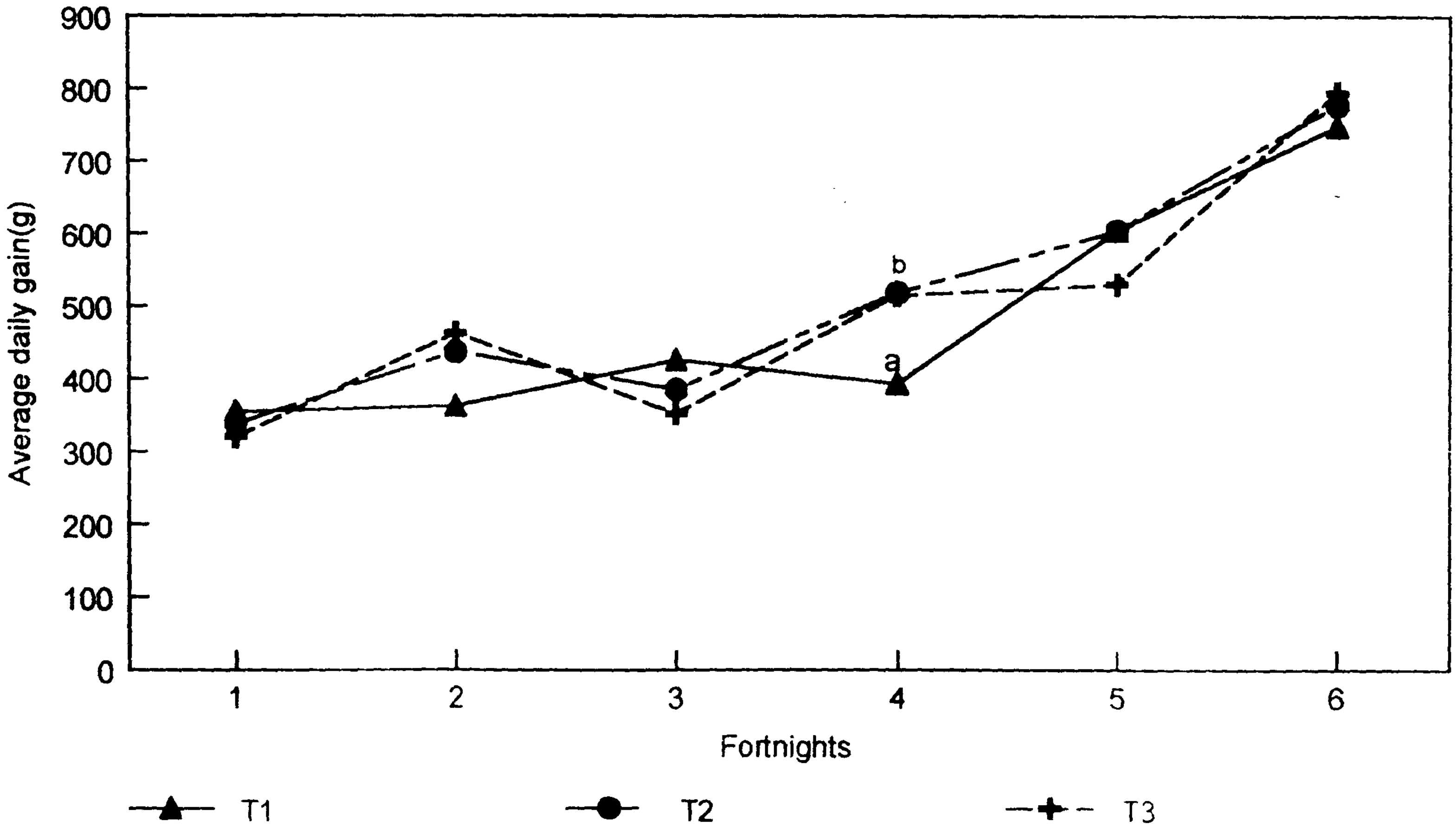
NS Not significant (P>0.05)

Table 8. Fortnightly average daily gain (g) of pigs maintained on the three dietary treatments (Mean ± SE)

Treatments	Fortnights					
	1	2	3	4	5	6
T_1	354.8 ± 46.46	363.0 ± 38.29	425.9 ± 30.44	392.6[a] ± 29.98	603.7 ± 21.24	748.2 ± 29.22
T_2	338.5 ± 42.05	437.0 ± 34.13	385.2 ± 36.33	518.5[b] ± 20.36	603.7 ± 41.05	777.8 ± 37.41
T_3	320.0 ± 22.47	463.0 ± 32.90	351.8 ± 15.81	514.8[b] ± 22.29	529.6 ± 34.53	794.8 ± 47.45
F	0.183	1.935	1.470	7.563	1.467	0.330

a,b Means within the column with different superscripts differ (P<0.01)

Fig.1. Fortnightly average daily gain of pigs maintained on the three dietary treatments



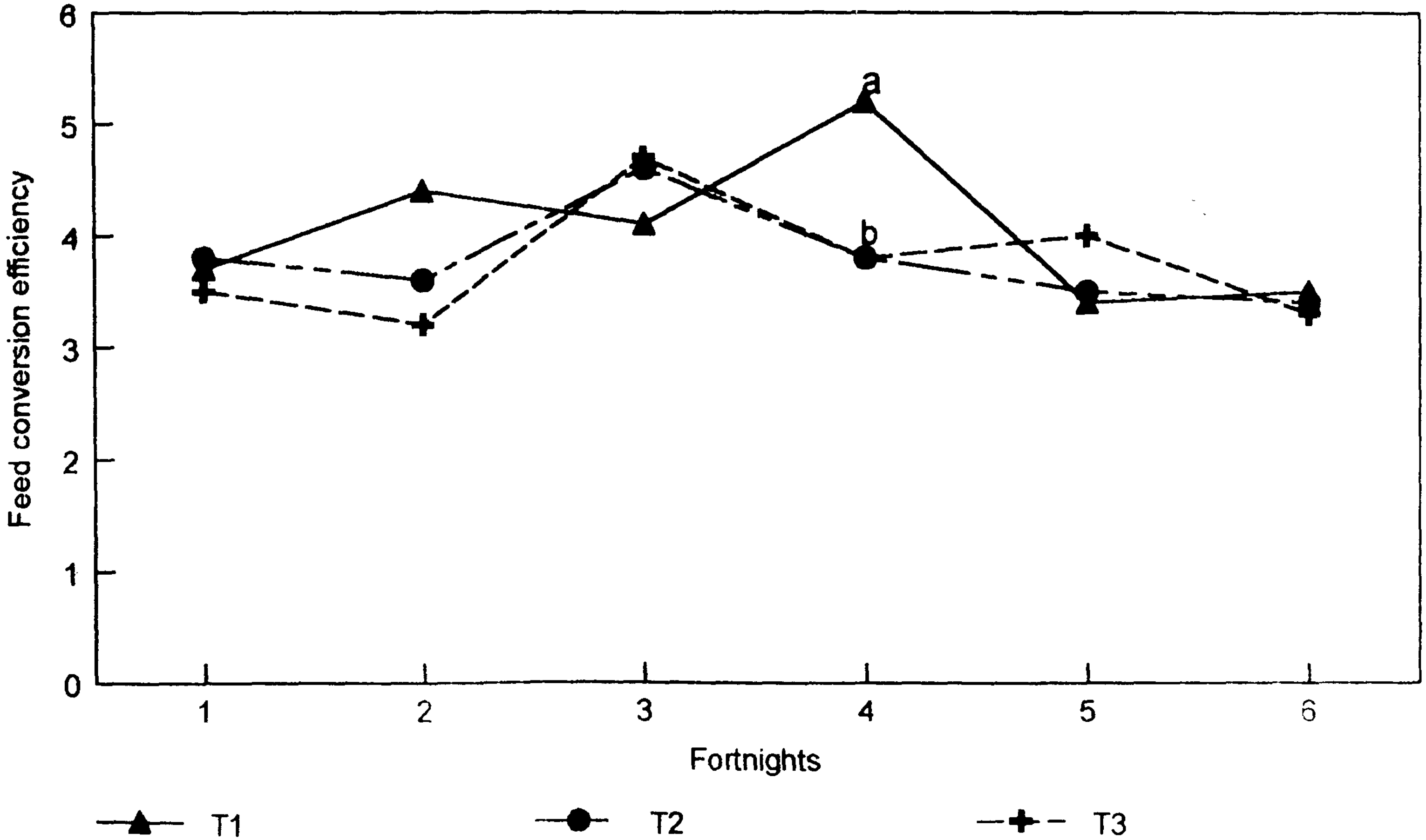
a,b significant (P < 0.01)

Table 9. Fortnightly feed conversion efficiency of pigs maintained on the three dietary treatments (Mean ± SE)

Treatments	Fortnights					
	1	2	3	4	5	6
T_1	3.7 ± 0.52	4.4 ± 0.56	4.1 ± 0.28	5.2 ± 0.44 [a]	3.4 ± 0.13	3.5 ± 0.13
T_2	3.8 ± 0.49	3.6 ± 0.35	4.6 ± 0.39	3.8 ± 0.16 [b]	3.5 ± 0.27	3.4 ± 0.20
T_3	3.5 ± 0.19	3.2 ± 0.18	4.7 ± 0.23	3.8 ± 0.11 [b]	4.0 ± 0.25	3.3 ± 0.19
F	0.096	2.400	1.064	8.048	1.623	0.147

a,b Means within the column with different superscripts differ (P<0.01)

Fig. 2. Fortnightly feed conversion efficiency of pigs maintained on the three dietary treatments



a,b significant (P < 0.01)

Table 10. Cumulative average daily gain and feed conversion efficiency of pigs maintained on the three dietary treatments (Mean ± SE)

Dietary treatment	Initial body weight (kg)	Final body weight (kg)	Total weight gain (kg)	Total feed intake (kg)	Average daily gain (g)	Feed conversion efficiency (kg feed/kg gain)
T_1	15.8 ± 0.82	59.1 ± 2.70	43.3 ± 2.06	160.5	481.4 ± 22.91	3.78 ± 0.19
T_2	16.0 ±	61.9 ± 0.79	45.9 ± 2.89	161.8 2.40	510.1 ± 26.75	3.63 ± 0.22
T_3	15.8 ± 0.79	60.4 ± 2.36	44.6 ± 1.74	159.4	495.7 ± 19.30	3.62 ± 0.13
F (NS)	0.025	0.253	0.342	ND	0.342	0.206

NS Not significant (P>0.05)
ND Not determined

Fig. 3. Cumulative average daily gain of pigs maintained on the three dietary treatments

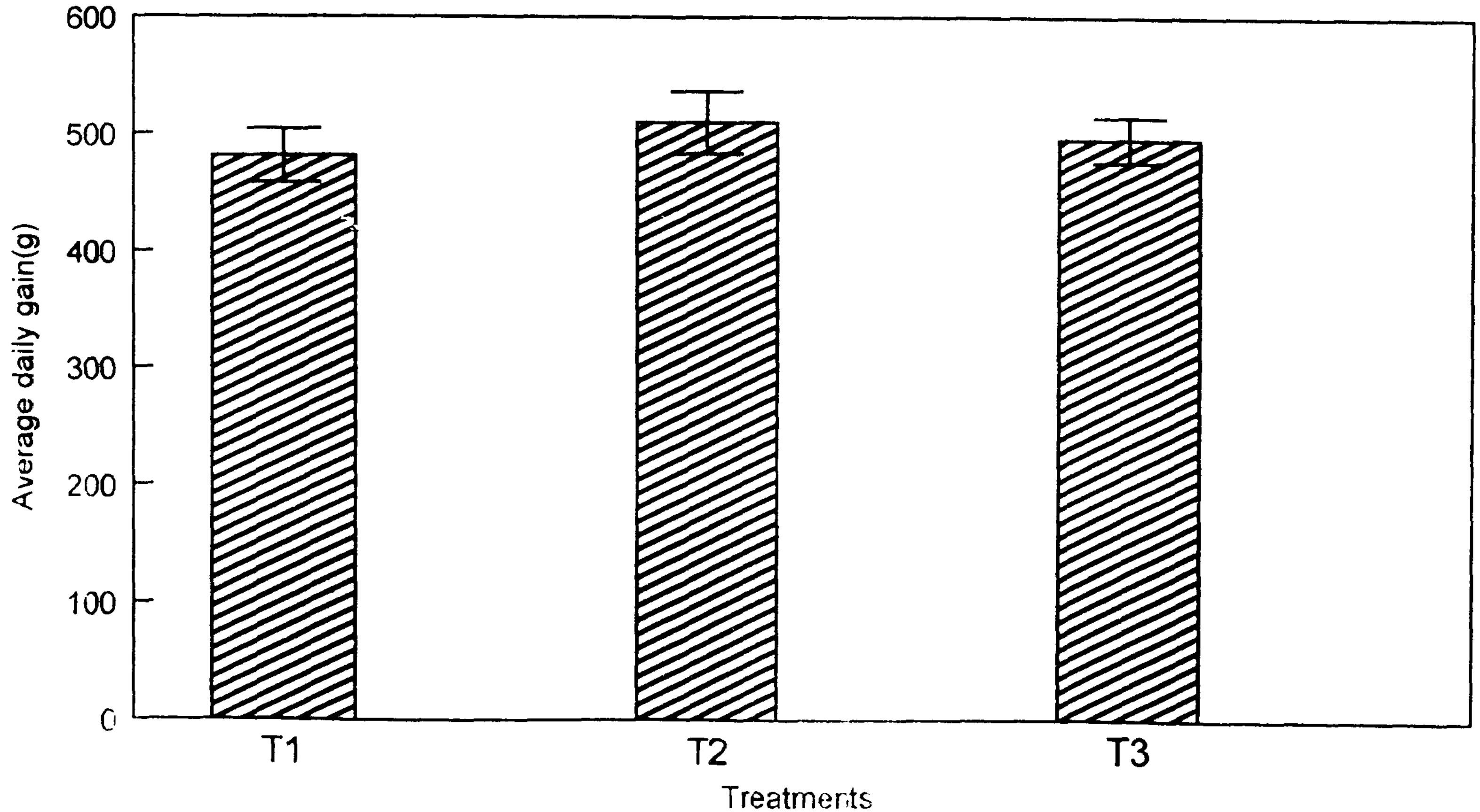


Fig. 4. Cumulative feed conversion efficiency of pigs maintained on the three dietary treatments

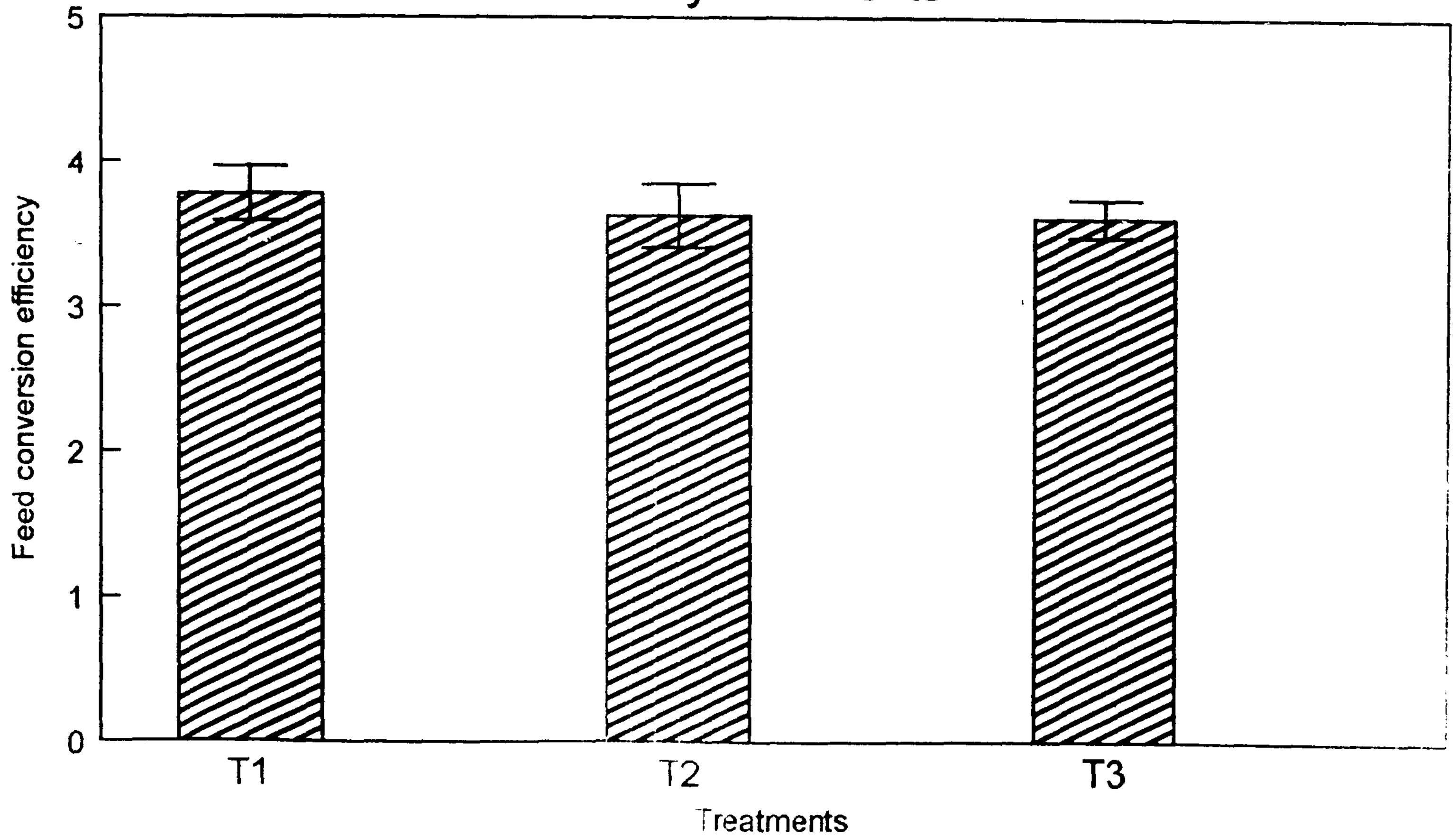


Table 11. Average digestibility coefficients of nutrients of the three experimental diets (Mean ± SE)*

Nutrients	Experimental diets		
	T_1	T_2	T_3
Dry matter	53.1 ± 0.05	48.8 ± 0.08	46.3 ± 0.15
Crude protein	65.2 ± 0.05	63.4 ± 0.05	60.3 ± 0.05
Ether extract	50.4 ± 0.09	52.5 ± 0.12	53.6 ± 0.14
Crude fibre	23.4 ± 0.15	20.3 ± 0.07	19.5 ± 0.12
Nitrogen free extract	67.7 ± 0.49	60.3 ± 0.66	54.9 ± 0.35

* Mean of three values

Fig. 5. Average digestibility coefficients of nutrients of the three experimental diets

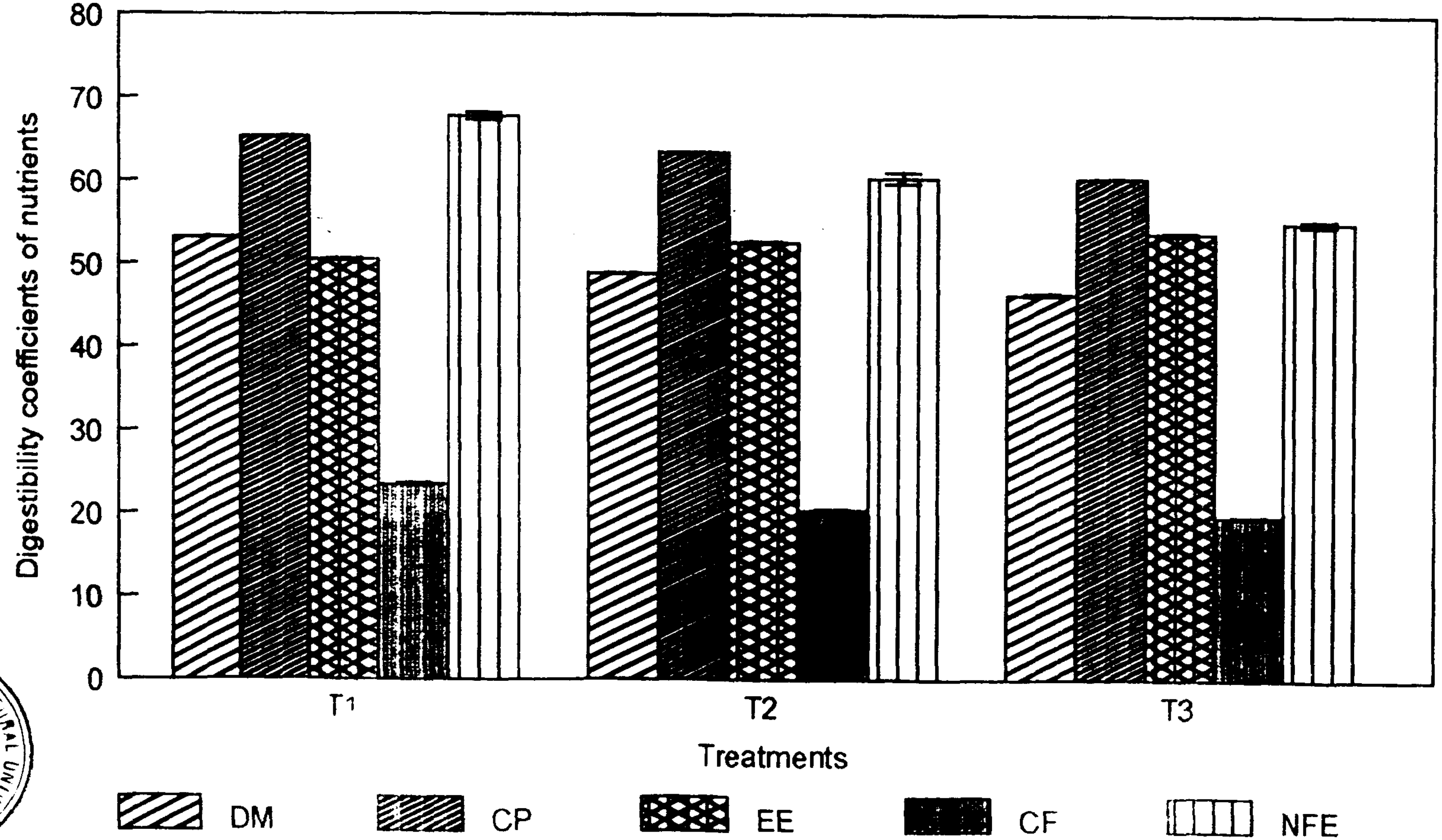


Table 12. Economics of gain:cost of production (Rs.) per kg live body weight of pigs maintained on different dietary treatments

	T_1	T_2	T_3	F
Cost/kg of grower ration[a] (Rs.)	6.24	6.04	5.85	-
Cost of production per kg live weight (Rs.)[b,c] Mean ± SE	31.46 ± 1.51	29.19 ± 1.76	28.20 ± 0.98	1.173

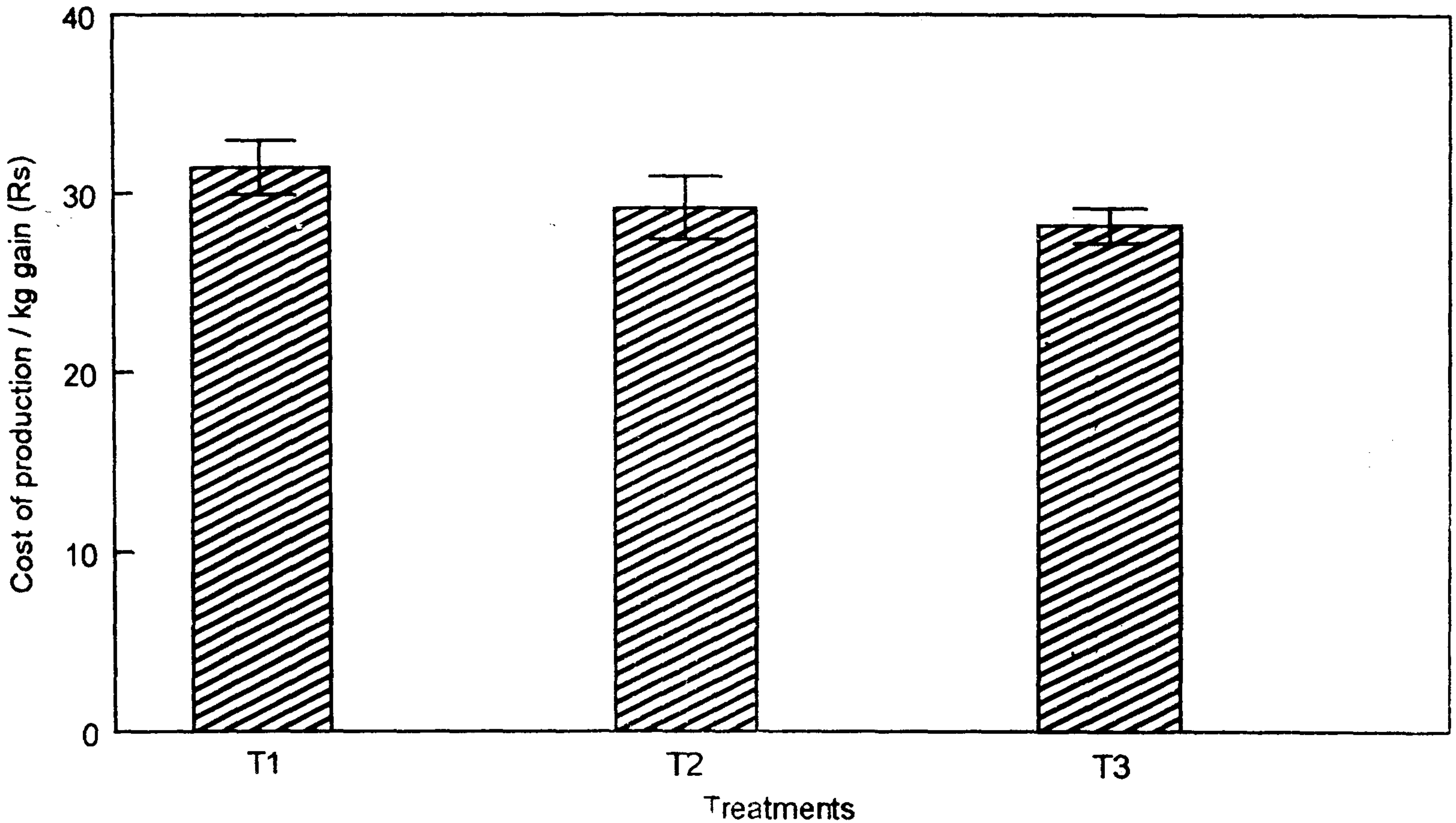
a. Cost of feed ingredients used

Ingredients	Cost/kg (Rs)
Yellow maize	5.08
Groundnut cake (expellar)	9.45
Rice polish	4.74
Wheat bran	5.57
Unsalted dried fish	10.50
Silk worm pupae meal (deoiled)	8.00
Mineral mixture	17.00
Salt	1.74
Vitamin supplement (Indomix[R])	453.94

b. Calculation based on the assumption that cost of feed accounts for about 75% of the total cost of production in pigs (Krider and Carroll, 1971)

c. Values within the row do not differ significantly (P>0.05)

Fig. 6. Cost of production per kilogram liveweight gain of pigs maintained on the three dietary treatments



Discussion

5. DISCUSSION

The results obtained during the course of the experiment are discussed under separate heads.

5.1 Chemical composition of silk worm pupae meal

Silk worm pupae meal used for the study contained 64.5 per cent crude protein, 4.3 per cent ether extract, 2.7 per cent crude fibre, 24.0 per cent nitrogen free extract, 4.5 per cent total ash, 1.4 per cent acid insoluble ash, 0.3 per cent calcium and 1.0 per cent phosphorus, on dry matter basis (Table 3).

It can be observed that the crude protein content of the silk worm pupae meal used in the present study was 64.5 per cent on dry matter basis. Almost a similar value of 62.6 per cent crude protein was reported by Thangamani (1995) while a slightly lower value (60.83%) was reported by Purushothaman and Thirumalai (1995). The lower crude protein content (55%) reported by Panda (1968) may be due to the high ether extract content of the material used.

The ether extract content of silk worm pupae meal was 4.3 per cent which is comparable to the value of 4.4 per cent, reported by Thangamani (1995) and 3.9 per cent reported by

Purushothaman and Thirumalai (1995). However a very high figure of 25 per cent has been reported by Panda (1968) for silk worm pupae.

The calcium and phosphorus contents of silk worm pupae meal were 0.3 and 1.0 per cent, respectively, which are comparable to the values reported by Thangamani (1995), but Purushothaman and Thirumalai (1995) reported a lower phosphorus value of 0.54 per cent on dry matter basis. The small differences in composition reported by different workers may be due to the difference in the processing technology employed in the preparation of silk worm pupae meal.

5.2 Body weights

From the results given in Table 4, it could be seen that the average fortnightly body weights of pigs maintained on three dietary treatments were similar except on fourth fortnight when a lower weight was recorded for the control group receiving 10 per cent unsalted dried fish in the diet. The lower body weights recorded by the pigs of the control group during fourth fortnight may be attributed to a mild digestive disorder noticed in one of pigs of the control group.

The effect of initial body weight of pigs on their final weights was analysed by covariance, which showed that initial body weight did not influence their final weights. The final body weight of the three treatment groups were 59.1, 61.9 and 60.4 kg, the differences between the groups being not significant (P>0.05).

Almost similar body weights have been reported by different workers for pigs of similar age groups. Sebastian (1972) observed body weights ranging from 55.0 to 57.6 kg for pigs when varying levels of tapioca starch waste was incorporated in the ration. Sinthiya (1998) observed that the body weight of pigs at 6 months of age ranged from 52.9 to 57.6 kg when varying levels of carcass meal was included in the diet. However, Mohan (1991) recorded body weights ranging from 32.6 to 59.7 kg for pigs of approximately 6 months of age, when varying levels of prawn waste was incorporated in the pig feed. The lower values observed in pigs fed rations containing prawn waste may be due to poor palatability and digestibility of prawn waste. Slightly lower values (45.3 to 51.5 kg) were also reported by Subramanian (1998) when the effect of modified environment during summer on the performance of growing pigs was studied.

5.3 Body Measurements

The data on body length, girth and height of pigs maintained on the three dietary treatments from first fortnight to sixth fortnight are presented in Table 5, 6 and 7 respectively. Statistical analysis of the data on each fortnight revealed no significant difference (P>0.05) between the three dietary treatments.

The final body length of pigs of the three dietary treatments T_1, T_2 and T_3 were 76.4, 76.1 and 78.6 cm, respectively. There was no significant difference (P>0.05) between the three treatment groups. Mohan (1991) observed almost similar body length in pigs ranging from 80.4 to 84.0 cm when prawn waste was added in different proportions in the diet. Similar body lengths were also reported by Subramanian (1998) and Sinthiya (1998). Higher body lengths (104.3 to 108 cm) were reported by Devi (1981) in studies where pigs were given diets incorporating dried tapioca chips at different levels.

The final body girth of pigs of three treatment groups (Table 6) were 85.3, 87.2 and 83.0 cm respectively which did not differ significantly (P>0.05). Similar girth values were also reported by Devi (1981), Mohan (1991), Sinthiya (1998) and Subramanian (1998) for pigs of almost similar body weights.

The data presented in Table 7 indicate that the final body height of pigs maintained on the three dietary treatments T_1, T_2 and T_3 were 47.6, 47.8 and 48.0 cm respectively. The body height of pigs reported by Devi (1981) and Sinthiya (1998) ranged from 52.0 to 56.2 cm and 54.3 to 57.3 cm respectively, while Subramanian (1998) recorded a value of 58 to 60.83 cm. The values reported by the above authors are higher than the values obtained in the present experiment.

Correlation regression analysis was done between fortnightly body weights and body measurements such as body height, girth and length and the results indicated that the fortnightly body weights were significantly ($P<0.01$) correlated with their body measurements. A linear relationship between live weight gain and body measurements in pigs was also reported by several other authors (Gruev and Machev, 1970; Mickwitz and Bobeth, 1972; Deo and Raina, 1983 and Sahayaruban *et al.*, 1984).

5.4 Fortnightly average daily gain

From the data presented in Table 8, it could be seen that the pigs maintained on the three dietary treatments T_1, T_2 and

T_3, gained at the rate of 354.8, 338.5 and 320.0 g/day, respectively, during the first fortnight and 748.2, 777.8 and 794.8 g/day, respectively, during the last fortnight. There was no significant difference in pigs maintained on the three dietary treatments in regard to their fortnightly body weight gain except during the fourth fortnight, where the pigs of T_1 group gained lesser ($P<0.01$) than those of T_2 and T_3. This may be attributed to the off-feed and digestive disorder exhibited by one pig of that particular group during the period.

An overall evaluation of the results obtained on body weight gain and body measurements of pigs maintained on the three dietary treatments indicates that the growth depression reported in chicks as a result of incorporation of silk worm pupae meal (Joshi *et al.*, 1979; Virk *et al.*, 1980a and Fagoonee, 1983) was not observed in present experiment conducted in pigs.

The cumulative average daily gain of pigs maintained on the three treatments T_1, T_2 and T_3 were 481.4, 510.1 and 495.7 g, respectively (Table 10). Though average daily gain of pigs fed diets containing silk worm pupae meal was more that of control group, the difference was nonsignificant ($P>0.05$).

The results obtained in the present study in this regard are in keeping with those of Cool *et al.* (1992) who also did not get any significant difference in average daily gain of pigs fed diets with silk worm pupae meal, replacing soyabean meal at 0, 25, 50, 75 and 100 per cent in swine ration, eventhough higher average daily gains of 832, 825, 836, 848 and 902 g, respectively, were recorded.

However, the values obtained in the present study are higher than those reported by Devi (1981) who recorded a cumulative average daily gain of 368.0 to 385.9 g when different levels of dried tapioca chips were incorporated in pig feed and those reported by Mohan (1991), Sinthiya (1998) and Subramanian (1998).

5.5 Feed conversion efficiency

From the results given in Table 9, it could be seen that average fortnightly feed conversion efficiency of pigs maintained on the three dietary treatments were similar except during the fourth fortnight in which the feed conversion efficiency was poor for the control group. Further there was no significant difference ($P>0.05$) in the cumulative feed conversion efficiency of pigs maintained on various dietary treatments (Table 10 and Fig.4), the values being 3.78, 3.63 and 3.62, for T_1, T_2 and T_3 respectively.

The values obtained in the present study are in accordance with those reported by Devi (1981) when different levels of dried tapioca chips were incorporated in swine ration. Bhagwat and Sahasrabuddhe (1971) reported an overall feed conversion efficiency of 4.2 in pigs on ration containing 19 per cent crude protein, while Ranjhan *et al.* (1972) reported a value of 3.0 and 4.1 for pigs upto 50 kg and 50 to 70 kg body weight respectively, when protein and energy levels in the ration were varied. However, slightly lower feed conversion efficiency than the results obtained in the present experiment were reported by Sebastian (1972), Mohan (1991), Sinthiya (1998) and Subramanian (1998).

A slightly better feed conversion efficiency values have been reported by Cool *et al.* (1992) in their studies when chrysalis meal of the silk worm was supplemented in pig ration at 0, 25, 50, 75 and 100 per cent levels replacing soyabean meal.

5.6 Digestibility coefficient of nutrients

5.6.1 Dry matter

Data set out in Table 11 reveal that the digestibility coefficient of dry matter of the three experimental diets T_1, T_2 and T_3 were 53.1. 48.8 and 46.3 respectively. Almost similar dry matter digestibility was reported by Mohan (1991) when pigs were fed diets containing 14 per cent crude protein with different levels of prawn waste.

Pond *et al.* (1962) observed the apparent digestibility percentage of dry matter as 68.8 and 84.1 for high fibre high protein diet and low fibre-high protein diet, respectively. Devi (1981) reported digestibility coefficients of dry matter that ranged from 79.6 to 82.4 for diets containing 16 per cent protein with varying levels of dried tapioca chips. Eggum *et al.* (1982) obtained digestibility coefficient of 79,7 and 67.6 for diets containing 4.7 and 10.5 per cent crude fibre, respectively with a crude protein content of 13 to 13.3 per cent. Thomas and Singh (1984) reported that lowering of digestible energy content of grower pig rations by 10 per cent from NRC level lowered the dry matter digestibility from 81.08 to 60.39 per cent. The digestibility coefficient of dry matter obtained in the present investigation were found to be lower than those reported by the above workers. The present observation is in keeping with those of Moughan *et al.* (1991) who reported that apparent digestibility coefficient of dry matter, organic matter and gross energy in pigs calculated by using chromic oxide was lower when compared to total collection.

5.6.2 **Crude** protein

A perusal of the data in Table 11 further indicates that the digestibility coefficient of crude protein in the experimental diets T_1, T_2 and T_3 were 65.2, 63.4 and 60.3 respectively.

Pond *et al.* (1962) reported that average digestibility coefficients of crude protein ranged from 60.7 to 71.7 for diets containing varying levels of crude fibre and crude protein, whereas Eggum *et al.*(1982) reported values ranging from 57.0 to 73.0 for diets containing varying levels of crude fibre. Mohan (1991) reported the average digestibility coefficients of crude protein ranging from 55.9 to 65.3. The values obtained in the present investigation are in agreement with those obtained by the above workers.

Devi (1981) and Yen *et al.* (1983) obtained average digestibility coefficients of crude protein that ranged from 73.0 to 80.3 and 70.4 to 75.9, respectively, which were higher than those obtained in the present investigation. Thomas and Singh (1984) reported that crude protein digestibility dropped from 80.04 to 68.17 when digestible energy content of the grower ration for pigs was lowered by 10 per cent from NRC level.

5.6.3 Ether extract

The digestibility coefficients of ether extract obtained in the present experiment were 50.4, 52.5 and 53.6 respectively, for the diets T_1, T_2 and T_3.

The values obtained in the present study are comparable to those reported by Mohan (1991) in his studies incorporating different levels of prawn waste in pig ration. However, higher values (66.9 to 69.9 per cent) were reported by Devi (1981) when diets with 16 per cent crude protein and varying level of dried tapioca chips were fed to pigs.

Pond *et al.* (1962) and Eggum *et al.* (1982) obtained digestibility coefficient values that ranged from 22.7 to 32.0 and 28.6 to 35.0, respectively, for crude fat in pigs on diets containing varying levels of crude fibre, which is lower than those obtained in the present investigation. Fernandez *et al.* (1986) conducted digestibility experiments in growing pigs with 26 feed stuffs and diets and reported that the digestibility of crude fat ranged from 6 to 90 per cent. Thomas and Singh (1984) reported that lowering of digestive energy content of grower pig rations by 10 per cent from NRC level resulted in lowering of ether extract digestibility from 91.76 to 76.84 per cent and a further lowering of digestible energy values by five per cent brought down the ether extract digestibility to 55.1 per cent.

5.6.4 Crude fibre

The data presented in Table 11 also reveal that the digestibility coefficients of crude fibre were 23.4, 20.3 and 19.5, for the experimental diets T_1, T_2 and T_3 respectively.

Mohan (1991) recorded the digestibility coefficients of crude fibre that ranged from 20.6 to 27.4 for the diets containing different levels of prawn waste which were comparable to the values of the present experiment.

Pond *et al.* (1962) reported that the average digestibility coefficients of crude fibre ranged from 22.8 to 38.8 in growing-finishing swine fed rations containing varying levels of crude fibre and a crude protein content of 18 per cent. Eggum *et al.* (1982) obtained digestibility coefficients of crude fibre that ranged from 24.0 to 31.2 in pigs fed on diets containing 13.0 to 13.3 per cent crude protein and varying levels of crude fibre. The values obtained for diet T_1 in the present investigation is in agreement with those reported by the above workers whereas the values recorded for diets T_2 and T_3 are found to be lower. Fernandez *et al.* (1986) observed a wide variation of 3 to 72 per cent in the digestibility of crude fibre in pigs, when 26 different feedstuffs were used in the study. Devi (1981) reported the digestibility coefficient of crude fibre from 37.1 to 40.0 for the diets containing 16 per cent crude protein and varying levels of dried tapioca chips which were higher than those obtained in the present study.

5.6.5 Nitrogen free extract

The data on digestibility coefficients of nitrogen free extract presented in Table 11 indicate that nitrogen free extract was digested to the extent of 67.7, 60.3 and 54.9, respectively, for the diets T_1, T_2 and T_3. Almost similar values have been reported by Mohan (1991) in his studies with diets containing varying levels of prawn waste.

Devi (1981) obtained the digestibility coefficient of nitrogen free extract that ranged from 86.3 to 90.1 for diets containing 16 per cent crude protein and varying levels of dried tapioca chips which were far higher than those obtained in the present experiment.

The values obtained in the present investigation were also lower when compared to the digestibility coefficient of nitrogen free extract obtained by Pond *et al.* (1962) and Eggum *et al.* (1982) who have reported values ranging from 80.5 to 90.6 and 84.5 to 91.6, respectively, for diets containing constant level of crude protein and varying levels of crude fibre. However, Fernandez *et al.* (1986) recorded a wide variation of 14.0 to 96.0 per cent in the digestibility of nitrogen free extract in pigs when 26 different feedstuffs were used in the study.

Virk *et al.* (1980b) studied the effect of deoiled silk worm pupae meal on metabolizability of nutrients for broiler chicks when silk worm pupae meal replaced fish meal protein at 0, 50, 75 and 100 per cent level and they found that metabolizable dry matter, digestibility of available carbohydrate and metabolizable energy of diets containing silk worm pupae meal were numerically lower than that of control diet. This was in agreement with the results of the present experiment as there was slight reduction in the digestibility coefficients of nutrients, except ether extract, of silk worm pupae meal contained diets.

5.7 Economics on gain

The cost of deoiled silk worm pupae meal was Rs.8.00/kg and that of unsalted dried fish was Rs.10.50/kg. The growth performance of pigs fed diets incorporating silk worm pupae meal was similar to those fed diets with unsalted dried fish.

A perusal of the data presented in Table 12 indicates that the cost of production per kilogram live body weight gain of pigs maintained on the three dietary treatments T_1, T_2 and T_3 were Rs.31.46, 29.19 and 28.20 respectively, which did not differ significantly (P>0.05). The lower cost and higher protein content of silk worm pupae meal were responsible for the slightly lower cost of production/kg live body weight gain when compared to unsalted dried fish.

A critical evaluation of the results obtained in the present study indicates that silk worm pupae meal can be used as a substitute for unsalted dried fish in growing pig rations as no significant difference either in average daily gain or feed conversion efficiency was noticed between the different groups.

Summary

SUMMARY

An investigation was carried out to assess the effect of dietary inclusion of silk worm pupae meal (a by-product from sericulture) replacing fish meal protein at three levels on the growth performance of Large White Yorkshire pigs.

Twenty seven weaned Large White Yorkshire female piglets with an average body weight of 16 kg were selected and divided into three groups of nine piglets each as uniformly as possible with regard to their age and body weight. The piglets of each group were then randomly allotted to three pens to form three replicates per treatment. The three groups of piglets were randomly allotted to three dietary treatments T_1, T_2 and T_3 which were isoproteimic and isocaloric and contained silk worm pupae meal replacing protein from unsalted dried fish at 0, 50 and 100 per cent level in grower ration. The animals were maintained on their respective diets with 16 per cent crude protein and 3000 kcal/kg of digestible energy under identical managemental conditions during the experimental period of 90 days.

Records of daily feed intake and fortnightly body weights and body measurements such as body length, girth and height were maintained throughout the period of the experiment. A digestibility trial was conducted towards the end of the experiment to determine the digestibility coefficients of

nutrients by using chromic oxide (Cr_2O_3) as an external indicator.

Animals under all the three dietary treatments gained weight satisfactorily, there being no significant difference in fortnightly average daily weight gain throughout the course of the experiment except during the fourth fortnight in which animals of the T_1 group showed a lower daily gain. The cumulative average daily gain of pigs maintained on the three dietary treatments T_1, T_2 and T_3 were 481.4, 510.1 and 495.7 g, respectively. Though the average daily gains observed in the pigs fed with diets containing silk worm pupae meal were numerically higher than that of the control group, the differences were non significant ($P>0.05$).

The data on body measurements indicated that change in body measurements were directly correlated to gain in body weight.

With regard to the feed conversion efficiency, there was no significant difference among the three dietary treatment groups except during the fourth fortnight, which recorded a lower feed conversion efficiency for the control group. The cumulative feed conversion efficiency values were 3.78, 3.63 and 3.62 for the animals in dietary treatments T_1, T_2 and T_3, respectively, which did not differ significantly ($P>0.05$).

Results of the digestibility experiment indicated slightly higher digestibility coefficients of dry matter, crude protein, crude fibre and nitrogen free extract for the diet T_1 when compared to those of diets T_2 and T_3.

The cost of production per kilogram live body weight gain of pigs maintained on the three dietary treatments T_1, T_2 and T_3 were Rs. 31.46, 29.19 and 28.20, respectively. Though the inclusion of silk worm pupae meal in diets seemed to reduce the cost of production when compared to the diet containing unsalted dried fish, the difference was not significant ($P>0.05$).

It can be concluded that silk worm pupae meal can be used to replace unsalted dried fish partially or completely in swine ration without adverse effects on the growth rate and feed conversion efficiency.

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EVALUATION OF SILK WORM PUPAE MEAL ON GROWTH PERFORMANCE IN LARGE WHITE YORKSHIRE PIGS

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ABSTRACT

An experiment was conducted to assess the effect of silk worm pupae meal, a by-product from sericulture industry, on growth, feed conversion efficiency and economics of production in growing pigs.

Twenty seven weaned Large White Yorkshire female piglets with an average body weight of 16 kg were selected from University Pig Breeding Farm, Mannuthy and were divided into three groups of nine piglets each, as uniformly as possible with regard to their age and body weight. The piglets were then randomly allotted to three pens to form three replicates per treatment. The three groups of piglets were maintained for 90 days on three isonitrogenous and isocaloric diets T_1, T_2 and T_3 in which protein from unsalted dried fish was replaced by silk worm pupae meal at 0, 50 and 100 per cent level.

The animals maintained under the three dietary treatments T_1, T_2 and T_3 had almost similar growth rate ($P>0.05$) with a cumulative average daily gain of 481.4, 510.1 and 495.7g. respectively.

The total feed intakes of the animals in different groups were almost similar. There was no significant difference ($P>0.05$) in cumulative feed conversion efficiency between the

groups, the values being 3.78, 3.63 and 3.62, respectively, for animals in the dietary treatments T_1, T_2 and T_3.

The digestibility coefficients of nutrients except that of ether extract, were slightly higher for the control ration compared to those with silk worm pupae meal.

The cost of production per kilogram live weight gain of pigs maintained on the three dietary treatments, T_1, T_2 and T_3 were Rs. 31.46, 29.19 and 28.20 respectively. Though there was a slight decrease in the cost of production due to incorporation of silk worm pupae meal in place of unsalted dried fish in swine ration, the difference was non significant ($P>0.05$).

The above results indicate that silk worm pupae meal can be effectively included in the diets of growing pigs without affecting growth, feed conversion efficiency and the cost of production.