STUDIES ON TEXTURE AND COLLAGEN CONTENT OF COMMERCIALLY IMPORTANT TROPICAL FISHES

By
FEMEENA HASSAN

THESIS

Submitted in partial fulfilment of the requirement for the degree

MASTER OF FISHERIES SCIENCE

Faculty of Fisheries
Kerala Agricultural University

DEPARTMENT OF PROCESSING TECHNOLOGY
COLLEGE OF FISHERIES
PANANGAD, COCHIN

1991

TO MY SON

ADIL

DECLARATION

I hereby declare that this thesis entitled " STUDIES ON TEXTURE AND COLLAGEN CONTENT OF COMMERCIALLY IMPORTANT TROPICAL FISHES" 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 any other similar title,of any other university or society.

Signature of the candidate

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31/12/1991

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Certified that this thesis entitled " STUDIES ON TEXTURE AND COLLAGEN CONTENT OF COMMERCIALLY IMPORTANT TROPICAL FISHES " is a record of research work done independently by Smt.Femeena Hassan under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship, or associateship to her.

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UTILISATION OF PRAWN WASTE AS PIG FEED

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THESIS

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Master of Veterinary Science

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Mannuthy - Trichur

1991

DECLARATION

I hereby declare that this thesis entitled **"Utilisation of Prawn Waste as Pig Feed"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

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14-8-1991

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CERTIFICATE

Certified that this thesis entitled **"Utilisation of Prawn Waste as Pig Feed"** is a record of research work done independently by **Dr. K.M. Syam Mohan** 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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To my parents

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Introduction

INTRODUCTION

Livestock production and development are important for the growth of primary sectors of economy as also for the improvement of the standard of living of the population. Levels of household consumption of animal products like milk, meat and egg are indicators of protein intake and would therefore give a measure of the change in the standard of living of the population. In developing countries like India where a large proportion of the population is engaged in primary productivity, the agricultural sector extends to all activities connected with the maintenance of livestock population and output of livestock products. Livestock rearing has helped the rural poor through remunerative self-employment as reflected from the reduction in percentage of the people below the poverty line from 51 to 37 per cent in the Seventh Five Year Plan (Anon. 1987).

It is well known that for efficient livestock and poultry production high density rations are essential. In India the annual requirements for feeds and fodders are estimated to be 25.4 million tonnes of concentrate, 353.0 million tonnes of dry fodder and 308.1 million tonnes of green fodder of which 16.5 million tonnes of concentrate 300.5 million tonnes of dry fodder and 261.0 million tonnes of green fodder only are available (Mudgal, 1988). One of the main factors responsible for the overall deficiency of feed stuffs is the enormous population of livestock in India. The livestock and poultry population in India consists of 201.4 million cattle, 75.6 million buffaloes, 10.5 million pigs, 57.0 million sheeps, 108.5 million goats, 206 million chicken and 9 million ducks which accounts for about 5 per cent of the world livestock poultry population (Anon. 1989). Because of the low productivity of livestock, large number of them have to be maintained, which in turn causes greater shortage of feeds and fodders resulting in further degeneration of the stock. Moreover, it is not feasible to use conventional grains for animal feeding in India as these are used largely for human consumption. It is desirable, therefore, to augment the feed resources, particularly those which are not being used for human consumption to meet the rise in demand for animal feeds.

Extensive research and development programmes have been carried out in India to achieve the required target of milk, meat, egg and other products from livestock and poultry. Although, the productivity of animals has increased through improving their genetic potential and by providing better quality feeds the production targets are far from being realised. This emphasizes the need to expand the feed resources further in terms of quality and quantity. A linear increase in human population in our country demands more and more land use for food production, thus allowing no additional land to produce more feeds and fodder. It is therefore imperative to improve the feed resource situation by adding non-conventional and less utilised feed ingredients to the animal feed reservoir. Researches have to be conducted to identify, develop and test non-conventional feed resources that are produced in the country which can replace all or part of the conventional feeds for livestock especially for swine and poultry. Researches are also required to identify the toxic factors present if any, to develop methods for their elimination, to improve the processing methods for optimum utilisation and to find out the nutritional value and feeding levels of these non-conventional feed resources available in the country as feeds for livestock.

Swine production assumes great importance due to the fact that pigs are the most efficient converters of feed stuffs and domestic and agro-industrial wastes into edible meat. It also increases the supply of animal protein, which represents one of the means of alleviating the present problem of protein shortage of animal origin. 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 weaker section of the rural community. The proper development of pig industry on scientific and profitable lines as followed in other progressive countries of the world will, not only help to solve the country's food problem to a great extent but also improves the nutritional standards of our growing population.

The swine population in India was estimated to be 10.3 million and that of the world 846 million (Anon. 1990). The swine population of Kerala was estimated to be 1.37 lakhs (Livestock Census, 1987). Out of the total meat production of 0.87 million metric tonnes in India, pork contributed only 0.08 million metric tonnes which was 0.42 per cent of that produced from Asia and 0.14 per cent of that produced from World (Annual Report, Ministry of Agriculture - 1985-86).

Profitable raising of pigs depends largely on a carefully planned and efficient feeding programme. Since more than 60 to 70 per cent of the cost of swine production is accounted for by feeds, economic formulation of swine rations assumes paramount importance. It is also well known that adoption of improved methods of feeding can produce much better carcass at a much earlier age and with greater financial returns.

One of the major constraints that beset the commercial pig rearing in India, is the non availability of suitable feeds. Being monogastric, pigs compete with human beings for feed. Eventhough there is a substantial increase in the production of cereal food grains and oil seeds, the increased production has been rapidly overwhelmed by the rapidly growing population. Hence it has become necessary for the scientists to identify alternate feed resources for feeding swine. Extensive studies on the identification and utilisation of various agricultural by-products and industrial wastes in the ration of livestock have been done in India (Punj, 1988; Gupta, 1988).

Various by-products of aquatic animal origin have been tried as feed supplements in the rations of livestock and poultry. Fish silage has been found to be a potential source of feed for growing-finishing swine (Tibbets et al., 1981; Batterham et al., 1983; Ward et al., 1985; Green et al., 1988 and Myer et al., 1990) finishing steers (Abazinge, 1984) growing calves (Offer and Hussain, 1987) and Chicken (Surdzhiiska et al., 1988). Crab meal has been found to be a potential source of nutrients in the rations of calves (Patton et al., 1975) and growing swine (Husby, 1980). Krill meal could be successfully incorporated in the rations of growing pigs (Luberda et al., 1981; Kroklina and Antonov, 1983) and broilers (Heinz et al., 1983).

Prawn waste is another by-product of aquatic animal origin obtained from the prawn processing industries that could be used as a source of feed for animals. The quantity of prawn waste available in India is estimated to be 60,000 tonnes per annum (Ramachandran Nair et al., 1986). With a coastal line of 600 kms and 4000 hectares of land suitable for rearing of prawn, Kerala is the first among the states in the production of sea foods. Frozen shrimp constitutes a major portion of the marine products that are exported from India. With the increase in the annual prawn processing, the availability of prawn waste is increasing. The product is now being wasted or used as manure in coastal areas.

Though prawn waste has been found to possess potential nutrients like protein and minerals (Morrison, 1948; Jarquin et al., 1972 and Ramachandran and Madhavan, 1975), very little work has been done to find out the suitability of prawn waste as feeds for livestock. An investigation was therefore, taken up to assess the feeding value of dried prawn waste as a partial or complete replacement of animal protein from unsalted dried fish in the feeds for growing pigs.

Review of Literature

REVIEW OF LITERATURE

Chronic deficiency of feeds and fodders constitutes a major constraint in the development of animal production in India. The overall deficiency of animal feed resources has been estimated to be 44 per cent for concentrates, 36 per cent for green fodders and 36 per cent for dry roughages (National Commission Report 1976). Utilisation of non-conventional feeds, agricultural crop residues and agro-industrial by-products and wastes is a step taken in the right direction to solve the present problem to a greater extent. Various aquatic animal by-products and wastes have been used in the rations of livestock for improving the nutritional value of cereal and oil cake-based diets.

Fish silage

Fish silage is a versatile animal feed. Ensiling offers a means by which most types of waste fish or fish offals can be used efficiently by conversion into a highly nutritious liquid feed.

Tibbets et al. (1981) found that ensiled fish waste could be incorporated in the rations of weanling and finishing pigs upto nine per cent without any significant difference in average daily gain, feed conversion ratios and carcass measurements, when compared to a diet containing corn-soybean meal diet. Johnsen (1982) observed a lowered milk yield in dairy cows fed with a ration containing fish viscera silage as against a diet with soybean meal. Samuels et al. (1982) reported that sea food waste could be ensiled with grass and made good quality silage and the addition of molasses could improve the quality further. Batterham et al. (1983) reported that addition of fish silage as a partial or complete replacement of soybean meal improved growth rate and feed conversion ratio in pigs during the 20-45 kg growth phase. Johnsen and Ekern (1983) observed that addition of fish viscera silage increased the digestibility of organic matter, protein and ether extract and with formaldehyde it increased the digestibility of dry matter and crude fibre also in sheep. But when the rumen of sheep was not adapted to fish silage before supplementation it drastically depressed the feed intake. Abazinge (1984) reported that addition of low levels of fish waste - straw silage to finishing steer diets did not adversely affect feed intake, rate of gain and carcass characteristics. Chirase et al. (1985) showed that fish silage and wheat straw, mixed and ensiled together fermented well as indicated by lactic acid production. Ward et al. (1985) found that fish waste could be ensiled to produce a product containing 13.2 to 14.8 per cent protein and that the silage could effectively replace part of the soybean meal in the diet of starter pigs. Cordova and Bello (1986) reported no significant difference between chicken given the dried fish silage and those given fish meal in weight gain or in feed intake per unit gain.

Offer and Hussain (1987) reported that over a 15 week feeding trial using early weaned calves, inclusion of fish silage significantly depressed feed intake and live weight gain. But the performance on fish silage improved as the trial progressed and for the last seven weeks of the trial, feed conversion was similar to that for fish meal. Fish silage did not depress diet digestibility of gross energy or organic matter.

Surdzhiiska et al. (1988) prepared a product, Ribotricin K from fish cannery waste, having a protein content of 24 to 25 per cent and metabolisable energy 3465 kcal kg^{-1}. They found that it could be incorporated at levels of three or four per cent, replacing fish meal in the diets for chicken. According to Green et al. (1988) growing pigs fed on fish silage diet grew faster than those given no fish silage and registered a higher feed conversion ratio. Myer et al. (1990) reported that supplementation of scallop viscera silage in the grower and finisher diets of swine produced no detrimental effects on average daily gain, feed intake or feed to gain ratio. Apparent digestibilities of dry matter, nitrogen and energy of the grower or finisher diets was also not affected.

Crab Meal

Patton et al. (1975) reported that crab meal could be included upto 20 per cent in the diets for calves without producing any significant difference in weight gain, feed intake or feed efficiency. Husby (1980) stated that King crab meal could effectively replace soyabean meal upto 50 per cent in the diets for growing pigs from 40 to 125 lb weights without causing significant difference in average daily gain and feed efficiency. Brundage et al. (1984) observed decreased dry matter intake and low milk yield, when cows were introduced to the concentrates containing 7.5, 22.5 or 30 per cent crab meal. He found that the cows on 7.5 and 22.5 per cent crab meal concentrates recovered much of the initial deficit, but those on 30 per cent crab meal did not establish a consistent pattern of intake and lost weight. Ayangbile et al. (1987) substituted 0, 15 and 30 per cent of crab waste into the finishing diets of 30 yearling steers. Average daily gain, feed efficiency and carcass weights were higher for those fed with ration containing 30 per cent crab waste-straw silage. Laflamme (1988) on the other hand reported that inclusion of crab meal at 35 per cent of the barley concentrate feed resulted in reduced feed intake and growth in calves with most of the negative effects being eliminated after a period of adaptation. Sticker et al. (1989) on the basis of his studies on ruminal degradation and subsequent absorption of Menhaden fish meal and blue crab meal in cannulated sheep and cattle reported that crab meal protein has similar escape potential to Menhaden fish meal.

Krill meal

Luberda et al. (1981) based on his findings stated that partial or complete replacement of animal protein in the ration of pigs can be done with krill meal, without causing any adverse effect on daily gain, dressing percentage and carcass length. Luberda and Iwanska (1981) reported that growing-finishing pigs, fed krill meal from 1.2 to 1.6 per cent in the feed did not influence the physico-chemical feature of depot fats. However, they found that a higher proportion of krill meal caused a decrease of fat and dry matter content and an increase of the poly unsaturated fatty acids in lard and outer layer of back fat. Kroklina and Antonov (1983) reported that in feed mixtures for growing pigs in which fish meal is the single high protein source, it is possible to replace upto 50 per cent of fish meal protein with krill meal protein. Heinz et al. (1983) stated that krill meal could substitute fish meal for broilers but should not exceed 70 to 80 g/kg feed.

Prawn waste

Morrison (1948) reported that shrimp meal contained 89.7 per cent dry matter, 46.7 per cent protein, 2.8 per cent fat, 27.8 per cent ash, a digestible crude protein content of

37.8 per cent and a total digestible nutrient value of 43.5 per cent. Jarquin *et al*. (1972) reported that chemical composition of shrimp meals varied depending on the proportion of meal made from shrimp heads to meal from bodies plus tails present. Meyers *et al*. (1973) observed variability in proximate analysis of different processed shrimp meals, due to difference in condition and species involved and also to different processing and recovery techniques. Shrimp heads make up 40-44 per cent of the whole raw shrimp and have 47-55 per cent corrected protein with a good amino acid balance. Meyers *et al*. (1973) demonstrated a 10 per cent reduction in protein content of heads after 24 hours. Madhavan and Ramachandran (1975) reported that prawn waste contains 39.76 per cent protein, 23.08 per cent chitin, 5.05 per cent fat and 31.3 per cent ash. Landau (1985) found that larger shrimp had a greater percentage of protein, total lipid and kcal/g values than small shrimp. The small shrimp had more fatty acid and glycogen. Barrat and Montano (1986) reported that the silage produced using prawn waste on chemical analysis after six days of treatment indicated that it contains net protein including chitin 16.5 per cent, lipids 6.4 per cent, ash 8.5 per cent and moisture 67.5 per cent.

Angel (1935) reported that out of the four levels of 5, 10, 15 and 20 parts of shrimp in the same basal ration of growing pigs, 10 per cent ration gave the best results during the first 70 days with regard to the rate of gain and feed consumed per unit weight gain. Fronda *et al*. (1938) stated that in order to produce the same number of eggs in ducks, shrimp meal had to be fed at a higher level than fish meal. The control groups receiving 30 per cent fish meal produced at the rate of 50.4 per cent of the optimum and the other three lots receiving 20 per cent, 35 per cent and 40 per cent, respectively of shrimp meal gave average production of 43.7, 46.4 and 51.6 per cent. Jarquin et al. (1972) reported that shrimp by product meal gave slower growth in poultry, compared with fish meal at equal protein levels. Menachery et al. (1978) reported that gain in weight of broiler chicks during the first eight weeks was less when shrimp shell powder replaced dry fish powder at 5 to 10 per cent. However, the weight of chicken given five per cent shrimp shell poweder were similar to those of control birds after six weeks. Watkin et al. (1982) based on his studies stated that crustacean wastes could be satisfactorily used as protein supplements for mink, provided that protein and energy concentration of the diet are maintained at sufficient levels and dietary calcium does not become excessive. Ilian et al. (1985) reported that shrimp by catch meal ground and heated to 55°, 70° and 90°C for 24 hours each, when incorporated at a level of 5 per cent in the diets of broiler chickes significantly improved the performance. Ria et al. (1985) observed that a meal consisting of a 1:1.15 dry mixture of shark filleting by-product and shrimp by-product, having a crude protein content of 55.66 per cent and an essential amino acid pattern similar to that of fish meal, could be supplemented at 3 to 6 per cent level in the diets of growing pigs. Barrat and Montano (1986) stated that the use of the silage prepared from prawn waste, in animal feeding is limited to 10 per cent in the diet. Meyers and Benjamin (1987) reported that, use of acid ensiling procedures for preservation of shrimp heads and their ultimate conversion into a protein hydrolysate allow maximal use of this renewable source for various dietary applications. Ramachandran et al. (1987) observed that incorporation of chitin in poultry feed at a level of 0.5 per cent decreased the food consumption ratio and increased the carcass weight by 12 per cent in comparison with birds fed on a chitin free diet. Anon. (1988) reported that inclusion of shrimp shell at 5 per cent and 10 per cent in the ration for swine reduced the growth rate and average dry matter intake and adversely affected feed to gain ratio when compared to pigs on diets containing 10 per cent fish. Mathew et al. (1989) studied the effect of addition of pure chitin from prawn shell, deproteinised prawn shell, demineralised prawn shell and dry prawn shell in carcass based control diets on albino rats. The diets contained 6.5 per cent chitin and 10 per cent protein. The results showed that addition of deproteinised prawn shell had the minimum weight gain. Based on this study Mathew et al. (1989) concluded that the presence of mineral in deproteinised prawn shell adversely affected both feed consumption and weight gain in albino rats.

Successful swine production requires a carefully planned and efficient feeding programme. Nutritional needs of the pig for protein, carbohydrates, fats, minerals and vitamins must be met for profitable and efficient production.

Protein requirements

Adequate supply of good quality protein in the diet is essential for optimum performance in swine. No significant improvement in the average daily gain and feed efficiency was noted on higher protein levels in the ration by Aunan et al. (1961); Dimisson et al. (1961), Washington and Cripp (1980) and Feng et al. (1983). Klay (1964) stated that as the level of dietary protein increased total intake of both protein and lysine increased, while rate of gain, feed conversion efficiency and feed consumption all showed significant linear decreases. It was also observed that the level of protein significantly affected the nitrogen digestibility, dietary nitrogen retention, biological value of nitrogen and nitrogen retained per unit of body weight. Most of the available literature indicate that the growth rate and feed efficiency are positively correlated with dietary protein levels during the growth period (Cunningham et al. (1973); Fetuga et al. (1975); Menge and Frobish (1976); Ramachandran (1977); Christian et al. (1980); Tyler et al. (1983) and Campbell et al. (1984). The National Research Council recommendation (NRC 1968) in respect of total protein in swine rations is 22 per cent at body weights of around 10 kg and 13 per cent at 60 kg. Baird et al. (1975) reported that the efficiency of protein conversion was greater on the low protein diets. Menge and Frobish (1976) noted a negative linear effect between dietary protein and percentage of ingested and absorbed nitrogen retained. Shields and Mahan (1980) reported that temporary moderate protein restriction can be placed in pig diets without adversely affecting overall gain or carcass quality. Approximate crude protein requirements of growing swine fed adlibitum as cited by Ranjhan (1981) were 22 per cent for 5-12 kg body weight, 18 per cent for 12-50 kg body weight and 14 per cent for 50-100 kg body weight. Skoryatina and Korop (1981) reported that optimum level of protein in a concentrate based diet for feeding Large White pigs was 18 per cent for weaners, 16 per cent for pigs upto 6 months of age and 14 per cent from 6 to 8 month on dry matter basis. Dollmann et al. (1984) reported that 17 per cent crude protein ration which supplies 8 to 9 g lysine per day is needed for maximum performance of starter pigs.

Costain and Morgan (1961) reported that pigs over the weight interval of 50-100 lb and 100-200 lb required 1.0 per cent and 0.5 to 0.6 per cent dietary lysine respectively. Klay (1984) stated that decreased absorption of lysine appeared to be a major cause of the increase in lysine requirement which accompanied the increases in dietary protein levels. He also observed a tendency for the feed intake to decrease as level of protein increased, so that the animals consumed nearly equal amounts of dietary lysine at all levels of dietary protein. Baker et al. (1969) stated that tryptophan is the first limiting amino acid and lysine the second limiting amino acid in corn protein. Boomgart and Baker (1973) stated that expression of amino acid requirement as a percentage of dietary protein is preferable to that as a percentage of total diet. The above authors have recorded the tryptophan requirements of growing swine as 0.71, 0.67 and 0.66 per cent respectively at dietary protein levels of 10, 14 and 18 per cent. Brown et al. (1973) observed that the estimated requirement of dietary lysine as a per cent of the diet for maximum daily gain was 0.48 per cent whereas for maximum gain per feed was 0.62 per cent. Taylor et al. (1984) demonstrated interaction between leucine, isoleucine and valine. Batterham et al. (1985) and Edmonds and Baker (1987) studied the feed intake, daily gain and feed conversion ratios of pigs fed varying dietary lysine levels. Edmonds and Baker (1987) reported that lysine levels three or four times the basal level lowered both weight gain and feed intake with commensurate reduction in feed efficiency. They concluded that lysine appeared to reduce growth via amino acid imbalance rather than antagonism. Fuller et al. (1989) reported that for the accretion of 1 g body protein for growing pigs the dietary amino acid requirements were (mg) threonine 47, valine 53, methionine + cystine 36, methionine 19, isoleucine 43, leucine 78, phenylalanine + tyrosine 84, phenylalanine 41, lysine 68 and tryptophan 12.

Energy requirements

Energy requirement is comparatively high in pig, because they grow rapidly and cannot consume fibrous feeds. Handlin et al. (1961) observed that hogs fed corn (grain portion) made significantly faster gain and required significantly less feed than those fed barley, milo and half corn half oats. Dinusson et al. (1961) reported that pigs ate on an energy basis, not on pounds of feed. Experiment conducted by Dinusson et al. (1961); Baird et al. (1970) and Baird et al. (1975) proved that levels of crude fibre had no effect on growth rate and feed efficiency, provided energy density was adequate. Baird et al. (1970); Talley et al. (1976); Makhaev (1981) and Campbell et al. (1982) reported that increased energy level in the swine ration produced faster gain and resulted in less feed required per lb of gain. The National Research Councl (NRC 1968) specification for energy is shown to be 3500 kcal digestible energy per kg of feed for animals weighing upto 20 kg and 3300 kcal for finishing pigs. Seerley et al. (1978) reported that average daily gain was not affected significantly by dietary energy levels in swine ration. Metz et al. (1980) reported that differences in daily energy intake by 20 per cent caused a 15 per cent lower live weight gain and a 12 per cent lower nitrogen retention. Ranjhan (1981) reported digestible energy requirement of 3500, 3500 and 3300 Mcal/kg for weaning (5-12 kg) growing (12-50) and finishing (50-100) categories of swine respectively. Devi (1981)reported that dried tapioca chips can be safely and profitably incorporated in swine rations at a level of 40 per cent in place of conventional cereal grains like maize.

Iliescu et al. (1982) showed that the net efficiency of utilisation of metabolisable energy, in young pigs between 10 and 50 kg body weight was 73.8 per cent and that for maintenance the pigs required 103.4 kcal ME/kg $^{0.75}$ or 76.3 kcal NE/kg $^{0.75}$ per day. Frank et al. (1983) reported that average feed intake increased linearly, but daily digestible energy intake tended to decrease with increasing dietary fibre level. Nitrogen and dry matter digestibilities, dietary digestible energy and the digestibilities of both neutral detergent fibre and acid detergent fibre decreased with increasing level of dietary fibre. Kairis (1983) reported that digestibility of organic matter and nitrogen free extract were unaffected by decreasing energy. Hartogden et al. (1984) reported that increase in the fibre content of the ration caused an increase in the rate of passage of ingesta in the large intestine of pigs. Thomas and Singh (1984) observed a reduction in average daily gain, and digestibilities of dry matter, organic matter, ether extract, crude carbohydrate and crude protein when digestible energy content of grower pig rations was lowered by 15 per cent from NRC standards. Varel et al. (1984) reported that pigs fed on high fibre diet gained less, had increased feed to gain ratio than those on low fibre diet. Campbell et al. (1985) showed that the rate of protein deposition increased linearly with increase in energy intake upto 33 MJ digestible energy daily, but was not significantly affected by further increase in energy intake. Stanogias and Pearce (1985) reported that both the amount and the type of dietary fibre significantly influenced the apparent digestibility of dietary dry matter, nitrogen and energy.

Clawson _et al_. (1962) found a significant improvement in both rate of gain and in feed per lb of gain by the addition of fat to the ration of pigs. Lowrey _et al_. (1962) reported that the apparent digestibility of practical type ration for growing swine was not influenced by the addition of fat.

Energy-protein inter relationship

Energy protein inter relationship in the diets of pig was well established. Costain and Morgan (1961) reported that pigs could tolerate a wider energy protein ratio at the finishing period of 100 to 200 pounds body weight than during any earlier growth period. Clawson _et al_. (1962) emphasized the need for a higher dietary protein level with increased energy content. He observed that, daily feed consumption and growth rate during the first 28 days on test, was significantly influenced by the narrow energy- protein ratio. Baird _et al_. (1975) reported that efficiency of protein conversion was greater on the low protein diets and high energy diets indicating that more efficient use of protein is at lower level of intake and that high energy diet has a protein saving effect by improving feed efficiency. Feng _et al_. (1983) based on his studies reported that there were no significant differences in daily gain and feed conversion efficiency among pigs given diets with high or with intermediate energy and protein. Sinacek and Prokop (1983) and Campbell et al. (1984) reported that decreased protein supply and increased fat and energy content in the diet lead to decreased protein content in the carcass whereas a decreased energy supply had no effect on the protein content, but a distinct effect with regard to the decrease of fat content. Sivaraman and Mercy (1986) reported no significant difference in average daily gain, feed efficiency and carcass characteristics of nine groups of pigs fed rations containing different energy protein ratios.

Feed efficiency

On the basis of the positive correlation of daily gain with daily feed consumption and daily gain with 'desirable feed efficiency' it has been assumed that daily feed consumption and 'desirable feed efficiency' would be positively correlated. But Magee (1962) reported that pigs which ate the most tended to be the least efficient. A significant negative relationship between daily feed consumption and 'desirable feed efficiency' was reported. Biswas et al. (1966) based on his observations on average daily gain and daily feed consumption indicated that selection for daily gain would probably result in improvement in feed efficiency. Kumar et al. (1974) recorded feed efficiency values of 3.4, 4.0 and 4.5 for pigs of body weight 50 kg, 50 to 70 kg and 70 to 90 kg respectively. Robison (1976) reported that the decrease in feed efficiency with increasing weights is primarily due to increased maintenance requirements and not to increased fat deposition.

Pond et al. (1962) and Eggum et al. (1982) observed significant reduction in apparent digestibility of dry matter, nitrogen free extract and crude protein on a low protein high fibre diet. Devi (1981) reported that varying levels of tapioca chips in a ration containing 16 per cent protein for growing-finishing pigs did not significantly influence the digestibility coefficients of nutrients. Yen (1983) postulated that genotype had no effect on the digestibility coefficient of nitrogen in pigs. Saitoh and Takahashi (1985) reported that the digestibility of dry matter, gross energy, crude protein and crude fibre decreased with increasing feed intake and nutrient digestibilities increased with increasing body weight. Variation in nutrient digestibilities was least when body weight was 30 to 70 kg and when feed was given at 3 to 4 per cent of body weight. Fernandez et al. (1986) after conducting digestibility experiments with 26 feed stuffs and diets reported wide variation in the digestibility coefficients of nutrients in pigs.

Body weight and body measurement

It has been found that body weight and body measurement are all indicators of body size and may therefore be expected to be more or less highly correlated with one another.

The regression of gain on age and on heart girth was investigated in Norwegian Landrace pigs from birth to over 250 kg body weight of Berge and Indrebo (1959). Increases were not uniform throughout the period as at time body length increased to a greater extent than did heart girth. Gruev and Machev (1970) reported that the six month body weight of both male and female pigs were correlated with body length, height at withers and heart girth. According to Mickwitz and Bobeth (1972) and Deo and Raina (1983) the body measurement most highly correlated with body weight was chest circumference. Bardoloi et al. (1978) obtained positive and significant coefficient of correlation between body weight and linear body measurements. Sahaayaruban et al. (1984) established that body weight was significantly correlated with body length, chest girth, shoulder height and hip width.

Factors influencing carcass quality

Carcass quality in swine has been found to be influenced by many factors. Aunan et al. (1961) reported that protein levels for weanling pigs within the range of 14 to 18 per cent have only minor effects on carcass quality. Higher levels of protein in the diet were reported to enhance lean growth (Cunningham et al., 1973; Baird et al., 1975 and Irwin et al., 1975) and decrease back fat (Wagner et al., 1963; Seymour et al., 1964; Curringham et al., 1973; Irwin et al., 1975 and Tyler, 1983) and increase loin eye area (Cunningham et al., 1973 and Tyler, 1983). On the other hand Meade et al. (1969) and Ramachandran (1977) could not notice any significant difference on carcass characteristics with different dietary protein levels. Shields and Mahan (1980) reported that temporary moderate protein restriction can be placed on pig diets without affecting carcass quality. Feng et al. (1983) observed no significant difference in the carcass dressing percentage among pigs given diets with high or with intermediate energy and protein.

Carcass characteristics in swine also depend on the energy level in the ration. Increased energy level increased carcass backfat thickness (Baird et al., 1970) and decreased energy level decreased carcass backfat. Metz et al., 1980; Kairis, 1983 and Sinacek and Prokop, 1983). Increased energy level in the diets of swine increased carcass yield, on the other hand energy increase of about 15 per cent in the diet reduced per cent lean cuts (Baird et al., 1970). Robinson (1965) recorded a positive correlation between energy intake and carcass length in swine. Significant effect of energy level on any of the carcass characteristics except carcass length was also not observed. Tally *et al*. (1976) observed that pigs fed the low energy diets and lower dressing percentage and those fed high diets had a lower specific gravity. Ramachandran (1977) reported that variation of dietary energy and protein levels in the rations for growing and finishing pigs did not produce any adverse effect on carcass characteristics. Kairis (1983) reported that reducing the energy content of the diet decreased eye-muscle area of the carcasses.

Baird *et al*. (1975) reported that low fibre diets produced leaner carcasses, when compared to high fibre diets.

Seerley *et al*. (1978) reported that supplementation of 9 per cent fat to the ration resulted in an increased dressing percentage and backfat, but decreased loin eye area and per cent primal cuts.

Sex of the animal is also found to influence the carcass quality. Agarwala (1963) reported that dressing percentage was higher in females than in male pigs, while the percentage of carcass weight was estimated to be higher in males than in females. Laird Jr. (1984) reported that castrates among the large white herd of experimental pigs reached slaughter weight about a week earlier, produced carcasses which were 11.5 mm shorter and had 3.5 to 4.5 mm more backfat. Laird Jr. (1964) observed that weaning weight had a positive correlation with carcass length and a negative correlation with backfat thickness, which suggested that an increase in body weight was associated with an improvement in carcass grading. Laird Jr. (1964) also observed a negative correlation between carcass length and backfat measurements. Robinson (1965), Seerley et al. (1965), Christian et al. (1980) and Shields and Mahan (1980) reported that gilts yield better carcasses with lesser backfat. Larger eye-muscle area was observed in gilts by Seerley et al. (1978) and Shield and Mahan (1980). Shanmughanandan and Ranganathan (1973) could not find any influence of sex on carcass characteristics.

Cole et al. (1968) observed that pigs which have been on restricted feed grew more slowly and contained less fat and more lean at 50 kg live weight. Vandergrift et al. (1985) reported that there were no difference in loin eye area, dressing percentage and carcass length in both 81 per cent adlibitum intake as well as adlibitum fed pigs.

Luberda and Iwanska (1981) reported that higher proportion of Krill meal, from 2.4 to 4.8 per cent in the feed caused a decrease of the fat and dry matter content and increase of the poly unsaturated fatty acid in lard and outer layer of backfat. Tibbets (1981) reported that ensiled fish waste could be incorporated in the ration's of weanling and finishing pig without producing any significant difference in carcass measurement when compared to a control diet containing corn soyabean meal diet. Luberda et al. (1983) reported that partial or complete replacement of animal protein in the ration of pigs, using Krill meal, produced no significant difference in dressing percentage and carcass length.

Materials and Methods

MATERIALS AND METHODS

Thirty-two Large White Yorkshire weanling pigs with an average body weight of 9.1 kg, belonging to the University Pig Breeding Farm formed the experimental animals. The piglets were distributed randomly and as uniformly as possible, to four groups of eight each, with regard to age, sex and body weight. The pigs were housed separately in pairs of the same sex and were maintained under identical conditions of management. They were dewormed using 'HELATAC'* and sprayed against ectoparasites with malathion (0.5 per cent) sufficiently before the commencement of the experiment. Clean drinking water was made available at all times.

Experimental diets

Four dietary treatments viz. A, B, C and D were assigned to pigs in groups I, II, III and IV respectively. Of the total protein contained in the various diets, 25 per cent in diets A, B and C and 12.5 per cent in diet D were provided from animal protein source. Unsalted dried fish was used as the animal protein source in diets C and D. The diet C served as the control diet. In diets A and B, 50 and 100 per cent of the animal protein from unsalted dried fish was replaced by protein from prawn waste respectively.

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*'HELATAC' - Parbendazole 4 per cent
Manufactured by Eskay labs Ltd.

The animals were fed to their requirements adjusting the level of crude protein content in the ration during the growing and finishing periods, to 18 and 14 per cent respectively. The experimental animals in the respective treatments were fed with grower diets till they attained an average body weight of 50 kg and thereafter with finisher diets till slaughter. The pigs were allowed to consume as much as they could within a period of one hour both in the morning and evening.

The percentage ingredient composition of the grower and finisher diets (Dietary treatments A,B,C and D) are given in Table 1 and 2 and the percentage chemical composition in Table 3 and 4 respectively.

Table 1. Percentage ingredient composition: Grower diets

Ingredients	A	B	C	D
Yellow maize	52.0	50.0	52.0	53.0
Groundnut cake (expellar)	16.0	17.0	16.0	21.0
Rice polish	7.4	8.5	10.0	10.0
Wheat bran	12.0	10.0	11.0	10.0
Unsalted dried fish	5.0	--	10.0	5.0
Prawn waste	6.6	13.5	--	--
Mineral mixture	1.0	1.0	1.0	1.0

Common salt and ROVIMIX AB_2D_3 were added at the rate of 2.5 kg and 100 g respectively per metric tonne of the feed.

Table 2. Percentage ingredient composition: Finisher diets

Ingredients	A	B	C	D
Yellow maize	57.0	57.0	40.0	40.0
Groundnut cake (expellar)	8.0	8.0	8.0	11.0
Rice polish	10.0	10.0	29.0	28.0
Wheat bran	15.3	13.7	14.2	16.0
Unsalted dried fish	3.5	--	7.8	4.0
Prawn waste	5.2	10.3	--	--
Mineral mixture	1.0	1.0	1.0	1.0

Common salt and *ROVIMIX AB_2D_3 were added at the rate of 2.5 kg and 100 g respectively per metric tonne of the feed.

Table 3. Percentage chemical composition on Dry matter basis: Grower diets

	A	B	C	D
Dry matter	88.9	89.7	88.9	87.8
Crude protein (N x 6.25)	18.1	18.0	18.1	18.2
Ether extract	5.3	5.6	5.8	5.8
Crude fibre	5.8	6.3	5.9	7.0
Nitrogen free extract	58.8	58.5	59.9	58.4
Total ash	12.0	11.6	10.3	10.6
Acid insoluble ash	4.6	3.6	5.7	5.0
Calcium	1.12	1.31	1.09	0.9
Phosphorus	0.68	0.62	0.74	0.6

*ROVIMIX AB_2D_2 contained Vitamin A 40,000 IU, Vitamin B_2 20 mg and Vitamin D_3 5000 IU/g. Manufactured by Roche Products Ltd.

Table 4. Percentage chemical composition on Dry Matter basis: Finisher diets

	A	B	C	D
Dry matter	88.3	88.9	89.4	88.5
Crude protein (N x 6.25)	14.3	14.1	14.3	14.0
Ether extract	6.3	6.5	7.4	7.7
Crude fibre	7.7	8.0	10.7	10.2
Nitrogen free extract	61.5	60.3	54.9	57.6
Total ash	10.2	11.1	12.7	10.5
Acid insoluble ash	4.1	4.3	6.7	4.7
Calcium	0.98	1.11	0.8	0.73
Phosphorus	0.71	0.68	0.67	0.54

Methods

The pigs were weighed at weekly intervals to record the gain in body weight. Per day feed consumption records were maintained. Body measurements like length and girth were recorded at weekly intervals as described below.

Body length

Body length was measured as described by Thomas (1981). 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-dormal line was taken as the anterior land mark. Similarly an imaginary line was then 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 between these two land marks was taken as the body length.

Body girth

The average value of the circumferences of the body barrel just behind the forelimb and just in front of the hind limb has taken as the body girth (g).

The digestibility coefficients of nutrients in the rations fed to the pigs in all the groups were determined when they attained six months of age. The feed and faecal samples collected during the digestibility trial were analysed for proximate composition as per methods prescribed by A.O.A.C. (1980).

The experimental pigs were slaughtered and carcass characteristics studied as and when they attained slaughter weight of 70 kg or when they attained eight months of age which-ever was earlier. The head was removed at the atlanto-occipital joint and the dressed weight of carcass without head was recorded to determine dressing percentage of the hot carcass. The carcass was split down the middle of the back bone with a saw to obtain half carcass weight. Length of carcass was measured from the anterior aspect of first rib to the anterior aspect of the aitch bone. Backfat thickness was measured at three sites, viz., at the region of the first rib, last rib and last lumbar vertebra. The cross sectional area of the eye-muscle was calculated from its impression obtained at the region of the 10th rib. The ham was removed by cutting at a point approximately 2½ inches from the most anterior part of the aitch bone by sawing through the sacral vertebra and shaft of ileum.

Statistical analysis of the data were carried out as per methods described by Snedecor and Cochran (1967).

Results

RESULTS

Proximate composition of prawn waste

Proximate composition of six samples of prawn waste collected for the experimental purpose was estimated and presented in Table 5. The average values in percentage for the various constitutents were: Dry matter - 91.6, crude protein - 34.6, ether extract - 2.3, crude fibre - 13.1, nitrogen free extract - 8.2, ash - 41.8, acid insoluble ash - 4.8, calcium - 13.52 and phosphorus 1.21.

Growth rate and feed conversion efficiency

The results on the growth and feed conversion efficiency of animals in the four groups I, II, III and IV under the respective dietary treatments A, B, C and D are set out in Tables 6 to 17 and represented by Fig.1 to 3. Results of the statistical analysis are presented in Tables 18 and 19. Consolidated data on growth rate and feed conversion efficiency are set out in Table 20. The average daily weight gain of the treatment groups I, II, III and IV were found to be 236 g, 200 g, 429 g and 416 g respectively and the average feed conversion efficiency values 4.8, 5.2, 4.05 and 4.13 respectively.

Dry matter intake

The average dry matter intake of pigs belonging to the groups I, II, III and IV receiving dietary treatments A, B, C and D were found to be 0.97, 0.94, 1.55 and 1.49 respectively and represented in Table 20.

Age at slaughter

The average age at slaughter of pigs belonging to the groups I, II, III and IV were 239, 238, 205 and 211 days respectively and presented in Table 20.

Digestibility coefficients of nutrients

Data on digestibility coefficients of nutrients in the four diets A, B, C and D are presented in Table 21. The digestibility coefficients of dry matter in the four diets, A, B, C and D were estimated to be 61.8, 48.9, 53.2 and 55.8 per cent and that of crude protein 64.1, 55.9, 65.3 and 63.9 per cent respectively. The digestibility coefficients of ether extract were found to be 58.2, 52.9, 56.6 and 68.2 per cent respectively, that of crude fibre 25.7, 20.9, 27.4 and 20.6 per cent respectively and for nitrogen free extract 76.1, 61.8, 65.1 and 67.1 per cent respectively for the diets A, B, C and D.

Body measurements

Data on body measurements of pigs in the four treatment groups I, II, III and IV recorded at weekly intervals from fourth week till the end of the experiment are presented in Tables 22-29. Table 30 contains the consolidated data on gain in body weight and body measurements from fourth to sixteenth week. The average values for gain in body length of animals belonging to the groups I, II, III and IV receiving dietary treatments A, B, C and D were 20.1, 21.7, 38.7 and 36.5 cm respectively and the gains in body girth (g) were 20.3, 17.3, 33.2 and 31.0 cms respectively.

Carcass characteristics

Data on carcass characteristics of animals slaughtered are presented in Tables 31 to 34 and the results of statistical analysis in Tables 35 to 40. The consolidated data on the carcass characteristics of pigs are presented in Table 41. Average values of carcass characteristics of pigs maintained on dietary treatments A, B, C and D were 66.9, 61.4, 67.0 and 66.9 respectively for dressing percentage, 65.3, 63.1, 74.6 and 73.8 respectively for carcass length, 1.4, 1.3, 2.1 and 2.0 cms respectively for backfat thickness; 21.3, 20.0, 28.8 and 28.9 cm^2 respectively for eye-muscle area; 17.2, 13.8, 23.7 and 23.4 kg respectively for half carcass weight and 4.7, 4.2, 6.8 and 6.5 kg respectively for weight of ham with regard to half carcass weight.

Table 5. Average per cent chemical composition of prawn waste on dry matter basis

Component	Average* with S.E.
Crude protein	34.6 ± 1.51
Ether extract	2.3 ± 0.20
Crude fibre	13.1 ± 0.46
Nitrogen free extract	8.2 ± 1.20
Total ash	41.8 ± 1.68
Acid insoluble ash	4.8 ± 0.79
Calcium	13.52 ± 0.37
Phosphorus	1.21 ± 0.14

* Average of six values

Table 6. Weekly body weights (kg) of pigs maintained on dietary treatment A (Group I)

Weeks	Animal number and sex								
	2/282 M	2/281 M	7/280 F	7/281 F	4/280 M	3/282 M	9/280 F	7/282 F	Average with S.E.
0	14.5	9.0	8.0	7.5	8.0	10.5	6.0	9.0	9.1±0.90
1	16.0	9.0	8.0	7.5	8.0	12.0	6.5	10.5	9.7±1.09
2	18.0	10.5	9.0	9.0	9.0	13.5	7.5	12.0	11.1±1.20
3	20.5	11.5	10.5	10.0	10.5	15.5	9.0	13.5	12.6±1.30
4	23.0	13.0	12.5	11.0	11.5	17.5	10.5	15.0	14.2±1.50
5	26.0	13.5	13.5	12.0	12.5	19.5	11.0	16.5	15.6±1.78
6	28.0	15.0	14.5	13.5	13.5	22.0	12.0	19.0	17.2±1.93
7	30.0	16.0	17.0	15.0	14.5	23.0	14.0	22.0	18.9±1.98
8	34.5	18.5	18.5	16.5	16.5	25.0	16.0	24.0	21.2±2.25
9	39.0	20.0	20.0	17.0	17.0	27.0	19.0	28.0	23.4±2.68
10	41.0	21.0	20.0	17.0	16.0	27.0	20.0	31.0	24.1±3.00
11	43.0	21.0	22.5	16.5	18.0	28.0	20.0	32.0	25.1±3.13
12	45.5	22.5	22.5	17.5	18.0	30.5	21.0	35.0	26.5±3.36
13	48.0	24.0	25.5	18.5	17.5	32.5	22.0	38.0	28.3±3.70
14	52.0	25.5	29.0	22.0	18.5	37.5	25.5	41.5	31.4±4.00
15	54.0	27.0	29.5	23.0	18.0	38.0	25.0	43.5	31.8±4.14
16	56.0	30.0	33.5	26.5	21.0	41.5	28.0	46.0	35.3±4.10
17	58.0	30.0	33.5	27.5	22.5	45.5	30.0	48.5	36.9±4.34
18	60.0	32.0	34.5	28.5	24.5	49.0	32.5	50.5	38.9±4.40
19	63.0	34.0	37.0	29.5	25.0	51.5	34.5	53.0	40.9±4.70
20	65.0	35.5	37.5	31.0	27.0	53.5	36.0	55.0	42.5±4.76
21	68.0	39.0	39.5	33.0	29.0	57.0	39.5	58.0	45.4±4.88
22	73.5	41.0	42.5	36.0	32.0	60.0	39.5	61.0	48.1±5.20
23*									
24		43.5	44.0	38.5	33.0	64.0	42.0	62.0	46.7±4.43
25		43.5	45.0	37.0	32.5	65.0	42.0	62.5	46.8±4.66
26		44.0	46.0	37.5	33.5		43.5		40.9±2.32

* Data for the 23rd week could not be gathered

Table 7. Weekly body weight (kg) of pigs maintained on dietary treatment B (Group II)

Weeks	Animal number and sex								
	6/281 F	6/282 F	6/280 F	4/282 F	3/280 M	1/282 M	5/281* M	5/280 M	Average with S.E.
0	8.5	9.5	8.0	10.5	8.5	10.5	7.5	9.0	9.0±0.39
1	8.5	10.5	8.0	12.0	8.5	11.0	8.2	10.0	9.6±0.53
2	9.5	12.0	9.0	14.0	9.5	12.0	9.5	11.5	10.9±0.62
3	11.0	14.5	10.5	16.5	11.5	13.5	10.5	12.5	12.6±0.76
4	13.5	15.5	11.0	19.0	15.0	13.5	11.5	13.5	14.1±0.89
5	14.0	16.0	11.5	21.0	14.5	16.0	12.0	14.5	14.9±1.04
6	15.5	18.5	12.0	22.5	14.5	17.0	12.5	16.0	16.1±1.23
7	17.0	20.0	13.0	24.5	17.0	20.0	14.0	17.0	17.8±1.27
8	18.5	23.0	14.0	27.5	19.5	21.5	16.5	18.5	19.9±1.47
9	19.5	26.5	15.5	31.5	21.0	23.0	18.0	21.5	22.1±1.78
10	19.5	26.5	15.0	32.5	23.5	25.0	19.0	21.5	22.8±1.89
11	19.5	28.0	15.0	32.5	24.0	26.0	19.0	22.0	23.3±1.97
12	20.5	27.0	15.0	35.5	26.5	26.5	22.5	26.0	25.0±2.09
13	21.0	28.5	16.5	37.0	28.5	28.0	23.0	28.0	26.3±2.17
14	23.5	30.0	18.0	42.0	32.0	31.5	26.5	29.0	29.1±2.47
15	26.0	32.0	18.0	43.5	34.5	33.5	28.5	30.0	30.8±2.59
16	27.5	34.5	18.0	47.0	37.0	34.0	30.0	32.5	32.6±2.92
17	28.0	36.5	19.0	47.0	38.5	35.5	31.0	34.0	33.7±2.89
18	33.0	38.0	19.5	49.0	41.0	38.0	35.0	36.0	36.2±2.93
19	32.0	39.0	20.0	49.0	44.0	38.0	34.5	38.0	36.8±3.04
20	36.0	42.0	20.0	53.0	48.0	40.0	37.0	39.5	39.4±3.43
21	36.5	43.5	21.5	57.0	50.5	41.0	39.0	42.5	41.4±3.68
22	38.5	46.5	22.5	58.5	50.5	41.5	40.5	45.0	42.9±3.69
23**									
24	40.5	48.0	21.5	58.5	52.0	42.0	40.0	47.5	43.8±3.94
25	41.0	48.5	22.5			43.0	(died)	48.5	40.7±4.78

* The animal died of pneumonia and hepatitis.

** Data for the 23rd week could not be gathered.

Table 8. Weekly body weight (kg) of pigs maintained on dietary tratement C (Group III)

Weeks	Animal number and sex								
	4/237 M	3/242 M	7/239 F	7/240 F	2/241 M	5/237* M	9/241 F	5/239 F	Average with S.E.
0	8.7	12.5	9.0	8.5	8.0	10.0	9.0	9.0	9.2±0.49
1	11.0	14.1	11.0	10.0	10.5	12.5	11.0	10.0	11.3±0.49
2	11.5	15.0	12.0	11.0	11.5	13.0	11.5	10.0	12.0±0.53
3	15.0	17.5	15.0	13.5	14.0	16.0	14.0	13.0	14.8±0.52
4	17.5	19.5	17.5	15.5	16.0	19.0	17.0	15.0	17.1±0.56
5	22.0	24.0	22.0	19.0	22.5	24.0	22.0	19.0	21.8±0.68
6	23.5	25.5	25.0	22.0	23.0	25.5	25.0	20.5	23.7±0.65
7	28.0	29.5	28.0	28.0	30.0	29.0	27.0	26.0	28.2±0.46
8	32.0	31.0	32.0	31.0	32.0	33.0	29.0	28.0	31.0±0.60
9	35.0	34.5	34.0	33.5	34.0	36.0	32.5	30.0	33.6±0.64
10	39.0	38.0	37.0	37.0	39.0	41.0	36.0	36.0	37.9±0.61
11	44.0	43.0	44.5	41.0	42.5	40.0	40.0	40.0	41.9±0.66
12	47.0	45.5	45.5	43.0	45.5	(died)	43.5	43.5	44.8±0.56
13	53.0	51.5	52.0	47.0	49.0		47.0	50.0	49.9±0.90
14	58.0	57.0	56.0	51.0	54.0		51.5	56.0	54.8±1.02
15	59.0	59.0	60.0	55.0	56.0		55.0	60.0	57.7±0.87
16	63.0	61.0	62.0	57.0	58.5		55.5	62.5	59.7±1.22
17	64.0	65.0	65.5	59.0	62.0		57.5	68.0	62.6±1.61
18	66.5	68.5	67.5	59.0	65.5		61.5	69.5	65.3±1.45
19	68.0	70.0	70.0	62.5	70.0		63.5		67.3±1.50
20	70.5		72.0	64.0	72.0		65.0		68.7±1.08
21				66.0			66.0		66.0±0.00
22				68.0			68.5		68.3±0.11
23				71.0			72.5		71.7±0.34

* The animal died of myocarditis.

Table 10. Average cumulative daily gain (g) of pigs maintained on dietary treatment A

Animal number	Sex	Initial body weight (kg)	Body weight at slaughter (kg)	Total weight gain (kg)	Number of days under experiment	Average daily gain (g)
2/282	M	14.5	74.0	59.5	161	370.0
2/281	M	9.0	44.0	35.0	183	191.0
7/280	F	8.0	46.0	28.0	183	207.0
7/281	F	7.5	37.5	30.0	183	164.0
4/280	M	8.0	33.5	25.5	183	139.0
3/282	M	10.5	65.0	54.5	177	308.0
9/280	F	6.0	43.5	37.5	183	204.0
7/282	F	9.0	62.5	53.5	177	302.0
Average with S.E.		9.06 ± 0.9	50.75 ± 5.13	41.68 ± 4.42	1.78 ± 2.71	236.0 ± 28.6

Table 9. Weekly body weight (kg) of pigs maintained on dietary treatment D (Group IV)

Weeks	Animal number and sex								
	3/236 M	5/238 M	5/242 F	4/241 F	6/237 M	1/238 M	10/240 F	6/241 F	Average with S.E.
0	12.5	10.0	9.5	9.0	8.5	8.0	7.5	7.5	9.1±0.58
1	13.7	11.6	11.0	10.5	9.6	8.8	9.0	10.0	10.5±0.56
2	14.5	13.0	11.5	11.5	10.5	9.5	11.0	11.0	11.6±0.55
3	17.0	16.0	13.0	14.0	12.0	10.0	12.0	12.0	13.3±0.82
4	19.5	19.0	16.0	16.0	14.5	11.5	14.5	15.0	15.8±0.91
5	23.0	24.5	17.5	18.5	16.5	12.0	18.5	17.0	18.7±1.50
6	25.0	25.5	20.0	21.5	19.5	13.0	20.0	20.0	20.6±1.36
7	30.0	30.0	25.0	26.0	27.5	15.0	25.5	25.0	25.5±1.66
8	33.0	34.5	29.0	28.0	31.0	17.0	28.0	28.0	28.6±1.87
9	35.0	37.5	33.0	31.5	36.0	18.0	33.0	33.0	32.1±2.13
10	41.0	41.0	36.0	34.5	39.5	20.0	36.0	36.0	35.5±2.38
11	40.0	46.0	39.0	37.0	46.0	22.0	38.0	39.0	38.4±2.64
12	45.0	49.5	42.5	38.5	50.0	25.0	43.0	44.0	42.2±2.79
13	49.0	56.0	44.0	42.0	50.0	26.0	48.0	49.0	45.5±3.15
14	53.5	60.0	50.0	44.0	56.0	17.0	53.0	56.0	50.0±3.68
15	58.0	64.0	53.0	46.0	59.0	30.0	56.0	59.0	53.1±3.79
16	59.5	66.5	56.0	50.0	65.0	32.0	59.0	62.0	56.3±3.92
17	64.0	68.5	60.0	49.0	66.0	33.5	63.0	65.5	58.7±4.17
18	68.0	70.0	63.0	50.0	69.5	34.0	65.5	68.0	61.0±4.97
19			66.5	52.0	72.5	39.0	70.0	71.0	61.8±5.49
20			70.0	53.0		41.0	70.5	72.0	61.3±6.13
21			70.0	54.5		42.5	72.5		59.9±7.03
22				57.5		44.5			51.0±2.92
23				61.5		50.5			56.0±2.48
24				63.0		57.0			60.0±1.35
25				68.5		60.0			64.3±1.91
26				73.0		63.0			68.0±2.25

Table 11. Average cumulative daily gain (g) of pigs maintained on dietary treatment B

Animal number	Sex	Initial body weight (kg)	Body weight at slaughter (kg)	Total weight gain (kg)	Number of days under experiment	Average daily gain (g)
6/281	F	8.5	41.0	32.5	183	178.0
6/282	F	9.5	48.5	39.0	177	220.0
6/280	F	8.0	22.0	14.0	177	79.0
4/282	F	10.5	59.5	49.0	172	285.0
3/280	M	8.5	52.0	43.5	174	250.0
1/282	M	10.5	43.0	32.5	183	178.0
5/281	M	7.5	40.0	32.5	170	191.0
5/280	M	9.0	48.5	39.5	185	216.0
Average with S.E.		9.0 ± 0.39	44.31 ± 3.9	35.3 ± 3.69	177 ± 1.96	200 ± 21.5

Table 12. Average cumulative daily gain (g) of pigs maintained on dietary treatment C

Animal number	Sex	Inital body weight (kg)	Body weight at slaughter (kg)	Total weight gain (kg)	Number of days under experiment	Average daily gain (g)
4/237	M	8.7	70.5	61.8	140	441.0
3/242	M	12.5	69.5	57.0	136	419.0
7/239	F	9.0	71.5	62.5	143	437.0
7/240	F	8.5	71.0	62.5	160	391.0
2/241	M	8.0	71.5	63.5	140	454.0
9/241	M	9.0	72.5	63.5	160	397.0
5/239	F	9.0	69.5	60.5	131	462.0
Average with S.E.		9.24 ± 0.56	70.9 ± 0.42	61.6 ± 0.86	144 ± 4.3	429 ± 10.32

Table 13. Average cumulative daily gain (g) of pigs maintained on dietary treatment D

Animal number	Sex	Initial body weight (kg)	Body weight at slaughter (kg)	Total weight gain (kg)	Number of days under experiment	Average daily gain (g)
3/236	M	12.5	67.5	55.0	131	420.0
5/238	M	10.0	69.0	59.0	122	484.0
5/242	F	9.5	70.0	60.5	148	409.0
4/241	F	9.0	73.0	64.0	183	350.0
6/237	M	8.5	72.5	64.0	136	471.0
1/238	M	8.0	63.0	55.0	183	301.0
10/240	F	7.5	72.5	65.0	148	439.0
6/241	F	7.5	72.0	64.5	143	451.0
Average with S.E.		9.1 ± 0.58	69.9 ± 1.21	60.9 ± 1.48	149 ± 7.98	416 ± 21.96

FIG.1 GRAPH SHOWING THE AVERAGE DAILY GAIN AT VARIOUS BODY WEIGHT OF PIGS MAINTAINED ON FOUR DIETARY TREATMENTS

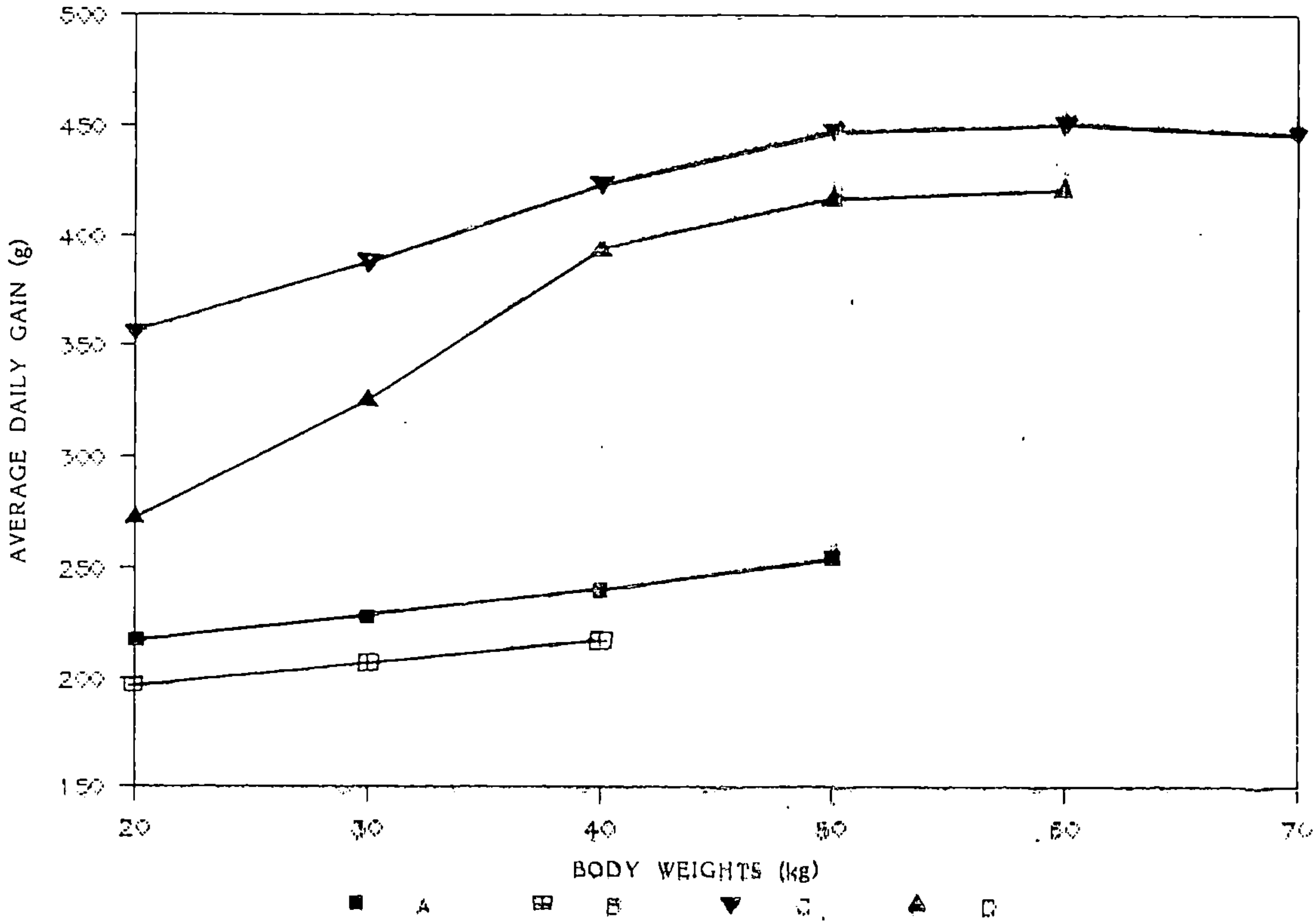

FIG.2 AVERAGE CUMULATIVE DAILY WEIGHT GAIN (g) OF PIGS MAINTAINED ON FOUR DIETARY TREATMENTS

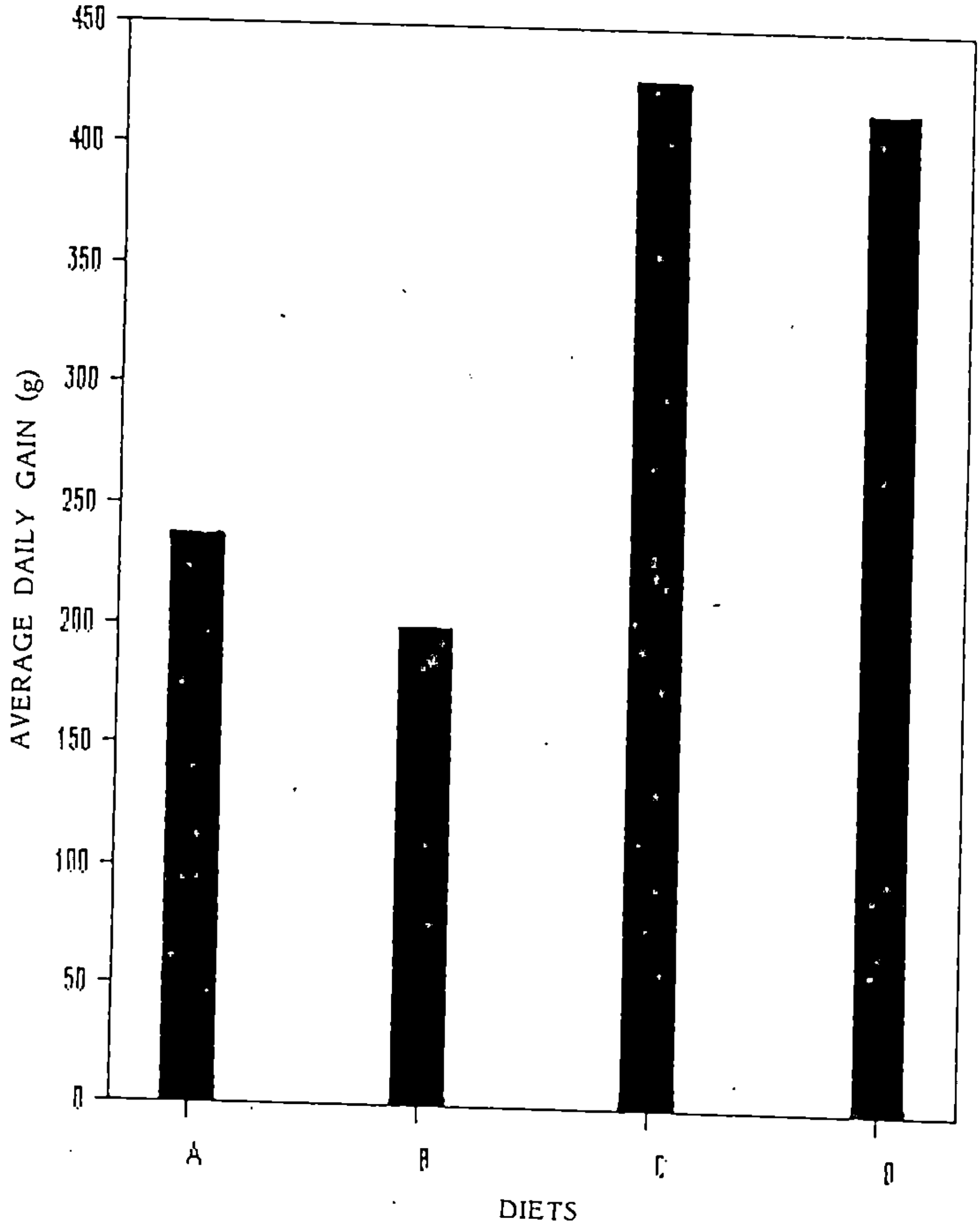

Table 14. Fortnightly average feed intake (kg), body weight gain (kg) and feed conversion efficiency of pigs maintained on dietary treatment A

Fortnights	Average initial weight (kg)	Average final weight (kg)	Average weight gain (kg)	Average feed intake (kg)	Feed conversion efficiency
1	9.1	11.1	2.0	8.85	4.4
2	11.1	14.2	3.1	10.97	3.5
3	14.2	17.2	3.0	12.63	4.2
4	17.2	21.2	4.0	13.97	3.5
5	21.2	24.1	2.9	16.80	5.8
6	24.1	26.5	2.4	16.09	6.7
7	26.5	31.4	4.9	16.97	3.5
8	31.4	35.3	3.9	18.48	4.7
9	35.3	38.9	3.6	18.21	5.1
10	38.9	42.5	3.6	18.58	5.2
11	42.5	48.1	5.6	18.26	3.3

Table 15. Fortnightly average feed intake (kg), body weight gain (kg) and feed conversion efficiency of pigs maintained on dietary treatment B

Fortnights	Average initial weight (kg)	Average final weight (kg)	Average weight gain (kg)	Average feed intake (kg)	Feed conversion efficiency
1	9.0	10.9	1.9	9.07	4.8
2	10.9	14.1	3.2	11.30	3.5
3	14.1	16.1	2.0	12.95	6.5
4	16.0	19.9	3.8	13.95	3.7
5	19.9	22.8	2.9	16.31	5.6
6	22.8	25.0	2.2	15.55	7.1
7	25.0	29.1	4.1	15.13	3.8
8	29.1	32.6	3.5	18.51	5.3
9	32.6	36.2	3.6	18.35	5.1
10	36.2	39.4	3.2	19.18	6.0
11	39.4	42.9	3.5	16.94	4.8

Table 16. Fortnightly average feed intake (kg), body weight gain (kg) and feed conversion efficiency of pigs maintained on dietary treatment C

Fortnights	Average initial weight (kg)	Average final weight (kg)	Average weight gain (kg)	Average feed intake (kg)	Feed conversion efficiency
1	9.3	12.0	2.7	8.35	3.1
2	12.0	17.1	5.1	14.04	2.8
3	17.1	23.7	6.6	17.13	2.6
4	23.7	31.0	7.3	19.47	2.7
5	31.0	37.9	6.9	21.48	3.1
6	37.9	44.8	7.0	25.80	3.7
7	44.8	54.8	10.0	34.60	3.5
8	54.8	59.7	4.9	23.67	4.8
9	59.7	65.3	5.6	26.60	4.8
10	65.3	68.7	3.4	19.04	5.6

Table 17. Fortnightly average feed intake (kg), body weight gain (kg) and feed conversion efficiency of pigs maintained on dietary treatment D

Fortnights	Average initial weight (kg)	Average final weight (kg)	Average weight gain (kg)	Average feed intake (kg)	Feed conversion efficiency
1	9.1	11.6	2.5	7.34	2.9
2	11.6	15.8	4.2	11.73	2.8
3	15.8	20.6	4.8	15.21	3.2
4	20.6	28.6	8.0	18.60	2.3
5	28.6	35.5	6.9	20.75	3.0
6	35.5	42.2	6.7	26.93	4.0
7	42.2	50.0	7.8	30.13	3.9
8	50.0	56.3	6.3	30.91	4.9
9	56.3	61.0	4.7	28.47	6.1
10	56.1	61.3	5.2	29.73	5.0

FIG.3 AVERAGE CUMULATIVE FEED EFFICIENCY OF PIGS MAINTAINED ON FOUR DIETARY TREATMENTS

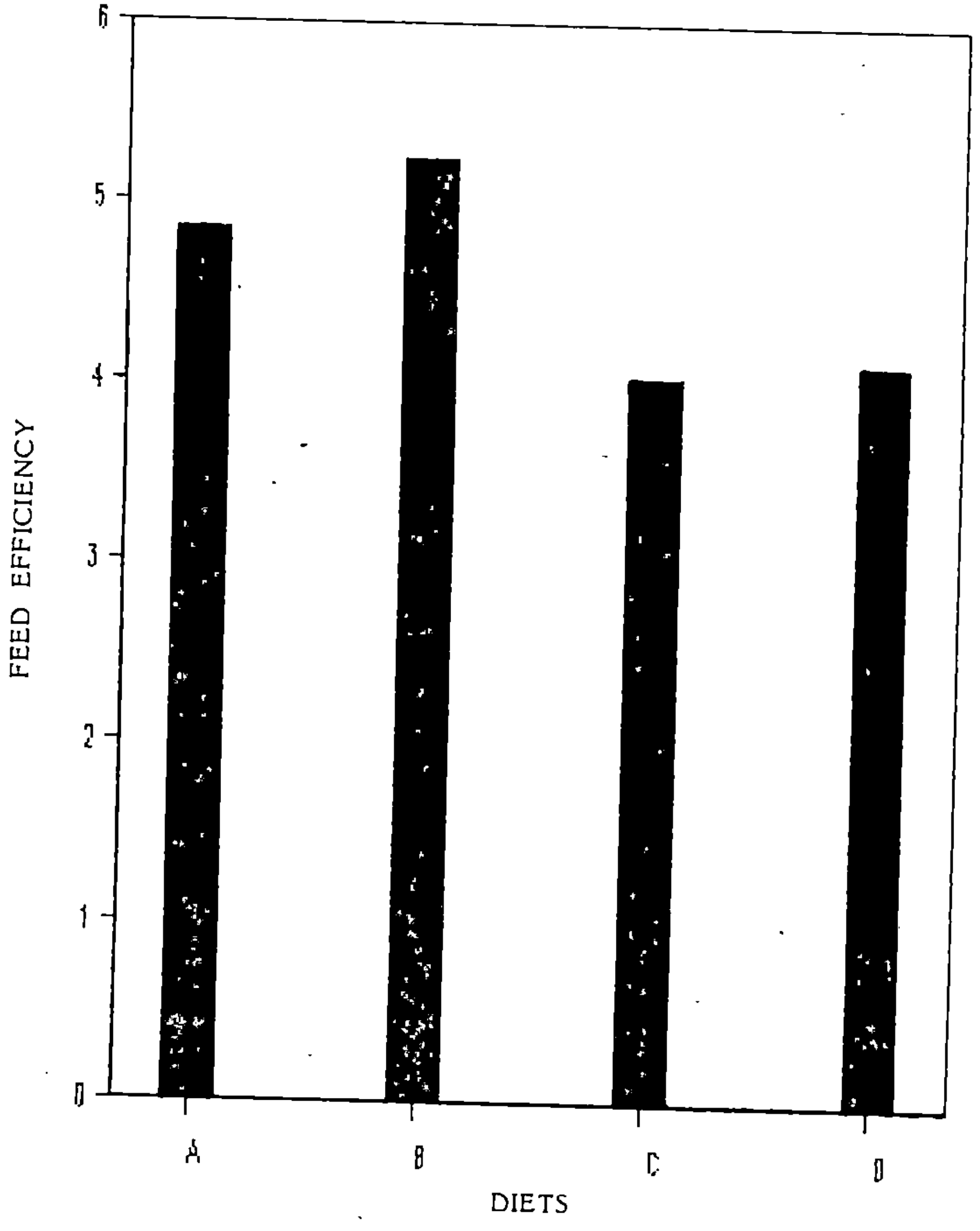

Table 18. Analysis of variance - Average daily gain (g)

Source	df	SS	MSS	F
Treatment	3	328354.5	109451.5	28.52914**
Error	27	103585.0	3836.482	
Total	30	431939.5		

** Significant at 1 per cent level

Table 19. Analysis of variance - Fortnightly feed efficiency

Source	df	SS	MSS	F
Treatment	3	14.93897	4.979655	3.695021*
Error	36	48.51599	1.347666	
Total	39	63.45496		

* Significant at 5 per cent level

Table 20. Summarised data on average daily gain, feed intake, feed conversion efficiency and age at slaughter of pigs maintained on four dietary treatments (Diets A, B, C & D)

	Dietary treatments			
	A	B	C	D
Average initial weight (kg)	9.1 ± 0.9	9.0 ± 0.39	9.2 ± 0.56	9.1 ± 0.58
Average final weight* (kg)	50.8 ± 5.13^{a}	44.3 ± 3.9^{a}	70.0 ± 0.42^{b}	69.9 ± 1.21^{b}
Average weight gain (kg)	41.7 ± 4.42^{a}	35.3 ± 3.69^{a}	61.7 ± 0.86^{b}	60.8 ± 1.48^{b}
Average daily gain (g)	236.0 ± 28.6^{a}	200.0 ± 21.5^{a}	429.0 ± 10.32^{b}	416.0 ± 21.96^{b}
Age at slaughter (days)	239.0 ± 2.71	238.0 ± 1.96	205.0 ± 4.3	211.0 ± 7.53
Days taken to attain slaughter weight	179.0 ± 2.71	177.0 ± 1.96	144.0 ± 4.3	149.0 ± 7.53
Average feed intake (kg)	196.8	184.6	249.62	251.37
Feed conversion efficiency	4.8^{b}	5.2^{a}	4.05^{b}	4.13^{b}
Average dry matter intake per day (kg)	0.97	0.94	1.55	1.49

* Body weights at slaughter of pigs in treatments A and B were at 8 months of age as the animals did not attain 70 kg body weight.

Means having same superscription in a row do not differ significantly.

Table 21. Average digestibility coefficients of nutrients in the four dietary treatments

Nutrients	Dietary treatments			
	A	B	C	D
Dry matter	61.8[a]	48.9[b]	53.2[b]	55.8[b]
Crude protein	64.1[a]	55.9[b]	65.3[a]	63.9[a]
Ether extract	58.2[a]	52.9[a]	56.6[a]	68.2[b]
Crude fibre	25.7[a]	20.9[a]	27.4[a]	20.6[a]
Nitrogen free extract	76.1[a]	61.8[b]	65.1[b]	67.1[b]

Values with same superscription in a row do not differ significantly

Table 22. Body length (cm) of pigs maintained on dietary treatment A

Weeks	Animal number and sex								Average with S.E.
	2/282 M	2/281 M	7/280 F	7/281 F	4/280 M	3/282 M	9/280 F	7/282 F	
4	59.0	47.0	44.0	43.0	43.0	47.0	41.0	49.0	46.6±2.00
5	58.0	48.0	47.0	45.0	45.0	50.0	42.0	53.0	48.5±1.80
6	67.0	50.0	51.0	50.0	50.0	58.0	47.0	51.0	53.3±2.26
7	63.0	51.0	51.0	49.0	49.0	57.0	48.0	55.0	52.9±1.82
8	67.0	52.0	56.0	48.0	50.0	58.0	47.0	56.0	54.3±2.30
9	69.0	55.0	56.0	53.0	51.0	56.0	52.0	59.0	56.4±2.02
10	71.0	58.0	53.0	55.0	54.0	59.0	51.0	61.0	57.8±2.22
11	74.0	57.0	57.0	52.0	54.0	62.0	51.0	61.0	58.5±2.61
12	69.0	56.0	54.0	51.0	55.0	64.0	59.0	70.0	59.8±2.52
13	74.0	62.0	60.0	57.0	59.0	66.0	61.0	72.0	63.9±2.20
14	78.0	61.0	66.0	61.0	54.0	71.0	59.0	71.0	65.1±2.77
15	81.0	64.0	66.0	62.0	55.0	71.0	60.0	71.0	66.3±2.84
16	79.0	60.0	66.0	65.0	56.0	73.0	62.0	73.0	66.8±2.72
17	82.0	66.0	69.0	67.0	58.0	76.0	72.0	79.0	71.1±2.75
18	83.0	69.0	74.0	69.0	59.0	75.0	70.0	81.0	72.5±2.68
19*									
20	84.0	72.0	73.0	70.0	62.0	79.0	68.0	80.0	73.5±2.53
21	87.0	71.0	78.0	75.0	63.0	81.0	68.0	83.0	76.5±3.14
22	92.0	77.0	81.0	74.0	67.0	86.0	73.0	91.0	80.1±3.17
23	94.0	74.0	81.0	76.0	69.0	85.0	77.0	87.0	80.4±2.84
24		78.0	82.0	77.0	69.0	89.0	79.0	89.0	80.4±2.67
25		77.0	80.0	77.0	70.0	88.0	80.0	91.0	80.4±2.51

* Data for the 19th week could not be gathered.

Table 23. Body length (cm) of pigs maintained on dietary treatment B

Weeks	6/281 F	6/282 F	6/280 F	4/282 F	3/280 M	1/282 M	5/281 M	5/280 M	Average with S.E.
	Animal number and sex								
4	47.0	50.0	42.0	50.0	49.0	46.0	45.0	48.0	47.1±0.81
5	50.0	53.0	43.0	57.0	49.0	51.0	44.0	48.0	49.4±1.61
6	57.0	55.0	48.0	58.0	51.0	53.0	48.0	51.0	52.6±1.35
7	53.0	57.0	47.0	65.0	53.0	53.0	49.0	53.0	53.8±1.92
8	54.0	61.0	48.0	60.0	59.0	63.0	54.0	55.0	56.8±1.73
9	54.0	60.0	50.0	70.0	58.0	58.0	54.0	57.0	57.6±2.09
10	56.0	61.0	50.0	72.0	62.0	63.0	56.0	57.0	57.1±1.65
11	57.0	64.0	52.0	68.0	61.0	62.0	53.0	56.0	59.1±1.97
12	55.0	64.0	54.0	65.0	61.0	68.0	55.0	53.0	59.4±2.06
13	55.0	65.0	53.0	74.0	68.0	72.0	59.0	60.0	63.3±2.46
14	62.0	65.0	52.0	74.0	68.0	70.0	65.0	61.0	64.6±2.34
15	63.0	66.0	54.0	76.0	66.0	71.0	63.0	62.0	65.1±2.30
16	64.0	69.0	53.0	73.0	69.0	69.0	65.0	64.0	65.8±2.13
17	68.0	75.0	56.0	73.0	73.0	71.0	66.0	68.0	68.8±2.12
18	71.0	75.0	59.0	81.0	77.0	76.0	72.0	71.0	72.8±2.30
19*									
20	72.0	79.0	59.0	78.0	76.0	76.0	73.0	72.0	73.1±2.22
21	73.0	81.0	62.0	81.0	79.0	79.0	75.0	74.0	75.5±2.22
22	77.0	83.0	62.0	88.0	85.0	85.0	80.0	81.0	80.1±2.85
23	80.0	82.0	67.0	90.0	80.0	84.0	79.0	79.0	80.1±2.28
24	82.0	81.0	68.0	91.0	82.0	87.0	79.0	80.0	81.3±2.36

* Data for the 19th week could not be gathered.

Table 24. Body length (cm) of pigs maintained of dietary treatment C

Weeks	Animal number and sex								Average with S.E.
	4/237 M	3/242 M	7/239 F	7/240 F	2/241 M	5/237 M	9/241 F	5/239 F	
4	48.0	53.0	47.0	44.0	46.0	50.0	47.0	48.0	47.9±0.95
5	55.0	63.0	55.0	51.0	54.0	56.0	50.0	52.0	54.5±1.43
6*									
7	65.0	62.0	62.0	59.0	59.0	61.0	58.0	57.0	60.6±0.97
8	66.0	65.0	67.0	59.0	64.0	61.0	63.0	62.0	63.4±0.94
9	68.0	74.0	68.0	66.0	67.0	62.0	65.0	67.0	67.1±1.20
10	68.0	72.0	68.0	66.0	66.0	66.0	65.0	69.0	67.6±1.25
11	70.0	67.0	71.0	67.0	65.0	66.0	70.0	69.0	68.1±0.77
12	74.0	80.0	76.0	72.0	81.0	(died)	76.0	77.0	76.6±1.19
13	79.0	90.0	80.0	77.0	79.0		80.0	80.0	80.7±1.50
14	82.0	86.0	83.0	81.0	75.0		79.0	84.0	81.4±1.27
15	84.0	87.0	83.0	81.0	78.0		86.0	85.0	83.4±1.10
16	87.0	88.0	84.0	80.0	80.0		84.0	87.0	84.3±1.17
17	86.0	91.0	89.0	83.0	85.0		85.0	87.0	86.6±0.95
18	84.0	93.0	89.0	84.0	89.0		85.0	89.0	87.6±1.19
19*									
20	20.0	100.0	90.0	82.0	91.0		87.0		90.0±2.41
21				82.0			89.0		85.5±3.50
22				83.0			85.0		84.0±1.01
23									

* Data for the sixth and 19th week could not be gathered.

Table 25. Body length (cm) of pigs maintained on dietary treatment D

Weeks	Animal number and sex								Average with S.E.
	3/236 M	5/238 M	5/242 F	4/241 F	6/237 M	1/238 M	10/240 F	6/241 F	
4	49.0	47.0	49.0	46.0	47.0	42.0	47.0	49.0	47.0±0.82
5	54.0	61.0	48.0	51.0	49.0	45.0	49.0	51.0	51.0±1.70
6*									
7	60.0	67.0	62.0	60.0	58.0	48.0	60.0	55.0	58.8±1.95
8	68.0	71.0	62.0	64.0	63.0	52.0	63.0	61.0	63.0±1.96
9	68.0	71.0	66.0	62.0	67.0	54.0	64.0	66.0	64.8±1.80
10	67.0	72.0	66.0	68.0	73.0	54.0	69.0	69.0	67.3±2.07
11	73.0	73.0	68.0	70.0	71.0	57.0	69.0	69.0	68.8±1.80
12	80.0	74.0	75.0	75.0	79.0	63.0	72.0	73.0	73.9±1.84
13	77.0	82.0	80.0	77.0	79.0	67.0	80.0	83.0	78.1±1.76
14	79.0	84.0	79.0	79.0	81.0	68.0	80.0	85.0	79.4±1.82
15	82.0	88.0	83.0	82.0	86.0	66.0	77.0	82.0	80.8±2.39
16	83.0	90.0	83.0	79.0	88.0	67.0	83.0	83.0	82.0±2.46
17	79.0	89.0	86.0	84.0	85.0	68.0	89.0	88.0	83.5±2.50
18	84.0	89.0	91.0	88.0	90.0	71.0	85.0	90.0	85.0±2.44
19*									
20			91.0	86.0	89.0	70.0	90.0	92.0	86.3±3.37
21				87.0		75.0			81.0±6.06
22				85.0		78.0			81.5±3.54
23				84.0		78.0			81.0±3.03
24				84.0		81.0			82.5±1.52
25				90.0		84.0			87.0±3.03

* Data for sixth and 19th week could not be gathered.

Table 26. Body girth (cm) of pigs maintained on dietary treatment A

Weeks	Animal number and sex								Average with S.E.
	2/282 M	2/281 M	7/280 F	7/281 F	4/280 M	3/282 M	9/280 F	7/282 F	
4	60.5	48.5	48.0	46.5	48.5	55.5	45.5	52.0	50.6±1.80
5	62.5	50.5	51.0	49.5	46.5	57.0	45.5	55.0	52.2±2.00
6	67.0	56.5	55.5	54.0	53.0	62.0	55.5	58.5	57.8±1.65
7	66.0	54.5	56.0	52.5	52.0	61.0	51.5	59.5	56.6±1.82
8	65.0	55.0	57.5	51.5	50.5	62.5	53.0	61.5	57.1±1.92
9	71.5	57.5	55.0	53.0	55.5	67.0	56.5	67.0	60.4±2.47
10	72.5	57.5	52.0	57.5	54.5	64.5	60.0	70.5	61.1±2.62
11	74.0	60.5	62.5	55.0	53.0	66.5	60.0	68.0	62.4±2.45
12	77.0	60.5	59.0	54.0	54.5	69.5	63.0	72.0	63.7±2.96
13	81.0	63.0	60.0	57.0	53.5	70.0	61.0	76.0	65.2±3.39
14	79.5	63.0	67.5	59.0	53.5	71.5	62.5	76.0	66.6±3.10
15	82.0	65.5	67.5	62.0	55.0	74.0	65.5	79.0	68.8±3.17
16	86.0	66.0	71.0	63.5	56.0	75.5	69.0	80.5	70.9±3.39
17	82.5	67.5	69.0	64.5	55.0	76.5	70.0	82.5	70.9±3.30
18	83.5	71.5	72.5	65.5	62.5	77.0	70.0	82.5	73.1±2.65
19*									
20	85.0	73.5	73.0	67.0	59.5	79.0	71.5	81.0	73.7±2.87
21	88.5	74.0	73.5	70.0	63.5	86.0	72.5	83.0	73.4±3.04
22	91.5	76.0	73.5	71.5	63.5	84.5	76.0	87.5	78.4±3.24
23	92.0	77.0	76.0	73.5	65.5	85.0	78.0	89.0	79.5±3.07
24		75.0	72.5	71.5	69.0	85.5	78.0	88.0	77.1±2.73
25		72.5	74.5	71.0	64.5	88.0	79.0	88.0	76.8±3.07

* Data for the 19th week could not be gathered.

Table 27. Body girth (cm) of pigs maintained on dietary treatment B

Weeks	Animal number and sex								Average with S.E.
	6/281 F	6/282 F	6/280 F	4/282 F	3/280 M	1/282 M	5/281 M	5/280 M	
4	51.0	52.0	47.5	54.0	52.0	53.0	49.0	50.5	51.1±0.74
5	51.0	53.5	50.5	59.0	51.5	51.0	47.0	51.5	51.9±1.21
6	58.0	60.5	51.5	66.0	53.0	55.0	51.0	57.5	56.6±1.79
7	60.0	56.0	48.0	63.0	54.5	55.0	53.0	57.5	59.9±1.60
8	54.0	60.0	51.0	61.5	58.5	63.0	51.0	56.5	56.9±1.61
9	55.5	62.5	49.5	66.5	58.5	61.0	54.0	60.5	58.5±1.89
10	60.5	62.0	51.0	52.5	61.5	63.5	56.5	63.5	60.9±1.59
11	58.5	64.0	53.5	68.0	63.0	65.5	57.5	62.0	61.5±1.67
12	58.0	66.0	54.5	68.0	61.5	61.0	57.5	62.0	61.1±1.57
13	56.0	64.5	54.5	72.5	67.0	65.5	64.0	65.5	63.7±2.07
14	60.0	66.0	52.0	73.0	67.5	65.5	66.5	66.0	64.6±2.18
15	66.0	66.0	56.5	77.5	70.5	70.0	66.0	70.5	67.9±2.12
16	67.5	68.0	59.0	74.0	72.0	68.5	69.5	71.0	68.8±1.61
17	67.5	71.5	54.5	74.5	73.0	68.0	68.0	70.5	68.4±2.18
18	67.5	71.0	58.0	77.5	77.5	72.0	72.5	75.0	71.4±2.25
19*									
20	71.0	72.0	58.0	75.5	78.5	74.0	71.5	74.5	71.9±2.16
21	73.0	73.0	60.5	74.5	79.0	73.0	71.5	75.5	72.5±1.89
22	77.0	75.5	62.0	82.5	83.5	75.5	75.5	77.0	76.1±2.30
23	75.0	74.0	63.0	84.5	82.0	75.5	77.0	79.0	76.3±2.28
24	74.5	76.5	63.5	82.0	79.5	77.5	77.5	80.0	76.5±2.60

* Data for the 19th week could not be gathered.

Table 28. Body girth (cm) of pigs maintained on dietary treatment C

Weeks	4/237 M	3/242 M	7/239 F	7/240 F	2/241 M	5/237 M	9/241 F	5/239 F	Average with S.E.
	Animal number and sex								
4	57.0	58.5	55.5	58.5	58.0	60.0	57.0	51.0	56.9±0.96
5	59.0	64.0	60.0	58.5	59.0	60.0	63.5	65.5	61.1±0.96
6*									
7	72.5	68.0	72.0	68.5	68.0	68.5	64.5	65.0	68.4±1.01
8	69.5	70.0	69.0	69.5	68.5	72.0	66.0	67.5	69.0±0.63
9	77.5	78.5	75.0	74.5	75.5	72.0	70.0	69.0	74.0±1.59
10	75.5	74.0	73.0	74.5	74.0	75.0	75.0	72.5	74.2±0.36
11	78.0	77.5	79.0	78.0	78.5	74.5	75.0	76.5	77.1±0.58
12	84.5	83.5	80.5	82.0	80.0	(died)	83.0	81.5	82.1±0.61
13	86.5	84.0	83.0	82.5	80.5		83.5	84.5	83.5±0.70
14	87.0	89.0	88.0	87.5	84.0		86.0	88.5	87.1±0.64
15	90.5	88.9	90.5	89.0	85.0		84.5	93.0	88.8±1.16
16	89.0	92.5	88.0	88.0	85.0		85.0	92.5	88.6±1.16
17	90.5	90.0	92.0	86.5	89.0		87.5	95.0	90.1±1.07
18	92.0	95.0	94.0	89.5	89.5		89.5	96.0	92.1±1.06
19*									
20	93.5	96.0	93.5	90.5	92.0		93.5		93.2±0.69
21				93.0			97.5		95.0±2.26
22				100.5			95.5		98.0±2.52

* Data for the sixth and 19th week could not be gathered.

Table 29. Body girth (cm) of pigs maintained on dietary treatment D

Weeks	Animal number and sex								Average with S.E.
	3/236 M	5/238 M	5/242 F	4/241 F	6/237 M	1/238 M	10/240 F	6/241 F	
4	57.0	58.5	55.5	58.5	58.0	60.0	57.0	51.0	56.9±0.97
5	59.0	64.0	60.0	58.0	59.0	60.0	63.5	65.5	61.1±0.98
6*									
7	72.5	68.0	72.0	68.5	68.0	58.5	64.5	65.0	67.1±1.60
8	71.0	70.0	69.5	66.0	68.5	56.0	67.5	65.5	66.1±1.65
9	75.0	72.5	71.5	68.5	75.5	57.0	73.5	73.5	70.9±2.13
10	74.5	74.5	72.5	72.0	78.0	60.5	76.5	75.5	73.0±1.91
11	76.0	77.0	75.5	73.5	82.0	61.5	78.0	78.5	75.3±2.15
12	83.5	82.0	75.5	74.5	86.0	66.5	80.5	82.0	78.8±2.20
13	82.0	86.5	78.0	75.0	86.5	65.5	80.5	85.5	79.9±2.53
14	84.0	88.5	85.0	79.5	89.0	66.0	86.5	90.5	81.6±2.79
15	86.0	88.5	88.0	79.0	90.5	69.5	83.0	90.5	84.4±2.53
16	90.5	89.0	88.0	85.5	91.0	69.5	88.0	91.5	86.6±2.54
17	91.5	93.0	88.5	82.5	94.5	71.0	89.5	93.0	87.9±2.76
18	92.5	93.5	88.5	88.0	96.0	70.5	87.5	95.5	89.1±2.89
19*									
20			92.5	86.5	97.5	76.5	92.5	97.5	90.5±3.26
21				88.5		79.0			83.8±4.76
22				90.0		85.0			87.5±2.51
23				92.5		85.5			89.0±3.51
24				96.5		90.0			93.3±3.26
25				99.0		91.5			95.3±3.76

* Data for the sixth and 19th week could not be gathered.

Table 30. Summarised data on average gain in body weight (kg) and body measurements (cm) recorded from fourth week to seventeenth week of experiment

Gain	Group I	Group II	Group III	Group IV
Body weight	24.1 ± 3.18^{a}	20.6 ± 2.5^{a}	46.1 ± 1.47^{b}	42.9 ± 3.65^{b}
Body length	20.1 ± 1.68^{a}	21.7 ± 1.26^{a}	38.7 ± 0.9^{b}	36.5 ± 1.6^{b}
Body girth	20.3 ± 2.4^{a}	17.3 ± 1.64^{a}	33.6 ± 2.0^{b}	31.0 ± 3.35^{b}

Means having same superscription in a row do not differ significantly

Table 31. Carcass characteristics of pigs maintained on dietary treatment A

Animal number	Sex	Live body weight (kg)	Dressed weight with head (kg)	Half carcass weight (kg)	Carcass length (cm)	Average backfat thickness (cm)	Eye-muscle area (cm^2)	Weight of ham (kg)	Dressing percentage without head
2/282	M	74.0	56.5	26.0	76.1	1.9	32.32	7.5	69.6
2/281	M	44.0	30.8	13.7	60.2	1.3	17.89	4.1	62.3
7/280	F	47.0	37.9	17.0	66.4	1.3	22.02	5.0	72.3
7/281	F	37.5	28.3	12.5	63.1	1.6	18.42	4.0	66.6
4/280	M	33.5	23.6	10.1	56.0	0.8	10.62	3.0	60.3
3/282	M	65.0	49.3	22.4	70.4	1.7	25.58	6.0	68.8
9/280	F	43.5	32.0	14.5	66.0	1.5	20.32	4.3	66.7
7/282	F	62.5	47.1	21.5	64.0	1.1	23.00	4.0	68.8
Average with S.E.		50.9±5.13	38.2±4.10	17.2±1.96	65.3±2.17	1.4±0.12	21.3±2.23	4.7±0.50	66.9±1.39

Table 32. Carcass characteristics of pigs maintained on dietary treatment B

Animal number	Sex	Live body weight (kg)	Dressed weight with head (kg)	Half carcass weight (kg)	Carcass length (cm)	Average backfat thickness (cm)	Eye muscle area (cm^2)	Weight of ham (kg)	Dressing percentage without head
6/281	F	41.0	28.0	12.5	66.0	1.1	20.93	4.0	61.0
6/282	F	48.5	35.1	15.75	61.0	1.2	21.16	4.7	64.9
6/280	F	22.0	15.4	6.55	50.3	0.7	11.11	1.85	59.5
4/282	F	59.5	39.5	18.0	67.0	1.7	23.33	5.5	60.5
3/280	M	52.0	37.1	16.5	64.5	2.1	22.36	5.4	63.5
1/282	M	43.0	28.2	12.6	67.0	1.3	18.88	3.5	58.6
5/280	M	48.5	33.0	15.0	65.8	1.3	22.24	4.5	61.9
Average with S.E.		44.9±4.5	30.1±3.04	13.8±1.43	63.1±2.26	1.3±0.17	20.0±1.57	4.2±0.48	61.4±0.83

Table 33. Carcass characteristics of pigs maintained on dietary treatment C

Animal number	Sex	Live body weight (kg)	Dressed weight with head (kg)	Half carcass weight (kg)	Carcass length (cm)	Average backfat thickness (cm)	Eye muscle area (cm^2)	Weight of ham (kg)	Dressing percentage without head
4/237	M	70.5	50.8	23.0	71.1	1.9	36.61	6.6	65.2
3/242	M	69 5	49.6	22.5	76.0	1.8	29.47	6.7	64.6
7/239	F	71.5	53.6	24.3	76.0	2.1	27.83	6.3	67.9
7/240	F	71.0	54.3	24.9	74.8	2.6	33.10	7.5	70.1
2/241	M	71.5	50.8	22.9	73.5	1.5	24.60	6.6	64.1
9/241	F	72.5	54.1	24.8	74.5	2.4	28.10	7.5	68.4
5/239	F	69.5	52.4	23.6	76.0	2.1	21.76	6.7	68.5
Average with S.E.		70.9±0.42	52.2±0.7	23.7±0.36	74.6±0.68	2.1±0.14	28.8±1.88	6.8±0.18	67.0±0.88

Table 35. Analysis of variance - Half carcass weight

Source	df	SS	MSS	F
Treatment	3	510.4746	170.1582	13.39606**
Error	26	330.2549	12.70211	
Total	29	840.7295		

** Significant at one per cent level

Table 36. Analysis of variance - Carcass length

Source	df	SS	MSS	F
Treatment	3	757.8906	252.6302	12.81011**
Error	26	512.75	19.72115	
Total	29	1270.6406		

** Significant at one per cent level

Table 37. Analysis of variance - Backfat thickness

Source	df	SS	MSS	F
Treatment	3	3.413963	1.137988	6.331567**
Error	26	4.673042	0.1797324	
Total	29	8.087005		

** Significant at one per cent level

Table 38. Analysis of variance - Eye muscle area

Source	df	SS	MSS	F
Treatment	3	305.9258	168.6419	5.104482**
Error	26	858.9882	33.03801	
Total	29	1364.914		

** Significant at one per cent level

Table 34. Carcass characteristics of pigs maintained on dietary treatment D

Animal number	Sex	Live body weight (kg)	Dressed weight with head (kg)	Half carcass weight (kg)	Carcass length (cm)	Average backfat thickness (cm)	Eye muslce area (cm^2)	Weight of ham (kg)	Dressing percentage without head
3/236	M	67.5	47.1	21.3	71.5	1.0	28.59	6.6	63.1
5/238	M	69.0	46.9	21.3	75.0	1.8	41.93	5.8	61.7
5/242	F	70.0	52.3	24.0	73.6	2.4	22.61	6.5	68.6
4/241	F	73.0	53.5	25.0	74.0	2.6	30.31	7.0	68.5
6/237	M	72.5	54.1	24.9	75.0	2.2	35.19	6.5	68.9
1/238	M	63.0	46.5	21.0	72.0	1.8	21.77	5.5	66.7
10/240	F	72.5	52.8	24.4	75.1	2.1	26.35	7.0	67.3
6/241	F	72.0	54.9	25.2	74.5	2.4	24.40	7.0	70.0
Average with S.E.		69.9±1.21	50.9±1.21	23.4±0.66	73.8±0.49	2.0±0.18	28.9±2.42	6.5±0.2	66.9±1.04

Table 39. Analysis of variance - Weight of ham

Source	df	SS	MSS	F
Treatment	3	36.62164	12.20721	11.7174**
Error	26	27.08685	1.041802	
Total	29	63.70849		

** Significant at one per cent level

Table 40. Analysis of variance - Dressing percentage without head

Source	df	SS	MSS	F
Treatment	3	162.5938	54.19792	6.10247**
Error	26	230.9141	8.881309	
Total	29	393.5079		

** Significant at one per cent level

Table 41. Summarised data on carcass characteristics of pigs maintained on four dietary treatments

	Treatment groups			
	A	B	C	D
Weight at slaughter (kg)	50.9 ± 5.13	44.9 ± 4.45	70.9 ± 0.42	69.9 ± 1.21
Weight of dressed hot carcass without head (kg)	34.05 ± 3.87	27.57 ± 2.86	47.49 ± 0.73	46.76 ± 1.38
Dressing percentage of hot carcass without head	66.9 ± 1.39[a]	61.4 ± 0.83[b]	67.0 ± 0.88[a]	66.9 ± 1.04[a]
Half carcass weight (kg)	17.2 ± 1.96[a]	13.8 ± 1.43[a]	23.7 ± 0.36[b]	23.4 ± 0.66[b]
Carcass length (cms)	65.3 ± 2.17[a]	63.1 ± 2.26[a]	74.6 ± 0.68[b]	73.8 ± 0.49[b]
Backfat thickness (cms)	1.4 ± 0.12[a]	1.3 ± 0.17[a]	2.1 ± 0.14[b]	2.0 ± 0.18[b]
Eye-muscle area (cm^2)	21.3 ± 2.23[a]	20.0 ± 1.57[a]	28.8 ± 1.88[b]	28.9 ± 2.42[b]
Weight of ham (kg)	4.7 ± 0.5[a]	4.2 ± 0.48[a]	6.8 ± 0.18[b]	6.5 ± 0.2[b]

Pigs belonging to the treatment A and B were slaughtered at 8 months of age as they failed to attain the slaughter weight of 70 kg.

Means having the same superscription in a row do not differ significantly.

Discussion

DISCUSSION

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

Growth

From the summarised data on body weight gain presented in Table, 20, represented by Fig.1 and 2 and the statistical analysis set out in Table 18, it will be seen that diets A and B containing prawn waste replacing 50 per cent and 100 per cent of the animal protein from unsalted dried fish respectively, did not promote growth in pigs as compared with control Diet C, containing unsalted dried fish to provide 25 per cent of the total protein in the diet. The average daily weight gain of pigs in groups I, II, and III maintained on diets A, B and C were 236 g, 200 g and 429 g respectively. The results with pigs receiving diet D (Group IV), containing 12.5 per cent of the total protein as animal protein, provided by unsalted dried fish, showed the same trend as shown by pigs maintained on control diet C, the average daily gain being 416 g and 429 g respectively and, the difference being not significant. Although, the pigs on diet C did not differ significantly with pigs on diet D, they registered a significantly higher ($P < 0.01$) growth rate than the pigs on diets A and B. The growth rate of pigs on diets A and B did not differ significantly. The results indicate that prawn waste as an animal protein source failed to support growth even to the extent, as produced by a ration containing 12.5 per cent of total protein provided by unsalted dried fish. The observations in this regard under the present study are at variance with those reported by Angel (1935) who obtained a beneficial effect on supplementing shrimps at 5 to 20 per cent level in the rations for growing pigs. However, a significantly lower growth rate has been reported in pigs fed shrimp shell at 5 per cent and 10 per cent levels in the rations replacing dry fish (Anon. 1988) which is in keeping with the results obtained in the present investigation. Husby (1988) obtained a higher daily weight gain of 1.72 lb in growing pigs, when crab meal replaced 50 per cent of soyabean meal. Similar observations were recorded by Luberda et al. (1981) who obtained an average daily gain of 641, 608 and 606 g, when krill meal was used at 10, 20 or 30 per cent to replace fish meal in the rations for growing pigs. The poor performance of diets containing prawn waste in promoting growth in pigs may be attributed to the poor digestibility and poor quality of the protein from this source.

Feed conversion efficiency

Data on feed conversion efficiency of the animals receiving diets A, B, C and D presented in Table 14 to 17, summarised in Table 20, represented by Fig.3 and statistically analysed in Table 19 indicated that the pigs fed diets A and B containing prawn waste at different levels exhibited a poor feed efficiency ratio of 4.8 and 5.2 as compared to those fed diets C and D, the values being 4.05 and 4.13 respectively. The feed conversion efficiency of animals receiving diet B containing prawn waste as the sole animal protein source was significantly poor ($P < 0.05$) as compared to those maintained on diet C containing unsalted dried fish as the animal protein source. However, there was no significant difference between feed conversion efficiency of pigs maintained on diets A, C and D.

Bhagwat and Sahasrabudhe (1971) reported an overall feed conversion efficiency of 4.2 in pigs on rations containing 19.5 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 rations were varied. Kumar et al. (1974) using standard grower and finisher rations obtained a feed conversion ratio of 3.4, 4.0 and 4.5 for body weights of 50 kg, 50 to 70 kg and 70 to 90 kg respectively. Similar observations were made by Husby (1980) and Batterham et al. (1983) in pigs maintained on king crab meal and prawn offal silage respectively. The feed conversion efficiency obtained for animals receiving the diets A and B containing prawn waste at different levels in the present study were poorer than those reported by the above workers. While, a feed conversion efficiency of 4.2 and 5.4 was reported in pigs fed rations containing 5 per cent and 10 per cent shrimp shell respectively (Anon. 1988) which is in agreement with the values obtained for pigs on diets A and B of the present study.

Dry matter consumption

The data on daily dry matter intake of pigs in group I, II, III and IV receiving diets A, B, C and D presented in Table 20 show an average daily dry matter consumption of 0.97, 0.94, 1.55 and 1.49 kg respectively. Pigs on diets A, B and D consumed 63 per cent, 61 per cent and 96 per cent of dry matter respectively, when compared to the dry matter intake of pigs maintained on control diet C. The low dry matter consumption of pigs indicate that diets containing prawn waste were less palatable to pigs. Higher values for dry matter consumption were reported for pigs receiving diets containing 5 per cent and 10 per cent shrimp shell in the ration (Anon. 1988) which is not in agreement with the result of the present study.

Age at slaughter

The data presented in Table 20 show that the animals in group III and IV receiving diets C and D attained an average body weight of 70kg at 205 and 211 days of age respectively, while the pigs on diets A and B (group I and II) attained an average body weight of 50.8 and 44.3 kg only at 239 and 238 days of age respectively. The inability of the animals in group I and II to attain the slaughter weight of 70 kg as compared to those animals in group III and IV are indicative of the poor growth effect of the diets containing prawn waste. Ramachandran (1977) reported an average age of 202 and 205 days for pigs reared upto 70 kg body weight on two dietary treatments with different energy-protein levels. The short period of time taken to attain 70 kg body weight by animals in group III and IV receiving diets C and D containing unsalted dried fish at varying levels as compared with the age at slaughter attained by pigs in group I and II receiving the diets A and B is further suggestive of the poor growth promoting effect of prawn waste.

Body measurements

From the summarised data on body measurements presented in Table 30 it will be seen that, the average values for increase in the body measurements from fourth to sixteenth week, of animals belonging to the treatment groups I, II, III and IV, receiving diets A, B, C and D respectively were 20.1, 21.7, 38.7 and 36.5 cms respectively for body length and 20.3, 17.3, 33.6 and 31.0 cms respectively for body girth. The almost identical increase in body length and girth of pigs receiving the diets containing prawn waste (diet A and B) was significantly lower ($P < 0.01$) than those obtained for pigs receiving diets Diets C and D containing unsalted dried fish.

A significant coefficient of correlation (r^2 = 0.9) could be observed between body weight, body length and body girth among the animals in all the four groups, an observation which is in keeping with those reported in the literature (Bardoloi et al., 1978; Sahaayaruban et al., 1984; Mickwitz and Bobetts, 1972; Deo and Raina, 1983 and Gruev and Machev, 1970).

Digestibility coefficient of nutrients

Dry matter

The digestibility coefficient of dry matter of diet A presented in Table 21 was significantly higher (P <0.01) than those obtained for the diets B, C and D, the values being 61.8, 48.9, 53.2 and 55.8 respectively. The apparent differences noticed between the values for the diets B, C and D were not significant.

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, where as Devi (1981) reported digestibility coefficients that ranged from 79.6 to 81.8 for diets containing 16 per cent protein with varying levels of dried tapioca chips. Eggum et al. (1982) obtained digestibility coefficients of 79.7 and 67.6 for diets containing 4.7 and 13.3 per cent crude fibre respectively with a crude protein content of 13.0 per cent. Thomas and Singh (1984) reported that lowering of digestible energy content of grower pig rations by 10 per cent from NRC level resulted in dry matter digestibility to drop from 81.08 to 60.39 per cent. The digestibility coefficients of dry matter obtained in the present investigation were found to be lower than those reported by the above workers. This may be attributed to the poor digestibility of the ingredients that constituted the diets.

Crude protein

The data on digestibility coefficients of crude protein presented in Table 21 show a significantly low digestibility (P <0.01) in pigs fed diet B as compared to those on diets A, C and D, the values being 55.9, 64.1, 65.3 and 63.9 respectively. However, apparent difference noticed in the digestibility of crude protein in the pigs fed diets A, C and D was not significant.

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 that ranged from 57.0 to 73.0 for diets containing varying levels of crude fibre. The values obtained for the diets A, C and D 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 that ranged from 73.0 to 80.3 and 72.4 to 75.3 respectively which are higher than those obtained in the present investigation. Similar observations were also made by Thomas and Singh (1984) who reported that crude protein digestibility dropped from 80.04 to 68.17 when digestible energy content of the grower rations for pigs was lowered by 15 per cent from NRC level.

Ether extract

The digestibility coefficients of ether extract presented in Table 21 showed a significantly higher value for diet D (P <0.05) than those obtained for diets A, B and C the values being 68.2, 58.2, 52.9 and 56.6 respectively. The apparent difference noticed between the values for diets A, B and C was not significant. Pond *et al*. (1962) and Eggum *et al*. (1982) obtained 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. Higher digestibility coefficients of either extract have been reported by Devi (1981), the values ranging from 66.9 to 69.9 for diets containing 16 per cent curde protein with varying levels of dried tapioca chips. Fernandez *et al*. (1986) conducted digestibility experiments in growing pigs with 26 feed stuffs and diets and reported that the digestibility coefficient of crude fat is widely variable. Thomas and Singh (1984) reported that lowering of digestible energy content of grower pig rations by 10 per cent from NRC level resulted in ether extract digestibility to drop from 91.76 to 76.84 and a further lowering by five per cent brought down the ether extract digestibility to 55.1 per cent which were almost similar to that obtained in the present investigation.

Crude fibre

No significant variation could be observed in the digestibility coefficients of crude fibre in all the treatments A, B, C and D, the values being 25.7, 20.9, 27.4 and 20.6 respectively, as presented in Table 21.

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 per cent crude protein and varying levels of crude fibre. The values obtained for Diets A, B, C and D in the present investigation are in agreement with those reported by the above workers. Devi (1981) on the other hand observed digestibility of crude fibre from 37.1 to 40.0 per cent in pigs fed rations containing 16 per cent crude protein and varying levels of dried tapioca chips which were higher than those reported in the presented study. 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 food stuffs were used in the study.

Nitrogen free extract

The digestibility coefficient of nitrogen free extract of the diet A presented in Table 21 was significantly higher (P <0.01) than those obtained for the diets B, C and D, the values being 76.1, 61.8, 65.1 and 67.1 respectively, the apparent difference noticed in the digestibility of nitrogen free extract in diets B, C and D being not significant.

The values obtained in the present investigation were lower when compared to the digestibility coefficient of nitrogen fee extract obtained by Pond et al. (1962) and Eggum et al. (1982) who have reported values ranging from 80.5 to 91.6 per cent for diets containing a constant level of protein and varying levels of crude fibre. Similar observations were reported by Devi (1981) in pigs fed with rations containing 16 per cent protein and varying levels of dried tapioca chips.

Carcass characteristics

Data on carcass characteristics of animals are presented in Tables 31 to 34 and the results statistically analysed in Tables 35 to 40. Table 41 presents a consolidated data on carcass characteristics.

Dressing percentage

The average values for dressing percentage without head for the pigs in the four dietary treatments A, B, C and D presented in Table 41 were 66.9, 61.4, 67.0 and 66.9 per cent respectively. The dressing percentage of pigs in treatment B was significantly lower ($P < 0.01$) than those in the other three treatments. The dressing percentage of pigs in treatments A, C and D did not vary significantly.

Baird _et_ _al_. (1970), Sebastian (1972), Ramachandran (1977), Devi (1981), Thomas and Singh (1984) and Sivaraman and Mercy (1986) reported dressing percentage without head ranging from 63.0 to 73.0 in pigs slaughtered from 70 to 90 kg body weight an observation which is in agreement with those obtained in present study. Talley _et_ _al_. (1976) observed that pigs fed low energy diets had lower dressing percentage. Luberda _et_ _al_. (1983) reported that partial or complete replacement of animal protein in the rations of pigs, using krill meal produced no significant difference in dressing percentage.

Carcass length

Data on the carcass length of pigs in the four dietary treatments A, B, C and D presented in Table 41 showed average carcass length of 65.3, 63.1, 74.6 and 73.8 cms respectively. Although pigs on diets A and B did not differ significantly in terms of carcass length, they showed significant difference (P <0.01) when compared to the pigs on diets C and D. Carcass length of pigs on diets C and D did not differ significantly.

Baird et al. (1970), Sebastian (1972), Ramachandran (1977), Devi (1981), Thomas and Singh (1984) and Sivaraman and Mercy (1986) observed values ranging from 70.0 to 79.1 cm for carcass length in pigs slaughtered from 70 to 90 kg. These values are similar to those obtained for pigs on diets C and D in the present investigation. Thomas and Singh (1984) obtained values ranging from 63.7 to 64.4 cm for carcass length of pigs slaughtered at 63 kg, which are in agreement with those of pigs on diets A and B.

Backfat thickness

The average values for backfat thickness of pigs on the four dietary treatments A, B, C and D presented in Table 41 were 1.4, 1.3, 2.1 and 2.0 cms respectively. The variation in backfat thickness between the treatments A and B, C and D are non significant. However, the backfat thickness of pigs belonging to the treatments C and D were found to be significantly higher ($P < 0.01$) than that on treatments A and B. Baird *et al*. (1970) observed in growing finishing pigs fed rations containing different levels of crude fibre with constant energy and protein, backfat thickness varied from 3.2 to 3.5 cm while, Baird *et al*. (1975), Talley *et al*. (1976), and Seerley *et al*. (1978) reported a similar observation in pigs fed ration containing varying levels of crude fibre, crude protein and dietary energy. Thomas and Singh (1984) observed a reduction in backfat thickness from 4.5 to 2.7 cm for growing pigs when the digestible energy content of the ration was lowered by 10 and 15 per cent of NRC standards. The values obtained in the present investigation was found to be lower than those reported by the above workers. However, Devi (1981) lends support to the observations in backfat thickness recorded in the treatments C and D of the present study, the values being in the range of 2.2 to 2.5 cm.

Eye-muscle area

The average values for eye-muscle area of pigs in the four treatments A, B, C and D presented in Table 41 were 21.3, 20.0, 28.8 and 28.9 cm^2 respectively. Although no significant difference could be obtained between the eye-muscle area of pigs belonging to treatments A and B, these values were significantly lower ($P < 0.01$) than in treatments C and D. The variation noticed in the eye-muscle area of pigs in the treatments C and D was not significant.

The observations in the present study in regard to eye-muscle area of animals in treatments C and D are in agreement with those reported by Baird et al. (1970) who on feeding pigs with rations containing varying levels of crude fibre with constant energy and protein, Baird et al. (1975) with rations containing varying levels of crude fibre, crude protein and energy, Talley et al. (1976) and Thomas and Singh (1986) with rations containing varying levels of dietary energy, the values ranging from 27.1 to 33.2 cm^2. Sebastian (1972) and Devi (1981) obtained values for eye-muscle area that ranged from 25.70 to 27.10 and 23.60 to 26.64 respectively, which were lower to that obtained for the pigs on diets A and B of the present study.

Weight of ham

The average values for the weight of ham of pigs belonging to the four dietary treatments A, B, C and D presented in Table 41 were 4.7, 4.2, 6.8 and 6.5 kg with respect to the half carcass weight and percentage yield of ham to the live weight were 18.4, 18.8, 19.2 and 18.6 per cent respectively. No significant difference could be observed between the weight of ham of pigs belonging to the treatment A and B and between treatments C and D. But the weight of ham of pigs belonging to treatments C and D were found to be significantly higher ($P < 0.1$) than those on diets A and B. The observations in the present study are in agreement with the values reported for yield of ham by Sebastian (1972), Baird et al. (1975), Ramachandran (1977), Devi (1981) and Sivaraman and Mercy (1986) in pigs maintained on rations containing varying levels of energy and protein.

From an overall assessment of the results obtained in the present study it is to be inferred that prawn waste as a partial or complete replacement of animal protein from unsalted dried fish did not support growth and feed conversion efficiency in pigs. As regards digestibility coefficients of nutrients, 50 per cent replacement of animal protein from unsalted dried fish by prawn waste (Diet A) was found to improve the digestibility of dry matter and nitrogen free extract whereas 100 per cent replacement (Diet B) reduced the digestibility of crude protein. Prawn waste is a poor source of animal protein in swine rations as evidence by low rate of growth, lower gain in body measurements, poor feed conversion efficiency and carcass characteristics as compared to unsalted dried fish. It is therefore concluded that inclusion of prawn waste has no positive indication as an economically viable alternative animal protein source in the rations for swine.

Summary

SUMMARY

An investigation was carried out to assess the feeding value of prawn waste as a partial or complete replacement of unsalted dried fish as animal protein source in the rations for growing-finishing pigs. Thirty-two Large White Yorkshire weanling pigs with an average body weight of 9.1 kg were distributed randomly and as uniformly as possible into four groups (Groups I, II, III and IV) of eight animals each, with regard to age, sex and body weight. The four dietary treatments A, B, C and D were assigned to the pigs in the groups I, II, III and IV respectively. Twenty-five per cent of the total protein in the diets A, B and C and 12.5 percent in the diet D were provided as animal protein. Unsalted dried fish was used as animal protein source in diets C and D. Diet C served as the control. In the diets A and B, 50 and 100 per cent replacement of animal protein from unsalted dried fish was effected respectively with protein from dried prawn waste. All animals were maintained on the respective diets with 18 per cent total protein upto an average live weight of 50 kg and with 14 per cent protein, till they attained a body weight of 70 kg or they attained eight months of age.

Records of daily feed intake, weekly body weights and body measurements were maintained throughout the period of the experiment. A digestibility trial was carried out

the digestibility coefficients of nutrients in the four diets when the pigs attained six months of age. The experimental pigs were slaughtered and carcass characteristics studied as and when they attained 70 kg body weight or when they attained eight months of age, whichever was earlier.

The pigs maintained on the diets C and D gained weight satisfactorily, while those maintained on diets A and B showed lower weight gain throughout the course of the experiment. The average daily gain for pigs receiving diets A, B, C and D were 236 g, 200 g, 429 g and 416 g respectively. The growth rate of animals in dietary treatments A and B receiving prawn waste in their diets were significantly lower ($P < 0.01$) when compared to those in dietary treatments C and D. The average daily dry matter consumption of pigs in the dietary treatments A and B were lower as compared to that of pigs on diets C and D, the values being 0.97, 0.94, 1.55 and 1.49 respectively. The animals in dietary treatments C and D reached an average body weight of 70 kg at 205 and 211 days of age while the animals on diets A and B failed to attain an average body weight of 70 kg and hence were slaughtered at eight months of age.

The gain in body measurements were significantly higher ($P < 0.01$) in pigs in the dietary treatments C and D when compared to those for pigs maintained on diets A and B. As regards feed conversion efficiency of pigs, there were no significant differences between the dietary treatments A, C and D,

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while that for diet B was significantly higher ($P < 0.05$). The values for feed conversion efficiency was 4.8, 5.2, 4.05 and 4.13 respectively for diets A, B, C and D.

Better digestibility coefficients of dry matter and nitrogen-free extract were observed when animal protein in unsalted dired fish was replaced by 50 per cent with prawn waste (Diet A), while 100 per cent replacement of unsalted dried fish using prawn waste (Diet B) reduced the digestibility coefficient of crude protein.

Carcass characteristics like dressing percentage without head, half carcass weight, carcass length, backfat thickness, eye-muscle area and weight of ham were adversely affected significantly by the inclusion of prawn waste in the rations as partial or complete replacement of unsalted dried fish.

From an overall assessment of the results obtained during the course of the present inestigation, it is reasonably concluded that prawn waste cannot be successfully incorporated in the rations of growing-finishing swine as a partial or complete substitute to unsalted dried fish.

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UTILISATION OF PRAWN WASTE AS PIG FEED

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ABSTRACT OF A THESIS

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ABSTRACT

An investigation was carried out to assess the feeding value of prawn waste as a partial or complete replacement of unsalted dried fish in the rations for growing-finishing pigs. Thirty-two Large White Yorkshire weanling pigs with an average body weight of 9.1 kg were distributed randomly and uniformly as far as possible to four groups (Groups I, II, III and IV) of eight animals each, with regard to age, sex and body weight and housed in pairs of the same sex. The four dietary treatments A, B, C and D were allotted to the pigs in the groups I, II, III and IV respectively. Of the total protein, 25 per cent in the diets A, B and C and 12.5 per cent in the diet D were provided as animal protein. Unsalted dried fish was used as animal protein source in the diets C and D. Diet C formed the control diet. In the diets A and B, 50 per cent and 100 per cent replacements respectively of animal protein from unsalted dried fish were made using dried prawn waste. All the animals were maintained on the respective diets with 18 per cent total protein upto an average live weight of 50 kg and with 14 per cent protein till they attained a body weight of 70 kg or 8 months of age, whichever was earlier, when they were slaughtered to study carcass characteristics.

The results indicated that diets containing prawn waste as an animal protein source promoted growth in pigs at a

significantly lower rate ($P < 0.01$) when compared to the diets containing unsalted dried fish as animal protein source. The average daily gain obtained for pigs on dietary treatments A, B, C and D were 236 g, 200 g, 429 g and 416 g respectively. The poor growth performance of pigs maintained on diets A and B also reflected on the gain in body measurements and average age at slaughter. Pigs on diets C and D reached an average body weight of 70 kg at 205 days and 211 days of age respectively while those on diets A and B failed to attain 70 kg body weight even at 8 months of age.

The results of the study on the digestibility coefficients of nutrients showed that replacement of animal protein at 50 per cent level in the ration with prawn waste increased the digestibility of dry matter and nitrogen-free extract whereas 100 per cent replacement with prawn waste decreased the digestibility of crude protein. Carcass characteristics like dressing percentage without head, half carcass weight, carcass length, backfat thickness, eye muscle area and weight of ham were adversely affected significantly by the inclusion of prawn waste in the rations as partial or complete replacement of unsalted dried fish.

No significant difference could be observed in the growth rate, gain in body measurements, average age at slaughter and carcass characteristics of pigs when prawn waste replaced 50 and 100 per cent of the animal protein portion of the diets.

An overall assessment of the results, indicated that incorporation of prawn waste in the ration of pigs as a partial or complete replacement of animal protein from unsalted dried fish did not promote appreciable growth and as such it has no significant value as a suitable animal protein source for feeding pigs.