UTILISATION OF DRIED CUTTLE FISH (*Sepia officialis*) WASTE SILAGE FOR GROWTH IN CROSSBRED (LARGE WHITE YORKSHIRE X DESI) PIGS

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requirement for the degree of

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DECLARATION

I hereby declare that this thesis entitled **"UTILISATION OF DRIED CUTTLE FISH (*Sepia officialis*) WASTE SILAGE FOR GROWTH IN CROSSBRED (LARGE WHITE YORKSHIRE X DESI) PIGS"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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Certified that this thesis entitled **"UTILISATION OF DRIED CUTTLE FISH (*Sepia officialis)* WASTE SILAGE FOR GROWTH IN CROSSBRED (LARGE WHITE YORKSHIRE X DESI) PIGS"** is a record of research work done independently by **Shri. Sakthivel, P.C.,** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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DEDICATED TO MY

BELOVED PARENTS AND

GUIDE

CONTENTS

Chapter	Title	Page No.
1	INTRODUCTION	1
2	REVIEW OF LITERATURE	3
3	MATERIALS AND METHODS	29
4	RESULTS	36
5	DISCUSSION	59
6	SUMMARY	69
	REFERENCES	72
	ABSTRACT	

LIST OF TABLES

Table No.	Title	Page No.
1	Ingredient composition of grower rations, %	34
2	Ingredient composition of finisher rations, %	35
3	Chemical composition of grower rations, %	38
4	Chemical composition of finisher rations, %	39
5	Chemical composition of dried cuttle fish waste silage, %	40
6	Mineral content of dried cuttle fish waste silage	41
7	Fortnightly average body weight of pigs maintained on three dietary treatments, kg	42
8	Fortnightly cumulative average daily gain of pigs maintained on three dietary treatments, g	44
9	Fortnightly cumulative feed conversion efficiency of pigs maintained on three dietary treatments	46
10	Chemical composition of faeces of pigs maintained on three dietary treatments, %	48
11	Average digestibility coefficient of nutrients of the experimental diets	49
12	Carcass characteristics of pigs maintained on three dietary treatments	51
13	Cost of feed per kg body weight gain of pigs maintained on three dietary treatments	57

LIST OF FIGURES

Figure No.	Title	Page No.
1	Fortnightly average body weight of pigs maintained on three dietary treatments	43
2	Cumulative average daily gain of pigs maintained on three dietary treatments	45
3	Cumulative feed conversion efficiency of pigs maintained on three dietary treatments	47
4	Average digestibility coefficient of nutrients of the experimental diets	50
5	Dressing and meat percentages of pigs maintained on three dietary treatments	52
6	Carcass length of pigs maintained on three dietary treatments	53
7	Back fat thickness of pigs maintained on three dietary treatments	54
8	Loin eye area of pigs maintained on three dietary treatments	55
9.	Meat bone ratio of pigs maintained on three dietary treatments	56
10.	Cost of feed per kg body weight gain of pigs maintained on three dietary treatments	58

Introduction

1. INTRODUCTION

India produces 560 thousand tonnes of pork contributing to 11.93 per cent of the total meat produced (FAO, 1997). Animal protein consumption per head per day is 9.5 g in India, as compared to the world average of 24.8 g. National Institute of Nutrition recommended per capita consumption of meat as 11 kg as against the present availability of 2 kg per year. This increased demand of meat can be met through pigs, because of their rapid growth rate, higher feed conversion efficiency, high prolificacy and shorter generation interval. Pig farming has a special significance as it can play an important role in improving the socio-economic status of the weaker sections of the society.

Profitable rearing of pigs depends largely on careful planning and efficient feeding programme. Since more than seventy per cent of the cost of production is accounted for feed, economic formulation of swine ration with better quality and cheaper ingredients assumes paramount importance.

Pigs being monogastric in nature, their diets must be balanced with regard to the essential amino acid contents. In order to balance the essential amino acid profile of the diet, animal protein source such as fishmeal is usually used. But, due to its escalating price and non availability of good quality material, it has become necessary that alternative animal protein sources such as hygienically preserved fish waste and other seafood wastes are to be utilized.

India has a long coastal belt stretching over 5000 kilometers and ranks eighth in total fish landing in the world. Kerala stands first among the Indian states in producing seafood. Seafood processing plants generate various kinds of wastes during various stages, which amount to nearly 50 per cent of raw material. More than 30,000 metric tonnes of cephalopod waste which includes squid and cuttle fish is generated in India. Disposal of this waste is a major problem, because of their objectionable odour, high moisture content and disposal regulations. At present, these wastes are being dumped in the nearby water sources and other terrestrial areas resulting in the loss of valuable protein and creating environmental pollution.

Conversion of fish processing wastes into meal by drying and grinding is not practical, because of the high investment required for machinery and transportation of the waste materials. Conversion of fish processing waste into fish silage is one of the cheaper alternatives with a very low investment for its utilisation as animal feed and thereby mitigates the protein deficit and environmental pollution in the country. Fish silage can be described "as a liquid product prepared by adding acid to whole fish or part of fish that are liquefied by the action of proteolytic enzymes in the fish and is greatly accelerated by the acid, which also helps to breakdown bone and prevent bacterial spoilage" (Tatterson and Windsor, 1974).

The main disadvantage of fish silage is its high water content which creates transportation and handling difficulties. To solve this problem the liquid fish silage could be blended with filler materials such as cereals, cereal byproducts and crop residues. The resultant high solid fish silage filler mixture can be dried using conventional dryers.

Co-dried fish silage made from different types of fish has been used as protein supplement in livestock and poultry rations. However, the information regarding the use of dried cuttle fish waste silage as animal feed is scanty in literature. Hence, the present experiment was planned to determine the effect of replacing unsalted dried fish with dried cuttle fish waste silage on protein basis in the diets of growing-finishing pigs with the following objectives.

1. To study the effect of incorporation of dried cuttle fish waste silage in feed on growth, feed efficiency and carcass characteristics in crossbred pigs.

2. To assess the economics of utilisation of dried cuttle fish waste silage in the ration of pigs.

Review of Literature

2. REVIEW OF LITERATURE

2.1 ADDITIVES USED FOR PRESERVATION OF FISH WASTES

2.1.1 Acid Preserved Fish Silage

Luscombe (1973) used 3.5 per cent formic acid for preservation of ground fish offal as silage. Smith (1976) used 3 per cent formic acid to preserve fish offal as liquid fish protein. Batterham *et al.* (1983) and Johnson *et al.* (1985) also used 3.5 per cent formic acid for preparation of silage from fish waste. Myer *et al.* (1990) used 3.5% formic acid for preparing scallop viscera silage.

Stone and Hardy (1986) reported that the conventional silage was prepared by mixing the minced fish waste with 1.41 per cent and 2.45 per cent sulphuric acid to form acid stabilized silage. Liquefied fish protein was made by heating the minced heads and viscera to 60°C for 30 minutes and then increasing the temperature to 90°C for 20 minutes to destroy endogenous enzymes and then adding 1.41 per cent sulphuric acid after cooling to lower the pH from 6.5 to 4.0.

Silage was produced from 75 per cent whole herring and 25 per cent herring offal from commercial fillet production line by addition of 2.5 per cent formic acid (Epse *et al.*, 1989). Rodriguez *et al.* (1990a) reported that the ensilage process was accelerated by addition of 3.5 per cent (w/w) acid mixture of dilute sulphuric acid (1:3) and concentrated formic acid in 1:4 proportions.

Gao *et al.* (1992) concluded that acid concentration in good quality fish silage could be reduced from 3 to 1.25 or 2.0 per cent and that at least 50 per cent of formic acid could be replaced with citric acid which was cheaper and easier to handle.

Rose *et al.* (1994) prepared acid silage by mixing one batch of fish with formic acid (76 mol per 100 kg) and storing in air tight plastic drums. The acid herring silage (White *et al.*, 1996), acid dog fish silage (White *et al.*, 1998) and acid silver hake silage (White *et al.*, 1999) were prepared with the addition of 2.5 per cent (w:w) formic acid (concentration 85 per cent) and 200 ppm ethoxyquin to the raw ground material. Kjos *et al.* (1999), Kjos *et al.* (2000) and Kjos *et al.* (2001) also used 1.5 to 2.5 per cent formic acid and 250 ppm of ethoxyquin as antioxidant for preparation of fish silage. Lien *et al.* (2000) observed that the whole fish could be preserved by ensiling with at least 2.0 per cent formic acid on wet weight basis.

Ali *et al.* (1995) concluded that formic acid treated silage was generally better in terms of colour, consistency, appearance and flavour. Formic acid also posed less hazard than sulphuric acid and need not be neutralized before use.

The formic hydrochloric acid silage was produced from fish wastes by adding hydrochloric acid to reach pH 2, then formic acid was added to reach pH 3.0, whereas formic sulphuric acid silage was produced by adding sulphuric acid to reach pH 2, then formic acid was added to reach pH 3.0 (Magana *et al.*, 1999).

2.1.2 Fermented Fish Silage

Tibbetts *et al.* (1981) reported that fish silage could be prepared by mixing ground fish with ground corn, dried molasses and *Lactobacillus acidophilus* culture in the 40:30:5:5 proportions (wet basis). Fermentation of minced fish and fish offal after inoculation with cereals pre-fermented with *Podiococcus acidilactia* and *Lactobacillus plantarum* initiated a rapid fall in pH to below 4.5 and the addition of 0.1 per cent sorbic acid inhibited the growth of yeast during initial stages and storage without affecting lactic acid fermentation (Lindgren and Pleje, 1983).

Johnson *et al.* (1985) prepared fermented silage by initiation of fermentation through the addition of 12 per cent molasses and 5 per cent active culture of *Lactobacillus plantarum*.

Wyk and Heydenrych (1985) reported that whey powder at 7.7 per cent could be used as carbohydrate source for silage production. However, initial decline in pH of the silage containing whey powder as the only carbohydrate source was low.

Ottati and Bello (1990a,b) and Ottati *et al.* (1990) prepared the microbial fish silage from fish of low commercial value by adding 15 per cent molasses, 1 per cent *Lactobacillus plantarum* and 0.25 per cent sorbic acid. Bello and Brito (1994) indicated that after processing the ground fish using 15 per cent molasses and 10 per cent of fruit waste at 40°C and storing for 90 days at room temperature, nine stable fish silages were obtained.

Fagbenro and Jauncey (1994b) used *Lactobacillus plantarum* at 30°C at the rate of 50 g per kg (wet weight); molasses, corn flour or tapioca flour at 150 g per kg for preparing fish silage from juvenile tilapia, while Bello and Fernandez (1995) prepared biological fish silage by mixing low cost fish with molasses, papaya and pineapple wastes and *Lactobacillus plantarum* inoculation.

Fermented silage was prepared in two stages by Rose *et al.* (1994). A bacterial culture of *Lactobacillus plantarum* and *Pediococcus acidilactica* was added to a mixture of barley (52 per cent), dried malt (10 per cent) and water (38 per cent). The initial temperature of the culture was 40°C, but it was allowed to cool to room temperature over next 12 hours. The culture mix was mixed with next batch of fish, ground barley and dried malt and stored in airtight containers. Beta hydroxy butyrate and potassium sorbate were added at 2 g and 1 g per kg as antioxidants. Perez (1995) suggested that the preserved whole or chopped by-catch fish or fish wastes in molasses in 1: 2 proportions would constitute a complete ration containing 8 to 10 per cent protein (on dry matter) for fattening pigs.

Fermented silage from fish viscera was prepared by homogenizing it with 10 per cent molasses, 0.5 per cent propionic acid (antimycotic agent) and 0.02 per cent ethoxyquin (Ahmed and Mahendrakar, 1996). The fermented herring silage

(White *et al.*, 1996), fermented dog fish silage (White *et al.*, 1988) and fermented silver hake silage (White *et al.*, 1999) were made with the addition of commercial biopreservative Marisil® containing finn sugar at 1 per cent and extruded wheat at 15 per cent to the raw ground material.

Borin *et al.* (2000) reported that fresh water fish silage could be prepared by mixing partly eviscerated fish with sugar palm syrup and rice bran in the ratio of 50:10:40, on fresh basis and storing anaerobically in sealed plastic bags, while Lien *et al.* (2000) used whole fish for ensiling with 20 per cent molasses on wet weight basis.

Ngoan *et al.* (2000) observed that shrimp by-product could be successfully preserved for at least 8 weeks by ensiling with sugarcane molasses in the ratio of 3:1 (wet weight) or with cassava root meal in the ratio of 1:1 (wet weight of shrimp byproduct to air dry weight of cassava root meal).

Phiny and Rodriguez (2001) concluded that ensiling small fresh water fish with rice bran (50 per cent of the fresh weight of fish) and either sugar palm syrup (7 per cent of the weight of fish) or freshly chopped cassava root (8 per cent of the weight of fish) or combinations of the two additives was a satisfactory method of preservation which retained the nutritive value of fish protein.

2.1.3 Other Additives

Samuels *et al.* (1991) ensiled finfish and crab processing wastes with ground wheat straw using dry sugarcane molasses (5 per cent, w/w) and glacial acetic acid (16 per cent, v/w). Ramachandran *et al.* (1992) ensiled fresh prawn waste with rice bran (1:1 wet basis), with or without tapioca flour and coconut cake at 10 and 20 per cent levels as additives. Samuels *et al.* (1992) ensiled crab and fish processing wastes with maize stover or groundnut hulls and with 5 per cent dry molasses or 1 per cent formic acid. They also ensiled seafood wastes with wilted Johnson grass with or without 5 per cent dry molasses.

Abazinge *et al.* (1993) found that addition of 10 to 20 per cent of dry molasses to crab waste straw mixtures prior to ensiling resulted in silages with substantial amount of lactic acid and lower pH. Abazinge *et al.* (1994) further reported that treatment of crab waste wheat straw mixtures with molasses produced palatable silage that was efficiently utilized by wethers. Salt at 7.5 per cent or greater level preserved shrimp or crab waste with an acceptable odour, minimal ammonia production and a high level of crude protein (Evers and Carroll, 1996).

2.2 FILLER MATERIAL USED FOR CO-DRIED FISH SILAGE

Johnson *et al.* (1985) stated that the acid and fermented silage meals could be prepared by mixing the ensiled fish (85 kg) with wheat bran (15 kg) after 10 days of incubation and drying in a batch dehydrator (six hours at <70°C).

The acid and neutral fish silages were mixed with filler materials such as maize, cassava flour, groundnut cake and wheat milling residues (Ologhobo *et al.*, 1988), while Machin *et al.* (1990) prepared dried silage by using cassava meal as a filler material.

The lactic acid and sulphuric acid silages were prepared from salmon viscera and were separately co-dried with poultry byproduct meal to give a final ratio of 1:1 dry weight and 9 to 11 per cent nitrogen (Dong *et al.*, 1993). Fagbenro and Jauncey (1994a) blended the liquid silage with soyabean meal as filler material in ratio of 1:1 (w/w) and the mixture was oven dried. Fermented tilapia silage was blended (w/w) with soyabean meal, poultry byproduct meal, hydrolysed feather meal or meat bone meal and oven dried at 45°C for 48 hours (Fagbenro, 1994; Fagbenro and Jauncey, 1995). Ali *et al.* (1994) and Ali *et al.* (1995) used wheat bran as a filler material for the preparation of dried fish silage. Magana *et al.* (1999) on the other hand mixed the silage with sorghum in the ratio of 70:30 and dried in an air stream dryer at 39°C for 10 hours.

2.3 MICROBIAL QUALITY OF FISH SILAGE

Ahmed and Mahendrakar (1997) reported that the coliforms, *Escherichia coli*, enterococci and staphylococci and salmonella were absent from 48 or 72 hours onwards during fermentation at 37 and 26°C, respectively and *Clostridium perfringes* was absent after 48 hours and spores after 72 hours of fermentation at both temperatures in fermented fish silage.

2.4 CHEMICAL COMPOSITION OF FISH SILAGE

2.4.1 Dry Matter

The dry matter content of fish silage ranged between 20 and 30 per cent (Tatterson and Windsor, 1974; Smith and Adamson, 1976; Whittemore and Taylor, 1976; Husain and Offer, 1987; Green *et al.*, 1988; Strasdine *et al.*, 1988; Myer *et al.*, 1990; Alwan *et al.*, 1993; Ngoan *et al.*, 2000). Higher dry matter content of 40 per cent was reported by Hoffman (1981), Tibbetts *et al.* (1981) and Rodriguez *et al.* (1990a). Lower dry matter in fish silage (15 per cent) was reported by Johnsen and Skrede (1981).

2.4.2 Crude Protein

The crude protein content of fish silage ranged between 40 and 70 per cent depending upon the type of fish waste used for ensiling and also the filler material used for drying (Smith and Adamson, 1976; Whittemore and Taylor, 1976; Hoffman, 1981; Johnsen and Skrede, 1981; Batterham *et al.*, 1983; Green *et al.*, 1983; Johnson *et al.*, 1985; Husain and Offer, 1987; Green *et al.*, 1988; Strasdine *et al.*, 1988; Ottati and Bello, 1990a; Rodriguez *et al.*, 1990a; Valdiveiso *et al.*,1992; Alwan *et al.*, 1993; Ali *et al.*, 1995). Higher crude protein content of 85 per cent was reported by Myer *et al.* (1990) in scallop viscera silage, while lower crude protein content of 26.9 per cent was reported in ensiled shrimp by-product by Ngoan *et al.* (2000).

High oil and low oil fish waste silages dried with cassava meal contained 22 and 24.7 per cent crude protein, respectively (Machin *et al.*, 1990), whereas tuna fish waste silage dried with sorghum in 70:30 proportions contained 28.3 per cent crude protein (Magana *et al.*, 1999).

2.4.3 Ether Extract

The ether extract content of fish silage was highly variable and it ranged between 5 and 21 per cent (Hoffman, 1981; Johnsen and Skrede, 1981; Tibbetts *et al.*, 1981; Batterham *et al.*, 1983; Green *et al.*, 1983; Johnson *et al.*, 1985; Husain and Offer, 1987; Rodriguez *et al.*, 1990a; Magana *et al.*, 1999). Lower fat content was reported by Smith and Adamson (1976), Myer *et al.* (1990), Ottati and Bello (1990a) and Ngoan *et al.* (2000). Ali *et al.* (1995) reported that the lipid and ash contents of trash marine fish silage were comparable to that of fishmeal. High fat content of 44 per cent was reported by Smith and Adamson (1976) in liquid herring protein and Green *et al.* (1988) in oily fish silage. Alwan *et al.* (1993) stated that the oil content of fish waste silage varied between 3 to 71 per cent depending upon the type of raw material used.

2.4.4 Crude Fibre

The crude fibre content of fish silage was very low and also varied with the type of filler material used for drying. Crude fibre content of 0.25 per cent in fresh water fish silage was reported by Hoffman (1981). Machin *et al.* (1990) reported that high oil and low oil fish silages dried with cassava meal contained 2.4 and 2.8 per cent crude fibre, respectively, whereas Magana *et al.* (1999) reported a crude fibre content of 1.0 per cent when tuna waste fish silage was dried with sorghum in 70:30 proportions. Total carbohydrate content of fish silage ranged between 31 and 32 per cent (Ottati and Bello, 1990a; Valdiveiso *et al.*, 1992).

2.4.5 Total Ash

The total ash content of fish silage ranged between 6 and 16 per cent (Smith and Adamson, 1976; Whittemore and Taylor, 1976; Johnsen and Skrede, 1981; Batterham *et al.*, 1983; Johnson *et al.*, 1985; Husain and Offer, 1987; Green *et al.*, 1988; Strasdine *et al.*, 1988; Machin *et al.*, 1990; Myer *et al.*, 1990; Ottati and Bello, 1990a; Magana *et al.*, 1999), whereas total ash content as high as 18 to 36 per cent was reported by Hoffman (1981), Green *et al.* (1983), Rodriguez *et al.* (1990a), Valdiveiso *et al.* (1992), Alwan *et al.* (1993) and Ali *et al.* (1995).

2.4.6 Nitrogen Free Extract

The nitrogen free extract content of fish silage ranged from 16.9 to 28.43 per cent and was mainly contributed by filler material used for drying (Ali *et al.*, 1995).

2.4.7 Calcium and Phosphorus

The calcium and phosphorus content of fish silage ranged from 0.50 to 6.5 per cent and 0.70 to 1.90 per cent, respectively, depending upon the raw material used for ensiling. (Smith and Adamson, 1976; Tibbetts *et al.*, 1981; Machin *et al.*, 1990; Myer *et al.*, 1990; Ottati and Bello, 1990a; Ngoan *et al.*, 2000).

2.5 AMINO ACIDS IN FISH SILAGE

Backhoff (1976) reported that the tryptophan was found to be partially lost during ensiling and storage of fish silage and the values for available lysine remained constant. Johnsen and Skrede (1981) reported a 50 per cent loss of tryptophan in fish viscera silage. They further stated that tryptophan was the first limiting amino acid in fish viscera silage followed by sulphur containing amino acids. Wyk and Heydenrych (1985) compared the tryptophan content of fermented silage made from minced hake with the tryptophan levels for similar but acid heated material. They found that the initial tryptophan levels were comparable, but the tryptophan content of fermented silage was superior over an extended period of storage. Magana *et al.* (1999) also reported some loss of tryptophan during ensiling which could be reduced by decreasing the storage time and maintaining the pH near 3.0.

Whittemore and Taylor (1976) reported that deoiled herring silage had 6.2 per cent lysine, 3.0 per cent threonine, 1.8 per cent methionine and 0.8 per cent cystine on dry matter basis. Tibbetts *et al.* (1981) observed the lysine, isoleucine, phenylalanine plus tyrosine, threonine and arginine in the fish silage as 51, 51, 51, 54 and 56 per cent, respectively, of the levels provided by the same quantity of soyabean meal. On the other hand, Perez (1995) reported that in fish silage, high levels of lysine, threonine and sulphur containing amino acids were present as they were in fishmeal and as a consequence, fish silage would be an excellent protein supplement in the diet of pigs.

Hall and Ledward (1986) observed that the limited autolysis in defatted silage might be beneficial in restricting the release of free amino acids capable of reacting with lipid oxidation products resulting in a lower nutritional value for silage based diets. Johnson *et al.* (1985) stated that the recovery of amino acids relative to the total crude protein content from fermented silage meal was only 78.7 per cent presumably as a result of formation of Maillard reaction products during drying.

2.6 HEAVY METALS IN FISH SILAGE AND ANIMAL TISSUES

Batterham *et al.* (1983) reported that the fish silage had total mercury content of 1.05 mg/kg which ranged from 0.24 to 4.05 mg/kg on dry matter basis and methyl mercury content in the semi membraneous muscle of pigs fed on fish silage and slaughtered at 45 kg live weight was 0.085 mg/kg on a wet weight basis.

Myer *et al.* (1990) reported cadmium accumulation of 2.5 mg/kg in kidney which ranged from 1.1 to 3.6 mg/kg and 0.9 mg/kg in liver tissues which ranged from 0.3 to 2.1 mg/kg in pigs given 24 per cent scallop viscera silage. Accumulation was less in muscle (masseter) tissues which was 0.3 mg/kg on wet basis. Bello *et al.* (1993) reported low levels of lead, mercury and chrome in the dry silage.

2.7 EFFECT OF FISH SILAGE ON GROWTH AND FEED EFFICIENCY

2.7.1 Pigs

Luscombe (1973) found that there were no significant differences in daily weight gain or feed efficiency of pigs weighing from 60 to120, 120 to 200, or 60 to 200 lb. when they were fed fish silage as a replacement for fishmeal or for both fishmeal and soyabean meal. Combination of fish silage and soyabean meal was slightly superior to either fishmeal and soyabean meal or fish silage on its own.

Tatterson and Windsor (1974) opined that the most suitable outlet for fish silage would be in pig farming, since it could be used in liquid feeding system. Feeding trials showed that pigs grew as fast on silage as on fishmeal.

Hillyer *et al.* (1976) conducted a feeding trial in which the deoiled herring silage containing 66 per cent protein and 4 per cent oil on dry matter basis was included in feeds at 15 and 7.5 per cent levels. Diet containing equivalent amounts of lysine and diet based on soyabean meal were used as control. The growth rate and feed conversion efficiency of growing pigs fed fish silage diets were significantly better than those fed the control diets.

The mean daily weight gains were 580, 560 and 560 g when pigs fed a control diet containing barley plus white fishmeal and treatment diets containing soyabean meal and barley plus liquefied white fish protein only or barley plus liquefied herring protein, respectively. Feed conversion efficiencies were 3.12, 3.29 and 3.28 for the above three groups, respectively (Smith, 1976).

Liquid white fish protein was fed in barley based diet for bacon pigs at a level of 10.3 per cent of dry matter and liquid herring protein at levels of 2.4 or 13.7 per cent replacing white fishmeal and soyabean meal of the control diet. Live weight gain and feed conversion efficiency were significantly lower when the liquid protein was fed (Smith and Adamson, 1976). Low palatability and decreased performance were observed in pigs when fishmeal was completely replaced by fermented silage made out of shrimp head, blood and molasses (Anon, 1993). Similarly, Rose *et al.* (1994) indicated that fish silage reduced the productive performance of young pigs weighing 6 kg compared with diet containing fishmeal. They further stated that one per cent increase in the fish content of the diet by adding fish silage caused a 4 per cent decrease in the pigs live weight gain indicating that fish silage was not a suitable feedstuff for use with very young growing pigs if other protein concentrates are available.

Growing pigs were fed diets containing deoiled herring silage with 67 per cent protein and 4 per cent oil or 25 per cent fishmeal on dry matter basis and results showed that the quality of fish silage protein was equal to that of fishmeal (Whittemore and Taylor, 1976). Wignall and Tatterson (1976) observed that the weight gain of pigs fed white fish offal silage at 10 per cent of dry matter level was almost as good as those fed diets containing conventional non-cereal protein. Similarly, Smith (1977) opined that fish silage with low oil content could be included at levels as high as 10 per cent of dry matter in the diet of growing-finishing pigs without any negative effects on performance.

The performance of pigs and common carp fed acid preserved fish silage was similar to those fed control diet containing fishmeal (Kompiang, 1979).

Tibbetts *et al.* (1981) observed that there were no significant differences in average daily gains or feed conversion efficiencies over 6 weeks test period between weanling pigs fed diets containing 0, 3, 6 and 9 per cent fish silage. During growing-finishing period, pigs on 0, 3, 6 and 9 per cent fish silage diets showed no significant difference in average daily gain up to market weight. Feed conversion efficiency for pigs fed 6 and 9 per cent fish silage diets were significantly lower than those fed 0 per cent fish silage diet.

Myer *et al.* (1990) reported that the inclusion of scallop viscera silage at 24 per cent did not influence average daily gain, average feed intake and feed to gain ratio in growing-finishing swine. Similar results were also reported by Avdalov *et al.* (1993) when pigs were fed a balanced stock diet or diet based on 50 per cent sorghum meal and 50 per cent fish silage from whole ham fish or filleting waste of hake. Similarly, Kjos *et al.* (1999) reported non-significant differences in growth performance of growing-finishing pigs fed either a control diet or one of three diets containing 50 g per kg fish silage and different levels of fish fat. Mantra (2000) also could not observe any difference in the growth performance of growing pigs fed fishmeal and fish silage.

Batterham *et al.* (1983) found that feeding with fish silage increased the growth rate and improved feed conversion in pigs relative to soyabean meal or a combination of both during the 20 to 45 kg growth phase. Green *et al.* (1988) reported that pigs fed oily fish silage at 50 g per kg diet dry matter grew significantly faster than those given no fish silage. Oeckel and Boucque (1992) opined that for obtaining normal feed intake and growth, fish oil should not be more than five per cent in the ration.

Hoffman (1981) reported the growth rates of 186, 186, 409 and 282 g per day when the pigs were fed 70 per cent coconut meal plus 30 per cent fish silage (wet basis), 35 per cent coconut meal plus 35 per cent bread fruit flour plus 30 per cent fish silage, 35 per cent coconut meal plus 15 per cent fish silage plus 50 per cent commercial pig meal and commercial pig meal, respectively. The growth rate of the different crossbred pigs varied from 325 to 476 g per day with an average of 405 g per day when they were fed a diet of *ad libtium* sugar palm juice, 500 g per day of rice bran and 400 g per day of fresh water fish silage (Borin *et al.*, 2000).

Strasdine *et al.* (1988) concluded that the processing waste of dog fish could be successfully made into fish silage, but that the end product should be combined with amino acids or other protein concentrates if it was used as a supplement for barley based diets in monogastric animals.

Coates *et al.* (1998) reported that gastric ulceration and features of vitamin A toxicosis were diagnosed in two of the twelve lame and recumbent grower pigs fed a diet of 50 per cent fish silage produced from the offal of farmed Atlantic salmon. Poor feed conversion ratio was reported in pigs fed fish silage diets due to significantly lower weight gains (Lien *et al.*, 2000).

Ngoan *et al.* (2001) concluded that from the economical as well as performance point of view, ensiled shrimp byproduct could replace 50 per cent of the crude protein of fishmeal in cassava root meal and rice bran based diets for growing pig with a low genetic growth potential.

2.7.2 Broiler Birds

McNaughton *et al.* (1978) observed that the addition of hydrolysed fish protein improved feed efficiency, but had no effect on fourth week body weight in broiler chicks when compared to those fed essential amino acids balanced corn-soyabean meal diet.

Growth performance of broiler chicks fed fish silage at 23 per cent of the ration was inferior to those fed fishmeal. However, when biological silage was incorporated at 8 per cent level in the diet, the body weight gain and feed efficiency were similar to those fed diet with fishmeal (Kompiang, 1979). Similarly, Johnson *et al.* (1985) observed no significant effect on dietary inclusion of acid or fermented fish silage meal at 100 g/kg feed on the performance of broiler chicken relative to those fed control diet. Similar results were also reported by Krogdahl (1985b) and Guevara *et al.* (1991). Ochetim (1992) replaced 15 and 20 per cent meat and bone meal from the starter and finisher broiler rations by locally produced fish waste meal without any adverse effect.

Cordova and Bello (1986) conducted a feeding trial in which dried fish silage was fed at 6 per cent level to broiler chicken as substitute for fishmeal and results showed that fish silage can be used as a substitute for fishmeal in the diet of chicks.

Broiler chicks were given diet containing 6 per cent fishmeal (control) or neutral or acid fish silage with maize or cassava as filler material. Corresponding weight gains and feed to gain ratios were 1.51, 1.06, 0.93, 1.03 and 0.89 kg and 2.56, 3.50, 3.45, 3.31 and 3.43, respectively (Ologhobo *et al.*, 1988).

Weight gain of chicken fed balanced diets containing 4.7 or 9.4 per cent crude protein from high oil fish silage (9.8 and 19.6 per cent dietary dry matter) and 5.2 or 10.4 per cent crude protein from low oil fish silage (6.8 and 13.5 per cent of dietary dry matter) were 99, 85, 98 and 91 and their feed conversion ratios were 97, 103, 101 and 99 per cent of the gain and feed conversion ratio achieved with corresponding fishmeal, respectively (Machin *et al.*, 1990).

Rodriguez *et al.* (1990b) observed that the fish silage was well accepted by the chicken and the best biological response was for the group fed 5.0 per cent fish silage diet, whereas Bello and Fernandez (1995) reported that chicken preferred diets containing fish silage up to 50 per cent. They stated that 5 to 20 per cent of dehydrated fish silage could be included in broiler diets.

Nwokola and Sim (1990) indicated that the feed to gain ratio was highest for chicks fed diet with 5 per cent fermented herring. Epse *et al.* (1992) also reported that the growth and feed efficiency were same or better when some of the protein was from fish silage and replacement of dietary fishmeal with fish silage did not reduce the dietary quality of the feed for young growing chicken. Raj *et al.* (1996) conducted a feeding trial in broiler chicken using control diet containing 8 per cent fishmeal and test diets with 50 per cent of the fishmeal replaced by fish viscera silage and poultry intestine silage and found that the feed conversion was better for those fed silage diets than those fed control diet. Fermented fish silage was incorporated in broiler diets with bran and barley

(Hammoumi *et al.*, 1998) which gave a net increase in broiler weight relative to that of control diet. Kjos *et al.* (2000) reported that chicks fed diets containing fish silage had greater weight gain, greater feed intake and lower feed to gain ratio.

Ahmed and Mahendrakar (1996) conducted an experiment in which 25 and 50 per cent of fishmeal was replaced with fish silage in broilers diets. Feed intake and growth of silage fed birds were reduced when compared to that of control. They suggested that a level less than or equal to 50 per cent fishmeal in broiler diets could be replaced with fish viscera silage.

Magana *et al.* (1999) found that fish silage dried with sorghum (70:30) could be successfully included in broiler starter diets up to 15 per cent level without any adverse effects.

2.7.3 Layers

Krogdahl (1985a) found that chicks fed 20 per cent of the protein from concentrated fish viscera silage showed significantly higher weight gain than those fed the reference diet with higher level of protein. Similar tendencies were observed when chicks were fed low protein diets. Total egg production and laying rate by hens fed fish viscera diets were as high as those fed the reference diet.

Egg production, egg weight and size were not affected when a basal diet containing 14 per cent vegetable protein was supplemented with fish silage (Khan *et al.*, 1997). Similarly, Kjos *et al.* (2001) reported that fish silage did not affect the food intake, egg production, fatty acid composition of yolk, yolk colour or sensory quality of eggs from hens fed a control diet, or one of four diets containing 50 g/kg fish silage and different levels of fish fat. The diets with 16.8 and 24.8 g/kg fish fat decreased the feed intake, egg production and hen day egg production, but increased yolk colour index. There was a linear relationship between dietary fish fat level and increased off-taste intensity of egg yolk.

2.7.4 Ducks

The performance of ducks fed viscera silage was high and silage influenced the total impression of the sensory quality of duck meat favourably (Krogdahl, 1985b). Higher daily weight gain and growth rate were achieved by Cherry Valley ducks than Aigamo crossbred ducks when fed a commercial grower ration and lucerne meal mixture (90:10) and an experimental diet containing barley based feed, tofu cake and fish silage in the ratio of 70:20:10 during fattening period which indicated the breed difference and better adaptability to tofu cake and fish silage (Barroga *et al.*, 2000).

2.8 OTHER SEAFOOD WASTES

2.8.1 Pig Ration

Krokhina and Antonov (1983) reported that krill meal did not lower the feed intake, but helped to achieve very high average daily body weight gain in growing pigs. They suggested that krill meal could replace up to 50 per cent of the fishmeal protein when fishmeal was the single high protein source for growing pigs.

For grower pigs, body weight gain per day were similar among the treatment diets containing 0, 5, 10 and 15 per cent crab meal, while feed consumed per day and feed to gain ratio by pigs fed 10 and 5 per cent crab meal diets were lower. Average daily gain by pigs fed 0 per cent crab meal diet was higher than those fed crab meal at 10 and 15 per cent (Anderson and Lunen, 1986).

Mohan and Sivaraman (1993) found significantly lower growth rate, dry matter consumption and feed efficiency when pigs fed diets containing dried prawn waste replacing 50 and 100 per cent of animal protein from unsalted dried fish.

Wohlt *et al.* (1994) reported that growth rate was similar in pigs from 18 kg to market weight (92 kg) when soyabean meal or clam viscera were fed as protein supplements.

2.9 APPARENT DIGESTIBILITY OF NUTRIENTS

2.9.1 Digestibility Measurements by Indicator Method

Kohler *et al.* (1990) used chromic oxide and titanium oxide as solid phase markers and Co-EDTA as liquid phase marker in pigs. The recovery rate of markers depended on fibre content of diets and marker recoveries were lowered in the pectin and fibre rich diet. Moughan *et al.* (1991) observed that total faecal collection gave higher apparent digestibility coefficient than those calculated by reference to chromic oxide for dry matter, organic matter and gross energy, but there were no differences in nutrient digestibilities determined by total collection and by using acid insoluble ash as marker.

The most appropriate inert marker for the determination of ileal and faecal apparent digestibility in pigs was titanium dioxide added at the level of 1 g/kg feed (Jagger *et al.*, 1992).

Saha and Gilbreath (1993) developed a modified chromic oxide indicator ratio technique for accurate determination of nutrient digestibility. The method considered analytical chromium recovery in diets and faeces and faecal recovery of dietary chromium when used as a marker.

The indicator most commonly added to feed to determine the digestibility coefficient of nutrients was chromium in the form of chromic oxide (McDonald *et al.*, 1995; Reddy, 2001). Hill *et al.* (1996) stated that the ileal recovery of chromic oxide was almost complete (94 per cent) and was greater than faecal recovery (87 per cent). Kemme *et al.* (1996) concluded that there were only small differences in the apparent total tract digestibility of phosphorus and calcium between the chromic oxide marker method and quantitative collection method.

Titgemeyer *et al.* (2001) reported that the faecal recovery of titanium dioxide (TiO_2) averaged 90 per cent, whereas that of chromic oxide (Cr_2O_3) averaged 98 per cent when steers were fed corn based diet *ad libtium*. Digestibilties calculated with reference to TiO_2 were under estimated by 1.6 to 4.3 percentage units, whereas those calculated with reference to Cr_2O_3 were not different from those based on total faecal collections.

Schiavon *et al.* (1996) suggested that seven days adaptation and four days collection were sufficient to obtain constant digestibility coefficients for organic nutrients when chromic oxide was used as an external indicator for determining apparent digestibility in pigs. Garcia *et al.* (1999) used microwave digestion and atomic absorption spectrophotometer to determine chromic oxide as a digestibility marker in feed, faeces and ileal content.

2.9.2 Digestibility of Fish Silage and Other Seafood Wastes

Growing pigs were fed diets containing either 25 per cent deoiled herring silage or 25 per cent fishmeal on dry matter basis and the efficiency of retention of digested nitrogen was 0.42 and 0.37, respectively (Whittemore and Taylor, 1976). The digestible energy and nitrogen were also higher for diets containing fish silage.

Strom and Eggum (1981) observed that the digestibility of the fish viscera silage protein was generally high and no difference in digestibility could be detected before or after autolysis. Tibbetts *et al.* (1981) observed no difference in the digestibility of any of the nutrients of diets containing fishmeal or 6 per cent fish silage in growing-finishing pigs.

Krogdahl (1985a) reported that the digestibility of amino acids of fish viscera silage was higher in hen than chicks except for arginine. Tryptophan digestibility was low in both hen and chicks. True digestibility of nitrogen was 88 and 95 per cent for fish viscera silage and concentrated fish visceral silage, respectively.

Inclusion of scallop viscera silage at a level of 24 per cent in the diet had no effect on apparent dry matter or energy digestibility of either grower or finisher diets of pigs. Digestible protein of fish viscera silage in grower diet was found to be slightly higher than that of the grower diet without viscera silage, but for finisher diets no difference in protein digestibility was noted (Myer *et al.*, 1990). Mohan and Sivaraman (1993) also reported lower crude protein digestibility when dried prawn waste replaced unsalted dried fish in the diets of growing pigs.

Ngoan *et al.* (2001) observed that the apparent organic matter and crude protein digestibilities were significantly higher for the fishmeal diet than those containing shrimp byproduct ensiled with molasses or cassava root meal in growing-finishing pigs. Although crude protein digestibility of shrimp byproduct ensiled with molasses or cassava root meal was similar, nitrogen retention was lowest for diets containing shrimp byproduct ensiled with molasses when compared to the diets containing fishmeal or that containing shrimp byproduct ensiled with cassava root meal.

Phiny and Rodriguez (2001) found that there were no effect of the different proportions of the additives (palm syrup and chopped fresh cassava root) on the apparent digestibilities of dry matter and nitrogen or on nitrogen retention, when fresh water fish silage was fed as a supplement to dilute (40 Brix) sugar palm syrup in the ratio of 64:36 (fresh basis) to MongCai pigs.

Madhukumar (2002) recorded higher digestibility coefficient of nutrients when 25 per cent of total dietary protein was from cooked prawn waste than the 0 and 50 per cent from prawn waste in diets of growing-finishing pigs.

2.10 CARCASS CHARACTERISTICS

2.10.1 Influence of Energy on Carcass Characteristics

Ranjhan *et al.* (1972) reported that the restriction of energy after 50 kg body weight reduced the fat deposition in pigs. Carcass of pigs fed low energy diet had lower carcass weight and fat but more marbling, whereas carcass of pigs fed high energy diet had higher fat content (Talley *et al.*, 1976). Cromwell *et al.* (1978) found that the carcass fat was less in pigs fed low energy diets compared with those fed high energy diets during growing-finishing period.

Seerley *et al.* (1978) observed that pigs fed low energy diets had less back fat, longer carcasses, lower dressing percentage and higher percentage of loin and primal cuts. Campbell *et al.* (1985) found that the body fat content increased at a decreased rate with increase in energy intake up to 33 MJ, DE per day and at an increased rate with further increase in energy intake.

Rekha (2001) reported that the body weight at slaughter and dressed weight without head were improved as the energy content of the ration was increased. However, dressing percentage, carcass length and back fat thickness were not significantly influenced by the energy content of the ration in growing-finishing pigs.

2.10.2 Influence of Protein on Carcass Characteristics

Baird *et al.* (1975) observed that high protein diets significantly improved the carcass leanness and resulted in significantly higher cooler shrinkage in pigs. Irvin *et al.* (1975) observed that the protein level did not affect the longissimus muscle area or percentage of lean cuts. However, the percentage of lean cuts was lower for the 12 per cent crude protein treatment than 14, 16 and 18 per cent crude protein during growing-finishing period.

Cromwell *et al.* (1978) observed that longissimus area and lean cut yield were influenced by protein level, the response being quadratic during growing-finishing periods. Intramuscular fat content of the longissimus was highest in pigs fed the low protein diet and was decreased as dietary protein level was increased to 16 and 20 per cent.

The protein source did not significantly affect the dressing percentage or back fat thickness in growing-finishing swine (Seerley *et al.*, 1978).

Campbell *et al.* (1984) reported that the body fat content at 90 kg body weight decreased when dietary crude protein was increased up to 210 and 164 g/kg at lower and higher level of feeding, respectively.

2.10.3 Influence of Energy Protein Ratio on Carcass Characteristics

Ramachandran (1977) reported that variation in dietary energy and protein levels in the rations of pigs did not have any effect on carcass traits. Similarly, Sivaraman and Mercy (1986) reported that there were no significant differences in the carcass parameters studied when pigs were fed different dietary energy and protein levels. However, leaf fat weight of animals in all groups showed a positive correlation with the energy content of the diet.

The leanest carcass were of pigs fed 16.2, 14.4, 12.10 and 11.7 per cent crude protein and 3500, 3300, 3300 and 3300 kcal DE/kg diet during 10 to 20, 20 to 35, 35 to 60 and 60 to 75 kg body weight periods, respectively and the dressing percentage and carcass length were not influenced to a great extent by the dietary treatments (Sharda and Sagar, 1986).

2.10.4 Influence of Dietary Fibre on Carcass Characteristics

Baird *et al.* (1975) observed that the low fibre diets produced leaner carcass than the high fibre diets which might be due to added fats in the high fibre diet to equate the energy levels.

2.10.5 Influence of Age and Slaughter Weight on Carcass Characteristics

Ranjhan *et al.* (1972) suggested that the slaughter weight could be taken at 70 kg rather than at 90 kg because the feed efficiency was depressed in animals weighing above 70 kg. Similarly, Kumar and Barsaul (1987) reported that the growth performance of pigs were good up to 70 kg body weight, after which there were fluctuations in growth, feed conversion and carcass quality.

Christian *et al.* (1980) found that the heavy slaughter weight group produced carcasses with less ham and loin percentages, larger loin eye area and increased carcass length, back fat thickness and dressing percentage.

Anjaneyulu *et al.* (1984) reported that the yields of head, hot and chilled carcass, dressing percentage, back fat thickness and loin eye area were significantly more in higher age groups, while percentage of ham and the lean cut of carcasses were significantly higher in young animals.

Mishra *et al.* (1992) reported that the carcass traits except dressing percentage and ham weight differed significantly among the pigs slaughtered at 71 to 80, 81 to 90 and above 90 kg body weight. Sivaraman and Mercy (1986) reported that there was significant difference in the back fat thickness, dressing percentage, leaf fat weight, tender loin weight and carcass length of pigs slaughtered at 50, 75 and 90 kg body weight and slaughtering at 75 kg was found to be better in terms of dressing percentage and leaner carcass. Singh *et al.* (1997) reported that weight and age of the animals at slaughter had significantly influenced all the carcass traits in exotic, desi and crossbred pigs except dressing percentage, which was not affected by age.

The overall acceptability of pork was almost uniform in 61 to 100 kg slaughter weight group (Ramaswami *et al.*, 1993). However, the low weight group with 41 to 60 kg slaughter weight recorded a higher overall acceptability score.

2.10.6 Influence of Sex on Carcass Characteristics

Seerley *et al.* (1978) observed that barrows gained faster and had more back fat than gilts, but gilts were longer with larger loin eye area and higher yield of lean cuts than barrows. Barrows grew faster than gilts, but had lower percentage of ham and loin, smaller loin eyes, shorter carcasses, more back fat and increased marbling (Christian *et al.*, 1980). On the other hand, Arora *et al.* (1994) reported that sex of animal did not affect most of the carcass traits except head weight, carcass length and shoulder percentage.

Campbell *et al.* (1985) found that entire males contained less fat and more protein and water in the empty body than females, while Kumar and Barsaul, (1987) reported that the gilts had good carcass quality due to optimum amount of muscle and fat than boar carcass which were leaner with less fat and were suitable only for lean meat preparations. Singh *et al.* (1997) reported that sex had no effect on any of the carcass traits and there was no interaction between sex and genetic group on carcass traits except dressing percentage in exotic, desi and crossbred pigs.

2.10.7 Influence of Breed and Genetic Group on Carcass Characteristics

Irvin *et al.* (1975) reported that the crossbred pigs deposited fat more rapidly than purebreds in both back fat layers during the first 42 days of growing period, but had similar rates of deposition during finishing phase. Increased protein level resulted in decreased back fat and increased lean for straightbreds but did not affect back fat thickness in crossbreds.

The lean cross (L-cross) pigs had higher average daily gain, lower marbling and colour scores, less back fat, longer carcasses, larger loin eye area and ham and loin percentages than did average pigs (A-cross) (Christian *et al.*, 1980).

Rao *et al.* (1992) observed that the loin eye area in indigenous pigs was lower than that of crossbred pigs, while back fat thickness in indigenous as well as half-bred was higher than that of the 75 per cent crosses. Arora *et al.* (1994) observed that genetic group had non-significant effect on all of the carcass traits except loin eye area. On the other hand, Singh *et al.* (1997) reported that genetic group had significant influence on all the carcass traits except back fat thickness in exotic, desi and crossbred pigs.

The slaughter weight, hot carcass weight, dressing percentage, ham, loin, bacon and picnic cuts and back fat thickness were significantly higher in Hampshire pigs followed by Large White Yorkshire and Naga local pigs (Rohilla *et al.*, 2000).

2.10.8 Influence of Feed Processing on Carcass Characteristics

Back fat was thicker in pigs fed dry mash than in pigs fed extruded dry pellet in Large White Yorkshire pig (Chae *et al.*, 1997). Carcass characteristics such as dressing percentage, carcass length, back fat thickness and loin eye area were not influenced by the particle size of maize in the diet of growing-finishing pigs (Vasudevan, 2000).

2.10.9 Effect of Fish Silage on Carcass Characteristics

Luscombe (1973) found that the fish silage had no adverse effect on the carcass and no difference was observed between treatments containing fishmeal or for both fishmeal and soyabean meal or fish silage for length, shoulder fat, loin and back fat measurements.

Hillyer *et al.* (1976) found no significant differences in killing out percentage and back fat thickness among the groups of pigs fed 15 per cent or 7.5 per cent deoiled herring silage or a control diet. Similar results were also reported by Tibbetts *et al.* (1981), Batterham *et al.* (1983), Green *et al.* (1988), Ottati and Bello (1990b), Avdalov *et al.* (1993) and Mantra (2000). Myer *et al.* (1990) also reported similar results when scallop viscera silage was added at 24 per cent in the diets of growing-finishing pigs. Kjos *et al.* (1999) also could not observe any significant difference in carcass characteristics when growing-finishing pigs were fed either a control diet or one of three diets containing 50 g/kg fish silage and different levels of fish fat.

Smith (1976) conducted a taste panel study and found no effect on smell or flavour in pork when fed a control diet containing white fishmeal and treatment diets containing liquefied white fish protein or liquefied herring protein. But liquefied herring protein diet produced a yellow discolouration of fat and acceptable flavour.

Carcass quality of pigs was not affected when the liquid white fish protein was fed at a level of 10.3 per cent of the dry matter, but a taint could be detected when liquid herring protein was added at 5.1 or 13.7 per cent of the dry matter of the diet (Smith and Adamson, 1976).

Wignall and Tatterson (1976) suggested that the oil content of the silage must be reduced to less than 2 per cent to avoid the possibility of taint in meat, when the silage was fed to animals at a significant level. Smith (1977) reported that when fish silage with low oil content was used, it could be included at 10 per cent of dry matter in the diet of growing-finishing pigs without any negative effect on carcass quality. However, herring silage fed at the same rate produced unacceptable carcass.

Green *et al.* (1983) suggested that the foreign flavours might be avoided by removing fish oil from the finishing pig's diet at about 20 kg before slaughter. Similarly, Lunen *et al.* (1988) observed that there were no fishy off-flavours detected in any sample and differences between 0, 10, 20 and 40 days withdrawal from 10 per cent fish silage diet in pigs for other off-flavours in the fresh pork were not significant. They recommended a 20 days withdrawal period prior to slaughter when including fish silage at 10 per cent of dry matter in growing-finishing swine diets. Similar results were also reported by Gambaro *et al.* (1996).

Back fat thickness was 2.38, 1.96, 2.25 and 1.79 cm when pigs were fed diets containing sorghum and maize meals without or with 2.5 or 5.0 per cent microbial fish silage or a commercial feed (Ottati and Bello, 1990a).

Oeckel and Boucque (1992) suggested that pig diet should not contain more than 100 to 125 g of fishmeal or 250 to 300 g of fish silage daily to avoid poor fat and meat characteristics and they stated that problems may also be reduced by withdrawing fish oil from the diet a few weeks before slaughter. Urbanczyk *et al.* (1997) observed that the optimum level of dietary fish silage ranged from 0.5 to 1.0 kg/head daily. The higher levels had an adverse effect on finishing results and organoleptic properties of meat.

2.10.10 Effect of Other Seafood Wastes on Carcass Characteristics

Carcass index was significantly better in pigs fed diet containing 15 per cent crab meal than in pigs fed 5 per cent crab meal diet and pigs fed diet containing 15 per cent crab meal diet had less back fat thickness than those fed diets containing either zero or five per cent crab meal (Anderson and Lunen, 1986).

Mohan and Sivaraman (1993) reported that the carcass characteristics such as dressing percentage, half carcass weight, carcass length, back fat thickness and eye muscle area were adversely affected in pigs fed diets containing dried prawn waste.

Wohlt *et al.* (1994) reported that cooked loin roasts from pigs fed one half or all supplemental protein from sea clam viscera (5 or 10 per cent viscera in diet dry matter) had distinctive fish aromas.

Carcass characteristics such as dressing percentage, carcass length, back fat thickness, loin eye area and ham weight were not significantly influenced by the inclusion of prawn waste at 10 and 19.5 per cent of the diet in the growing-finishing pigs (Madhukumar, 2002).

2.11 ECONOMICS OF GAIN

Ologhobo *et al.* (1988) reported the cost of feed (per kg diet or per kg body weight gain) was only slightly reduced with replacement of fishmeal by fish silage.

Materials and Methods

3. MATERIALS AND METHODS

3.1 EXPERIMENTAL MATERIALS

3.1.1 Experimental Animals

Fifteen male and fifteen female weaned crossbred (Large White Yorkshire x Desi, 50 per cent) piglets with an average body weight of 13.5 kg belonging to the University Pig Breeding Farm, Mannuthy were used as experimental animals. Male animals were castrated and all the animals were dewormed using fenbendazole at the rate of 10 mg/kg body weight one week before the commencement of the experiment.

3.1.2 Experimental Diets

The experimental rations consisted of grower rations containing 18 per cent crude protein and 3200 kcal of digestible energy per kg and finisher rations containing 14 per cent crude protein and 3100 kcal of digestible energy per kg. For each period the following three isonitrogenous and isocaloric diets were formulated.

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

T_2 – 50 per cent of crude protein from unsalted dried fish was replaced with dried cuttle fish waste silage.

T_3 – 100 per cent of crude protein from unsalted dried fish was replaced with dried cuttle fish waste silage.

The ingredient composition of grower and finisher rations are given in Tables 1and 2, respectively.

3.1.3 Dried Cuttle Fish Waste Silage

Dried cuttle fish waste silage was obtained from Central Institute of Fisheries Technology (CIFT), Cochin under the National Agricultural Technology Project (NATP).

3.1.3.1 Preparation Method

From the cuttle fish processing waste (consisting of skin and viscera) bone and other foreign materials were separated and commercial grade formic acid was added at the rate of 3 per cent (v/w) of the waste. It was mixed thoroughly and the pH was kept below 4. Liquefaction of silage was attained in 4 to 7 days depending upon the environmental temperature and nature of the raw material. This liquid silage was mixed with rice bran in the ratio of 2:1 and dried under the sunlight.

3.2 EXPERIMENTAL METHODS

3.2.1 Experimental Design

The piglets were divided into three homogeneous groups of ten piglets in each with regard to age, sex and body weight. The animals of each group were randomly allotted to five pens with two in each, forming five replicates for each treatment. The three groups of animals were allotted to three dietary treatments T_1, T_2 and T_3 randomly.

3.2.2 Housing and Management

Each replicate was housed in a separate pen and all the animals were maintained under identical conditions of management throughout the experimental period of 152 days. The piglets in each pen were group fed and restricted feeding was followed throughout the experimental period. Animals were fed twice daily as part of the ration was fed in the morning (8.30 AM) and remaining part in the evening (4.00 PM) and were allowed to consume as much feed as they could, within a period of one hour. Balance of feed was collected and weighed before the next time feeding. Clean drinking water was provided in all the pens for 24 hours throughout the experimental period. All the animals were dewormed during the tenth week of the experiment.

3.2.3 Feeding Trial

Piglets of the three groups were fed their respective grower ration until they attained an average body weight of 50 kg and thereafter changed to finisher ration until the animals were slaughtered. The quantity of feed given was increased every fortnight according to their requirement. Records of daily feed intake and fortnightly body weight were maintained throughout the experimental period.

3.2.4 Digestibility Trial

A digestibility trial was conducted towards the end of the experiment to determine the digestibility coefficient of nutrients of the experimental diets. Chromic oxide (Cr_2O_3) was added at 0.05 per cent to each experimental diet as external indicator for finding the digestibility coefficient of nutrients. Chromic oxide was premixed with small quantity of feed and then it was mixed with the already mixed feed in a vertical mixer for 15 minutes to ensure proper mixing.

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

Faecal grab samples uncontaminated with urine, feed or dirt were collected from different places of each pen at 10.00, 15.00 and 22.00 hours during the collection period of three days. Feed samples were also collected daily from each pen during the collection period of three days. Feed and faecal samples collected each day were placed in double lined polythene bags, sealed air tight and stored in the deep freezer for analysis.

The feed and faecal samples collected for three days for each animal were pooled, mixed thoroughly and sub samples were taken for proximate analysis. The digestibility coefficient of nutrients was calculated using appropriate formulae (Maynard *et al.*, 1979; McDonald *et al.*, 1995).

3.2.5 Chemical Analysis

Dried cuttle fish waste silage, feed and faecal samples were analysed for the proximate composition as per methods described in Association of Official Analytical Chemists (AOAC, 1990). One gram of dried feed, faecal and dried cuttle fish waste silage samples were digested with 10 ml of nitric acid and 5 ml of perchloric acid and made up to 100 ml. Chromium content of the feed and faecal samples and calcium, magnesium, iron, manganese, zinc, copper and cobalt content of the dried cuttle fish waste silage were analysed using Atomic Absorption Spectrophotometer (Perkin-Elmer Model 3110). Phosphorus content of the dried cuttle fish waste samples were analysed by colorimetric method using Spectrophotometer (Spectronic 1001 Plus, MiltonRoy, USA).

3.2.6 Slaughter Studies

At the end of the experimental period of five months, six animals from each treatment were selected randomly and were slaughtered at Department of Livestock Products Technology, Mannuthy to study the carcass characteristics and dressing percentage.

The length of the carcass was measured from the anterior edge of the aitch bone (os-sacrum) to the anterior edge of the first rib. The back fat thickness was estimated as an average of the measurements of subcutaneous fat with skin at the level of the first rib, last rib and last lumbar vertebra. The loin eye area or the area of longissimus dorsi muscle at the tenth intercostal space was cut and traced on a transparent paper and the area was measured. Deboned meat and bone from each carcass were weighed to find out meat bone ratio.

3.2.7 Economics of Gain

Economics of gain, when dried cuttle fish waste silage replaced unsalted dried fish in the ration of pigs was calculated by taking account of feed cost.

3.2.8 Statistical Analysis

Data on body weight of pigs maintained on the three dietary treatments were analysed by covariance analysis using MSTATC. For other parameters such as fortnightly cumulative average daily gain, fortnightly cumulative feed conversion efficiency, digestibility coefficient of nutrients and carcass characteristics were analysed by Completely Radomised Design (CRD) method as described by Snedecor and Cochran (1985). Means were compared using Least Significant Difference (LSD) test.

Table 1. Ingredient composition of grower rations, %

Ingredients	Grower rations (%)		
	T_1	T_2	T_3
Yellow maize	37.5	39.0	40.5
Rice polish	34.0	27.0	21.0
Soyabean meal	16.0	18.0	19.50
Unsalted dried fish	10.0	5.0	-
Dried cuttle fish waste silage	-	8.5	16.5
Mineral mixture*	2.0	2.0	2.0
Salt	0.5	0.5	0.5
CP % (calculated)	18.14	18.14	18.14
DE kcal. /kg. (calculated)	3256	3256	3234

* Mineral mixture without salt (manufactured by Pristine Nutrition Pvt. Ltd., Bangalore) containing calcium 23.0 %, phosphorus 12.0 %, magnesium 6.5 %, iron 0.5 %, sulphur 0.5 %, zinc 0.38 %, manganese 0.12 %, copper 0.077 %, iodine 0.028 %, cobalt 0.012 %, moisture 5 %, fluorine 0.075 % and acid insoluble ash 2.5 %.

Indomix – A, B_2, D_3 (Nicholas Primal India Ltd., Mumbai) containing vitamin A 40,000 IU, vitamin B_2 20 mg and vitamin D_3 5000 IU per gram was added @ 25 g per 100 kg of feed.

Rovi– BE (Roche Products Ltd., Derbyshire, UK.) containing vitamin B_1 4 mg, vitamin B_6 8 mg, vitamin B_{12} 40 mcg, vitamin E 40 mg, niacin 60 mg and pantothenic acid 40 mg per gram was added @ 25 g per 100 kg of feed.

Table 2. Ingredient composition of finisher rations, %

Ingredients	Finisher rations (%)		
	T_1	T_2	T_3
Yellow maize	41.5	43.5	45.5
Wheat bran	40.5	32.5	24.5
Soyabean meal	5.5	7.0	8.5
Unsalted dried fish	10.0	5.0	-
Dried cuttle fish waste silage	-	9.5	19.0
Mineral mixture*	2.0	2.0	2.0
Salt	0.5	0.5	0.5
CP % (calculated)	14.03	14.05	14.08
DE kcal. /kg. (calculated)	3126	3126	3126

* Mineral mixture without salt (manufactured by Pristine Nutrition Pvt. Ltd., Bangalore) containing calcium 23.0 %, phosphorus 12.0 %, magnesium 6.5 %, iron 0.5 %, sulphur 0.5 %, zinc 0.38 %, manganese 0.12 %, copper 0.077 %, iodine 0.028 %, cobalt 0.012 %, moisture 5 %, fluorine 0.075 % and acid insoluble ash 2.5 %.

Indomix – A, B_2, D_3 (Nicholas Primal India Ltd., Mumbai) containing vitamin A 40,000 IU, vitamin B_2 20 mg and vitamin D_3 5000 IU per gram was added @ 25 g per 100 kg of feed.

Rovi – BE (Roche Products Ltd., Derbyshire, UK) containing vitamin B_1 4 mg, vitamin B_6 8 mg, vitamin B_{12} 40 mcg, vitamin E 40 mg, niacin 60 mg and pantothenic acid 40 mg per gram was added @ 25 g per 100 kg of feed.

Results

4. RESULTS

4.1 CHEMICAL COMPOSITION

The chemical composition of the grower and finisher diets are presented in Tables 3 and 4, respectively.

The chemical composition of six samples of dried cuttle fish waste silage was estimated and is presented in Table 5. Crude protein, ether extract, crude fibre, total ash and nitrogen free extract content of the dried cuttle fish waste silage varied from 23.65 to 26.75, 2.0 to 3.5, 13.60 to 15.90, 16.5 to 18.50 and 37.53 to 41.35 per cent, respectively.

4.1.1 Mineral Content of Dried Cuttle Fish Waste Silage

Average mineral content such as Ca, P, Mg, Fe Mn, Zn, Cu and Co of dried cuttle fish waste silage is given in Table 6.

4.2 LIVE WEIGHT GAIN AND FEED CONVERSION EFFICIENCY

The mean fortnightly body weight of pigs maintained on three dietary treatments T_1, T_2 and T_3 are presented in Table 7 and is graphically represented in Fig.1. The data on fortnightly cumulative average daily gain and feed conversion efficiency of experimental animals are shown in Tables 8 and 9, respectively. Data on cumulative average daily gain and feed conversion efficiency of animals of the three dietary treatments are graphically represented in Fig. 2 and 3, respectively. The total body weight gain of animals belonging to the groups T_1, T_2 and T_3 were 55.93, 53.33 and 55.10 kg, respectively (Table 13).

4.3 APPARENT DIGESTIBILITY COEFFICIENT OF NUTRIENTS

The chemical composition and the chromium content of faeces of pigs fed three experimental diets are presented in Table 10. Chromium content of the three experimental diets T_1, T_2 and T_3 were 0.033, 0.032, 0.032 per cent, respectively. Data on average digestibility coefficient of nutrients of the three experimental diets T_1, T_2 and T_3 are presented in Table 11 and are graphically represented in Fig. 4. The digestibility coefficient of nutrients of the diets T_1, T_2 and T_3 were: 57.46, 55.77 and 61.37 for dry matter; 68.61, 62.25 and 64.81 for crude protein; 49.25, 40.54 and 44.45 for ether extract; 18.63, 12.39 and 24.60 for crude fibre; 74.17, 73.55 and 75.89 for nitrogen free extract, respectively.

4.4 CARCASS CHARACTERISTICS

Data on carcass characteristics of pigs maintained on the three dietary treatments T_1, T_2 and T_3 are presented in Table 12 and are graphically represented in Fig. 5 to Fig. 9. The average dressing percentage of the experimental animals were 72.28, 71.97 and 72.33, respectively for the treatments T_1, T_2 and T_3 and their meat bone ratios were 4.22:1, 4.52:1 and 4.42:1, respectively.

4.5 ECONOMICS OF GAIN

Cost of feed per kg live weight gain of pigs maintained on the three dietary treatments were Rs.35.15, 34.40 and 32.25 for T_1, T_2 and T_3, respectively and are presented in the Table 13 and Fig. 10.

Table 3. Chemical composition of grower rations*, %

Components	Grower rations (%)		
	T_1	T_2	T_3
Dry matter	87.79 ± 0.15	87.41 ± 0.05	86.81 ± 0.09
Crude protein	18.82 ± 0.12	18.81 ± 0.33	18.90 ± 0.08
Ether extract	5.86 ± 0.40	5.63 ± 0.70	5.43 ± 0.66
Crude fibre	6.94 ± 0.55	6.33 ± 0.06	7.47 ± 0.33
Total ash	14.06 ± 0.05	12.72 ± 0.08	10.83 ± 0.06
Nitrogen free extract	54.32 ± 0.46	56.51 ± 0.87	57.37 ± 0.70
Acid insoluble ash	6.76 ± 0.07	5.32 ± 0.01	4.09 ± 0.06

* On dry matter basis

Table 4. Chemical composition of finisher rations*, %

Components	Finisher rations (%)		
	T_1	T_2	T_3
Dry matter	87.42 ± 0.07	86.87 ± 0.08	86.48 ± 0.04
Crude protein	14.56 ± 0.10	14.58 ± 0.09	14.18 ± 0.08
Ether extract	2.23 ± 0.03	1.97 ± 0.05	1.95 ± 0.08
Crude fibre	12.79 ± 0.12	12.45 ± 0.07	11.90 ± 0.04
Total ash	12.54 ± 0.05	11.44 ± 0.07	10.69 ± 0.06
Nitrogen free extract	57.88 ± 0.18	59.56 ± 0.08	61.28 ± 0.17
Acid insoluble ash	6.71 ± 0.05	5.81 ± 0.09	5.24 ± 0.05

* On dry matter basis and average of ten values

Table 5. Chemical composition of dried cuttle fish waste silage*, %

Components	Cuttle fish waste silage (%)
Dry matter	84.88 ± 0.62
Crude protein	25.32 ± 0.45
Ether extract	2.80 ± 0.24
Crude fibre	15.04 ± 0.35
Total ash	17.38 ± 0.32
Nitrogen free extract	39.46 ± 0.64
Acid insoluble ash	9.83 ± 0.25

* On dry matter basis and average of six values

Table 6. Mineral content of dried cuttle fish waste silage*

Mineral	Cuttle fish waste silage
Calcium (g %)	0.43 ± 0.03
Phosphorus (g %)	1.73 ± 0.03
Magnesium (g %)	1.30 ± 0.02
Iron (mg/kg)	900.16 ± 56.24
Manganese (mg/kg)	223.28 ± 5.80
Zinc (mg/kg)	109.97 ± 3.27
Copper (mg/kg)	26.70 ± 1.39
Cobalt (mg/kg)	18.90 ± 0.20

* On dry matter basis and average of six values

Table 7. Fortnightly average body weight of pigs maintained on three dietary treatments*, kg

Fortnights	Body weight (kg)			P value
	Treatments			
	T_1	T_2	T_3	
0	13.58 ± 0.66	13.58 ± 0.71	13.50 ± 0.45	-
1	18.03 ± 0.96	18.13 ± 1.05	17.73 ± 0.83	- (NS)
2	22.85 ± 1.15	22.45 ± 1.43	22.18 ± 1.02	- (NS)
3	28.40 ± 1.19	27.00 ± 1.90	27.35 ± 1.14	- (NS)
4	34.50 ± 1.11	32.15 ± 2.06	32.25 ± 1.20	0.10 (NS)
5	39.25 ± 1.20	37.00 ± 2.20	37.75 ± 1.33	0.25 (NS)
6	45.05 ± 1.31	42.90 ± 2.35	43.25 ± 1.74	- (NS)
7	51.05 ± 1.45	49.45 ± 2.58	50.00 ± 1.83	- (NS)
8	56.10 ± 1.53	54.75 ± 2.72	55.70 ± 2.15	- (NS)
9	62.50 ± 1.85	60.60 ± 3.10	61.80 ± 2.24	- (NS)
10	69.50 ± 2.49	66.90 ± 3.31	68.60 ± 2.56	- (NS)

* Average of ten values

NS Non-significant

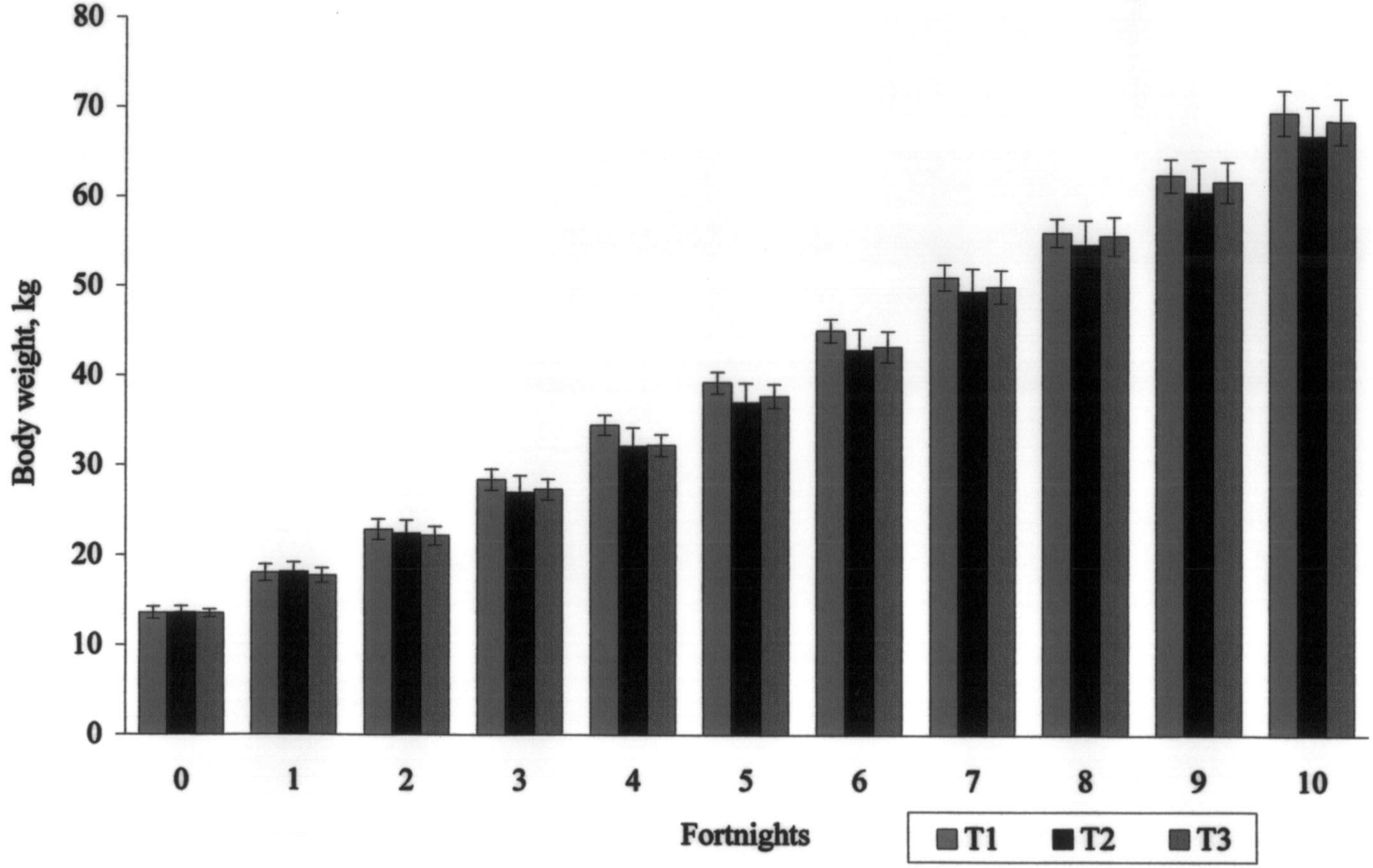

Fig. 1. Fortnightly average body weight of pigs maintained on three dietary treatments

Table 8. Fortnightly cumulative average daily gain of pigs maintained on three dietary treatments*, g

Fortnights	Body weight gain (g)			P value
	Treatments			
	T_1	T_2	T_3	
1	296.67 ± 24.70	303.33 ± 28.95	281.67 ± 30.07	0.86 (NS)
2	309.17 ± 18.53	295.83 ± 27.56	289.17 ± 22.60	0.83 (NS)
3	329.44 ± 13.51	298.33 ± 28.73	307.78 ± 19.11	0.58 (NS)
4	348.75 ± 8.47	309.58 ± 23.95	312.50 ± 16.19	0.23 (NS)
5	342.33 ± 7.89	312.33 ± 21.37	323.33 ± 14.78	0.40 (NS)
6	349.72 ± 8.18	325.83 ± 19.70	330.56 ± 16.78	0.53 (NS)
7	356.90 ± 9.08	341.67 ± 19.45	347.62 ± 15.62	0.78 (NS)
8	354.38 ± 9.19	343.13 ± 18.07	351.67 ± 16.92	0.86 (NS)
9	359.74 ± 10.34	345.77 ± 18.78	355.15 ± 15.71	0.81 (NS)
10	370.31 ± 13.59	353.15 ± 18.50	364.90 ± 15.99	0.75 (NS)

* Average of ten values

NS Non-significant

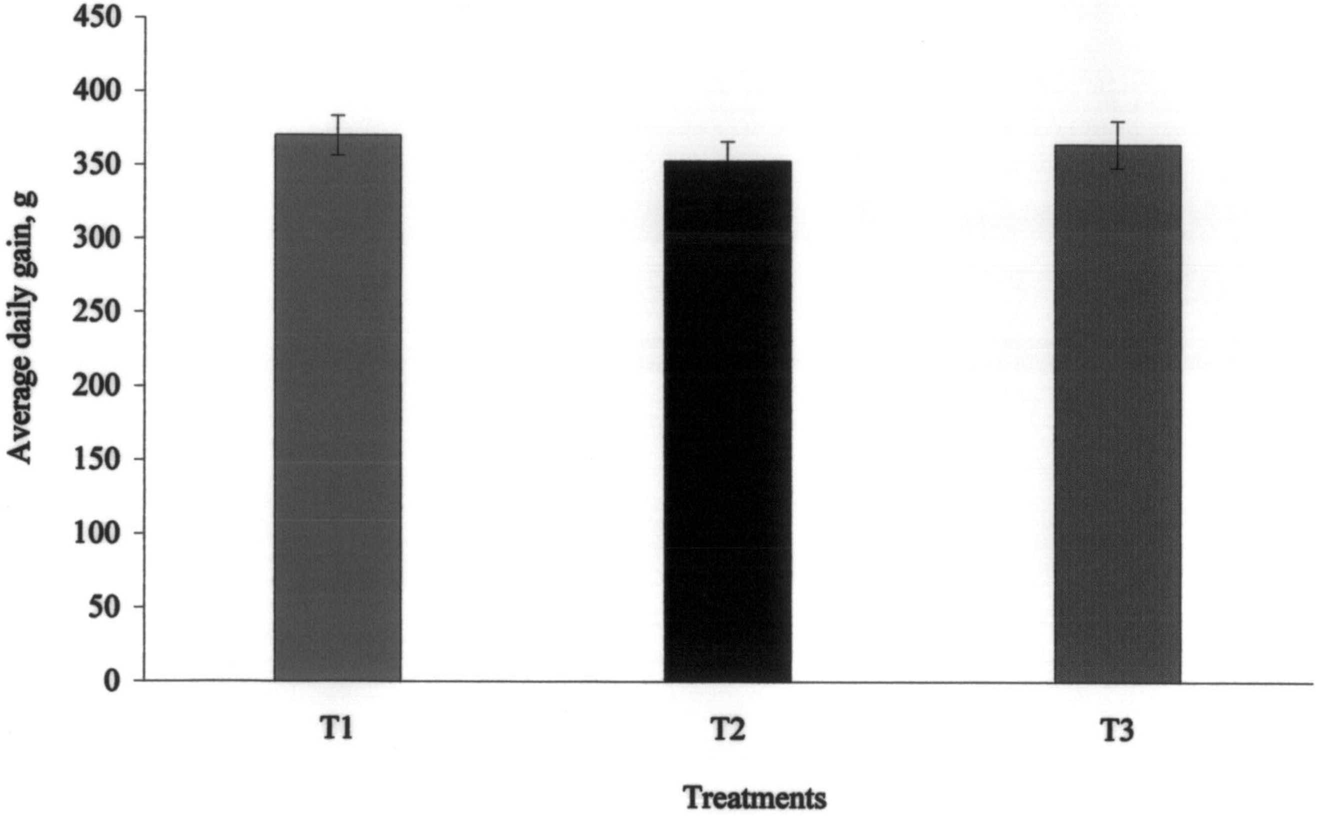

Fig. 2. Cumulative average daily gain of pigs maintained on three dietary treatments

Table 9. Fortnightly cumulative feed conversion efficiency of pigs maintained on three dietary treatments*, kg

Fortnights	Feed per kg gain (kg)			P value
	Treatments			
	T_1	T_2	T_3	
1	3.32 ± 0.13	3.20 ± 0.22	3.45 ± 0.23	0.69 (NS)
2	3.18 ± 0.08	3.25 ± 0.16	3.35 ± 0.20	0.75 (NS)
3	3.19 ± 0.07	3.41 ± 0.21	3.38 ± 0.16	0.58 (NS)
4	3.12 ± 0.05	3.39 ± 0.16	3.46 ± 0.15	0.18 (NS)
5	3.38 ± 0.08	3.58 ± 0.15	3.54 ± 0.07	0.41 (NS)
6	3.50 ± 0.09	3.62 ± 0.12	3.68 ± 0.12	0.51 (NS)
7	3.61 ± 0.08	3.67 ± 0.11	3.70 ± 0.11	0.83 (NS)
8	3.81 ± 0.09	3.85 ± 0.12	3.84 ± 0.11	0.97 (NS)
9	3.95 ± 0.10	4.03 ± 0.13	4.02 ± 0.13	0.88 (NS)
10	4.16 ± 0.16	4.28 ± 0.15	4.26 ± 0.13	0.84 (NS)

* Average of ten values

NS Non-significant

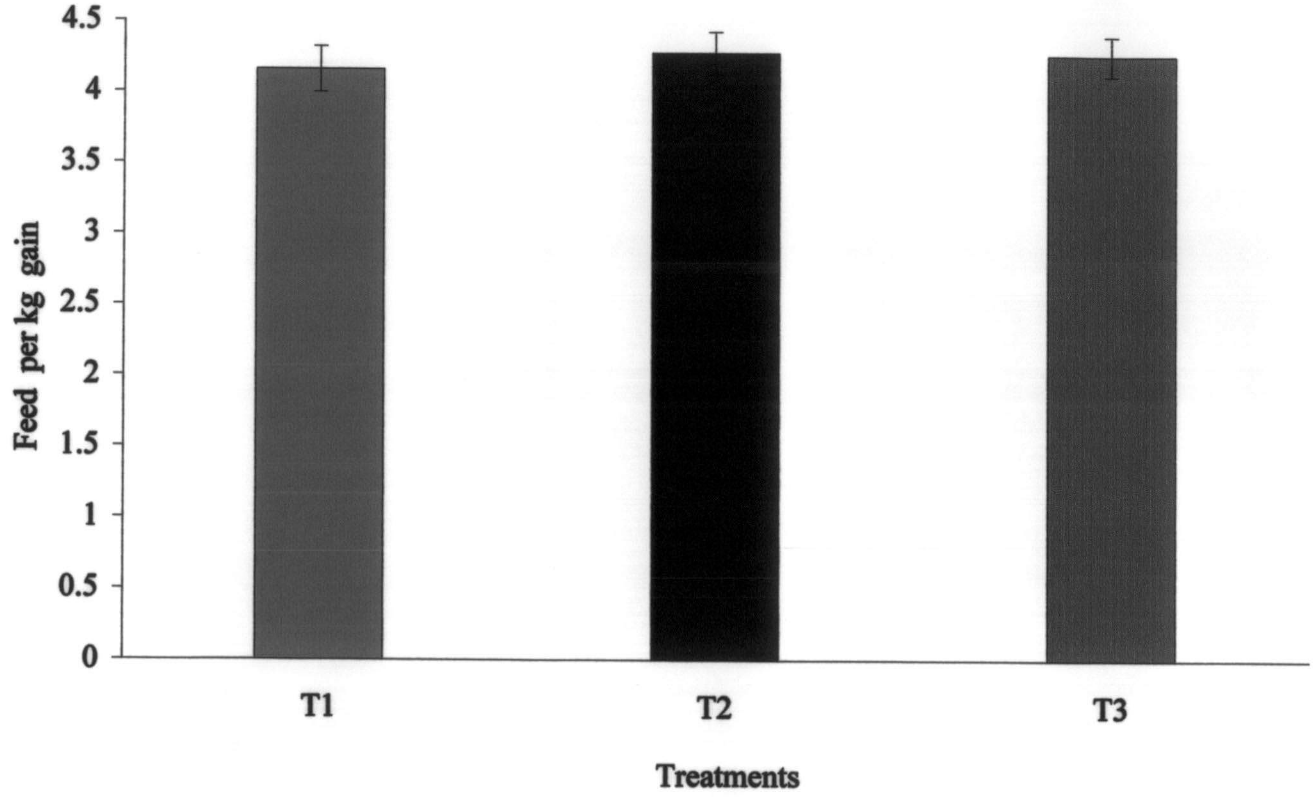

Fig. 3. Cumulative feed conversion efficiency of pigs maintained on three dietary treatments

Table 10. Chemical composition of faeces of pigs maintained on three dietary treatments*, %

Components	Treatments (%)		
	T_1	T_2	T_3
Dry matter	33.13 ± 0.30	33.08 ± 0.46	33.20 ± 0.32
Crude protein	10.79 ± 0.25	12.42 ± 0.24	12.95 ± 0.18
Ether extract	2.68 ± 0.15	2.64 ± 0.15	2.73 ± 0.10
Crude fibre	24.45 ± 0.42	24.69 ± 0.50	23.26 ± 0.44
Total ash	27.04 ± 0.47	24.64 ± 0.23	22.84 ± 0.14
Nitrogen free extract	35.04 ± 0.79	35.61 ± 0.72	38.22 ± 0.64
Acid insoluble ash	16.89 ± 0.30	14.60 ± 0.19	13.08 ± 0.17
Chromium	0.078 ± 0.003	0.073 ± 0.003	0.083 ± 0.003

* On dry matter basis and average of ten values

Table 11. Average digestibility coefficient of nutrients of the experimental diets[$]

Nutrients	Treatments			P value
	T_1	T_2	T_3	
Dry matter*	57.46 ± 1.39^{ab}	55.77 ± 1.76^{a}	61.37 ± 0.97^{b}	0.03
Crude protein**	68.61 ± 0.79^{a}	62.25 ± 1.83^{b}	64.81 ± 0.54^{ab}	0.003
Ether extract	49.25 ± 1.27	40.54 ± 2.89	44.45 ± 3.80	0.12 (NS)
Crude fibre	18.63 ± 4.33	12.39 ± 5.08	24.60 ± 2.32	0.15 (NS)
Nitrogen free extract	74.17 ± 1.74	73.55 ± 1.61	75.89 ± 1.02	0.53 (NS)

NS Non-significant

$ Average of ten values

a, b Means with different superscript within a row differ significantly

* Significant (P< 0.05)

** Significant (P<0.01)

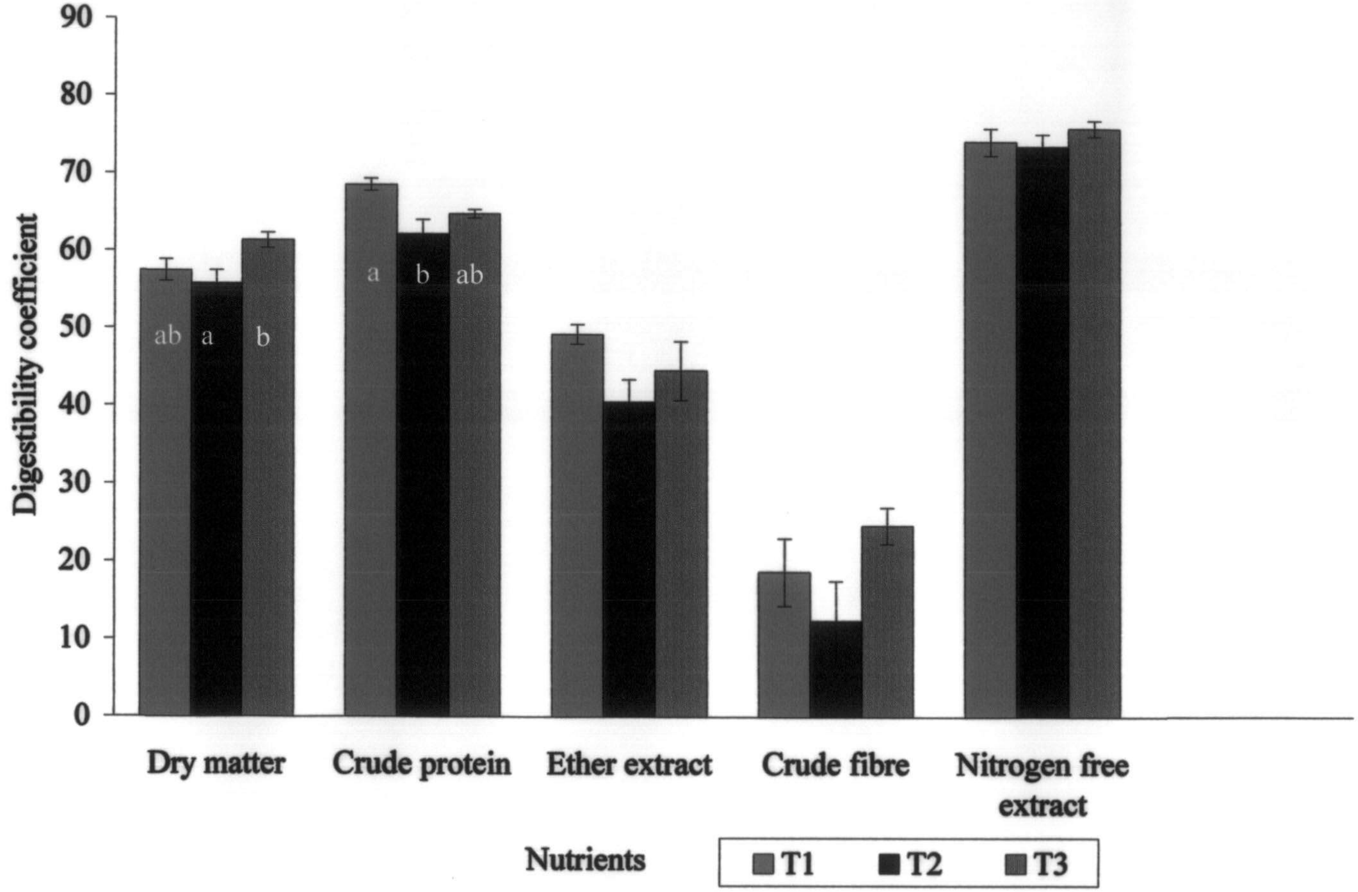

Fig. 4. Average digestibility coefficient of nutrients of the experimental diets

Table 12. Carcass characteristics of pigs maintained on three dietary treatments *

Item	Treatments			P value
	T_1	T_2	T_3	
Live body weight (kg)	66.67 ± 3.14	69.50 ± 3.87	67.00 ± 3.07	0.81 (NS)
Carcass weight (kg)	48.22 ± 2.46	50.12 ± 3.12	48.50 ± 2.48	0.87 (NS)
Dressing percentage	72.28 ± 0.78	71.97 ± 0.64	72.33 ± 0.89	0.94 (NS)
Carcass length (cm)	59.71 ± 1.94	60.92 ± 1.45	60.67 ± 1.01	0.84 (NS)
Back fat thickness (cm)	3.32 ± 0.11	3.07 ± 0.25	3.31 ± 0.13	0.43 (NS)
Loin eye area (cm^2)	24.22 ± 1.52	23.87 ± 1.27	22.40 ± 1.70	0.67 (NS)
Weight of deboned meat (kg)	38.67 ± 2.34	40.50 ± 2.63	39.67 ± 2.03	0.86 (NS)
Meat percentage	57.86 ± 1.26	58.11 ± 0.69	59.20 ± 1.29	0.67 (NS)
Bone weight (kg)	9.13 ± 0.32	8.93 ± 0.31	8.98 ± 0.34	0.90 (NS)
Meat bone ratio	4.22 ± 0.17:1	4.52 ± 0.21:1	4.42 ± 0.14:1	0.50 (NS)

* Average of six values

NS Non-significant

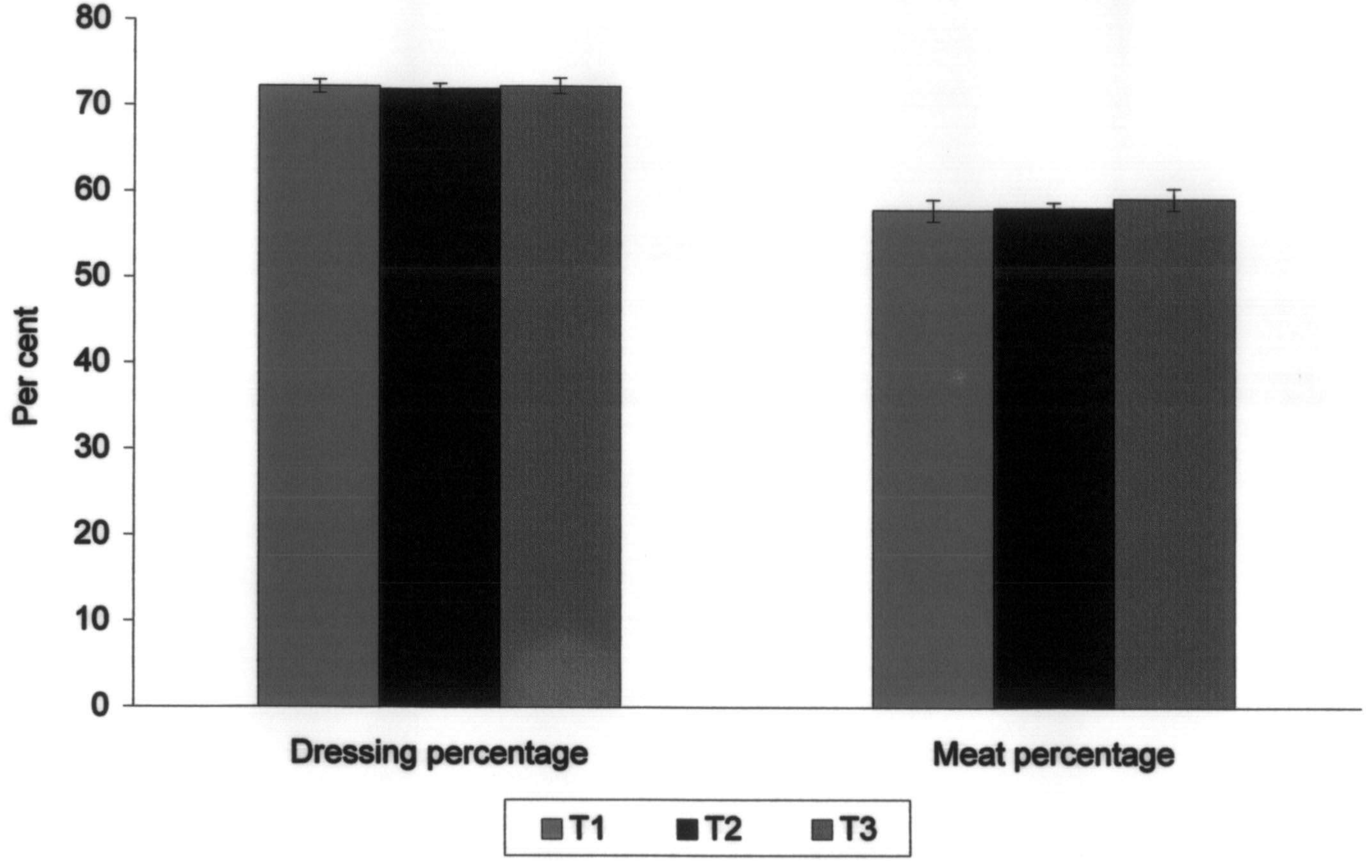

Fig. 5. Dressing and meat percentages of pigs maintained on three dietary treatments

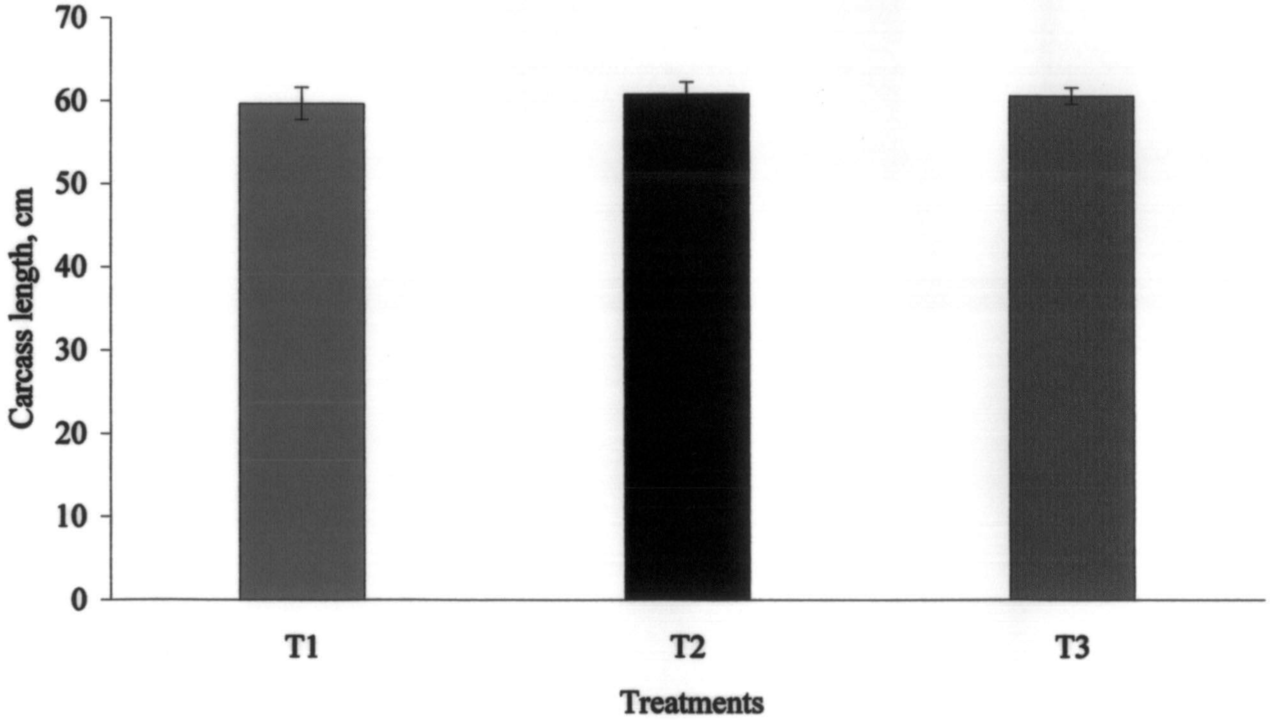

Fig. 6. Carcass length of pigs maintained on three dietary treatments

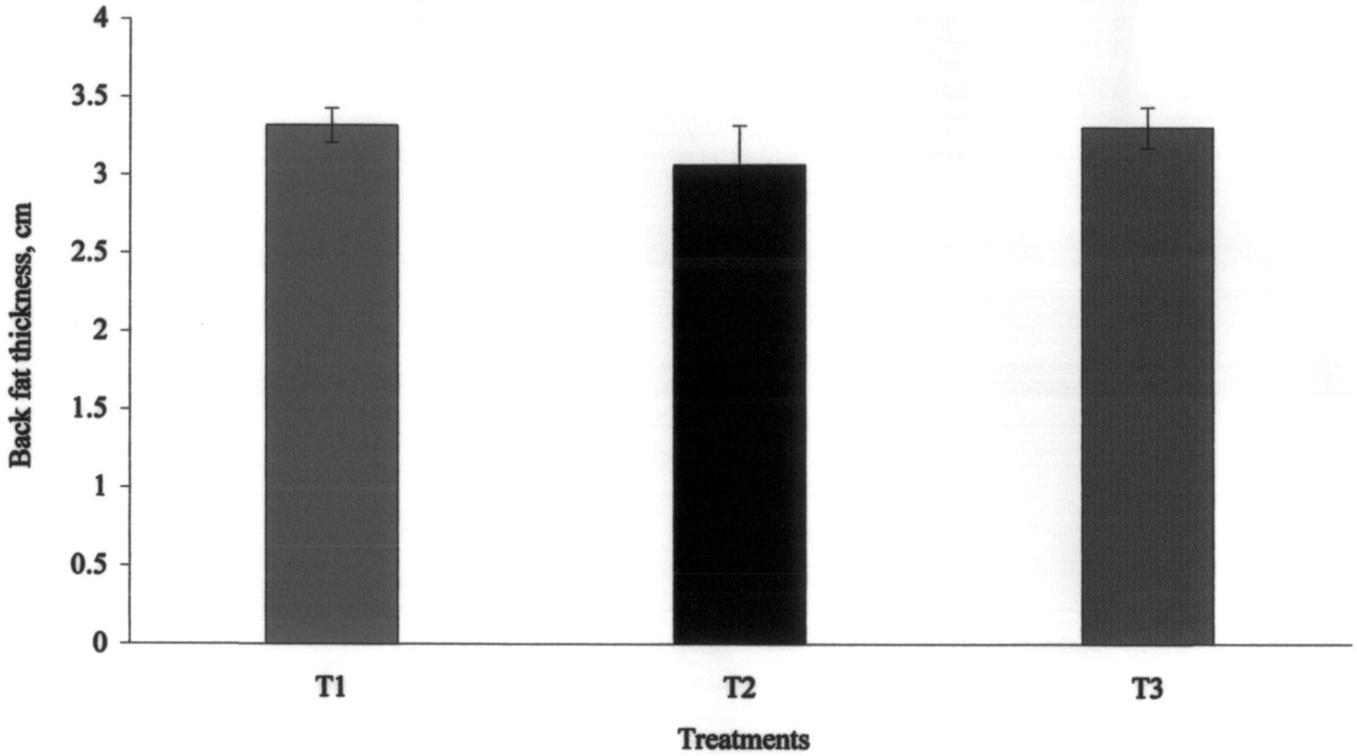

Fig. 7. Back fat thickness of pigs maintained on three dietary treatments

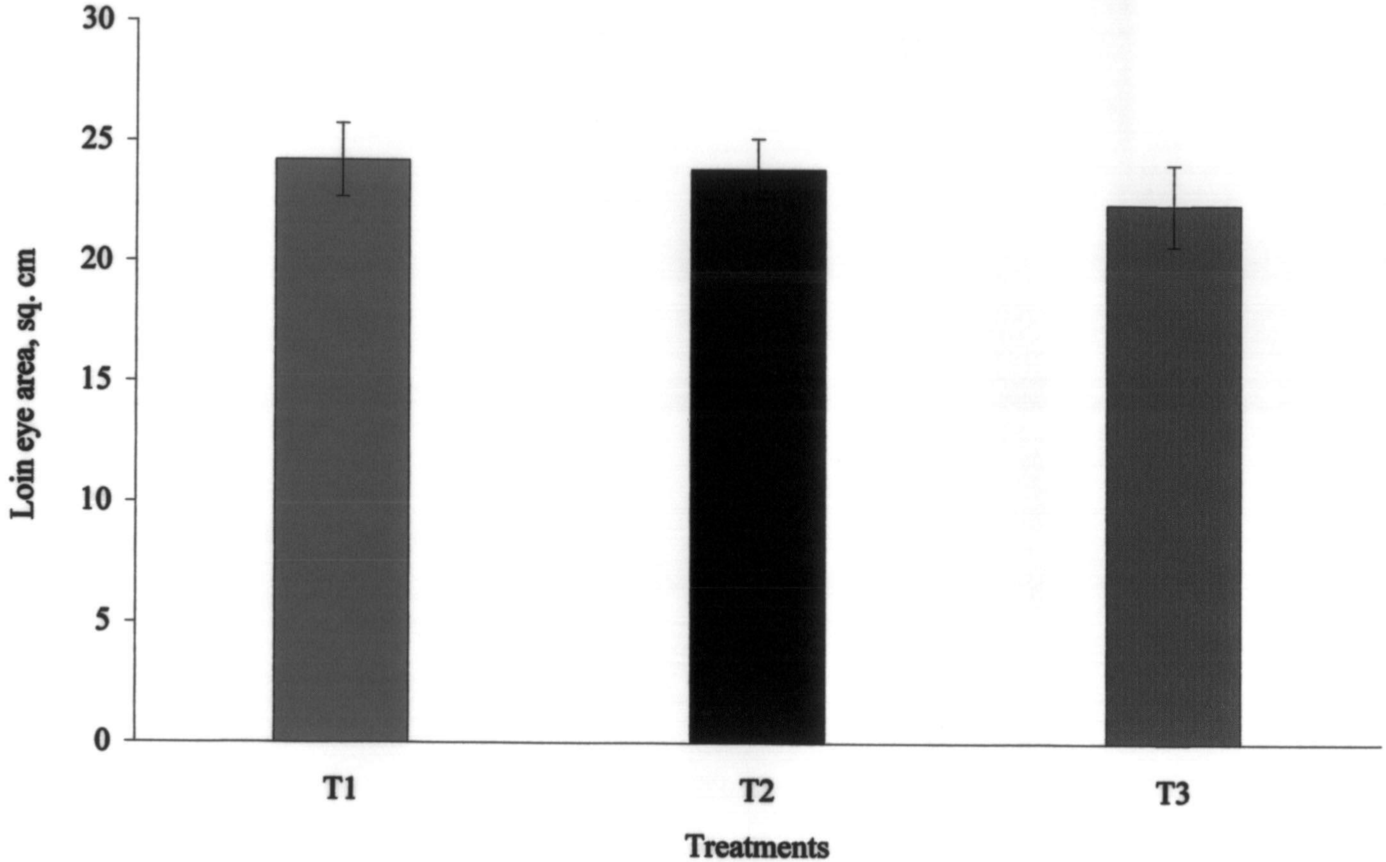

Fig. 8. Loin eye area of pigs maintained on three dietary treatments

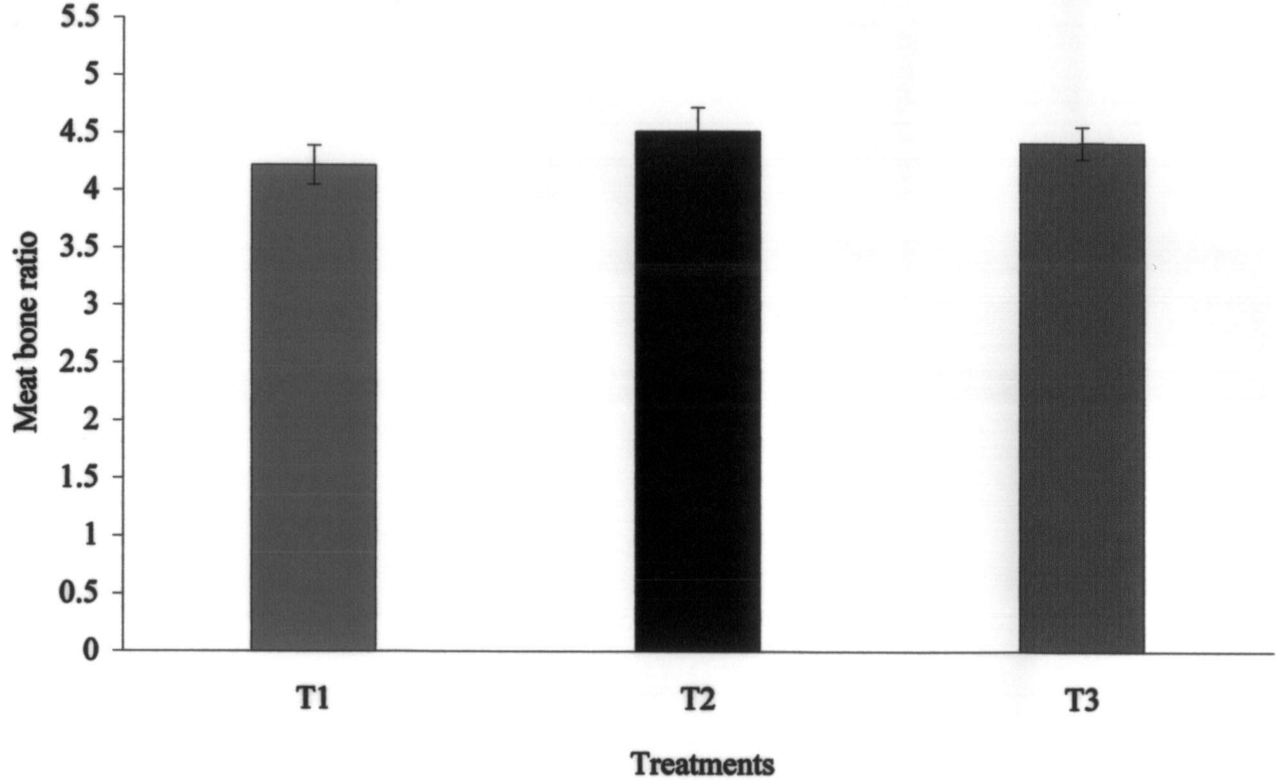

Fig. 9. Meat bone ratio of pigs maintained on three dietary treatments

Table 13. Cost of feed per kg body weight gain of pigs maintained on three dietary treatments

Item	Treatments			P value
	T_1	T_2	T_3	
Total consumption of grower ration (kg / animal)	135.13 ± 0.65	130.89 ± 2.11	134.60 ± 0.64	0.08 (NS)
Total consumption of finisher ration (kg / animal)	95.82 ± 1.65	95.50 ± 0.76	98.87 ± 0.50	0.09 (NS)
Cost per kg of grower ration* (Rs.)	8.78	8.42	7.98	-
Cost per kg of finisher ration* (Rs.)	7.97	7.53	7.08	-
Total feed cost (Rs. / animal)	1950.08 ± 6.78^a	1821.15 ± 2.96^b	1774.11 ± 7.99^b	5.65E-07
Total body weight gain (kg / animal)	55.93 ± 2.05	53.33 ± 2.79	55.10 ± 2.41	- (NS)
Cost of feed per kg live weight gain (Rs.)	35.15 ± 1.36	34.40 ± 1.21	32.25 ± 1.03	-

* Cost calculated using the rate contract values fixed for the feed ingredients by the College of Veterinary and Animal Sciences

NS Non-significant

a, b Means with different superscripts differ significantly (P< 0.01)

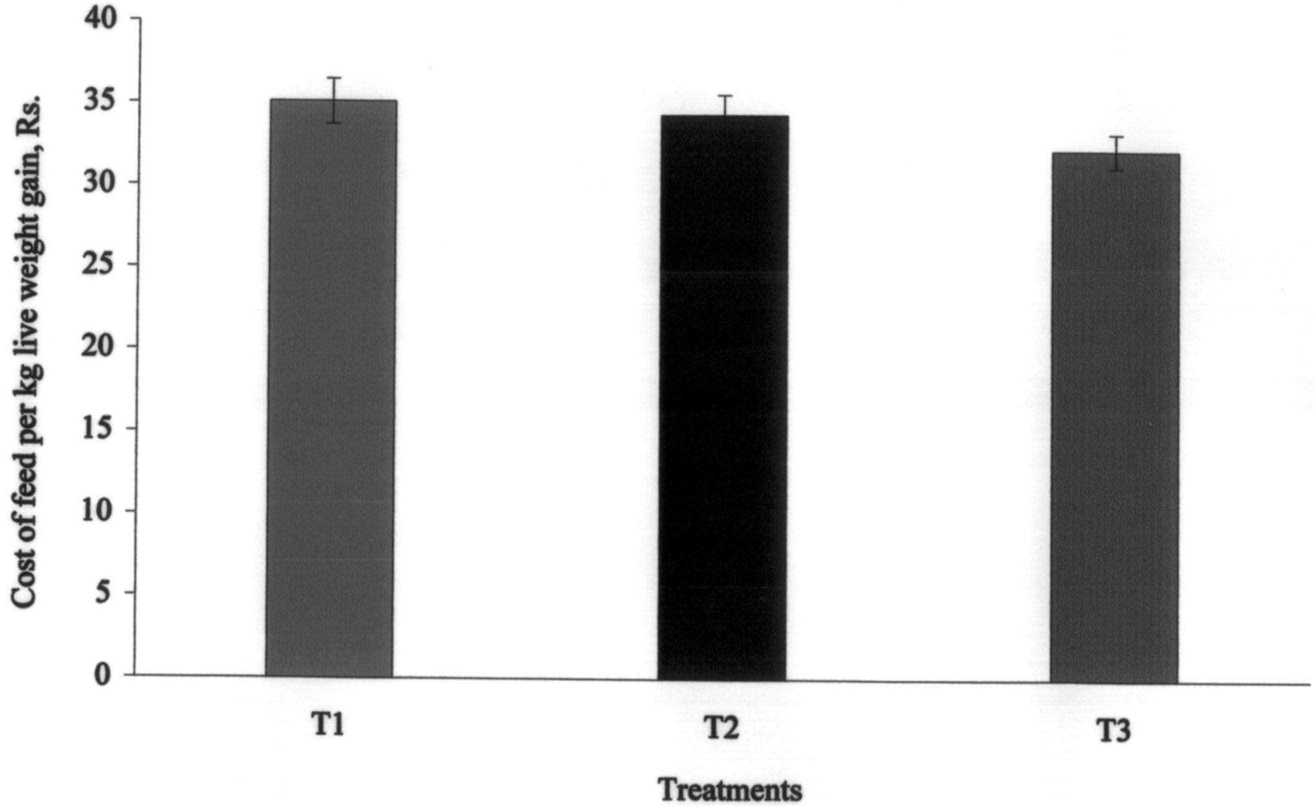

Fig. 10. Cost of feed per kg body weight gain of pigs maintained on three dietary treatments

Discussion

5. DISCUSSION

5.1 CHEMICAL COMPOSITION OF DRIED CUTTLE FISH WASTE SILAGE

5.1.1 Dry Matter

The dry matter content of fish silage varied depending upon the type of fish used, type of product (dried or wet), drying method (sun dried or oven dried) and nature of filler material used. It could be observed from the data presented in Table 5 that the dry matter content of the dried cuttle fish waste silage used in the present study varied from 83.5 to 87.5 per cent. Lower dry matter content (20 to 30 per cent) than those obtained in the present study was reported for fish silage by Smith and Adamson (1976) and Myer *et al.* (1990). Machin *et al.* (1990) obtained dry matter content of 96.4 and 94.3 per cent, when high oil and low oil fish silages were dried with cassava meal at 2:1 proportions, respectively. Similarly, Magana *et al.* (1999) obtained dry matter content of 95 per cent when tuna fish waste silage was dried with sorghum in 70:30 proportions which was higher than those obtained in the present study.

5.1.2 Crude Protein

Crude protein content of the dried cuttle fish waste silage varied from 23.65 to 26.75 per cent. Crude protein content of 22 to 23 and 22 to 24 per cent was reported by Machin *et al.* (1990) when high oil and low oil fish silage was mixed with cassava meal in 2:1 proportions, respectively. High crude protein content (85 per cent) than those obtained in the present study was reported by Myer *et al.* (1990) in scallop viscera silage when no filler material was used. Ali *et al.* (1995) reported that crude protein content of fish silage prepared from fish offal was between 21.61 and 27.27 per cent which is in accordance with the values obtained in the present study. Almost similar value to that of present study

(28 per cent) was reported by Magana *et al.* (1999) when tuna fish waste silage was dried with sorghum in 70:30 proportions.

5.1.3 Ether Extract

Ether extract content of the dried cuttle fish waste silage used in the present study varied from 2.0 to 3.5 per cent. Smith and Adamson (1976) reported ether extract content of 3.1 per cent for liquid white fish protein and similar values were also reported by Tibbetts *et al.* (1981) and Ngoan *et al.* (2000) for ensiled fish waste and shrimp byproduct, respectively, which are in accordance with the values obtained in the present study. However, higher ether extract content (25 to 45 per cent) was reported by Smith and Adamson (1976) and Whittemore and Taylor (1976) for herring silages and Green *et al.* (1983) for different fish waste silage. Similarly, higher ether extract content (5 to 21 per cent) was also reported by Johnsen and Skrede (1981) for fish viscera silage, Batterham *et al.* (1983) for fish waste silage and Magana *et al.* (1999) for tuna fish waste dried with sorghum in 70:30 proportions.

5.1.4 Crude Fibre

The crude fibre content of the dried cuttle fish waste silage ranged between 13.6 and 15.90 per cent. Machin *et al.* (1990) reported that the high and low oil fish silages contained 2.4 and 2.8 per cent crude fibre when the silage was dried with cassava meal in 2:1 proportions. Magana *et al.* (1999) reported crude fibre content of 1 per cent when fish waste silage was dried with sorghum in 70:30 proportions which was lower than the values obtained in the present study. The high crude fibre content of dried cuttle fish waste silage may be from the filler material (rice bran) used.

5.1.5 Total Ash

The total ash content of the dried cuttle fish waste silage used in the present study varied from 16.5 to 18.5 per cent. Similar ash content was reported by Smith and Adamson (1976) for liquid white fish protein, Batterham *et al.* (1983) for fish waste silage and Ottati and Bello (1990a) for microbial fish silage. However, a lower ash content (8 to 12 per cent) was reported by Smith and Adamson (1976) and Whittemore and Taylor (1976) for herring silages, Johnsen and Skrede (1981), Johnson *et al.* (1985), Machin *et al.* (1990) and Magana *et al.* (1999) for different types of fish waste silage. Higher values than those obtained in the present study were also reported by Rodriguez *et al.* (1990a), Alwan *et al.* (1993) and Ngoan *et al.* (2000).

5.1.5 Nitrogen Free Extract

The nitrogen free extract of the dried cuttle fish waste silage ranged from 37.53 to 41.35 per cent. Ali *et al.* (1995) found that the nitrogen free extract of fish silage ranged between 16.91 and 28.43 and was mainly due to the filler material used for drying. The values obtained in the present study were higher than those reported by Ali *et al.* (1995).

5.1.6 Calcium and Phosphorus

Calcium and phosphorus content of the dried cuttle fish waste silage ranged from 0.35 to 0.49 and 1.60 to 1.84 per cent, respectively. The liquid white fish protein and liquid herring protein contained 3.8 and 2.1 per cent calcium and 1.9 and 1.6 per cent phosphorus, respectively (Smith and Adamson, 1976). Tibbetts *et al.* (1981) reported that fish silage contained 1.8 per cent calcium and 0.5 per cent phosphorus. The higher phosphorus and lower calcium content of dried cuttle fish waste silage may be due to filler material (rice bran) added in 2:1 proportions.

5.2 BODY WEIGHT AND TOTAL BODY WEIGHT GAIN

From the Table 7 it could be seen that the average fortnightly body weight of pigs maintained on the three dietary treatments were almost similar and the difference between groups was non-significant for all fortnight periods. Almost similar body weight and body weight gain were reported by Mohan and Sivaraman (1993) in pigs fed diets containing different levels of dried prawn waste.

Kjos *et al.* (1999) reported non-significant differences in growth performance between pigs fed a control diet containing fishmeal or one of the three experimental diets containing 5 per cent fish silage and different levels of fish fat. Similarly, Mantra (2000) reported that there was no significant difference in the effect of fishmeal and fish silage on growth performance in growing pigs which is in agreement with the results obtained in the present study. In contrary, Batterham *et al.* (1983) found that feeding of fish silage increased the growth rate in pigs relative to those fed soyabean meal or combination of both soyabean and fish silage during 20 to 45 kg growth phase.

5.3 AVERAGE DAILY GAIN

From the data presented in the Table 8 it could be seen that the cumulative average daily gain (370.31, 353.15 and 364.90 g, respectively) of pigs maintained on the three dietary treatments T_1, T_2 and T_3 were statistically similar. Though the cumulative average daily gain of pigs fed diets containing dried cuttle fish waste silage was numerically lower than that of control diet containing unsalted dried fish, the difference between the groups was non-significant.

Tibbetts *et al.* (1981), Batterham *et al.* (1983) and Green *et al.* (1988) reported average daily gain that ranged from 597 to 740 g when growing and finishing pigs were fed diets containing different levels of fish silage which were higher than those obtained in the present study. Myer *et al.* (1990), Anon (1993) and Wohlt *et al.* (1994) also obtained higher average daily gain (860 to 870, 487 to 583 and 602 to 608 g, respectively) in pigs fed diets containing different levels of scallop viscera silage, fish silage and sea clam viscera. Higher average daily gain (446 to 602 g) was reported by Lien *et al.* (2000) when different levels of fish silage were incorporated in swine ration. The lower average daily gain recorded in the present study may be due to the genetic makeup since fifty per cent crossbred (Large White Yorkshire X Desi) pigs were used.

Luscombe (1973) observed no significant difference in daily weight gain of pigs weighing from 60 to 200 lb. (27 to 90 kg) when they were fed fish silage as a replacement for fishmeal or for both fishmeal and soyabean meal which is in agreement with the results of the present study. Similarly, Wignall and Tatterson (1976) observed that weight gain of pigs fed white fish offal silage at 10 per cent of dry matter were almost similar to those fed diets containing conventional non-cereal protein. Similar results were also reported by Tibbetts *et al.* (1981) and Myer *et al.* (1990) when pigs were fed diets containing 0, 3, 6 and 9 per cent fish silage and 24 per cent scallop viscera silage, respectively.

5.4 FEED CONVERSION EFFICIENCY

From the results given in Table 9, it could be seen that the cumulative feed conversion efficiency (4.16, 4.28 and 4.26, respectively) of pigs maintained on the three dietary treatments T_1, T_2 and T_3 were similar.

The efficiency of feed conversion by animals fed fish silage was related to the balance of essential amino acids in the silage, which was dependent on the type of fish used. Ngoan *et al.* (2001) reported similar values when different levels of ensiled shrimp by product were incorporated in swine ration. However, better feed conversion efficiency than those obtained in the present study were reported by Smith (1976), Myer *et al.* (1990), Anon (1993) and Lien *et al.* (2000) when different levels of fish silage was incorporated in swine ration.

Luscombe (1973) observed that there was no significant difference in feed conversion efficiency of pigs weighing from 60 to 200 lb. (27 to 90 kg) when they were fed fish silage as replacement for fishmeal or for both fishmeal and soyabean meal which is in accordance with the results obtained in the present study. Similar results were also reported when pigs were fed different levels of scallop viscera silage (Myer *et al.*, 1990) and a balanced stock diet or diet based on 50 per cent sorghum meal and 50 per cent fish silage (Avdalov *et al.*, 1993).

5.5 APPARENT DIGESTIBILITY COEFFICIENT OF NUTRIENTS

5.5.1 Dry Matter

From the data presented in the Table 11, it could be seen that the dry matter digestibility of diet T_3 (61.37) was significantly higher ($P<0.05$) than that of T_2 (55.77), but there was no significant difference between diets T_1 (57.46) and T_2 or T_1 and T_3.

Myer *et al.* (1990) recorded higher dry matter digestibility ranging from 83.9 to 84.3 per cent when different levels of scallop viscera silage was incorporated in the ration of finisher pigs. Higher digestibility coefficient of dry matter than those obtained in the present study was also reported by Phiny and Rodriguez (2001) in MongCai pigs fed diets containing sugar palm juice and ensiled fresh water fish. The lower dry matter digestibility recorded in the present study may be due to the lower digestibility of rice bran added in the cuttle fish waste silage.

5.5.2 Crude Protein

Data on digestibility coefficients of crude protein presented in the Table 11 indicate significantly lower digestibility ($P<0.01$) for diet T_2 (62.25) as compared to diet T_1 (68.61), but there was no significant difference between diets T_2 and T_3 (64.81) or T_1 and T_3.

Tibbetts *et al.* (1981) and Phiny and Rodriguez (2001) recorded higher crude protein digestibility (80 to 81 and 83.4 to 88.4 per cent, respectively) in pigs fed diets containing different levels of fish silage. Myer *et al.* (1990) obtained digestibility coefficient of crude protein that ranged from 76.6 to 76.9 when pigs were fed diets containing two levels of scallop viscera silage which was higher than those obtained in the present study.

Lower crude protein digestibility of dried cuttle fish waste silage incorporated diets may be due to the lower digestibility of cuttle fish skin, which formed a major part of the cuttle fish waste.

5.5.3 Ether Extract

The digestibility coefficient of ether extract (Table 11) of the three experimental diets (49.25, 40.54 and 44.45) was statistically similar.

Tibbetts *et al.* (1981) obtained digestibility coefficient of ether extract that ranged from 63 to 64 when different levels of fish silage was incorporated in swine ration which was higher than those obtained in the present study. Mohan and Sivaraman (1993) also recorded higher digestibility coefficient of ether extract that ranged from 52.9 to 68.2 when different levels of prawn waste was incorporated in the rations of finisher pigs. However, lower values (33.27 to 37.95) than those obtained in the present study were reported by Madukumar (2002) when Large White Yorkshire pigs were fed diets containing varying levels of prawn waste.

5.5.4 Crude Fibre

From the data presented in the Table 11, it could be seen that the crude fibre digestibility of experimental diets (18.63, 12.39 and 24.60 per cent, respectively) T_1, T_2 and T_3 were statistically similar. Tibbetts *et al.* (1981) obtained higher crude fibre digestibility (39 to 45 per cent) in pigs fed diets containing different levels of fish silage. Almost similar crude fibre digestibility was reported by Mohan and Sivaraman (1993) when different levels of prawn waste was incorporated in the rations of swine. A reduction in the crude fibre digestibility obtained in the present study may be due to the high crude fibre content in the finisher ration.

5.5.5 Nitrogen Free Extract

The digestibility coefficient of nitrogen free extract (Table 11) of the three experimental diets (74.17, 73.55 and 75.89, respectively) T_1, T_2 and T_3 were similar. Mohan and Sivaraman (1993) reported lower nitrogen free extract digestibility (61.8 to 76.1 per cent) in pigs fed diets containing different levels of dried prawn waste. Similar nitrogen free extract digestibility to those obtained in the present study was reported by Madhukumar (2002) in pigs fed rations containing different levels of cooked prawn waste.

The overall data on digestibility coefficient of nutrients reveal that there was no significant difference in the digestibility coefficient of nutrients between the control diet containing 10 per cent fishmeal and the diet in which 100 per cent of crude protein from fishmeal was replaced with dried cuttle fish waste silage in finishing pigs. Since the digestible nutrients in the diets containing fish silage were equal to those in control diet, diets with cuttle fish waste silage could be used to support normal growth performance in pigs. The results obtained in the present study are in agreement with Tibbetts *et al.* (1981), Epse *et al.* (1989) and Myer *et al.* (1990) who reported no difference in digestibility of nutrients of fish silage incorporated rations compared to those of fishmeal incorporated control ration in growing pigs.

5.6 CARCASS CHARACTERISTICS

5.6.1 Dressing Percentage

From the data on carcass characteristics presented in the Table 12, it could be seen that the dressing percentage (72.28, 71.97 and 72.33, respectively) of pigs maintained on the three dietary treatments T_1, T_2 and T_3 were similar. Luscombe (1973) and Kjos *et al.* (1999) obtained similar dressing percentage (71.09 to 71.81 and 71.2 to 72.8, respectively) when growing and finishing pigs were fed diets containing different levels of fish silage. However, Tibbetts *et al.* (1981), Wohlt *et al.* (1994) and Ngoan *et al.* (2001) recorded slightly higher dressing percentage

(72.6 to 76.2) when pigs were fed diets containing different levels of fish silage, sea clam viscera and ensiled shrimp by product, respectively.

5.6.2 Carcass Length

The carcass length (59.71, 60.92 and 60.67 cm, respectively) of pigs maintained on the three dietary treatments T_1, T_2 and T_3 were similar. Tibbetts *et al.* (1981) and Ngoan *et al.* (2001) recorded carcass length that ranged from 77.7 to 78.3 and 86.0 to 91.4 cm in pigs fed diets containing different levels of fish silage and ensiled shrimp by product, respectively, which were higher than those obtained in the present study. The lower carcass length recorded in the present study may be due to the breed difference since fifty per cent crossbred (Large White Yorkshire X Desi) pigs were used for the present study.

5.6.3 Back Fat Thickness

The back fat thickness (3.32, 3.07 and 3.31 cm, respectively) of the pigs maintained on the three dietary treatments T_1, T_2 and T_3 were similar. Myer *et al.* (1990) recorded similar values (2.9 to 3.2 cm) when diets containing different levels scallop viscera silage were fed to pigs.

Tibbetts *et al.* (1981) and Wohlt *et al.* (1994) recorded higher back fat thickness (3.3 to 3.6 and 2.97 to 3.60 cm, respectively) in pigs fed diets containing different levels of fish silage and sea clam viscera, respectively. However, a lower back fat thickness of 1.79 to 2.38 and 2.42 to 3.08 cm were reported by Ottati and Bello (1990a) and Ngoan *et al.* (2001) when different levels of microbial silage and ensiled shrimp by product were incorporated in the rations of pigs.

5.6.4 Loin Eye Area

The loin eye area (24.22, 23.87 and 22.40 cm^2, respectively) of the pigs maintained on the three dietary treatments T_1, T_2 and T_3 were similar. Tibbetts *et al.* (1981) and Myer *et al.* (1990) recorded higher loin eye area (31.70 to 34.50

and 27.60 to 28.70 cm^2, respectively) when diets containing different levels of fish silage and scallop viscera silage were fed to pigs. Ngoan *et al.* (2001) recorded loin eye area that ranged from 23.27 to 24.84 cm^2 when pigs were fed diets containing different levels of ensiled shrimp by product which was similar to the values obtained in the present study.

The overall data on carcass characteristics presented in Table 12 reveal that there was no significant difference between dietary treatments in any of the parameters studied. This is in accordance with the results reported by Luscombe (1973), Smith and Adamson (1976), Tibbetts *et al.* (1981), Kjos *et al.* (1999) and Mantra (2000) who did not observe any difference in the carcass characteristics when fish silage was incorporated in the rations of growing and finishing pigs.

5.7 ECONOMICS OF GAIN

The production cost of dried cuttle fish waste silage was Rs.2.71 per kg and the cost of unsalted dried fish was Rs.10.75 per kg. The growth performance of pigs fed diets containing dried cuttle fish waste silage was almost similar to those fed diets containing unsalted dried fish.

Data presented in the Table 13, indicate that the diets T_2 and T_3 containing dried cuttle fish waste silage at 50 and 100 per cent replacement of protein from fishmeal were economically efficient at 2 and 8 per cent, respectively, over diet T_1 containing fishmeal. Though the crude protein content of the dried cuttle fish waste silage was only half that of unsalted dried fish, the lower cost of dried cuttle fish waste silage reduced the cost per kg body weight gain.

A critical evaluation of the results obtained in the present study indicates that dried cuttle fish waste silage can be used economically as a substitute for unsalted dried fish, on protein basis without any adverse effect on average daily gain, feed efficiency, apparent digestibility of nutrients and carcass characteristics of growing and finishing pigs.

Summary

6. SUMMARY

An investigation was carried out to assess the effect of dietary inclusion of dried cuttle fish waste silage (silage prepared from cuttle fish processing waste which was mixed with rice bran in 2: 1 proportions and dried) replacing fishmeal protein on growth performance of crossbred pigs.

Fifteen male and fifteen female weaned crossbred (Large White Yorkshire x Desi, 50 per cent) piglets with an average body weight of 13.5 kg were selected and male animals were castrated one week before commencement of experiment. The piglets were divided into three homogeneous groups of ten piglets in each, with regard to age, sex and body weight. The animals of each group were randomly allotted to five pens with two in each, forming five replicates for each treatment. Each replicate was housed in a separate pen and all the animals were maintained under identical conditions of management throughout the experimental period of 152 days.

The three groups of animals were randomly allotted to the three dietary treatments T_1, T_2 and T_3 which were isonitrogenous and isocaloric. Dried cuttle fish waste silage was added to replace crude protein from unsalted dried fish at 0, 50, 100 per cent level in grower and finisher rations. The animals were maintained on their respective grower rations containing 18 per cent crude protein and 3200 kcal digestible energy per kg until they attained an average body weight of 50 kg and thereafter changed to finisher rations containing 14 per cent crude protein and 3100 kcal digestible energy per kg until the animals were slaughtered. The piglets in each pen were group fed and restricted feeding was followed throughout the experimental period. Records of daily feed intake and fortnightly body weight were maintained throughout the experiment.

A digestibility trial was conducted towards the end of the experiment to determine the digestibility coefficient of nutrients of the experimental diets by using chromic oxide (Cr_2O_3) added at 0.05 per cent to each diet as an external indicator. At the end of the experiment, six animals from each treatment were selected randomly and were slaughtered to study the carcass characteristics and dressing percentage.

Animals under all the three dietary treatments gained weight satisfactorily. There were no significant difference ($P>0.05$) in fortnightly body weight and cumulative average daily gain of the animals maintained on the three dietary treatments. The cumulative average daily gain of pigs maintained on the three dietary treatments was 370.31, 353.15 and 364.90 g, respectively. The feed conversion efficiency of pigs maintained on the three dietary treatments was similar throughout the course of experiment. The cumulative feed conversion efficiency values were 4.16, 4.28 and 4.26 for the pigs maintained on the three dietary treatments T_1, T_2 and T_3, respectively, which did not differ significantly ($P>0.05$).

The digestibility coefficient of dry matter was higher ($P<0.05$) for diet T_3 than T_2, but there was no significant difference between T_3 and T_1 or T1 and T_2. Crude protein digestibility of diet T_1 was significantly higher ($P<0.01$) than that of T_2, but there was no significant difference between T_1 and T_3 or T_2 and T_3. The digestibility coefficient of ether extract, crude fibre and nitrogen free extract were almost similar for all the three dietary treatments.

Dressing percentage and carcass characteristics such as carcass length, back fat thickness, loin eye area, meat percentage and meat bone ratio were not significantly different ($P>0.05$) between dietary treatments. The cost of feed per kg weight gain of animals maintained on the three dietary treatments was found to be Rs.35.15, 34.40 and 32.25 for T_1, T_2 and T_3, respectively. The diets T_2 and T_3 containing dried cuttle fish waste silage at 50 and 100 per cent replacement of protein from fishmeal were economically efficient at 2 and 8 per cent, respectively, over diet T_1 containing fishmeal.

It can be concluded that dried cuttle fish waste silage can be used economically as a substitute for unsalted dried fish in the ration of growing and finishing pigs on protein basis, without any adverse effects on growth rate, feed conversion efficiency, digestibility of nutrients and carcass characteristics.

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UTILISATION OF DRIED CUTTLE FISH (*Sepia officialis*) WASTE SILAGE FOR GROWTH IN CROSSBRED (LARGE WHITE YORKSHIRE X DESI) PIGS

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ABSTRACT

An experiment was conducted to assess the effect of dried cuttle fish waste silage, on growth, feed conversion efficiency, digestibility of nutrients, carcass characteristics and economics of gain in growing and finishing pigs. Fifteen male and fifteen female weaned crossbred (Large White Yorkshire x Desi, 50 per cent) piglets with an average body weight of 13.50 kg were divided into three homogeneous groups of ten piglets in each, with regard to age, sex and body weight. The three groups of piglets were maintained for 152 days on three isonitrogenous and isocaloric diets T_1, T_2 and T_3 in which crude protein from unsalted dried fish was replaced by the protein of dried cuttle fish waste silage at 0, 50 and 100 per cent level. The piglets on the three groups were fed their respective grower rations which contained 18 per cent crude protein and 3200 kcal digestible energy per kg until they attained an average body weight of 50 kg and thereafter changed to finisher rations containing 14 per cent crude protein and 3100 kcal digestible energy per kg until the animals were slaughtered. A digestibility trial was conducted towards the end of the experiment using chromic oxide added at 0.05 per cent to each diet as external indicator. At the end of the experiment six animals from each treatment were slaughtered randomly to study the carcass characteristics.

The animals maintained under the three dietary treatments T_1, T_2 and T_3 had almost similar growth rate (P>0.05) with a cumulative average daily gain of 370.31, 353.15 and 364.90 g, respectively. There was no significant difference (P>0.05) in cumulative feed conversion efficiency between groups, the values being 4.16, 4.28 and 4.26 for the three dietary treatments T_1, T_2 and T_3, respectively. The digestibility coefficients of dry matter and crude protein were higher for the diets T_3 and T_1 than that of T_2, respectively. The digestibility coefficients of ether extract, crude fibre and nitrogen free extract were similar for the three diets T_1, T_2 and T_3. Dressing percentage and carcass characteristics such

as carcass length, back fat thickness, loin eye area, meat percentage and meat bone ratio were not significantly influenced by the inclusion of dried cuttle fish waste silage. The cost of feed per kg live weight gain of pigs in the three dietary treatments T_1, T_2 and T_3 were Rs.35.15, 34.40 and 32.25, respectively. The dietary treatments T_2 and T_3 were economically efficient at 2 and 8 per cent over T_1

The above results indicate that the dried cuttle fish waste silage can be used economically as a substitute for unsalted dried fish in the rations of growing and finishing pigs on protein basis, without any adverse effect on growth rate, feed conversion efficiency, digestibility of nutrients and carcass characteristics.