DETRITUS OF PLANT ORIGIN AS A FOOD SOURCE FOR *PENAEUS INDICUS* H. MILNE EDWARDS

By
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THESIS

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TO MY PARENTS AND SISTER

DECLARATION

I hereby declare that this thesis entitled "DETRITUS OF PLANT ORIGIN AS A FOOD SOURCE FOR PENAEUS INDICUS H.MILNE EDWARDS" is a bonafide record of research work done by me during the course of research and 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 University or Society.

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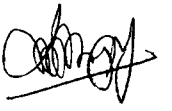
Dr.D.M.THAMPY Dean-in-charge, Professor and Head, Department of Aquaculture, College of Fisheries,Panangad.	CHAIRMAN	
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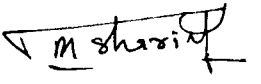
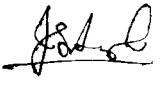
Dr.P.M.SHERIEF Asst.Professor-Biochemistry, Department of Processing Technology, College of Fisheries,Panangad.	MEMBER	
Dr.I.S.BRIGHT SINGH Lecturer, School of Environmental studies, Cochin University of Science and Technology, (Formerly Asst.Professor - Microbiology, Department of Processing Technology, College of Fisheries, Panangad.)	MEMBER	

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INTRODUCTION

I INTRODUCTION

Aquaculture, the farming of aquatic organisms, has been a way of life for centuries in many Asian countries. Culture of shrimp is practised resorting to traditional methods in coastal impoundments and ponds in majority of these countries. In Thailand, Malaysia, Singapore and India the juvenile prawns are allowed to enter coastal lagoons, backwaters and paddy fields, whereas in the Philippines and Indonesia juvenile prawns are let into traditional milkfish farms during tidal exchange Of late, the scenerio has changed radically and most of the traditional fields have been converted into scientific prawn farms due to better returns.

Shrimp farming continues to expand owing to its importance as a foreign exchange earner and an employment generator in many developing countries. From a level of about 2% of the total world shrimp production in 1980, the contribution from aquaculture increased to 25% in 1990 (Anon , 1990) Of the reported 2 5 million tons in 1990, 0.6 million ton was produced by aquaculture techniques (Peckhain, 1991).

India by producing nearly 32,000 mt of cultured shrimp became the fifth leading producer of farm raised shrimp in 1990 (Anon., 1990). Though in recent years, a great deal of interest is shown towards the development of prawn culture in the country, the

growth rate is still low, compared to that of Indonesia and Thailand. Of the total estimated brackish water area of about 1.4 million ha, about 0 6 million ha is presently put under aquaculture (Kant, 1991) The yield per ha is as low as 400-500 Kg/ha for extensive farms which hardly use any formulated feed (Ferdouse, 1990). In semi-intensive farming where artificial feed is employed to supplement natural food produced from pond manuring and fertilization, the yeild ranges from 1500-2000 Kg/ha/crop in 4-5 months (Ferdouse, 1990)

Semi-intensive and intensive farming of prawns are of recent origin. The interest in the intensive culture of shrimp was triggered by higher market demand and inadequate supply from the wild, to meet the roaring demand. Developed countries like Japan and USA form the markets for prawns from many developing nations As this opened up opportunities for earning foreign exchange, shrimp farming has attracted diverse groups of investors, many of whom, though new entrants, were prepared to take up challenges and to utilize the latest technology. More and more big houses, encouraged by the economic incentives and policies of the Governments, continue to enter the aquaculture industry of many of the developing countries.

Swift development of intensive shrimp farming in many of the South East Asian countries has led to a condition where the demand

of the shrimp is no longer limited by supply. On the other hand, it is the supply which is searching out demand (Chong, 1990). This may lead to a glut in the international shrimp market. Moreover the cost of feed has increased owing to rising cost of fish meal, a critical ingredient in prawn feeds (Mc Coy, 1990). This may lead to a condition where the intensive farming may become less attractive as an economically viable venture. Though recent slump in shrimp prices has adversely affected the profit margins, shrimp farming generally remains profitable, especially for extensive and semi-intensive operations.

For countries like India it is the semi-intensive system which is conducive, rather than going in for capital intensive farming methods tried and met with failure in some South-East Asian countries.

Pelleted feed represents 60% or more of total operating cost in intensive farms (Primavera, 1989). Cost of commercial shrimp feed is extremely time and place specific and it depends on a large range of factors including current ingredient and production costs (New, 1990). With the rapid increase in demand and decline in supply of fish meal, there is every chance of increase in feed prices (Mc Coy, 1990). This naturally will lead to explore the possibilities of using low cost, easily available protein sources which could be employed in shrimp aquaculture operations.

In a country like India, where the entire economy depends on agriculture, improved technologies should be developed to make use of prodigious amounts of agricultural wastes and other low value by-products (straw, sugarcane bagasse, rice hulls, other food processing wastes, trash vegetation and aquatic weeds) as dietary supplements to fish and prawn. They can be used as supplementary detritus, added to culture ponds as microbial substrates, either alone or mixed with manure. This could greatly help in reducing the demand for high quality feeds employed in present day aquaculture, an important step especially in a country like India where feed stuffs are expensive and scarce.

But, at present there is no farming system where the attributes of detritus are specially manipulated as fish food source (Moriarty, 1987). The relative contribution of algal and detrital carbon and nutrients to the fish production are quite unknown Only few studies have been carried out to test the feasibility of using plant detritus directly or indirectly towards fish production. Workers have added plant materials including wheat bran, wheat straw, hay, bagasse (Caillouet et al., 1976) and mangrove leaves (Von Prahl and Gardeazabal, 1977) directly to shrimp ponds Venkataramiah et al (1978) and Sumitra-Vijayaraghavan and Ramadhas (1980) have tried to incorporate decomposed plant material in the diet of prawns. But a lot of

research has yet to be done in this field to find out the prospects and problems of using plant detritus as a food source The present study is aimed at finding out the suitability of using plant detritus as a source of food for the Indian white prawn Penaeus indicus

REVIEW OF LITERATURE

II REVIEW OF LITERATURE

2 1 Food and Feeding Habits of Penaeids

Penaeids feed on a variety of food organisms and their feeding habits vary with different life stages. Penaeid diet usually includes detritus, bottom living animals, plant materials and even microorganisms They possess a very elaborate food capturing, triturating and engulfing mechanism, and can consume food particles having size greater than the size of their body. The food and feeding habit shifts from a primarily vegetarian diet in the early larval stages to rather diverse modes of feeding, described as omnivorous, detritivorous or carnivorous type, during the later stages of life history

The presence of animal matter, vegetable matter, detritus etc in the gut of penaeids has led many to conclude that penaeids are omnivorous-scavengers or detritus feeders (Williams, 1955, Gopalakrishnan, 1952, Panikkar and Menon, 1955, Rao, 1967, Dall, 1967; Kuttiyamma, 1973). Williams (1955) generalized the penaeids as omnivorous scavengers or 'detritus feeders', as a purely herbivorous or carnivorous feeding habit is not seen in any of the species Panikkar (1952) stated that the food of young penaeids composed of organic detritus, algal material and other small organisms present in the bottom substrata. Panikkar and Menon (1955) stated that food of Metapenaeus dobsonii and Penaeus

indicus consists of detritus, both animal and plant, which accumulate at the muddy bottom habitats. George (1959), after studying the bionomics of Metapenaeus monoceros, reported that the species is an omnivore. Eldred et al. (1961) have reported that animal remains, algal fragments and detritus comprise recognizable components of the diet of Penaeus duorarum.

Hall (1962) found the food of juvenile P indicus and P monodon from Malaysian prawn ponds comprised mainly of Crustacea, vegetable matter and Polychaeta. Subrahmanyam (1963) reported Metapenaeus affinis as an omnivore Rao (1967), after studying the food and feeding habits of P. indicus and P monodon, concluded both the species as omnivorous in feeding habit By studying the food of M monoceros in Godavari estuarine system, Subrahmanyam (1973) reported the prawn as omnivorous in feeding habit

Kuttiyamma (1973) studied the food and feeding habits of five species of penaeids and concluded all the species as omnivorous or detritus feeders Thomas (1980) observed that Penaeus semisulcatus mainly feeds on detritus, polychaetes, molluscs, foraminiferans, radiolarians, and fishes.

Some workers are of the view that penaeids, in general, cannot be considered as omnivorous, as many of them have got a

preference for animal based diet Ikematsu (1955) observed that Metapenaeus joyneri feeds mainly on crustaceans, bivalves, gastropods and polychaetes Kubo (1956), while reviewing the biology of shrimps and prawns of Japan, reported that Penaeus japonicus prefers meat of fishes, molluscs and small crustaceans, though they feed on other items like detritus and decaying organic matter lying on the sea bottom. Kittaka (1976) also reported that this species is primarily carnivorous in feeding habit and is found to eat various kinds of benthic animals Hall (1962) reported that estuarine phase of M. monoceros and larger P indicus have a preference for crustacean based diet. Subrahmanyam (1963) and Marte (1980) indicated P. monodon as carnivorous in feeding habit. So also Thomas (1972), after studying the food and feeding habits of the species from Korapuzha estuary, reported that the species preferred food of animal origin. Studies by George (1974) revealed that larger M. monoceros is carnivorous and shows a preference for small crustaceans.

Many investigators have reported that prawns do feed on the plant materials also in their natural habitat. Panikkar and Menon (1955) observed that P. indicus and M dobsonii consume large quantities of vegetable matter while P. stylifera rarely takes in plant materials. Hall (1962) found that M. affinis, collected from Malaysian prawn ponds, feeds mainly on vegetable matter and

he pointed out that metapenaeids, in contrast to penaeids, feed largely on vegetable matter. So also Kuttiyamma (1973) reported that M monoceros preferred vegetable matter like sea weeds and algae. Tiews et al (1972) reported that Penaeus merguiensis feeds mainly on phytoplankton.

Several researchers pointed out that a probable shift in the feeding regime could occur with the age of the prawns Menon (1951) observed that young ones of M dobsonii feed on small animals and diatoms along with sand and mud, whereas vegetable matter was more in the diet of larger individuals Hall (1962) observed larger specimens of P indicus taking in more crustaceans including penaeids and brachyurans while smaller ones are omnivorous in feeding habit Subrahmanyam (1963) reported that larger ones of M affinis preferred a molluscan diet, while smaller specimens are omnivorous in feeding habit. Kuttiyamma (1973) observed that larger prawns of the species preferred a polychaete diet whereas young ones depended more on vegetable matter But such a shift in the feeding regime was not observed in the case of many other species. Gopalakrishnan (1952) and Kuttiyamma (1973) did not notice any variation in the food and feeding habit of various size groups of P. indicus So also Thomas (1972) observed no significant change in the food and feeding habits of P monodon

Food and feeding habits of the Indian white prawn P indicus was studied in detail by several investigators (Gopalakrishnan, 1952, Panikkar and Menon, 1955; Hall, 1962, Kuttiyamma, 1973) Gopalakrishnan (1952) analysed the gut contents of 380 juveniles and found that vegetable matter and crustaceans formed the bulk of the food consumed, indicating an omnivorous feeding habit He observed that the species does not show any significant change in food habits during different months of the year Panikkar and Menon (1955) also reported the species as omnivorous in feeding habit. They observed that the species consumes large quantities of algal matter when available, in addition to small living creatures like molluscs and worms Hall (1962) found the food of the juveniles as Crustacea (small and large), vegetable matter and Polychaeta, while the large adults took in more crustaceans in Malaysian prawn ponds But in contrast, Kuttiyamma (1973) could not find any size oriented difference in feeding regime for this species She observed that 50 7% of the gut contents to be of debris, of which 25% was constituted by plant material and 22% by animal matter

Prawns eat practically any food, living or dead, that comes their way (Chopra, 1939) Gopalakrishnan (1952), based on the periodic fluctuation of various items of food observed in the gut, concluded that prawns feed on what ever food material they come

across. The food items present in the gut varies according to the different feeding habitats. Hall (1962) found that P semisulcatus collected from different areas had varied diet composition Tiews et al. (1972) pointed out that difference in availability of food items rather than selective feeding seems to determine the diet composition. But George (1974) suggested the existence of food preference, to some extent in M. monoceros, as there is selective feeding in different size groups. Kuttiyamma (1973) pointed out that prawns can adjust to various types of environmental conditions and the difference in feeding regime is due to change in the habitat.

All these findings suggest that penaeids in general are omnivorous in feeding habit. Penaeus indicus is a typical example of the group which feeds on both animal and plant matter Stomach content analysis during several investigations has revealed the presence of large quantity of unidentifiable finely ground up matter But whether the 'debris' had been ingested as such or ground up in the stomach is a matter which is yet to be found out Similarly controversy still exists, regarding the change in food and feeding habit of the species with the change in size of the prawn Gopalakrishnan (1952), Kuttiyamma (1973) and Hall (1962) differ in their opinion on this subject

2.2 Protein Requirement of Prawns

2 2 1 Factors Influencing the Level of Protein Required

The necessity for defining nutritional requirements of prawns was felt more in the late nineteen sixtees, when several attempts to culture them in closed systems met with failure Attempts were then made by many to study the nutritional requirements, especially of that of protein, so that the prawns could be grown in closed systems based on artificial feeds. Subrahmanyam and Oppenheimer (1969) were able to maintain shrimp in laboratory tanks on a pelleted diet consisting of fish meal, stick water and vitamins. A slight headway has been made towards establishing nutritional requirements of shrimp, that will maintain optimum growth and survival, when pelleted diets were designed by Kanazawa et al (1970) for Penaeus japonicus. Several investigations followed, to explore the nutritional requirements of several species of shrimps. (New, 1976; Zein-Eldin and Meyers, 1973, Castell et al., 1981; Claybrook, 1983; Dall and Moriarty, 1983 and Kanazawa 1984)

Although there are many studies on the nutritional requirements of many cultivable prawns (table 1), a comparison of results is often difficult owing to the fact that a large number of biotic and abiotic factors get involved, complicating the issue The main abiotic factors affecting the nutrient

requirements of shrimps are temperature and salinity Most of the studies on nutrient requirements have been carried out under a temperature range of 26 - 28°C But the requirements are bound to differ according to the temperature of the medium Tacon and Cowey (1985) have pointed out that distinct temperature effects could be observed in terms of growth, the greater demand for protein at high water temperature is satisfied through increased consumption of the diets Studies to find the protein requirement have been carried out at various salinities (vide table 1) There exist a complex relationship between salinity and energy budget Hernandorena (1974), while working on Artemia, found that at high salinities non essential amino acids take over the role of energy source, that carbohydrates and lipids play at lower salinities. Other factors like pH, dissolved oxygen, depth, light etc are also found to influence the growth and food utilization of crustaceans (Venkatramiah et al., 1975)

The biotic factors like the age of the species, genetic differences, moulting etc are also found to influence nutrient requirement values (Colvin and Brand, 1977; Sindhu and Pandian, 1988) Decapods lose a significant fraction of converted energy in each moult (Pandian, 1989) In the case of Macrobrachium rosenbergii, 7.3% of total energy reserves is expended towards moulting (Nelson et al , 1977). Sindhu and Pandian (1988)

estimated that the functional cost of moulting was equivalent to 4667 J for juvenile Macrobrachium nobilii During the post larval and juvenile phases, the quantity of energy used for the above purpose could be more as the time interval between two moults is less than 8-10 days during these phases (Stern et al., 1976).

Age of the test animals is another factor affecting the nutritional requirements Balazs et al. (1973) reported that protein requirement of fresh water prawns was high (35%) during the early stages of rearing ie., from 0-119 days and it came down to 15% during the last phase of rearing ie., 120-175 days.

Variations in the results regarding the protein requirement could also be due to the differences in dietary protein source and non-protein energy substitutes used, and feeding regimes employed (as to whether it is a fixed quantity or ad libitum) by various investigators The protein sources employed in these studies include those of plant origin, animal origin, non-conventional sources like yeast and mixtures of pure amino acids (vide table 1) Non-protein energy components represent one of the potential sources of variation in the composition of experimental diets It has also to be stressed further that the quality and quantity of non-protein energy sources like lipids used in the diet could influence the protein requirement value reported by different

workers (Andrews et al , 1972, Sick and Andrews, 1973, Forster and Beard, 1973; Deshimaru and Kuroki, 1974, Colvin, 1976, Aquacop, 1978, Sedgwick, 1979, Teshima and Kanazawa, 1984).

Addition of starch was found to facilitate the growth of prawns (Andrews et al., 1972; Colvin, 1976; Sedgwick, 1979, Nezaki et al , 1986) But addition of glucose to the prawn diet has resulted in a decrease of growth (Andrews et al., 1972, Aquacop, 1978). This has been attributed to be due to the inefficient utilization of this non-protein energy source as a result of rapid absorption and dissimilation of the monosaccharide by the prawns (Andrews et al , 1972).

Excessive lipid level is known to have a detrimental effect on growth and survival of prawns (Andrews et al., 1972, Sedgwick, 1979) Teshima and Kanazawa (1984) reported that varying levels of lipids have no positive influence on the growth and survival of Penaeus japonicus But Sick and Andrews (1973) found an improvement in growth of Penaeus duorarum fed on a diet supplemented with 10% lipid Lipid supplementation, especially those containing high levels of polyunsaturated fatty acids, improved the growth of P monodon (Mendoza, 1982; Catacutan and Kanazawa, 1985, Bautista, 1986, Meyers, 1989)

Among the other factors, which may possibly influence the protein requirement, the most important one may be the feeding regime employed (vide table 1)

2.2.2 Levels of Protein Required by Different Prawns.

Animals, unlike plants cannot synthesize protein from simple inorganic nitrogen Therefore dietary proteins are essential for all animals including shrimp Many of the studies on the protein requirement of prawns have utilized complex mixtures of plant and animal sources of protein, pure proteins and mixture of amino acids The latter two had given poor results with prawns (New, 1976) The earliest compounded ration for Penaeus japonicus was developed by Kanazawa et al. (1970) with reference to the proximate composition of short necked clam, Tapes philippinarum, which had been used widely as feed component of prawn diets There is a consensus with regard to the level of protein required by juveniles of various species of prawns. This level according to New (1976) is between 27 and 35%. He had pointed out that there are reports claiming good results for both penaeids and carideans using diets with protein levels as low as 14 and 15% Protein values as high as 55-60% for Metapenaeus monoceros (Kanazawa et al, 1981) and above 60% for P japonicus (Deshimaru and Shigueno, 1972) are reported

Initial trials to find out the optimum protein requirement of Macrobrachium rosenbergii reported values ranging from 25-30% (Balazs et al , 1973, Balazs and Ross, 1976, Manik, 1976, Clifford and Brick, 1979). However Millikin et al. (1980) reported the

optimum protein requirement value for M. rosenbergii as 40%. This higher value may be due to the limitation in the quantity of feed as they have used fixed feeding regime (vide table 1), which inturn may directly influence the outcome of the observed dietary requirement as suggested by Tacon and Cowey (1985) in the case of fishes. Boonyaratpalin and New (1980), evaluating the effect of three protein levels (15%, 25% and 35%) on M rosenbergii cultured in outdoor ponds, reported 15% protein as a desirable level from the economic point of view, as there was not much variation in the performance of the prawn fed with the above diets Perry and Tarver (1984) evaluated protein levels ranging from 10 to 30% on M. rosenbergii and concluded the optimum protein level as 25%.

Pandian (1989) attributed the lower optimum protein value reported to be sufficient for Macrobrachium spp. to the higher feed efficiency (about 16% when fed with a diet containing 20-30% protein) of the group compared to the lower efficiency (14% when fed with diet containing 40-50% protein) of penaeids.

In the case of Palaemon serratus, Forster and Beard (1973) reported a protein requirement value of 35%, after feeding with diets containing protein sources like fish meal and casein to the prawns at levels ranging from 38 to 62%.

The optimum protein requirement reported for penaeids range

from 22 to more than 60% In the case of Penaeus setiferus comparatively lower value was reported by Andrews et al (1972) Fenucci et al (1980) The optimum protein value reported to be required for the species range from 28-32% (Andrews et al , 1972 Fenucci et al , 1980) Colvin and Brand (1977) studied the protein requirement for two size groups of Penaeus stylirostris and reported that the small sized prawns (average size 0 005g) need a protein value of 44%, while the larger ones (average size 0 045 g) a lower level of 30-35% protein. Later study by Fenucci et al. (1980) showed that large sized prawns of this species (0.7-4 11 g) need 32 2-33 8% protein in their diet

Colvin and Brand (1977) also investigated the optimum protein value required for the normal growth and survival of Penaeus californiensis and reported that the species requires 35% protein in its diet These authors (Colvin and Brand, 1977), using diets having protein levels ranging from 25 to 40% and containing protein sources like fish meal, shrimp meal and soyabean meal, investigated the protein requirement value of Penaeus vannamei and reported the optimum protein value as 35%. They found that the protein requirement of early post-larvae exceeded 40%, and then decreased to less than 30% during the latter phase of life This variation in the protein requirement value during different life stages could be correlated to the higher physiological energy

demand of young prawns due to increased moulting frequency (Stern et al., 1976) and better growth rate during the early phase of growth (Pandian, 1989)

Early workers (Balazs et al., 1973; Shewbert et al , 1973) reported the protein requirement for Penaeus aztecus as 22-30% Later Venkataramiah et al (1975) and Fenucci and Zein-Eldin (1979) reported the optimum value to be of 40% and 43-45% respectively. Venkataramiah et al. (1975) observed that the incorporation of vegetable matter in the diet improved the growth of prawns and protein levels above 40% led to a decline in food conversion efficiency and growth.

Colvin (1976), by using diets prepared with yeast and prawn meal as major protein sources, found the optimum protein level required for Penaeus indicus as 43%.

For Penaeus merguiensis, using a casein based diet Aquacop (1978) reported the protein requirement as 50-55% Sedgwick (1979), on the other hand, reported the optimum protein level for the species as 34-42%, when fed with Mytilus edulis meal based diet The higher value reported by Aquacop (1978) may be that they have used casein as the protein source, which is poor in arginine content

Penaeus monodon was reported to require 40-46% protein by Lee (1971), Aquacop (1977), Khannappa (1979) and Alava and Lim

(1983). But Bages and Sloane (1981) observed the optimum protein requirement for the species as 35%.

Millamena et al (1986) observed that 50-55% protein (from a combination of fish meal, squid meal, and shrimp head meal) is required for P monodon brood stock. This comparatively higher value reported for the brooders could be due to large scale diversion of energy towards gonadal development of the prawn. Pandian (1989) had also reported such an increased demand (50%) for the brooders of Macrobrachium nobilii, while it is only 35% for the juveniles.

Carbohydrate levels in the diet are found to influence the protein requirement of prawns. Thus Nezaki et al. (1986) reported the optimum protein value needed for P. monodon as 45%, when diet contained 25% carbohydrate and the optimum protein value required increased to 55% when the carbohydrate level in the diet was reduced to 15% Bautista (1986) revealed that 40-50% protein gave the best growth and survival for P. monodon juveniles when 20% carbohydrate and 5-10% lipid were present in the diet

Metapenaeus monoceros was found to give better growth rate with a diet containing 55% casein (Kanazawa et al., 1981) Royan et al, (1977) also reported that the growth of M. monoceros was considerably enhanced when diets containing very high level of

protein (60%) was provided

Penaeus japonicus is a species that requires high quantity of protein in its diet due to the fact that the animal is carnivorous in its feeding habit (Deshimaru and Shigueno, 1972). Results of the studies on the protein requirement for this species by Deshimaru and Shigueno (1972), Balazs et al. (1973) and Deshimaru and Yone (1978) strongly support the above finding. The optimum protein value reported by these authors ranged from 40 to 60%

Although the juveniles of Penaeus japonicus require diets high in protein, Teshima and Kanazawa (1984) found that the level of protein required for the larvae could be brought down by increasing the level of carbohydrate in the feed Thus protein levels for prawn larvae were estimated to be around 55%, 45-55% and 45%, when the diets contained 5%, 15% and 25% levels of carbohydrate respectively.

Table 1 Quantitative dietary protein requirement of different prawn species

Species	Protein % level tested	Protein sources used	Temperature range ('c).	Salinity range (‰)	Initial weight/(g) length(mm)	Feeding regime employed	Optimum protein level reported(%)	Reference
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9).
Macrobrachium rosenbergii	35	Soyabean meal Hawaiian fish meal Shrimp meal.	---	0	9.3mm (eye socket to telsontip)	ad libitum	More than 35	Balazs et al (1973).
M. rosenbergii	15-30	Soyabean meal, Tuna meal, Shrimp meal, Tilapia meal, Activated sludge, Duck weed meal, fish meal.	22-27.6	0	0.1 g	ad libitum	35	Balazs and Ross (1976).
M. rosenbergii	10-30	---	---	---	---	---	25	Manik (1976).
M. rosenbergii (larvae).	10-20	---	---	---	---	---	15-20	Sick (1976).
M. rosenbergii	15-40	Menhaden meal, Soyabean meal.	29.5±0.5	0.5	0.096-1.6g	NA	25	Clifford and Brick (1979).
M rosenbergii	23-49	Menhaden meal, Soya proteinate	28.5±1.5	0	0.15 g	0 3-5	week-12% week- 9%	35 Millikin et al (1980).

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9).
M. rosenbergii	15-35	Shrimp meal, Fish meal, Peanut meal, Soyabean meal (5 2 1·1).	---	---	0.12 g	Highest amount which appeared to have been consumed by any of the eight ponds.	No significant difference was observed between the levels	Boonyaratpalin and New (1982).
M rosenbergii	10-30	Fish meal, fish soluables, blood meal, cotton seed meal.	21-34°C	1.2-7.2	8-12 mm	3 to 35 % of body weight	25%	Perry and Tarver (1984).
Palaemon serratus	38-62	White fish meal, Shrimp meal, Peruvian and, Norwegian fish, meal, Casein, Pea nut meal, Maize and gluten meal.	28+2°C	-----	0.1 g	ad libitum	35	Forster and Beard. (1973).
Penaeus japonicus	62.6-76.2	Squid meal, Mysid shrimp meal, Brine shrimp meal, Petroleum Yeast, Fish meal, Whale meal, Activated sludge, Gluten, Soybean protein and casein.	23-28	34	0.92-7.43g	ad libitum	above 60	Deshimaru and Shigueno (1972).

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9).
P. japonicus	25-40	Soyabean meal, Hawaiiyan fish meal, shrimp meal, Brewer's Yeast	27	34	1.50-2.25g	Ad libitum	More than 40%	Balazs et al. (1973).
P. japonicus	25-50	Casein Egg albumin + Pure amino acids.	23-28	34	--	--	50 (10:1, Cas alb).	Deshimaru and Kurok (1974).
P. japonicus	2-66.2	Casein Egg albumin. (9 1)	25-28	--	0.8g	Ad libitum	52-57	Deshimaru and Yone (1978).
P. japonicus (Larvae).	--	--	--	--	--	--	45% at 25% CHO - level 45-5% at 15% CHO level and 65-3% at 5% CHO level.	Teshima and kanazawa (1984).
Penaeus aztecus	25	Soyabean meal, Hawaiiyan fish meal, shrimp meal, Brewers Yeast	27	34	0.58g	Ad libitum	--	Balazs et al. (1973).
P. aztecus	18-35	--	--	--	--	--	22-30	Shewbert et al. (1973).
P. aztecus	40-80	Vegetable materials, Eg. (Turnip green). fish meal.	25±1°C.	Batch A-15-17 Batch B-8-10	A-0.024g B-0 135g.	A-100% B- 50%	40%	Venkatara miah et al.(1973)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9).
P. aztecus	43-69	Menhaden, Shrimp meal, Rice bran, a-Soy flour. Squid meal	Exp.I-28.6-31.6 Exp.II-26.8-30	21.5-24.8 21.4-23.6	0.42-0.55g	ad libitum	43-45%	Fenucci and Zein-Eldin (1976).
Penaeus setiferus	14-52	Menhaden meal.	24-28	20-25	4g	5% of biomass	28-32%	Andrews et al (1972).
P setiferus	19.4-36.5	Shrimp meal, squid meal, a Soy Fish meal, Yeast.	28±1	34	1.5-1.53g	ad libitum	31.2	Fenucci et al (1980).
Penaeus stylirostris.	25-40	Menhaden meal, Sundried shrimp meal, Soy bean meal.	--	--	0.045g	ad libitum	30-35	Colvin and Brand (1977).
P stylirostris.	25-40	Shrimp meal, Fish meal, Petroleum yeast, Soy protien.	--	--	0.005g	ad libitum	44	Colvin and Brand (1977).
P stylirostris.	31.2 - 36.5	Squid meal a soy, Fish meal, Shrimp meal.	27-30.5	20-22	4.11-4.27g	ad libitum	33.8	Fenucci et al. (1980).
P stylirostris.	19.4 - 36.5	Fish meal, Squid meal, a Soy, yeast.	27-31	27-30	0.7-0.72g	ad libitum	32.2	Fenucci et al. (1980).

(1)	(2)	(3)	(4)
Penaeus californiensis	25-40	Menhaden meal, Sundried Shrimp Meal, Soyabean meal.	--
Penaeus vannamei	25-40	Menhaden meal, Sundried Shrimp Meal, Soyabean meal.	--
P monodon	30-50	Casein	27-31
P monodon	52.8-56.49	Squid meal shrimp head meal, and Fish meal	26-31
.monodon	25-55	Frozen shrimp tails, Squid, fish roe, fresh eggs	26±0.77
enaeus ndicus	21-53	Yeast Prawn meal.	28-30

(5)	(6)	(7)	(8)	(9).
--	0.122g	Ad libitum	35	Colvin and Brand(1977).
--	0.032g	Ad libitum	35	Colvin and Brand(1977).
30-32	0.6±16g	10% of bio mass	40-50% when, 5-10% lipid and 20% cHo are present (ie: 330 Kcal /100g diet)	Bautista (1986)
30-32.5	--	5% of total bio mass	52.8%	Millamena et al.(1986).
15-35	2mg	Ad libitum	35	Bages and Sloare(1981)
33-36	0.95g	Ad libitum	43	Colvin(1976)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9).
Penaeus merguiensis	29-55	Casein	25-29	35	1.2g	Ad libitum	50-55	Aquacop (1978).
P. merguiensis	16.6-50.9	Mytilus edulis meal	28±1°c.	25-28	0.29-0.30	Ad libitum	34-42	Sedgwick (1979).
[illegible] monoceros	--	Casein	--	--	--	--	55	Kanazawa et al. (1981).

2.3 Plant Protein Sources Used in Prawn Feeds

Several investigators have reported that prawns could efficiently utilize plant proteins and addition of plant protein in the diet have improved the growth and survival of prawns (Kitabayashi et al , 1971; Balazs et al., 1973) Williams (1958) stated that penaeids grow better on a plant-and-animal diet than on an animal or plant diet alone.

Swaminathan (1967), while investigating the availability of amino acids in plant protein sources, pointed out that the major problems in the utilization of protein from plant sources are the growth inhibitors, trypsin inhibitors, and the differences in the capacity of utilization of such protein sources by different animal groups Many of the sources studied by him were deficient in one or more essential amino acids For example, soyabean protein lacked methionine cereals and millets deficient in lysine and threonine while peanut proteins deficient in lysine, methionine and threonine Green leafy vegetables and leaves were also found to be deficient in methionine.

A deficiency in methionine, cystine, lysine and tryptophan among plant protein sources is reported by Fetuga et al (1973) and Felker and Bandurski (1977) Tryptophan, a limiting amino acid in the plant kingdom, could not be detected because it gets destroyed when the carbohydrate content of the sample is higher

than 20% (Simpson et al., 1976).

Many workers have tried to incorporate plant protein sources in prawn feeds (Forster and Gabbot, 1971; Kitabayashi et al , 1971). Forster and Gabbot (1971) reported that wheat gluten is a good source of protein and improved the growth rate of prawns. Kitabayashi et al. (1971) pointed out that the efficiency of plant protein is due to the presence of high content of polysaccharide when compared to monosaccharide. Deshimaru and Shigueno (1972) reported that protein sources like wheat gluten is rich in protein and could be used for feeding shrimps. They also revealed that soyabean, though a protein of vegetable origin, has an amino acid composition quite similar to that of prawns. Forster and Beard (1973) have tried soyabean meal in a diet for Palaemon serratus, wherein they obtained promising results.

Balazs et al. (1973) made use of soyabean protein and wheat gluten for feeding Penaeus japonicus and they obtained better growth for the prawns fed with this diet than those fed with fish-soya combination Sick and Andrews (1973) concluded that soyabean could be used as an exclusive protein source for Penaeus duorarum, while many other plant proteins could not serve this purpose. Hirata et al., (1975) reported that soyabean can serve as a partial or complete diet for Penaeus japonicus.

Since fish meal is becoming more and more scarce and costly,

efforts are now made to replace it partially or completely with soyabean meal Thus Akiyama (1989) used soyabean meal to replace fish meal in commercially processed Penaeus monodon feeds and demonstrated that soyabean could replace a considerable quantity of fish meal, provided the nutritional levels are maintained Same was the observation of Lawrence et al. (1987) who found that levels upto 30-45% could be used for replacing more expensive fish and shrimp head meals for penaeids Akiyama et al (1989) reported apparent protein digestibility values of soyabean meal and fish meal as 89.9 and 80.7%, for Penaeus vannamei while Piedad-Pascual et al (1990) report it as 98 and 61% respectively for P. monodon. As suggested by Akiyama (1988) the quantity of soyabean that could be substituted for fish meal in supplemental diets would vary from species to species. Piedad-Pascual et al, (1990) observed no significant difference in growth of P monodon when fed with diets containing different levels of defatted soyabean meal (DSM) The diet with 35% DSM and 16% fish meal gave the highest growth rate. They suggested that supplemental diets with various levels of soyabean meal are effective in growing P monodon to marketable size

Diets based exclusively on plant protein sources have often produced poor results Thus Subrahmanyam and Rao (1968) proved that post-larvae of Penaeus indicus grew slowly when fed

exclusively with vegetable matter. By feeding Palaemon serratus with two different diets made of plant protein sources of low nutritional value (gelatin and zein respectively), it was found that the prawns had grown only at 1/5th the rate at which those fed with fresh mussel mantle had grown (Cowey and Forster, 1971)

Stern et al. (1976) concluded that a single species plant diet could not satisfy the nutritional requirements of Macrobrachium rosenbergii Loss of weight and high mortality of prawns fed with plant diet were attributed to the fact that aquatic plants do not have the amino acid profile similar to that of animal tissue and have lower levels of all essential amino acids required for Macrobrachium (Boyd, 1969; Stern et al , 1976, Miyajima et al., 1977). Stern et al. (1976) stated that though the energy value of the plant diet was sufficient to support the growth of Macrobrachium juveniles, the prawns might not have ingestd or assimilated plant material to meet their energy requirements

Fenucci and Zein-Eldin (1976) reported that excess soyaflour caused lack of methionine in the diet and led to variation in texture of feed which in turn resulted in low ingestion of feed by the prawn Penaeus aztecus Spinelli et al. (1979) observed that the nutritional inadequacies of soya are in part related to compounds such as phytates and/or other ion-absorbing compounds

that impair or reduce the bioavailability of elements like iron, zinc and copper

Efforts were made by many to supplement plant diets with deficient amino acids. Kanazawa et al.(1970) found purified soya bean protein supplemented with essential amino acids, glucosamine and chitin serving the nutritional requirements of P Japonicus. Cowey and Forster (1971) found that supplementation of deficient amino acids like tryptophan and lysine plus tryptophan to diets containing gelatin as exclusive protein source and zein as sole protein source respectively, failed to augment the nutritional value of the diet. They attributed this to the deficiency of other essential amino acids (other than those that were added from outside) in the proteins concerned Supplementation of amino acids with intact proteins, whether plant or animal, has produced erratic results This could be due to poor availability of these crystelline amino acids to the prawns when compared to that of intact proteins (New 1976)

Penaeid post-larvae were found to grow better on a plant and animal diet than on either component alone (Williams, 1958). Balazs et al. (1973) observed an all vegetable diet inferior to fish-soya-shrimp combination for M. rosenbergii. They pointed out that the gluten protein used, served as an adhesive and improved the diet stability Venkataramiah et al (1975) reported that an

addition of 5 5% vegetable matter to test diets, at various protein levels, improved the relative protein conversion efficiency and survival rates of juvenile P aztecus They correlated the association of young shrimp with grass beds and marshes of estuaries to their preference for the plant materials.

Trials conducted with multi-ingredient rations, incorporating plant protein sources as major ingredients, have shown that such feeds are acceptable to the prawns and can produce better results Aquacop (1976) found Acacia meal or copra meal as suitable ingredients in the diet of M. rosenbergii, as the mineral and carotenoid requirements of the prawn are being met by these ingredients. Balazs and Ross (1976) evaluated the suitability of different plant sources such as soyabean meal, copra meal, or duck weed meal in combination with various animal protein sources A combination of soyabean and tuna meal produced greater growth of prawns than soyabean, tuna or shrimp meals individually, while growth on the other sources did not differ significantly Multi-ingredient rations, which incorporated plant protein sources as one of the ingredients, were found promising in the case of penaeids by Zein-Eldin and Corliss, (1976); Colvin and Brand, (1977), Maguire and Hume, (1982); Chen et al. (1985); Pascual, (1988) and palaemonids by Boonyaratpalin and New, (1980) and Millikin et al (1980)

Several locally available, low value plant protein sources (Eg agricultural by-products, mangrove leaves, sugar cane bagasse, aquatic weeds etc.) have been tried successfully as major ingredients in a multi-ingredient ration, besides utilizing them as feed supplements in pure form (Von Prahl and Gardeazabal, 1977, Miltner et al , 1983) and incorporating as plant detritus in prawn diets (Sumitra-Vijayaraghavan and Ramadhas, 1980). Goyert and Avault (1977) found that dried sweet potato could produce highest final average weight of crayfish, followed by sweet potato trimmings, rice stubble and rice hay while soyabean stubble and dried sugarcane stalks were not suitable as supplemental food for crayfish Alfred et al , (1977) fed Metapenaeus monoceros with low protein diets (primarily composed of mangrove leaf protein) and the production obtained was found to be low, which was attributed to the low food conversion just sufficient to meet the metabolic needs and the low energy availability for body building They pointed out that protein and its source are important factors in food conversion, perhaps species specific.

Many have studied the effect of adding plant materials including wheat bran, wheat straw, hay, bagasse (Caillouet et al , 1976; Miltner et al , 1983) and mangrove leaves (Von Prahl and Gardeazabal, 1977) directly to ponds, all reporting promising results from their experiments Venkataramiah et al (1978)

evaluated the feasibility of using laboratory decomposed high marsh grass directly and also as a feed component to P. aztecus diet. The results obtained were not satisfactory But favourable results were obtained in experiments with M monoceros, where the prawns were fed with mangrove leaves (Ramadhas and Sumitra-Vijayaraghavan, 1979) and mangrove leaves at various stages of decomposition in combination with rice bran (Sumitra-Vijayaraghavan and Ramadhas, 1980, Sumitra-Vijayaraghavan and Wafer, 1983)

Goswami and Goswami (1979) compounded cheaper feeds using locally available plant protein sources (coconut oilcake, soya flour, mangrove leaves, wheat flour) and animal sources like slaughter house waste products and factory by-products in different combinations They suggested that beef liver and coconut oil cake are rich in protein and could be utilized in the formulation of prawn diets Similar diets, employed in feeding M monoceros, M. affinis and P. indicus, produced best food conversion efficiency in P. indicus and lowest in M affinis (Goswami and Goswami,1982)

Sylso and Hughes (1981) evaluated the quality of the feed by substituting animal protein source with sea weed in the case of lobster Homarus americanus They found that 50% of fish or shellfish could be replaced with sea weed without producing any

adverse effect on the growth of lobsters, but 100% substitution of animal source by plant source led to loss of weight of test animals

Efforts to reduce cost of aquacultural grow out feeds have focussed on the use of leaf supplements and agricultural wastes as direct or indirect nutritional supplements Sambasivam and Krishnamurthy (1986) pointed out that diets prepared from mangrove leaves having promoted appreciable rate of growth in juvenile P indicus, hold out great promise as viable, cheap and efficacious alternatives to costly feeds. Addition of fresh leaves (Ailanthus altissima and Malva parviflora) to the diet of the prawn M rosenbergii, during a twelve month long laboratory study by Herpaz and Schmalbach (1986), resulted in elimination of black death syndrome, reduction of incidence of blackspot as well as increased average body weight Similar observations, on the nutritional improvement engendered by the presence of green plant material in the rearing water, were reported in the case of M. rosenbergii larvae (Maddox and Manzi, 1976, Brock, 1983). Freeman (1987) evaluated the merits of a low-cost, sugarcane bagasse based feed for semi-intensive production of juvenile P. vannamei and observed that growth rates from bagasse treatment were greater than manure and no feed treatments. Dempsey and Kitting (1987) hypothesized that bacteria symbiotic in digestive tract of P aztecus degrade

algal polysaccharide or other complex plant polymers in the animal's diet and possibly increase digestive efficiency of their host. Bruson and Taylor (1987) found that many varieties of rice (Oryza sativa) could be used as an efficient forage in crayfish ponds due to slow vegetative degradation of the plant

Primavera and Gacutan (1989) fed P. mondon juveniles with dead and decaying aquatic macrophytes and found that these are directly grazed or fed as detritus (after decomposition) by penaeids and other omnivorous detritivores. Barshaw (1989) observed early juvenile lobster, Homarus americanus, feeding on plant materials Brown et al. (1990) have reported that the macrophytes form an important nutritional source for the red swamp cray fish, Procambarus clarkii. Wong (1989) utilized waste grown green algae for feeding fresh water shrimp Macrobrachium hainanese

Although many workers have used different plant protein sources, these alone may not be able to provide all the nutritional requirements of the shrimp since many essential amino acids are lacking in them (Swaminathan, 1967; Schroeder, 1978). Penaflorida (1989) after evaluating the suitability of several indegenous plant and animal protein sources as potential components in diet of P monodon reported that arginine is a common limiting amino acid in plant and animal protein sources

Leaf proteins, Ipil-ipil, though high in iso-leucine content, was found to have lower level of methionine. Sweet potato, Acasia and Tamarind are found to be low in lysine.

2 4 Animal Protein Sources Used in Prawn Feeds

Different animal protein sources such as clam meal, squid meal, prawn meal, fish meal, mussel meal, egg yolk protein, casein etc. are being utilized in the preparation of compounded diets for prawns Kanazawa *et al* (1970) reported that a compounded diet approaching the biochemical composition of clam meal, had given a better growth rate for *Penaeus japonicus* (72% of the growth obtained for the control group fed with short necked clam) He found that glucosamine and chitin are the two indispensable ingredients of the prawn diet. Later Shudo *et al* (1971) proved that addition of 4% squid liver oil and 2% cholesterol could produce maximum efficiency to a formula feed for kuruma prawn Kitabayashi *et al*. (1971) observed that diets having 56-74% squid meal and containing 0 53% glucosamine, 1.04% phosphorus and 1 24% calcium produced highest growth rate in *P japonicus* Diet containing excess of any of the above three tested ingredients inhibited growth Later study by Kitabayashi *et al* (1971) proved that glucose cannot be used as a source of glucosamine They found that the quantity of squid extract in the diet could be reduced, if 0.83% arginine is substituted. They also reported a growth promoting effect of methionine when it was added at a level of 0.52% to squid based diet.

An admixture of certain protein sources together with additives or any single protein source alone,having the special pattern of amino acid distribution similar to that of prawn,could give better growth rate for prawns (Deshimaru and Shigueno,1972) Improvement in growth rate of prawns achieved by feeding diets based on short necked clam (Kanazawa et al., 1970; Kittaka, 1976; Sherief, 1987) or shrimp meal (Cowey and Forster, 1971, Andrews and Sick, 1972, Sick et al., 1972, Forster and Beard, 1973) or squid meal (Kitabayashi et al., 1971; Deshimaru and Shigueno, 1972; Shigueno et al., 1972, Kittaka, 1976, Fenucci and Zein-Eldin, 1979) could well be correlated to the above observation of Deshimaru and Shigueno (1972). The report of Kanazawa et al (1970) that soyabean is a superior protein source for penaeid prawn cannot agree with the above contention So also poor growth rate of Penaeus duorarum observed by Sick and Andrews (1973), when the prawns were fed with fish meal, could be attributed to the fact that wide differences exist between amino acid profile of fish meal and the prawn, especially in phenylalanine and basic amino acids

The importance of the amino acid composition of the protein source used in the diet was stressed by many investigators Cowey and Forster (1971) observed that protein sources that are normally deficient in certain essential amino acids could not improve growth rate of prawns Andrews et al (1972) pointed out that

growth inhibition produced by fish meal, when incorporated at high levels, might be due to the imbalance in its amino acid composition Studies by Shewbart et al. (1973) stressed the need for identifying the amino acid values of a protein source to judge the quality of the source Thus composition of the source used is an important factor and lower protein levels may be adequate, provided a favourable amino acid balance could be achieved (Balazs and Ross 1976, Zein-Eldin and Meyers, 1973). Forster and Beard (1973) obtained higher growth rates for Palaemon serratus with shrimp meal diets than with fish meal diets, when they tried to substitute 45% white fish meal with a number of high protein materials including shrimp meal. But growth rate of prawns fed with the above diets was low when compared to those fed with shrimp meal or mussel mantle. The better growth rate attained when fed with shrimp meal or mussel mantle, was attributed to the balanced amino acid composition Cowey and Forster (1971) also reported that addition of shrimp meal or mussel mantle could considerably improve growth rate of prawns.

Investigations combining animal protein sources with suitable plant protein sources to achieve favourable growth rate were also carried out by several workers Balazs et al. (1973) found that best growth rates were obtained in the prawn Macrobrachium rosenbergii when diets containing fish, soyabean and shrimp were fed to the prawn In a later trial, Balazs et al. (1974) reported that better growth rates for M rosenbergii could be attained by

combining tuna meal and soyabean meal, than using any of the above sources individually. This according to Nelson et al (1977 a) could be related to lower energy cost of utilizing these diets (ie., lower specific dynamic effect). Nelson et al. (1977 b) showed that the assimilation rate of juvenile M rosenbergii fed on mixed diet was low, hence lower specific dynamic effect and a lower non-growth component of energy utilization, while the rate was high for prawns fed on an exclusively plant based diet Pelleted diets using shrimp meal: fish meal: peanut meal. soyabean meal (5:2.1:1) as the major protein sources were successfully employed for rearing M. rosenbergii by Boonyaratpalin and New (1980) A protein formulation consisting of menhaden meal and soya proteinate in a 1.65:1 ratio at 40% protein level had given the best rate of growth for M. rosenbergii in an experiment by Millikin et al. (1980) They pointed out that this requirement could be lower if amino acid balance of protein sources is adjusted to provide specific requirement Similar reports on the improved performance by a mixture of plant and animal protein sources were provided by Williams (1958) and Venkataramiah et al (1975) in Penaeus aztecus, Zein-Eldin and Corliss (1976) and Colvin and Brand (1977) in Penaeus californiensis, Chen et al (1985) in Penaeus setiferus and Penaeus vannamei, Rajalakshmi et al (1986), Chakraborti et al (1986) Ghosh et al (1987) and Pascual (1988) in Penaeus monodon

It was observed by many that incorporation of squid extract stimulated the growth of prawns. But higher levels of incorporation of squid extract was reported to be required to produce better growth rate of P japonicus Thus Kitabayashi et al. (1971) reported the required level to be as 56-74% and Deshimaru and Shigueno (1972) reported it to be as 20-47% Fenucci and Zein-Eldin (1976), on the other hand, pointed out that larger quantities of squid meal (30 and 49%) incorporated diets resulted in high mortality and growth depression in P aztecus They obtained best growth rate of P. aztecus when fed with diets containing 5 and 15% squid meal.

Another potential protein source is the egg white protein It is considered as an attractant for crustacean larvae (Ling, 1969). Sick (1976) reported it as a potential source and stated that the high efficiency of the source is due to the relatively large variety of amino acid contained in ovalbumin The ovalbumin is considered to aid in increasing the ingestion rate of prawns

The feasibility of using shrimp meal in the diet for prawns has been tested by several investigators. Sick et al. (1972) observed that formulated feed having high content of shrimp meal produced best growth and survival of P setiferus and P aztecus Colvin (1976) found prawn meal protein being well assimilated (80-85%) by Penaeus indicus, with the uptake efficiency relatively independent of the level of the prawn meal in the diet Shrimp

head meal, a rich source of poly unsaturated fatty acids essential for crustaceans (Joseph and Meyers, 1975), could serve as a good source of fatty acids and pigments for use in prepared diets for M. rosenbergii (Sandifer and Joseph, 1976) and many marine animals (Joseph and Williams, 1975). Similarly this contains several essential amino acids, high protein (44%) and fair amounts of calcium carbonate which could induce high growth rate in prawns (Forster, 1976, Venkataramiah et al , 1978). Studies have revealed that glucosamine, a breakdown product of chitin, has growth promoting effect on prawn (Kitabayashi et al , 1971; Vaitheswaran and Ahamad Ali, 1986).

Manik et al. (1977) suggested that shrimp head waste, fish meal, peanut cake and soyabean waste containing high level of protein could be used for formulating shrimp feeds Boghen and Castell (1981), after evaluating the nutritional value of protein sources like casein, egg, feather and shrimp meal to lobsters, concluded that the shrimp protein was the best among the four protein sources evaluated and factors other than amino acid composition (eg mineral content, digestibility etc) play an important role in making this source superior than other sources Ahamad Ali and Sivadas (1983) found that a combination of prawn waste, mantis shrimp, fish meal, groundnut oil cake and casava produced the best growth rate of P. indicus Udayakumara and Ponniah (1988) obtained better growth when prawn muscle meal based

diets were tested on P. indicus. Galgani et al. (1986) studied the effect of various animal protein sources on the reproduction of P. indicus and found that diets containing both natural (mollusc) and artificial components including 9% broken penaeid prawn gave the best results.

There are few observations that are contrary to the above results. Thus Balazs et al. (1973) and Forster and Beard, (1973) did not obtain good growth rates when shrimp meal was used as the major protein source in prawn diets Colvin and Brand (1977) reported that the growth of Penaeus californiensis was improved when the marine protein (either shrimp meal or fish meal) was reduced and replaced with soyabean meal. The better growth rates obtained are attributed to an improvement in mineral and amino acid balance of the diet, obtained by the replacement of marine protein by vegetable sources

Milk casein as a sole source of protein supplies all essential amino acids, but growth stays below that expected with an artificial diet (New, 1976; Aquacop, 1978). A casein gelatin mixture was employed by Bautista (1986) to rear P monodon Recently, Lim and Persyn (1989) reported that poor utilization of casein by many shrimp species could be attributed to the low arginine content of the source

It has been pointed out that a combination of prawn meal with fish meal gives better performance than using any of these animal

protein sources alone. Colvin (1976) reported that a combination of fish meal and shrimp meal in the ratio 3.2 was superior to using either prawn or fish meal alone. So also Pascual and Destajo (1978) found that in P. monodon a combination of equal quantities of shrimp head meal and fish meal gave better growth than those fed with prawn head meal alone. Colvin (1976) stated that with the notable exception of tyrosine and possibly also phenylalanine, fish meal is a richer source of proven essential amino acids than prawn meal and this deficiency could be compensated by prawn meal-fish meal combination. As pointed out by Stahl and Ahearn (1978), searching for optimum amino acid levels for incorporation into commercial diets might be less important, especially where natural pond productivity provides prawns with many of their requirements

Feeding trials using mussel mantle as the protein source for prawns have produced inconsistent results When Penaeus japonicus was fed with fresh mussel and fish meal diet, Lumare et al (1985) obtained poor growth rates This is contrary to the report by Kittaka (1976) that fresh Mytilus is a good food source for Penaeus japonicus Favourable results were obtained with mussel meat in Palaemon serratus (Cowey and Forster, 1971, Forster and Beard, 1973) and in Penaeus merguiensis (Sedgwick, 1979)

Squid meal is reported to contain growth promoters and feeding stimulants for prawns. Thus Lim et al. (1978) reported

that squid meal is a superior source of protein than shrimp meal, mussel meat, casein and Spirulina for post-larvae of P monodon Cruz-Ricque and Aquacop (1987) proved that inclusion of 10% squid meal could rapidly improve growth of the juvenile P monodon According to Cruz-Suarez and Guillaume (1983) fresh squid has got three fractions: hydroalcohol soluable fraction, lipid fraction, protein fraction, and the first fraction contains feeding stimulants and feed attractants which help to enhance feed intake, while the lipid fraction is not better than any other source (like cod liver oil, and soyabean lecithin) used in the basal diet They concluded that growth promoting effect of squid meal is due to a protein fraction of squid tissue having an unknown growth factor, and not due to similarity in amino acid profile of the source with that of prawns. Addition of the protein fraction of squid (SPF) (1 5, 3 0, 6 0 and 16%) by Cruz-Ricque et al (1987) in the diet of four species of shrimps such as Penaeus stylirostris, P vannamei, P. monodon and P. indicus showed that this growth factor' has positive influence on the growth of prawns At levels as low as 1.5 and 3.0% there was good response in P stylirostris and P vannamei and this response may not be due to the improvement in the amino acid profile of the diet, but due to the influence of the 'growth factor'. In the case of P monodon, wherein it required 6 and 16% squid protein fraction (SPF) to get a positive response, it could be due to the

attainment of amino acid profile similar to shrimp muscle (Cruz-Ricque et al 1987)

Cruz-Suarez et al. (1987) studied the dietary effect of different levels of squid protein fraction (SPF) on juvenile Penaeus japonicus and found that growth rate and food conversion ratios enhanced even with a level of incorporation as low as 1.5% SPF in the diet Recent studies by Cruz-Ricque et al (1989) indicated that squid extract has got an effect on the absorption of nutrients (intestinal transport or endocytosis of free amino acid and glucose), and influence of the squid fraction on the digestive physiology of the prawns. Meyers (1989) suggested that inclusion of the squid meal in a penaeid diet would be most economical, as under more intensive culture conditions nutritional demand is met fully from the given feed

In the case of Penaeus stylirostris, a differnce in response was shown by different size groups of prawns, when they were fed with squid meal based diets. Thus Fenucci et al. (1980) found that smaller ones (0 7 g) grew better on diets having high quantity of squid meal, while larger animals (4 g) performed better on a diet having squid meal and soyabean meal in equal proportion or one in which the later is more

Clam meat is the most widely used conventional protein source for the prawns (Kittaka, 1976) Sherief (1987) working on M

rosenbergii reported clam meal as a better source than fish meal Kompiang (1990) reported it as a superior source of protein for penaeids.

Although the positive response with clam meal could be attributed to the similarity in amino acid profile the prawns have with that of clam, the work by Deshimaru et al. (1985) proved otherwise. They could not get positive results when crystelline amino acids were supplemented to whole egg protein and a casein albumin mixture, to produce diets having essential amino acid profile similar to that of clam protein. This may be due to poor capacity of prawns to utilize crystelline amino acids supplemented in the diets (New, 1976) or due to the absence of a growth factor', similar to the one described for squid meal (Cruz-Ricque et al. , 1987)

Penaflorida (1989) on the basis of essential amino acid index (EAAI), evaluated the suitability of several animal protein sources like shrimp meal, fish meal, squid meal. plant protein sources like soyabean meal, swamp cabbage, sweet potato, Ipil-ipil, Acacia, Tamarind and protein concentrates like casein, gelatin and reported that arginine is a common limiting amino acid in plant and animal sources, shrimp and squid meals being close to arginine levels of prawn muscle He found that protein concentrates, in general, are low in arginine and gelatin and zein are low in tryptophan

2 5 Unconventional Protein Sources used in Prawn Feeds

2.5.1 Single Cell Proteins

In recent years there has been growing interest in exploring the possibility of using various unconventional protein sources, as a replacement for fish meal in aquaculture diets Single cell proteins used in animal feeds include a wide range of algae, fungi (including yeasts) and bacteria, which are produced by fermentation Tacon and Jackson (1985) pointed out that compared to conventional plant and animal proteins, these microorganisms could be produced advantageously from raw carbon substrates (coal, petrochemical, natural gas) or from agricultural or cellulosic waste products, that they are rich in protein and that they have a low generation time

2.5 1 1 Yeast

Kawano and Ohsawa (1971) attempted mass culture of marin yeast, Saccharomyces sp and the possibility of its use as larval feed for prawns has been indicated by Furukawa (1972), Furukawa and Hidaka (1973) and Furukawa et al (1973)

There is no agreement in the results obtained by different workers, with regard to the use of petroleum yeast in the diet of prawns Forster and Gabbot (1971) reported that petroleum yeast was well assimilated by the prawns Deshimaru and Shigueno (1972)

observed good growth of post larvae of Penaeus japonicus when petroleum yeast was added to a diet at a level of 20% On the other hand, Forster and Beard (1973) observed an adverse effect on the growth of Palaemon serratus, when petroleum yeast was substituted for fish meal at a level of 45% in a standard diet.

Feeding trials using brewers yeast have produced good growth of prawns. Fenucci et al (1980) used brewers yeast to substitute a part (12 5%) of the vegetable protein in a multi-ingredient diet for the prawn Penaeus setiferus, and found that this diet could produce the highest mean weight increase in the prawn.

Different varieties of yeast protein were used for incorporation in the feed for prawns, wherein they produced promising results. Brewers yeast was incorporated in the diet for Palaemon serratus and Pandalus platyceros by Forster and Gabbot (1971), torula yeast in the diet of Metapenaeus maclaye by Maguire and Hume (1982), brewers yeast and n-paraffin yeast in the diet of Penaeus monodon by Rajalakshmi et al (1986), marine yeast in the diet of P. monodon by Aujero et al. (1984).

Yeast protein was found to be superior to blood meal protein in the case of Penaeus californiensis by Brand and Colvin (1977) They also found that yeast protein is equally good as fish meal

protein and can be used for replacing the latter source in a diet of P californiensis Aujero et al (1984) made use of Saccharomyces cerevasiae and Rhodotorula aurantica for the larval rearing of Penaeus monodon and obtained higher survival rate than those reared on algae.

A variety of single cell proteins including yeast protein have been utilized for rearing larval stages of penaeid prawns by Furukawa et al (1973), Watanabe (1980), El-Amad (1982) and Al-Hajj et al (1983) The better performance of the yeast protein has been attributed to the high content of poly unsaturated fattyacids, vitamins and minerals

2.5 1 2 Bacteria

Studies have indicated that single cell protein, especially the bacterium Methylophilus methilotrophus, could replace 75% of fish meal protein in a salmonid diet (Bergström,1979, Tiews et al , 1979, Beck et al., 1979; Spinelli et al ,1979, Tacon et al ,1983) Compared to yeast single cell protein, the bacterial single cell protein is reported to have more nutritive value to common carp (Atack et al., 1979)

Studies on the direct utilization of bacterial single cell protein in prawn production diet is scanty However many researchers have indicated the possibility of using this protein

source, directly or indirectly, in the diets of prawns (Untawale et al , 1977, Goyert and Avault, 1977; Sumitra-Vijayaraghavan and Ramadhas, 1980, Freeman, 1987) Compounded feeds that are added to prawn culture ponds serve as substrates for the building up of bacteria. Moriarty (1986) reported that the bacteria that are developed on the feeds added to culture ponds serve as a good protein source (having 40-50% conversion efficiency) for penaeids So also Freeman (1987) observed that the bacteria that had developed on bagasse based feed after its addition to culture pond, were ingested by P. vannamei

2 5 1 3 Algae

Different species of algae have been tried in the larval rearing of penaeid prawns The important species of diatoms used as live food for protozoeal stages of penaeid prawns include Skeletonema sp., Melosira sp , Thalassiosira sp., Nitzschia sp Rhizosolenia sp. and Chaetoceros sp (Shigueno, 1976; Muthu, 1980) A detailed review of the algal and other live food organisms used in the larval rearing of penaeids is provided by Neelakantan et al (1988) Alfono and Mariel (1984) suggested that Tetraselmis chuii fertilized with earth worm meal could improve the growth and development of cultured shrimp protozoea Heterotrophically cultured spray dried Tetraselmis suecia was suggested by Beidenbach et al (1990) as a partial replacement for live algae in larviculture of P vennamei

Dried algal single cell protein has been found to have a lower food value for fish than either yeast single cell protein, bacterial single cell protein or fish meal (Matty and Smith, 1978, Atack and Matty, 1979; Atack et al., 1979). Lim et al. (1978) obtained the lowest growth rate for P.monodon fed exclusively on Spirulina James et al (1990) evaluated the suitability of S fusiformis as a protein source for Macrobrachium rosenbergii and reported that it could not serve as a sole protein source. They suggested that it could be efficiently used as a supplementary protein source as reported by Meske and Pfeffer (1978), Hepher et al. (1979) and Appler and Jauncey(1983) for fishes.

2 5 2 Others

Tiensongrusmee et al. (1978) found chironomid larvae as a good protein source for P. monodon. Goswami and Goswami (1979 formulated cheap artificial diets using locally available natural food stuffs, including slaughter house by-products and factory by-products for prawns such as P. indicus, M affinis and M. monoceros with promising results.

The flesh of African snail Achatina fulica, the mass culture technique of which is perfected in India (Unnithan and Vinci 1990), was used as an exclusive food source for M rosenbergii by Costa (1980) and found that this particular source could be used as an exclusive protein source for the prawn Ung and Itoh (1989)

evaluated the suitability of tropical sergestid meal (Acetes sp) against Antartic euphausid meal and found that the former source could serve as a sole protein source for penaeids due to its short generation time and high nutritive value

2 6 Detritus as a Food Source for Prawns

Organic detritus, derived mainly from macro vegetation, is considered as a link of major importance between primary and secondary production in shallow water areas Many animals, including prawns, have been shown to feed on detritus (Newell, 1965, Odum, 1968, Leh and Sasekumar, 1980).

The penaeids, in general, are described as 'omnivorous scavengers' or 'detritus feeders' (Williams, 1955, Dall, 1967) Williams (1958) attributed the preference of prawns for areas rich in organic detritus to their feeding habit Kuttiyamma (1973), after studying the food and feeding habits of five species of penaeids, concluded that all the species are omnivorous or detritus feeders She found 50 7% of the gut contents as constituted by plant and animal matter Studies by George (1974) revealed that Metapenaeus monoceros juveniles of 15-50 mm size had more detritus in their gut while those above 50 mm had less in their gut Leh and Sasekumar (1980) found that penaeid prawns collected from natural habitat consumed 64-88% animal material by volume and 12-36% of plant matter, of which 11-59% was identified positively as of mangrove detrital origin

Organic detritus is not clearly defined and is known to be of heterogenous nature, harbouring microbial communities The composition and quantitative importance of these communities have

not been tested in detail by many early researchers Of late, there has been growing interest towards detailed investigations on these aspects. Studies were conducted to investigate the microbial composition and microbial processing of the detritus Newell (1965) stated that microorganisms constitute the real food source for detritus consumers rather than nitrogen poor residues of macro vegetation Fenchel (1969, 1970) investigated the general composition of microbial communities associated with turtle grass detritus (both from the field and artificially prepared ones under aerobic conditions). The artificially prepared turtle grass detritus was found colonized by microbial flora within a period of four to six days after it is placed in sea water at 24 C, which was quite similar to one that was observed on the detritus collected from the field Fenchel (1970) suggested that plant residue get decomposed by bacteria and fungi and these microorganisms serve as the real food of at least some animals feeding on detritus Odum and Heald (1975) observed that decaying mangrove leaves are permeated by fungii, protozoans, micro algae and bacteria They reported an increase from 6 to 20% protein in Rhizophora leaf litter kept in sea water for six months

The dynamics of microbial action on mangrove litter are unknown but the major sequences leading to detritus formation appear comparable to those described by Lee (1980) and Boulton and Boon (1990) for plant litter decomposition in other aquatic

environments As pointed out by Macintosh (1982), an understanding of the dynamics of mangrove detritus formation would have direct practical value, because of the differences in the approach towards the use of mangrove leaves as a manure cum food by the fish farm operators.

Laboratory studies on the degradation of detritus by microbial action have shown that there is an increase in nutritional value of organic matter undergoing decay Untawale et al (1977) found that during decomposition of mangrove leaves, Rhizophora mucronata and Avicenia officianalis, there has been a reduction of carbohydrates and lipids, while the protein value gradually increased, thereby enhancing nutritional value of detritus They suggested that the gradual increase in protein could be the result of microbial colonization and the introduction of desirable microbial flora which inturn accelerated the decomposition process

Aerobic decomposition of ten agricultural by-products was studied in terms of C:N ratio changes with time by Goyert and Avault (1977) They found that there was decrease in C N ratio and increase in the nutritional value of the inundated plant material They observed that when the plant material entered the detrital system, there was a build up of microbial population which utilized the carbonaceous material as a substrate and energy

source The detritus with its attached micro fauna has thus been reported to have a higher protein content and a lower C N ratio than the original plant material (Fenchel, 1970, Untawale et al., 1977; Goyert and Avault, 1977, Sumitra-Vijayaraghavan and Ramadhas, 1980; Sumitra-Vijayaraghavan and Wafar, 1983) Schroeder (1978) found the digestion of straw and cotton results in building up of microorganisms on cellulose fibres and fishes appear to harvest the bacteria and protozoa by ingesting these microbial substrates Schroeder (1978) stressed that due attention should be given to this type of protein generation.

Considering the benefits of microbial quality upgradation of the plant material, many (Goyert and Avault, 1977, Venkataramiah et al , 1978, and Srinivasan, 1987) suggested that agricultural by-products should be processed for a period of time to enhance their nutritional value through the process of microbial decomposition before they are added as supplemental feeds Pullin (1987) suggested that the nutrient value of macrophyte feed inputs could be improved by microbial pre-conditioning ie , by decomposing the plant materials. He pointed out that this process could, avoid in-pond oxygen demand, reduce the health hazards from pathogens and also reduce the bulk of the plant material, bringing down the cost of transportation and storage

The use of detritus as a supplementary food source has been

stressed by many investigators (Venkataramiah et al , 1978, Wiedenbuck, 1980, Vijayaraghavan and Jayamanne, 1989, Primavera and Gacutan, 1989) Qasim and Easterson (1974) obtained high assimilation efficiency and gross food conversion efficiency when M monoceros was fed with estuarine detritus Penaeus duorarum fed with rice bran detritus, at a stocking density of 75,000/ha showed the same growth rate as those prawns fed on a catfish ration at a [illegible] stocking density of 1,50,000/ha (Caillout et al 1974)

Von Prahl and Gardeazabal (1977) reported that addition of mangrove leaves, Rhizophora sp to shrimp nursery ponds resulted in 30% increase in growth compared to shrimp in ponds without leaf addition Von Prahl (1978) found that the first stage postlarvae of Penaeus stylirostris were able to digest wax from surface of mangrove leaves, while late post-larval and juvenile stages of this species grazed on epiphytic microorganisms that colonize the decaying leaves Morrissy (1979) stated that in crustacean culture ponds the predominant pathway of energy flow is through detritus food circuits Pierce and Laws (1982) pointed out that by more intelligent management of benthic microbial productivity, production of crustaceans could be increased without incurring increase in feed costs

Paddy straw and similar agricultural by-products hold promise

as detrital forage to supplement pelleted rations in extensive and semi-intensive systems of prawn culture. Decaying paddy straw in seasonal paddy fields is reported to contribute to the increased prawn productivity in Pokkali' fields of Kerala (Menon, 1954, George, 1974) Miltner et al (1983) added rice hay directly as a detrital feeding substrate in M rosenbergii culture ponds The maximum average prawn weight (29 g in 133 days) obtained in hay + pellet ponds was attributed to the presence of detrital substrate in that pond These authors suggested that further research is required to quantify optimum loading rates, nutritional contribution and effects on water quality. Primavera and Gacutan (1989) suggested that many aquatic macrophytes, when added to prawn culture ponds, could contribute to detritus used as food by prawns and other benthic organisms

Incorporation of detritus as an ingredient in the supplementary feeds of prawns has been stressed (Alfred et al , 1978, Sumitra-Vijayaraghavan et al , 1980, Wiedenbuck, 1980) Mangrove leaves (Rhizophora mucronata) at different stages of decomposition in combination with rice bran was fed to M monoceros by Sumitra-Vijayaraghavan and Ramadhas (1980) They found that maximum conversion efficiency could be obtained when the prawns were fed with diets prepared from completely decomposed mangrove leaves Sumitra-Vijayaraghavan et al (1980) stated that decaying leaves of Rhizophora mucronata with their high energy and

protein content are good food source for detritivorous organisms Wiedenbuck (1980) pointed out that prawns are inefficient at ingestion of extruded foods and are often unresponsive to applied feeds before enrichment by bacteria He suggested that the prawns adjust to the absence of supplementary feeds by rapidly increasing consumption of detritus and vegetation. Moriarty (1986) observed that in a prawn culture pond, where excess of supplementary feed becomes high quality detritus for bacterial build up, a conversion efficiency of 40-50% would be possible, because detritus formed from pelleted feed is of high nutritional quality

Anderson and Parker (1987) investigated the utilization of food given to P. vannamei in grow-out ponds They worked out that added feeds supplied only 23 47% of growth carbon while 53 77% of growth is due to grazing on pond biota This observation gives support to the findings of Schroeder (1983) that supplied foods are less utilized by pond reared shrimp than might be expected Freeman (1987) reared P vannamei on pellets made from processed bagasse and observed that shrimp ate not only the decomposing fibres of bagasse pellets but also the bacteria,algae and microscopic zooplankton that feed on pellets and proliferate The pellets, formed new surfaces where the microorganisms could remain attached and eat These microorganisms together with pellets are relished by the prawns.

MATERIALS AND METHODS

III MATERIALS AND METHODS

3 1 Prawns

The post-larve of Penaeus indicus were brought from the Marine Products Export Development Authority Hatchery, Vallarpadam, Cochin They were transported to the laboratory at the College of Fisheries, Panangad in oxygen filled polythene bags After slow acclimation to a salinity of 20 ppt from 34 ppt, they were maintained in 2 ton FRP tanks for further growth and acclimation to laboratory conditions.

The juvenile prawns used to study their preference for different plant detritus as food, were of the size range of 25-32 mm and 110-150 mg The size range of those used for the first set of feeding experiment was 21-29 mm and 80-105 mg and those used for the second experiment had a size range of 18-21 mm and 32-45mg

3 2 Preparation of Plant Detritus

To study the preference of P indicus juveniles for plant detritus from different sources, four plant sources found in the vicinity of prawn culture fields were selected The selected items were, leaves of the mangrove plant Rhizophora apiculata (Fig 1), whole plant of the floating aquatic weed Pistia

Fig 1 *Rhizophora apiculata*

Fig 2 ***Chromolaena odorata***

stratiotes, tender twigs and leaves of the weed plant Chromolaena odorata growing profusely close to prawn fields (Fig 2) and paddy (Oriza sativa) straw. All these materials were chopped to a size less than 1 cm, and 250 g of each were introduced into separate plastic containers of 15 litre capacity with 8 litres of filtered brackishwater (22ppt salinity). All the tanks were covered to cut off sunlight so as to avoid algal growth. The plant materials were allowed to decay for a period of thirty five days by which time all the plant materials disintegrated fully

3.3 Experiment to Study the Preference of Prawns for Different Plant Detritus Materials as Food

From the four different plant sources, two most preferred ones were selected by conducting an experiment to find the preference of the prawns. For this, ~~about~~ twenty uniform sized juveniles of P indicus were introduced into an oval tank of 1 ton capacity with 300 litres of brackishwater of 20 ppt salinity The prawns were allowed to acclimate to the new tank conditions for a period of 12 hours

Samples of decomposed materials prepared from the four different plant sources were then placed at the four sides of the tank, keeping all the four items separately in each side, at equal

distance from the centre ensuring that all the four items were available for the prawns to choose according to their preference. After ten minutes, by which time majority of the prawns have distributed themselves to the different samples kept and started feeding on their preferred plant detritus, the number of prawns that had occupied a particular sample of detritus was noted at every five minutes. The experiment was continued for a period of 1 hour. By this time mixing of different detritus had taken place due to continuous feeding activity of the prawns, which made it difficult to judge accurately as to which plant detritus one prawn was feeding at a particular time. The experiment was repeated four times. Based on this experiment, two plant sources which were best preferred, judged on the basis of the number of prawns that were observed feeding on a particular detritus, were selected for further studies.

3.4 Digester Used for the Bulk Decomposition of Plant Materials

The two better preferred plant sources were used for bulk digestion using a digester designed for the purpose (Fig.3)

The capacity of the cylindroconical digester was 100 litres.

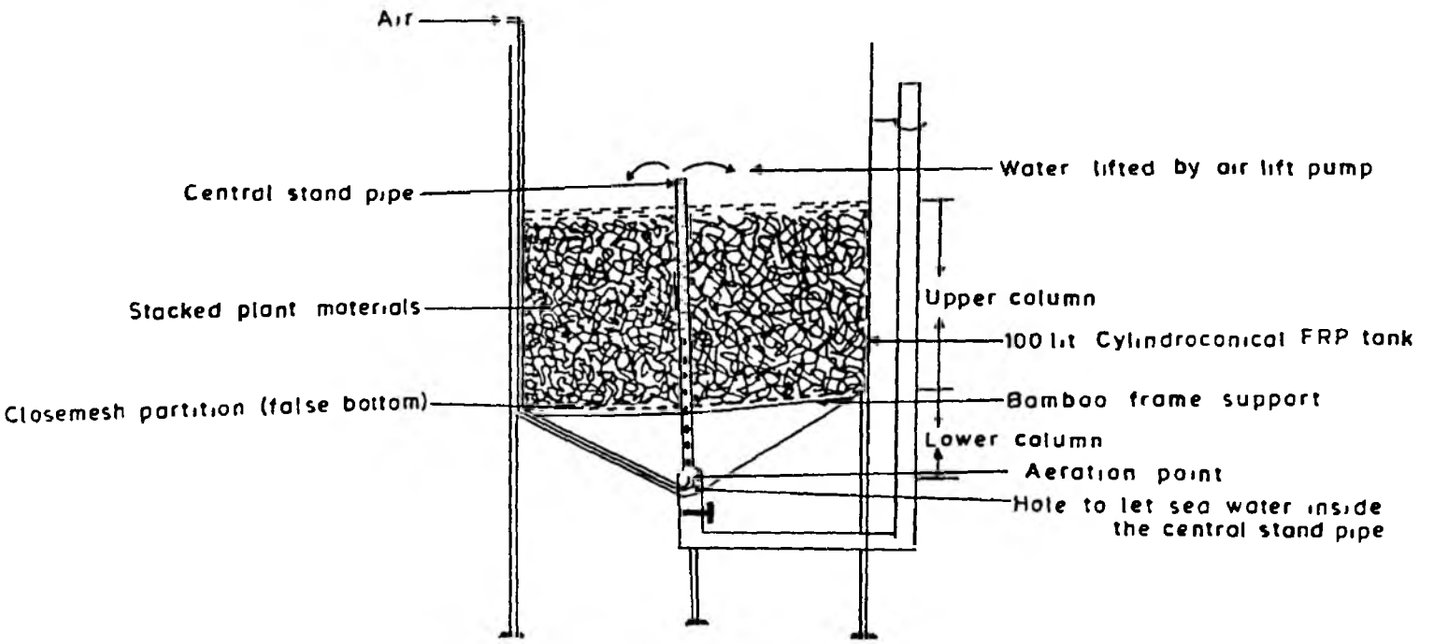


Fig 3 Digester

The cylindrical portion was separated from the conical portion by a fine meshed synthetic netting supported by a bamboo frame A central stand pipe of 1 5 cm diameter was erected at the centre of the conical portion which extended to a height of 30 cms above the false bottom

The central stand pipe was perforated at the bottom portion to facilitate the entry of water into the pipe At the base of the stand pipe air from an air compressor channelled through P.V C tubes was provided so as to air lift the bottom water upwards and get discharged out at the open end of the stand pipe Water from the lower chamber got contineously lifted through the stand pipe The water, trickling through the decaying vegetable matter stacked in upper column reached the lower column and completed the cycle, thus providing a gentle water circulation and aerobic condition inside.

The false bottom provided in the digester has helped to retain the decaying plant material in the cylindrical portion and in avoiding possible clogging of the holes provided at the base of the stand pipe Ten such digesters were used for decaying the leaves

After chopping the leaves to a size less than 1 cm, about fifteen kilograms of chopped leaves of each source were prepared Three kilograms of leaves were introduced to each digester. Five

such digesters each were maintained for each plant material, to study the progression of digestion process. Thirty litres of filtered seawater having 10 ppt salinity was added to each of the digesters so that the leaves were completely immersed in water. The salinity ranged between 10 and 13 ppt. The mean temperature at the time of observation (6 p.m) was 29° C.

3.5 Analysis of Protein Levels of Detritus during the Process of Decay

Separate samples were taken from each tank once every five days for analysis of protein levels. The samples taken were spread uniformly in enamel trays and dried at 60° C overnight. The dried detritus samples were pulverized and kept in separate air tight plastic dishes. Once in every five days a total of ten such samples were collected, dried and nitrogen content of each of the sample was estimated by Micro-Kjeldhals method (AOAC, 1980). The nitrogen content was multiplied by the factor 6.25 to arrive at the crude protein content The optimum duration of decay for attaining the maximum protein level was found out. From the two plant detritus sources, the source which gave highest protein level was selected for incorporation in-to formulated feeds for the juveniles of Penaeus indicus.

3.6 Experiments to Study the Feasibility of Using Detritus of Plant Origin as the Sole Food Source and the Level of its Incorporation in the Diet for *P. indicus*

Chromolaena odorata leaf detritus was selected for these studies on the basis of its higher protein content.

Two experiments were conducted, the first to evaluate the suitability of using *C. odorata* leaf detritus as a sole food source for *P. indicus* juveniles and the second to find the level at which *C. odorata* leaf detritus could be used to replace—an animal protein source in the diet for *P. indicus* juveniles.

3.6.1 Feed Formulation

3.6.1.1 Feed Ingredients

Chromolaena odorata leaf detritus was selected for further studies on the basis of its comparatively higher protein content. This was used as the main ingredient in the preparation of test diet for the first experiment. Tapioca powder served as the binder. Dried clam meal formed the main ingredient of control diet, tapioca powder served as the binder and cellulose as the filler.

For the second experiment, the main ingredients used were *C. odorata* leaf detritus, dried clam meal, ground nut oil cake, rice bran and tapioca powder.

All the sources except the plant detritus were procured from the local market

3 6 1 2 Proximate Composition of Ingredients.

Proximate composition of all the feed ingredients was analysed before formulating the feed Moisture content was estimated by keeping the feed ingredients overnight at 105 C Crude protein content was analysed by Micro-Kjeldhals method (AOAC,1980) Solvent extraction method (Pearson,1976) (using petroleum ether having boiling point 40-60 C) was used for extracting the crude fat in a soxhelet apparatus for 10-16 hrs Ash content was determined by igniting the sample at 550 C for 6 hours in a muffle furnace The carbohydrate content (NFE nitrogen free extract) was determined by the difference method(Hastings, 1976)

ie NFE (including fibre)= 100 -(% moisture+% crude protein + % crude fat + % ash)

Table 2 (i) Proximate composition of the ingredients (%) used for preparing the diets employed in feeding experiment-I

Ingredients	Moisture	Crude Protein	Crude fat	NFE	Ash
Detritus	9 19	26 02	6 10	34 56	24 13
Clam meat	8 45	50 68	13 64	20 73	6 50
Tapioca	10 72	6 92	5 26	75 75	1 35

(ii) Proximate composition (%) of the ingredients used for preparing diets employed in feeding experiment-II

Detritus	9.80	25.50	5.90	34.78	24.02
Clammeat	8.20	51.24	11.60	21.27	7.78
Rice bran	8.40	11.50	5.41	62.70	11.99
Ground nut Oil coke	10.50	33.00	7.68	41.63	7.19
Topioca	11.00	6.60	5.42	75.68	1.30

3.6.1.3 Formulation and Preparataion of Test Diets.

C. odorata leaf detritus compounded with tapioca powder as binder, made into pellets, was given to the prawns as feed to verify whether this could be used as the exclusive food source for P. indicus. The dried, pulverized detritus material was seived through a 680 u mesh sieve and was then mixed well with tapioca powder to formulate the feed mix.

The control diet was formulated using dried, pulverized and sieved clam meal as major protein source. This was mixed with tapioca powder. Cellulose served as a filler to make the latter diet isonitrogenous with that of the former.

For the second feeding experiment, eight diets were prepared by replacing clam meal with Chromolaena odorata leaf detritus at various levels. The levels at which C. odorata leaf detritus was

substituted for the animal protein source (clam meal) were 0, 10, 20, 30, 40, 50, 75 and 100% in the diets FD1, FD2, FD3, FD4, FD5, FD6, FD7 and FD8 respectively. Rice bran and groundnut oil cake were the other two ingredients employed in all these eight different diets.

In all the above cases, for preparing the feed, the different ingredients were mixed well and were hand kneaded with sufficient water to get a dough. The dough thus prepared was steamed for thirty minutes in an autoclave. When sufficiently cooled the dough was passed through a noodling mechine having 3 mm die. The noodles obtained were spread uniformly in an enamel tray and dried at 60 C for 24 hours in a hot air oven. The dried noodles were severed into small pellets of 3-5 mm length. These were stored separately in air tight plastic containers and kept in a refrigerator at 4 C.

3.6.1.4 Proximate Composition of Formulated Feeds.

Proximate composition of the feeds was determined after compounding the feeds. The methods employed for finding out the moisture, protein, fat, ash and nitrogen free extract were the same as those used for analysing the ingredients.

3.7. Experimental Procedure.

The first experiment, to evaluate the suitability of plant detritus as an exclusive food source for Penaeus indicus, was

conducted for a period of 28 days. The second experiment to evaluate the level at which plant detritus could be used for replacing animal protein in the feed of this prawn was conducted for a period of 21 days.

Both the experiments were done in cylindrical fibreglass tanks of 55 cm diameter and 35 cm height. 50 litres of 20 ppt saline water was filled in the tank which occupied a height of 20cm. Separate aeration points with diffuser stones were provided in the tanks during the course of the experiments.

Table 3(a)(i) Proximate composition (%) of the diets used in the feeding experiment I

Diets	Moisture	Crude protein	Crude fat	NFE	Ash
Detritus diet	9.95	24.59	5.28	34.13	26.05
Clammeal Diet	7.05	24.92	3.35	57.03	7.35
(ii) Feeding experiment - II					
FD1	7.78	31.35	6.88	45.86	8.13
FD2	8.19	30.60	6.45	46.28	8.48
FD3	9.13	28.45	6.68	46.81	8.93
FD4	9.28	27.63	6.68	48.12	8.29
FD5	9.72	26.45	6.41	47.53	9.89

FD6	9.87	26.12	6.39	47.06	10.56
FD7	9.82	21.14	6.56	50.60	11.88
FD8	9.83	19.27	7.22	49.56	14.12

Table 3(b) Percentage composition of different ingredients in the diets

Feeding experiment-I

Ingredients	Plant detritus diet	Clam meal diet
Detritus	95.0	--
Clam meal	--	48.7
Tapioca powder	5.0	5.0
Cellulose	--	46.3
Total	100.0	100.0

Feeding experiment II

Ingredients	FD1	FD2	FD3	FD4	FD5	FD6	FD7	FD8
Clam meal	30.00	27.00	24.00	21.00	18.00	15.00	7.50	--
Detritus	--	3.00	6.00	9.00	12.00	15.00	22.50	30.00

Ground nut oil cake	18.75	18.75	18.75	18.75	18.75	18.75	18.75	18.75
Rice bran	18.75	18.75	18.75	18.75	18.75	18.75	18.75	18.75
Tapioca powder	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50
Total	75.00	75.00	75.00	75.00	75.00	75.00	75.00	75.00

Uniform sized prawn juveniles having an average size of 26.15mm and 91.00 mg maintained at 20 ppt salinity were used for the first feeding experiment and 20.70 mm and 39.00 mg for the second feeding experiment.

Before introducing to the experimental tanks the prawns were starved for 24 hours to ensure complete gut evacuation and were carefully weighed in a monopan electric balance of sensitivity 0.01 mg to find the initial biomass. All the ten prawns introduced into a tank were weighed together and average taken as the individual weight.

The prawns were fed ad libitum, every morning and evening, during the experimental period. The left over food and faecal matter were removed from each tank before fresh feed was given to the prawns. The feed remnants and faecal matter were removed from the tanks using a simple device designed by Lazarus and Reddy (1988).

This device consists of a cylindrical glass bulb (35 mm diameter, 100mm long) connected to a long tube of 280mm length and 10mm diameter with an opening at the end. The other end of the bulb opens in the form of a conical flare and the flared opening continues as an inner narrow tube which runs along the axis of the bulb. During collection, the opening at the top end is closed with the finger and the device is lowered into the tank so that the flared opening is kept just above the faecal matter/feed remnants. The finger is then released so that water along with the materials to be removed is sucked up into the inner tube and got collected in the bulb.

The collected materials were washed with fresh water to remove salt content and were separately dried by keeping at 60°C in a hot air oven. At the end of the rearing period these were weighed to find out the food consumption and faecal output of the prawns during the experimental period.

Samples were taken for biomass assessment on the 10th, 20th and 28th day during the first experiment and on the 10th and 21st day during the second experiment. The growth and survival of the prawns were determined on the days of biomass assessment. At the end of the rearing period, the survival and growth were recorded.

Water quality parameters like dissolved oxygen, pH, temperature and salinity of each tank were monitored.

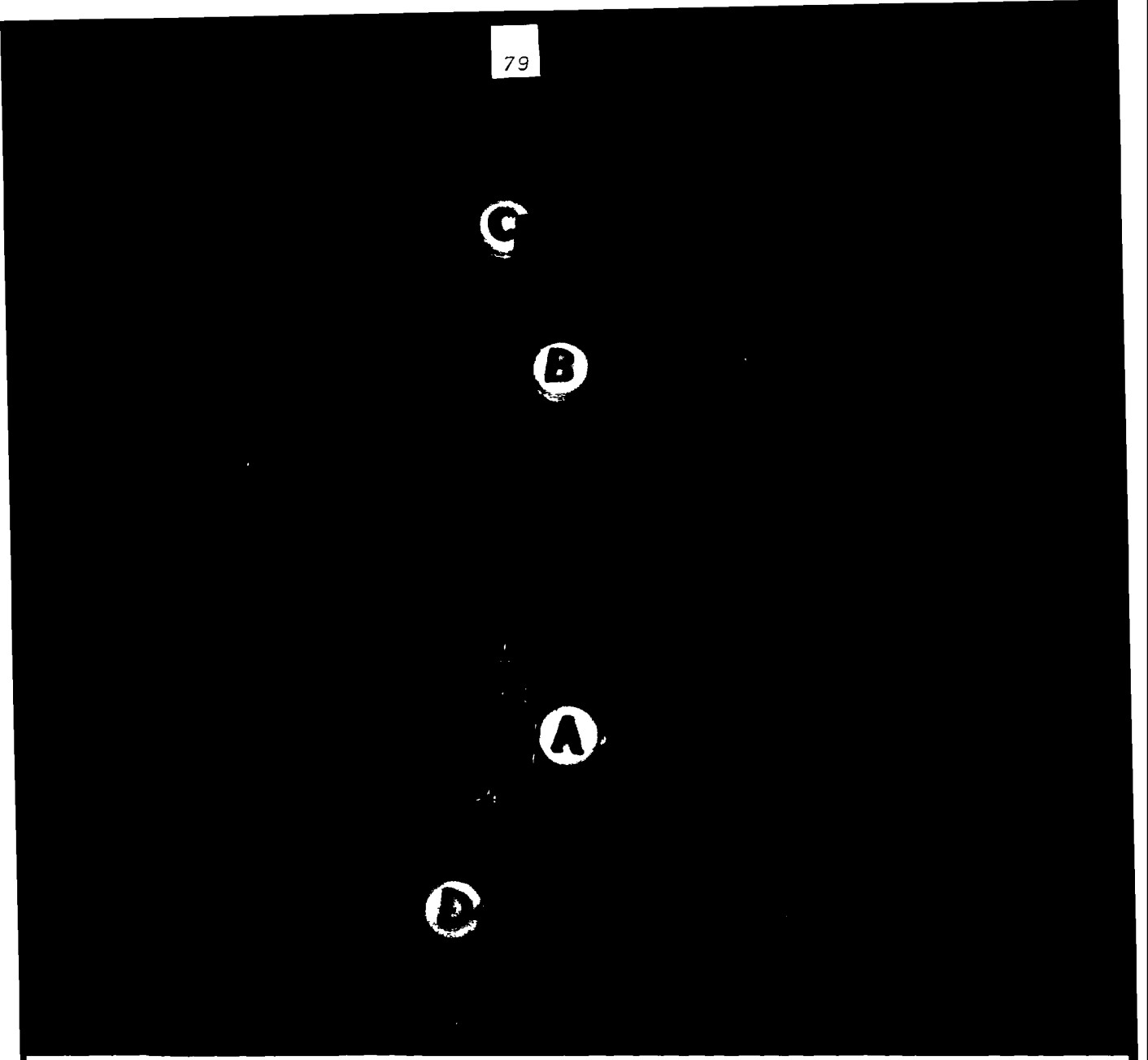


Fig 4 **Feed/Faecal remnants collecting device (Lazarus and Reddy, 1988)**

A	Glass Bulb
B	Long Tube
C	Top Opening
D	Bottom Flared Opening
E	Inner narrow tube

In the first feeding experiment, with one test diet and one control diet, seven replicates were maintained for each treatment, thus maintaining a total of fourteen tanks during the course of study. In the second feeding experiment, where eight diets were evaluated, three replications each were maintained and a total of twenty four tanks maintained for a period of twenty one days.

3.8 Determination of Apparent Digestibility Coefficient

The faecal matter collected after the first week of the experiment was used for digestibility analysis. The faeces was transferred to a piece of bloting silk and was then washed with distilled water to make it completely free of salt. Later it was transferred to a pre weighed beaker and dried in a hot air oven at 60 C, to a constant weight. The faeces so collected was weighed and the protein value analysed (AOAC, 1980).

3.9 Determination of Water Quality Parameters

The following water quality parameters were analysed using the methods/instruments against each:

Salinity	: Refractometer
Dissolved Oxygen	: Standard Winklers method. (Strickland and Parsons, 1972)
pH	: Universal indicator solution
Temperature	: Mercury bulb thermometer with an accuracy of 0.1 C.

3.10 Evaluation Criteria

3.10.1 Survival Rate.

Percentage survival was found out using the formula:

$$\text{Survival}(\%) = \frac{\text{No. of test animals introduced} - \text{No. of test animals harvested}}{\text{No. of test animals introduced}} \times 100$$

3.10.2 Growth.

Growth is one of the most widely applied criterion by which the diet and the protein level are evaluated.

$$\text{Growth}(\%) = \frac{\text{(Final weight/length measurement)} - \text{(initial weight/length measurement)}}{\text{Initial weight/length measurement}} \times 100$$

3.10.3 Specific Growth Rate.

This gives the average percentage increase in body weight over the experimental period. Specific growth rate is calculated using the formula.

$$\text{specific Growth Rate} = \frac{\log_e W2 - \log_e W1}{T2 - T1} \times 100$$

Where, W1 = Weight at the time T1

W2 = Weight at the time T2

3.10.4 Food Conversion Ratio.

Food conversion ratio, which gives the amount of food required to produce one unit weight of shrimp, has been worked out using the formula

$$\text{Food conversion ratio} = \frac{\text{Weight of food consumed (g) over experimental period}}{\text{Wet weight gain}}$$

3.10.5 Protein Efficiency Ratio

This criterion, which directly evaluates the quality of Protein in the diet, has been worked out as follows

$$\text{Protein efficiency ratio} = \frac{\text{Wet weight gain}}{\text{Crude protein fed}}$$

3.10.6 Apparent Digestibility Coefficient of Protein.

Apparent digestibility coefficient of protein is used to directly evaluate the quality of the protein in the diet.

$$\text{Apparent digestibility coefficient} = \frac{\text{Protein digested}}{\text{Protein ingested}} \times 100$$

i.e.
$$\frac{\text{(Food consumed x Protein in food) - (Excreta produced x Protein in excreta)}}{\text{(Food consumed x Protein in food)}} \times 100$$

3.11 Statistical Design and Analysis

The feeding experiments were designed on the basis of completely randomised design. The results obtained from the experiment I, which involve two treatments, were analysed using Student's - t test, While for the second experiment , having eight tretments, the results were subjected to analysis of variance (ANOVA). An F test was performed to determine if difference between treatment means existed. If the value was found to be significant , the data was analysed by a least significant difference test (LSD). All possible differences between the means of each treatment were computed and compared to LSD. If the absolute value of the difference (d) was greater than LSD , the difference was found to be significant at $P < 0.05$.

RESULTS

IV RESULTS

4.1 Experiment to Evaluate the Preference of *Penaeus indicus* juveniles towards Different Plant Detritus Sources

When four samples of detritus prepared from different plants, were presented simultaneously to *Penaeus indicus* juveniles, they exhibited distinct preference towards the *Rhizophora* and *Chromolaena* detritus (table 4). 49.87% of the *Penaeus indicus* juveniles were observed to feed on *Rhizophora* detritus whereas *Chromolaena* detritus was found utilized by 36.86% of the prawn juveniles introduced in to the tank. *Pistia* and paddy straw detritus, on the other hand, were utilized by 7.18 and 5.83% of the animals respectively. The preference exhibited by the prawns towards *Rhizophora* detritus was found to be significantly higher ($P < 0.01$) when compared to other plant detritus sources. *Chromolaena* detritus was found to be the next preferred source, being significantly better ($P < 0.05$) when compared to the other two sources (table 5). Pistia and paddy straw detritus were less accepted by the juvenile prawns and they did not show significant difference in acceptability between themselves ($P > 0.05$).

Table 4.—Preference of *P. indicus* juveniles towards various plant detritus (as percentage)

	Rhizophora apiculata	*Chromolaena odorata*	Paddy (*Oriza sativa*) straw	*Pistia stratiotes*
1	47.86	38.46	2.56	11.11
2	56.25	33.04	5.36	5.36
3	47.37	38.95	8.42	5.26
4	48.00	37.00	7.00	7.00
Mean	49.87	36.86	5.83	7.18

Table 5. Analysis of variance of the data on the preference of *P. indicus* towards different plant detritus sources

Source of variation	Degrees of freedom	Sum of squares	Mean of squares	F value computed	F value tabular
Between plant detritus	3	2924.407	974.802		
Error	12	86.21	7.177	135.828	5.95
Total	15	3010.528			

Standard error of transformed treatment means = 1.894

Critical difference t 0.05 : 4.127

Comparison of transformed means based on critical difference

Plant detritus	RHI.	CHR.	STR.	PIST.
Transformed mean values	44.927	37.373	15.502	13.839

4.2 Experiment to Find the Improvement in Protein levels of *Rhizophora apiculata* and *Chromolaena odorata* during Decay

Proximate analysis of the two plant materials, conducted to evaluate the initial nutritive value showed that *R. apiculata* and *C. odorata* have crude protein values of 5.75% and 20.50% repsectively. The nutrient composition of the dried and pulverized plant materials is shown in table 6.

Table 6. Nutrient composition of the dried and pulverized *R. apiculata* and *C. odorata* leaves

Plant material	Nutrient composition (%) Moisture	Protein	Fat	Ash	Nitrogen free extract
Rhizophora apiculata	11.41	5.75	6.05	13.73	63.06
Chromolaena odorata	8.94	20.50	6.23	8.99	58.53

Analysis of protein levels of the two selected plant materials during different stages of decay showed that *Chromolaena odorata* is a superior protein source at all stages of decay.

From the table 7, it can be seen that the level of increase in protein for *Rhizophora* was marginal, being 7.39% on the 25th day from an initial value of 5.75%, while it was very pronounced for

Chromolaena, being 25.716% on the 15th day from an initial value of 20.5%. The increase in the protein level of Rhizophora detritus was only 1.77% during the process of decomposition. The initial increase in protein level, in different digesters, from 0 to 5th day, was in the range of 0.14-1.32% (Av. 0.812%). Fifth day sample had a protein value ranging from 5.89 to 7.07% (Av. 6.562%). Samples collected during the 10th day did not show much variation in protein values; they ranged from 5.8 to 7.13% (Av. 6.528%). There was a slight increase in the levels during the 15th day, being 6.9 to 7.67% (Av. 7.2%). The protein values of samples collected during the 20th day did not vary much from those of the 15th day, being 7.09 to 7.20% (Av. 7.39%). On the 25th day, samples collected from four digesters had a minor increase in protein value (0.27 - 0.88%), while in one there was a slight reduction in the level (0.62%).By the 30th day,there was a reduction in protein value in all the five digesters, ranging from 7.5 to 6.0% (Av 7 02%). In general there was not much of an increase in protein values of Rhizophora leaf at different stages of decay as could be seen from table 7 and figure 5.

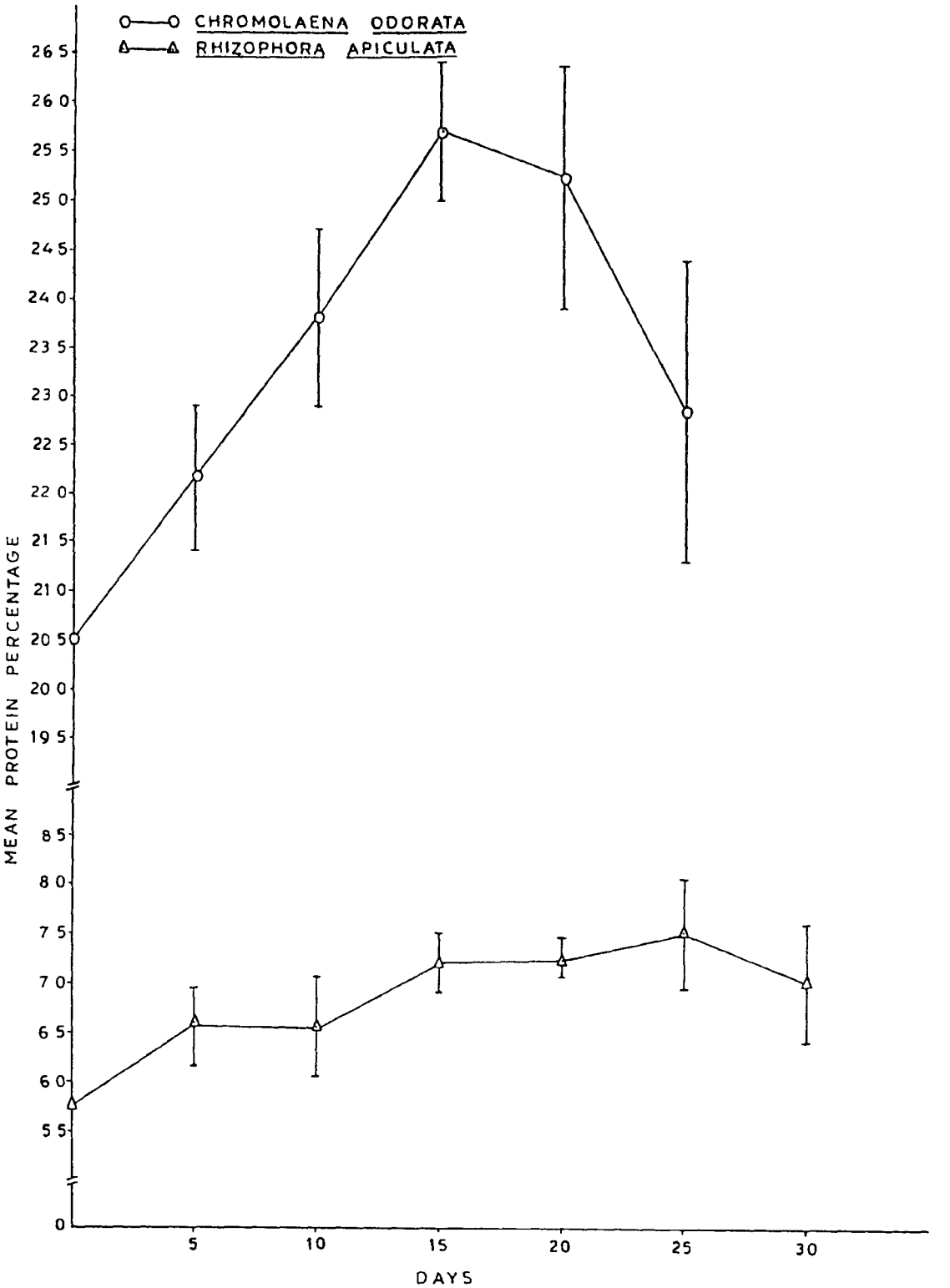
In the case of Chromolaena, the initial increase (from 0 day to 5th) day ranged from 0.7 to 2.8% in different digesters (Av 1.676%). On the 5th day, protein values recorded for the samples taken from the five digesters ranged from 21.2 to 23.3% (Av. 22.176%). On the 10th day all the five samples collected recorded an increase of 1.7 to 4.14% (Av. protein value being 23.814%),

from the original value. The decayed plant material collected on the 15th day recorded the highest increase in protein content. There was an increase of 4.3 to 6.15% protein from the original level (Av. protein value : 25.716%). On the 20th day, protein level did not vary much from that recorded on the 15th day, showing a range of 25.39 to 26.71% (Av. 25.214%). But the protein content of the sample drawn from two digesters declined on the 20th day, one being very marked (a decrease of 2.7%). All the samples showed a decrease in protein content on the 25th day (Fig.5). The level of decline varied from 1.41 to 3.26% (Av. protein value 22.842%) in different digesters.

Table 7. Variations in protein value (%) of plant materials during the process of decomposition

Days	Plant materials	R1	R2	R3	R4	R5	AV.
0	R. apiculata	5.75	5.75	5.75	5.75	5.75	5.750
	C. odorata	20 50	20.50	20.50	20.50	20.50	20.500
5	R. apiculata	6.58	5.89	6.55	7.07	6.72	6.562
	C. odorata	22.44	21.20	21.96	21.98	23.30	22.176
10	R. apiculata	6 16	5.80	7.13	7.00	6.60	6.538
	C. odorata	24.56	22.80	22.83	24.24	24.64	23.814
15	R. apiculata	7.17	7.28	7.67	6.98	6.90	7.200
	C. odorata	25.21	25.90	24.80	26.65	26.02	25.716
20	R. apiculata	7.54	7.20	7.15	7.16	7.09	7.390
	C odorata	25.39	26.20	24.50	26.71	23 27	25.214
25	R. apiculata	7.81	6.58	7.48	7.80	7.97	7.528
	C. odorata	23.98	23.50	22.70	23.82	20.21	22.842
30	R. apiculata	7.50	6.00	7.10	7.00	7.50	7.020
	C. odorata *	-	-	-	-	-	-

* Discontinued since there was decline in protein level in all the samples from the 25th day.



g.5 Variations in protein value (%) of plant materials during the process of decomposition

4.3 Experiment to Evaluate the Feasibility of Using Plant Detritus as Exclusive Protein Source in the Diet of P. indicus juveniles

Diet formulated using plant detritus as exclusive protein source, was compared with the one (control diet) formulated using the conventional clam meal as protein source, with the juveniles of P. indicus. The evaluation was done on the basis of the survival, growth, food conversion ratio, protein efficiency ratio and apparent digestibility.

4.3.1 Survival Rate.

Percentage survival of juveniles of P. indicus fed with detritus based diet (test) and clam based diet (control) are provided in table 8 and represented in fig. 6 . It was found that significant difference exists in percentage survival of P.indicus fed with two diets ($P < 0.01$) (table9). The values ranged from 10 to 40% (Av. 24.29%) for the prawns fed with test diet ,and 70 to 90% (Av. 78.57%) for those fed with control diet, the rate of survival being very low in the case of those fed with the detritus based diet.

4.3.2 Growth.

Growth attained by juveniles of P. indicus fed with the diet made exclusively of detritus was not satisfactory (vide table 10)

Table 8. Survival rate (%) obtained for *P. indicus* juveniles fed with detritus diet(test) and clam meal diet(control) in feeding experiment-I.

Diets	Replication	Survival obtained(%)	Mean
Detritus diet (Test)	1	30	
	2	30	
	3	40	
	4	30	24.29
	5	10	
	6	10	
	7	20	
Clam meal diet (Control)	1	90	
	2	70	
	3	70	
	4	90	78 57
	5	70	
	6	70	
	7	90	

Table 9. The Computed t value and the table value of t for various parameters tested in the experiment to evaluate the exclusively plant detritus based diet for *P. indicus* juveniles.

Parameter tested	Computed t value	Table value (1% level, 12 degrees of freedom)
1. Survival	8.038	3.055
2. Length increment	9.996	"
3. Weight increment	16.510	"
4. Specific growth rate	18.391	"
5. Food conversion ratio	11.287	"
6. Protein efficiency ratio	18.400	"
7. Apparent digestibility coefficient	12.928	"

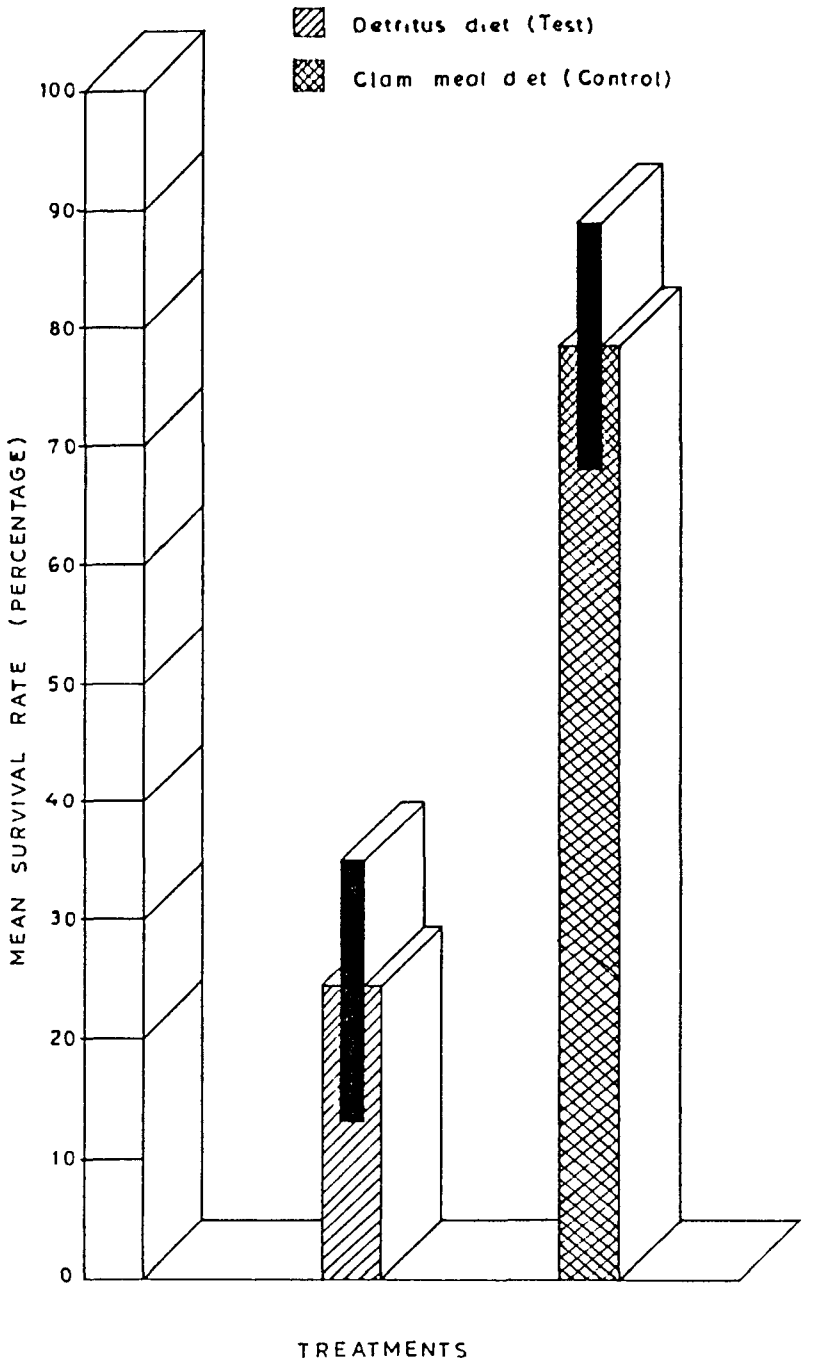


Fig.6 Survival rate (%) obtained for P. indicus juveniles fed with detritus diet and clam meal diet

The length and weight gained by the individual prawns on detritus diet ranged from 2.27 to 2.85 cm and 0.094 to 0.136 g (Av.2.49cm and 0.111 g) while it varied from 3.51 to 4.43 cm and 0.365 to 0.494 g (Av 4.05 cm and 0.430 g) in those fed with clam meal based diet (control). The gain in length and weight of the latter in comparison with the former is two times and four times respectively. It could be seen that the net average length and weight gain of individual prawns in different tanks ranged from -0.49 to 0.15 cm and 0.001 to 0.054 g for the animals fed with test diet and 1.00 to 1.85 cm and 0.285 to 0.411 g for those fed with control diet . The overall average net gain in length and weight of prawns fed with test and control diets were -0.17 cm and 0.016 g and 1.48 cm and 0.342 g respectively.

The variation in length and weight gain by juveniles of P. indicus during different time intervals is shown in figures 7 and 8 respectively according to which growth rate of prawns fed with test diet is distinctly lower than that of the prawns fed with control diet, throughout the experimental period.

The juvenile prawns fed with detritus based diet showed significantly lower ($P<0.01$) increment in length and weight than those prawns fed with clam based (control) diet (Table.9).

Table 10. Average length (cm) weight (g) attained by P. indicus juveniles fed with detritus diet and clam meal diet in feeding experiment - I.

Treatments	Replications	0 day		10th day		20th day		28th day		Growth%	
		l	w	l	w	l	w	l	w	l	w
Detritus	1	2.49	0.082	2.51	0.082	3.61	0.093	2.40	0.136	-3.61	65.85
diet (test)	2	2.67	0.097	2.70	0.093	2.73	0.094	2.27	0.098	-14.98	1.03
	3	2.73	0.104	2.77	0.104	2.70	0.105	2.73	0.128	00.00	23.08
	4	2.76	0.102	2.81	0.103	2.80	0.107	2.27	0.110	-17.75	7.84
	5	2.46	0.085	2.53	0.081	2.50	0.099	2.40	0.094	-2.44	10 59
	6	2.80	0.105	2.76	0.109	2.63	0.101	2.50	0.107	-10.71	1.90
	7	2.70	0.093	2.63	0.087	2.70	0.102	2.85	0.104	5.56	11 83
	Av.	2.66	0.095	2.67	0.093	2.67	0.100	2.49	0.111	-6.27	17.45
Clam meal	1	2.48	0.099	3.10	0.190	3.99	0.316	4.32	0.478	74.19	382.83
diet	2	2.61	0.085	3.06	0.124	3.50	0.215	3.86	0.383	47.89	350.59
(control)	3	2.59	0.085	3.21	0.175	3.83	0.301	4.31	0.470	66.41	452 94
	4	2.51	0.080	2.87	0.146	3.22	0.240	3.51	0.365	39.84	356.25
	5	2.54	0.081	2.92	0.170	3.29	0.276	3.59	0.392	41.34	383.95
	6	2.58	0.083	3.24	0.147	3.90	0.276	4.43	0.494	71.71	495.18
	7	2.66	0.099	3.25	0.178	3.84	0.286	4.32	0 426	62.41	330 30
	Av.	2.57	0.087	3.09	0.161	3.65	0.273	4.05	0.430	57.68	393.15

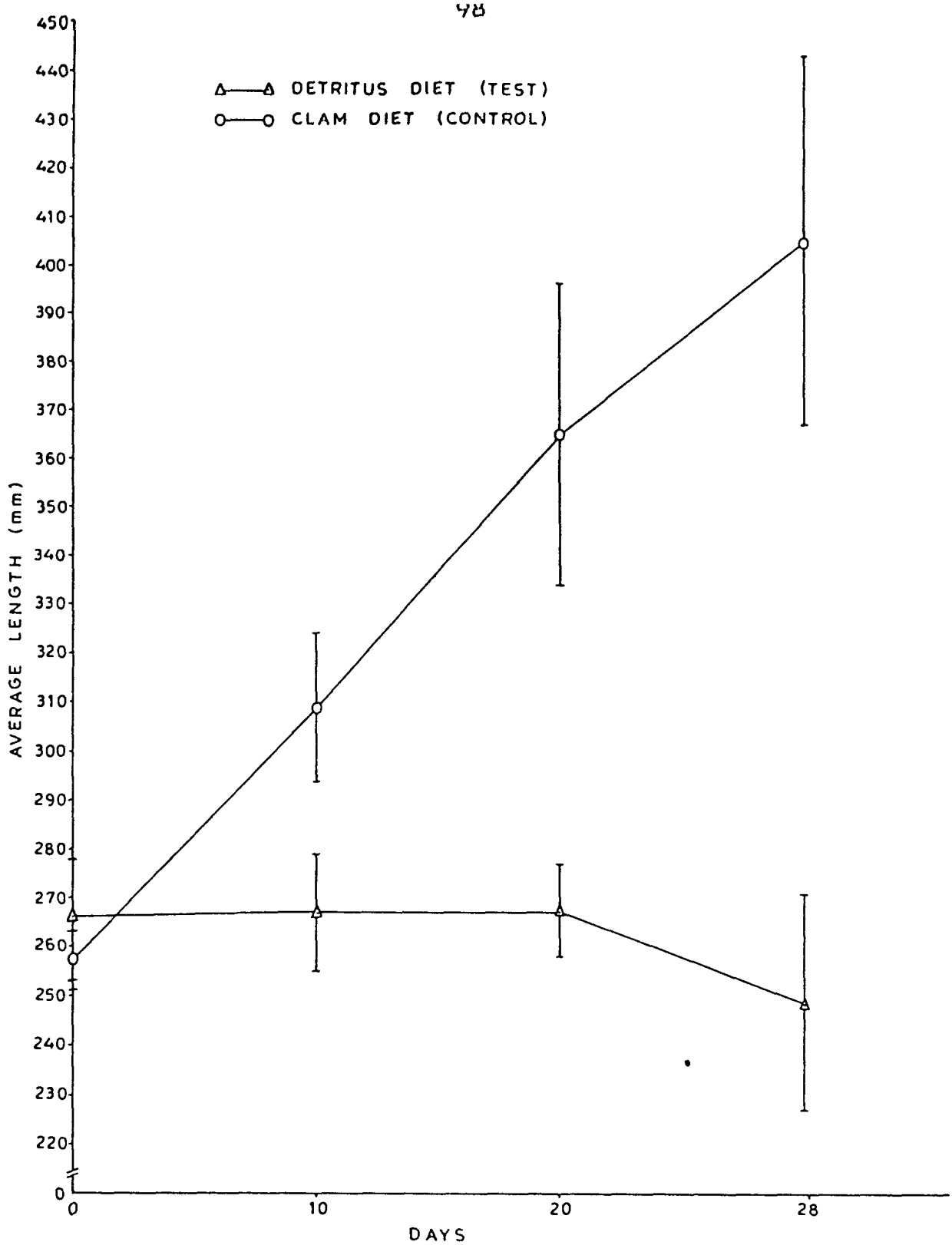


Fig.7 Length increment of P. indicus juveniles fed with detritus diet and clam meal diet

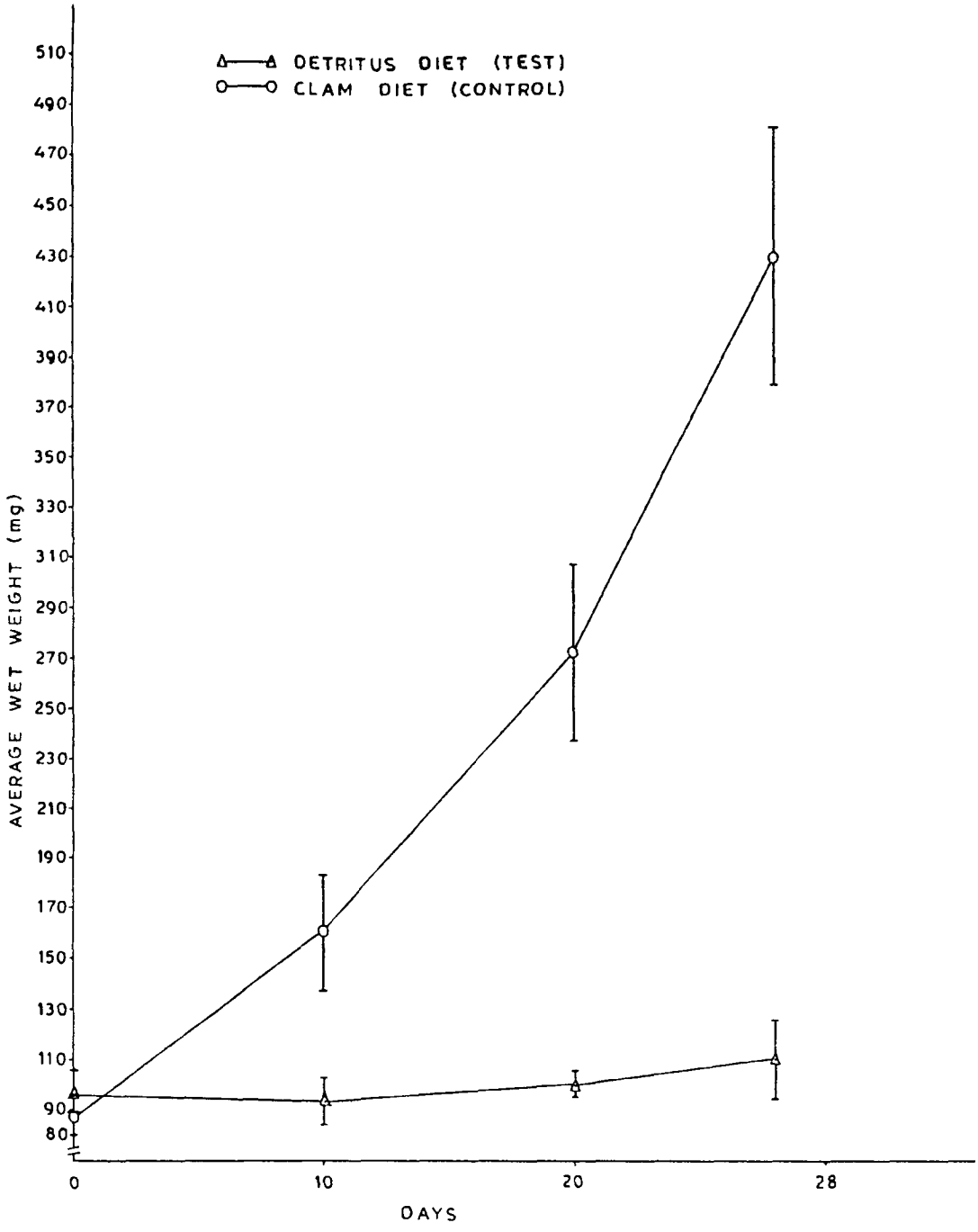


Fig.8 Weight increment of P. indicus juveniles fed with detritus diet and clam meal diet

Percentage length and weight increments of juvenile P. indicus, fed with detritus diet (test) and clam meal (control) diets, are shown in figures 9 and 10 respectively. It can be seen, from the table.10, that the percentage weight increment ranged between 1.03 and 65.85 (Av. 17.45) while the percentage length increment ranged between -17.75 and 5.56 (Av. -6.27). The values obtained for those prawns fed with clam meal diet (control) ranged between 330.3 and 495.18 (Av. 393.15) ; 39.84 and 74.19 (Av. 57.68).

4.3.3 Specific Growth Rate.

Prawns fed with detritus diet (test) produced significantly lower ($P < 0.01$) specific growth rate than the control fed with clam meal diet (vide table 9). The specific growth rate observed ranged from 0.037 to 1.807% (Av. 0.526%) for the prawns fed with test diet and 5.212 to 6.370% (Av. 5.677%) for those fed with control diet (Table 11, fig. 11).

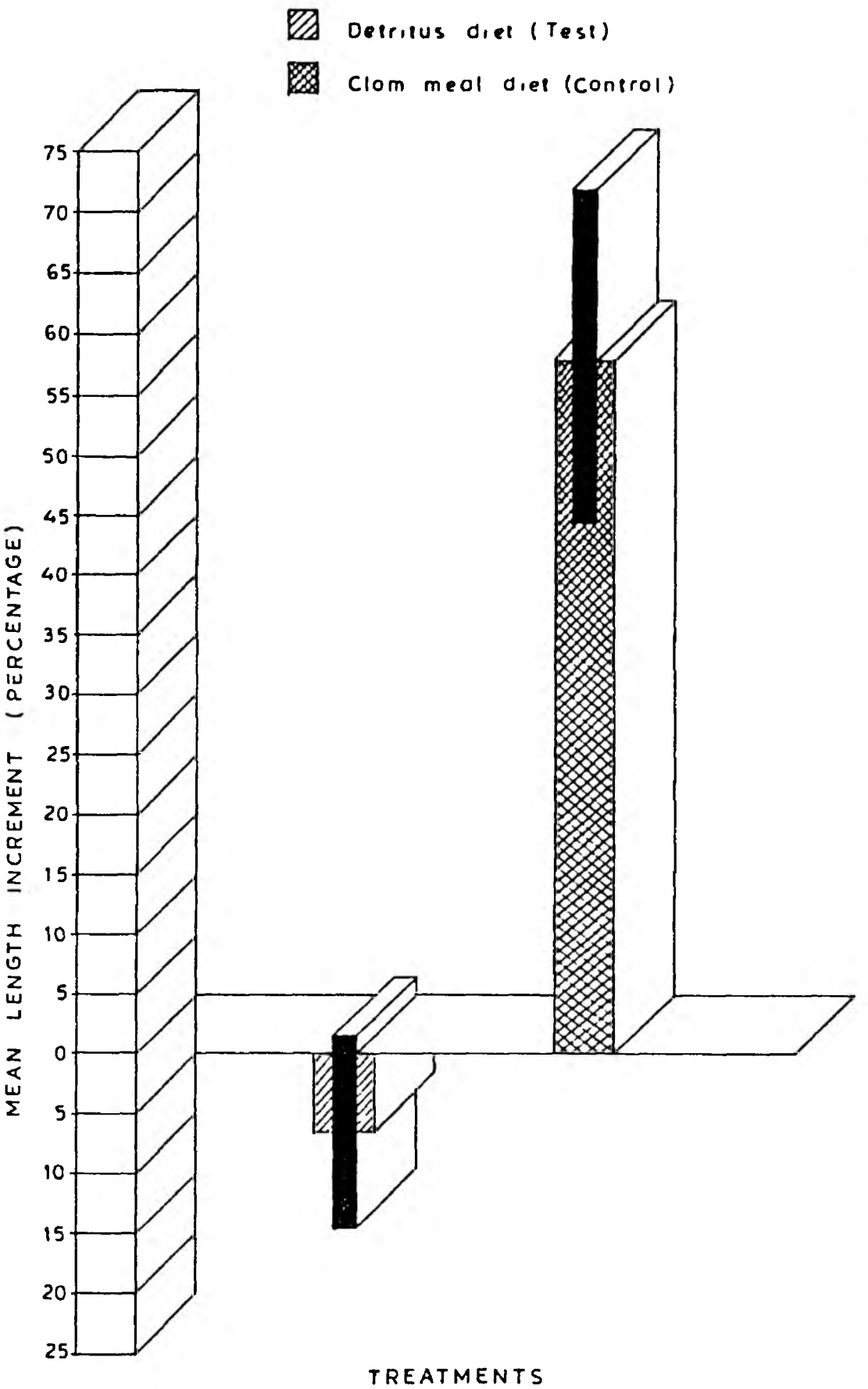


Fig.9 Percentage length increment of P. indicus juveniles fed with detrit diet and clam meal diet

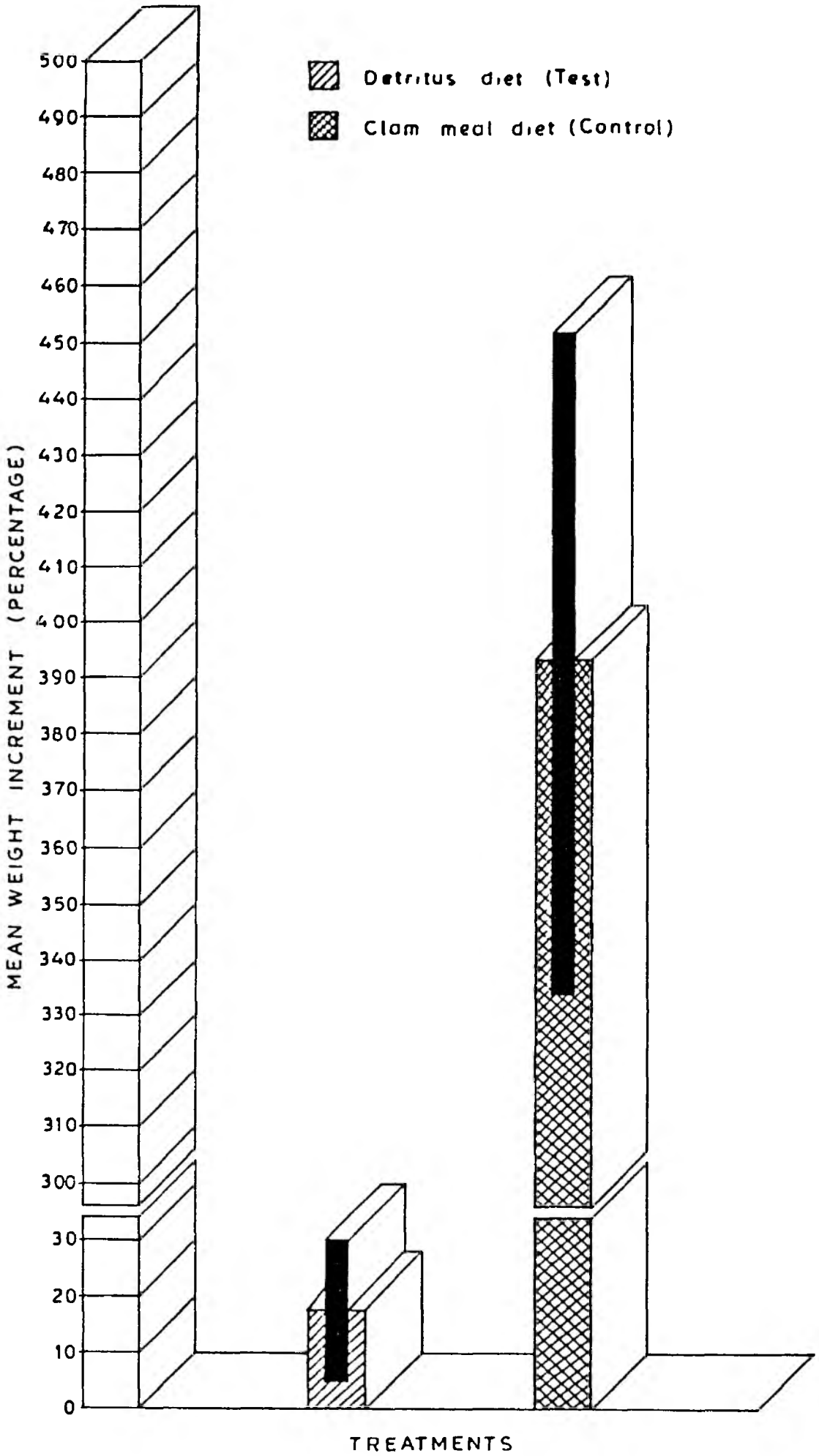


Fig.10 Percentage weigtht increment of P. indicus juveniles fed with detritus diet and clam meal diet

Table 11. Specific growth rate (%) of P. indicus juveniles fed with detritus diet and clam diet

Diets	Replication	Av. initial wt. (g)	Av. final wt. (g)	Sp. Gr. rate (%)	Mean (%)
Detritus	1	0.082	0.136	1.807	
	2	0.097	0.098	0.037	
	3	0.104	0.128	0.742	
	4	0.102	0.110	0.270	0.526
	5	0.085	0.094	0.359	
	6	0.105	0.107	0.067	
	7	0.093	0.104	0.399	
Clam	1	0.099	0.478	5.623	
	2	0.085	0.383	5 376	
	3	0.085	0.470	6.107	5.677
	4	0.080	0.365	5.421	
	5	0.081	0.392	5.631	
	6	0.083	0.494	6.370	
	7	0.099	0.426	5.212	

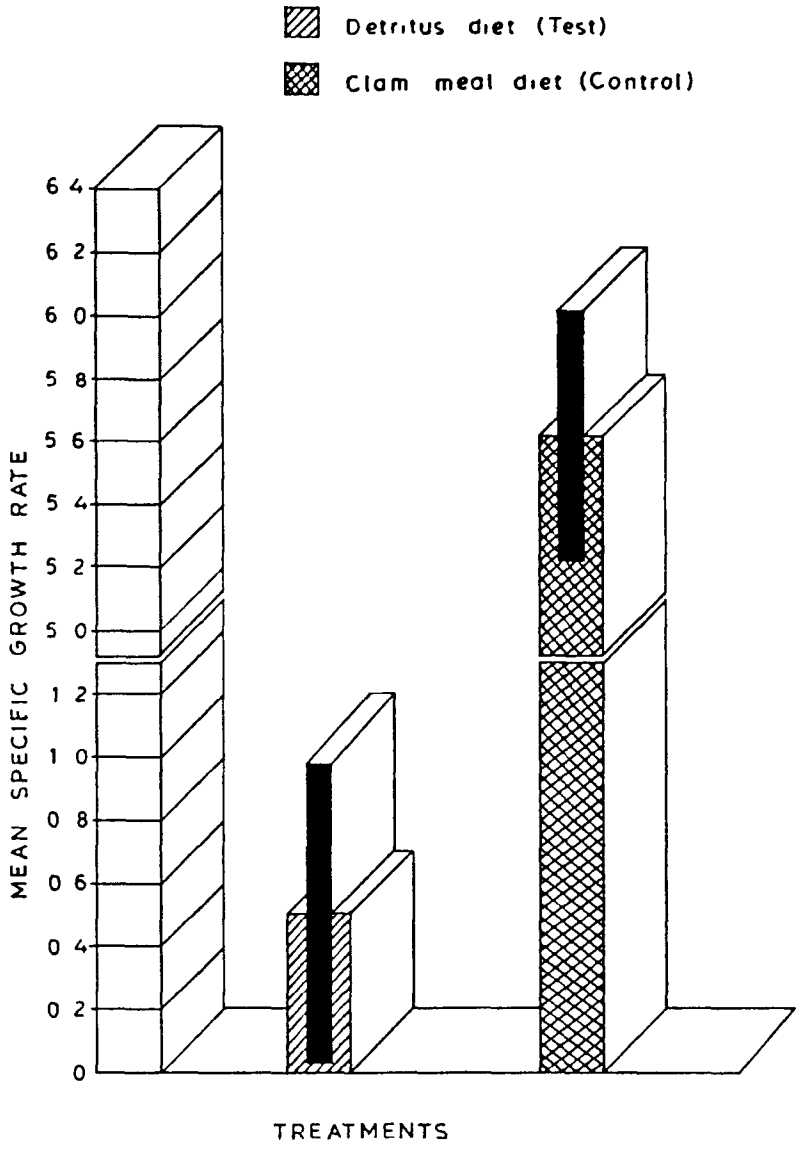


Fig.11 Specific growth rate of P. indicus juveniles fed with detritus diet and clam meal diet

4.3.4 Food Conversion Ratio (FCR)

The food conversion ratio obtained for those prawns fed with the detritus based diet was significantly ($P<0.01$) higher than that obtained for prawns fed with clam meal based diet (vide table 9). As can be seen from table 12, food conversion ratio ranged from 14.970 to 52.823 (Av. 35.883) for the test diet and 1.910 to 2.26 (Av. 2.111) for the control diet (Fig.12).

4.3.5 Protein Efficiency Ratio (PER)

Protein efficiency ratio observed for the plant detritus based diet was significantly lower ($P<0.01$) than that observed for clam based diet (vide table 9). The protein efficiency ratio ranged from 0.077 to 0.272 (Av.0.144) for the test diet and 1 776 to 2.102 (Av. 1.909) for the control diet (Table 13, Fig.13).

4.3.6 Apparent Digestibility Coefficient

Table 14 provides the apparent digestibility coefficient obtained for the detritus based diet (test) and clam meal based diet (control). Mean apparent digestibility coefficient of the former ranged from 59.904 to 69.160% (Av. 64.515%), while that of the latter ranged from 84.411 to 88.478 % (Av. 86.859%). Apparent digestibility coefficient of the two diets was found to have significant difference ($P < 0.01$) and the test diet was found to have lower digestibility when compared to that of the control diet (Fig 14).

Table 12. Food conversion ratio of *P. indicus* juveniles fed with diets based on plant detritus (test) and clam meal (control)

Diet	Replication	Initial weight (g)	Total weight (g)	Total net weight (g)	Total food consumed (g)	FCR	Mean
Detritus	D1	0.817	1.042	0.225	3.369	14.970	
	D2	0.967	1.031	0.064	3.209	50.140	
	D3	1.036	1.235	0.199	3.287	16.518	
	D4	1 023	1.085	0.062	3.275	52.823	35 883
	D5	0.848	0.934	0.086	2.408	28.000	
	D6	1.051	1.107	0.056	2.307	41.196	
	D7	0 929	1.008	0.079	3.755	47.532	
Clam	C1	0.993	4.614	3.621	7.919	2.187	
	C2	0.853	3.237	2.384	5.074	2.128	
	C3	0.847	3.940	3.093	6.697	2 165	
	C4	0.803	3.522	2.719	5.997	2.206	2.111
	C5	0 813	3.462	2 649	5.060	1 910	
	C6	0.834	4.283	3.449	6.616	1 918	
	C7	0.992	4.125	3.133	7.080	2 260	

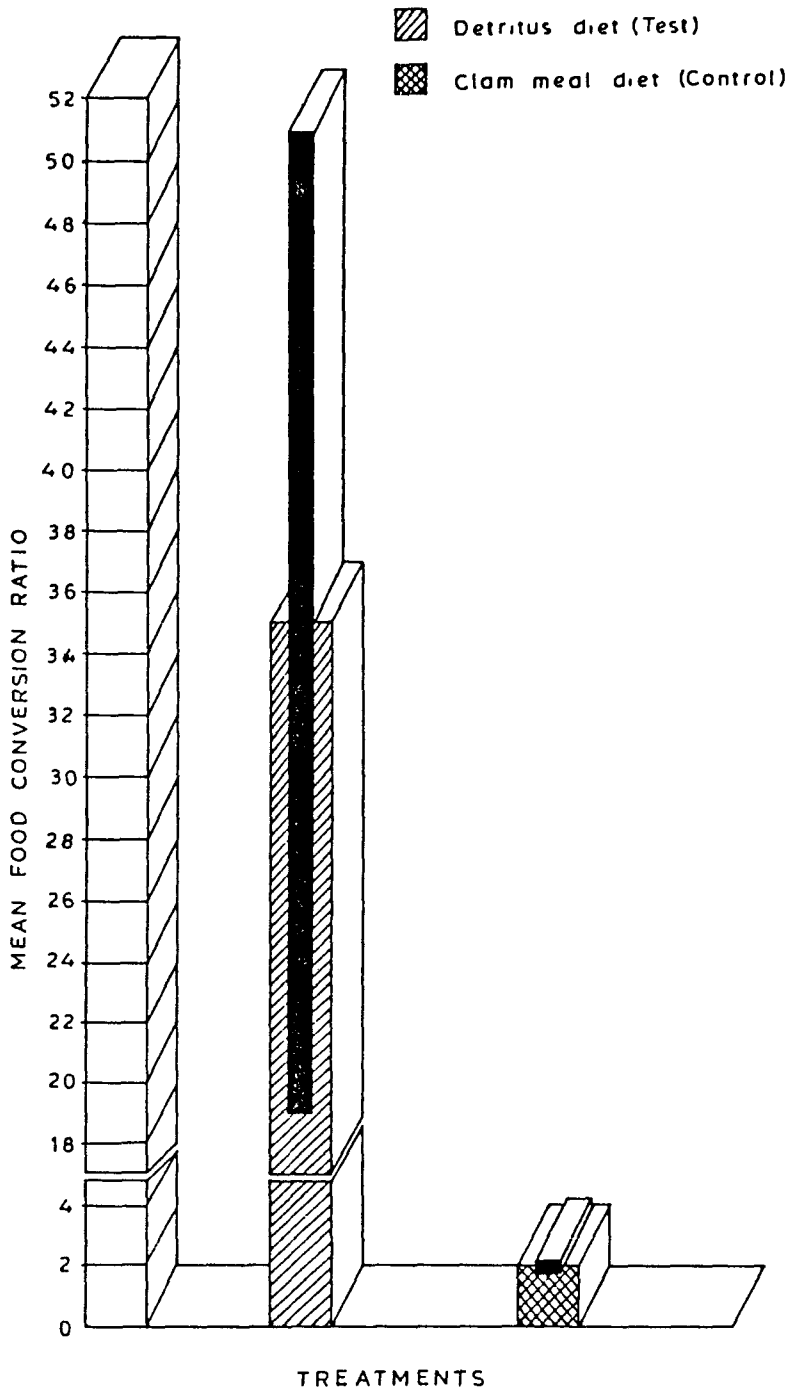


Fig.12 Food conversion ratio obtained for P. indicus juveniles fed with detritus diet and clam meal diet

Table 13. Protein efficiency ratio of *P. indicus* juveniles fed with diets based on plant detritus (test) and clam meal (control)

Diet	Replication	Initial weight (g)	Total weight (g)	Total net weight (g)	Total protein consumed (g)	PER	Mean
Detritus	D1	0.817	1.042	0.225	0.828	0.272	
	D2	0.967	1.031	0.064	0.789	0.081	
	D3	1.036	1.235	0.199	0.808	0.246	
	D4	1.023	1.085	0.062	0.805	0.077	0.144
	D5	0.848	0.934	0.086	0.592	0.145	
	D6	1.051	1.107	0.056	0.567	0 099	
	D7	0.929	1.008	0.079	0.923	0.086	
Clam	C1	0.993	4.614	3.621	1.973	1.835	
	C2	0.853	3.237	2.384	1.264	1.886	
	C3	0.847	3.940	3.09	1.669	1.853	
	C4	0.803	3.522	2.719	1.494	1 820	1.909
	C5	0.813	3 462	2.649	1.260	2 102	
	C6	0.834	4.283	3.449	1.649	2.091	
	C7	0.992	4.125	3.133	1.764	1 776	

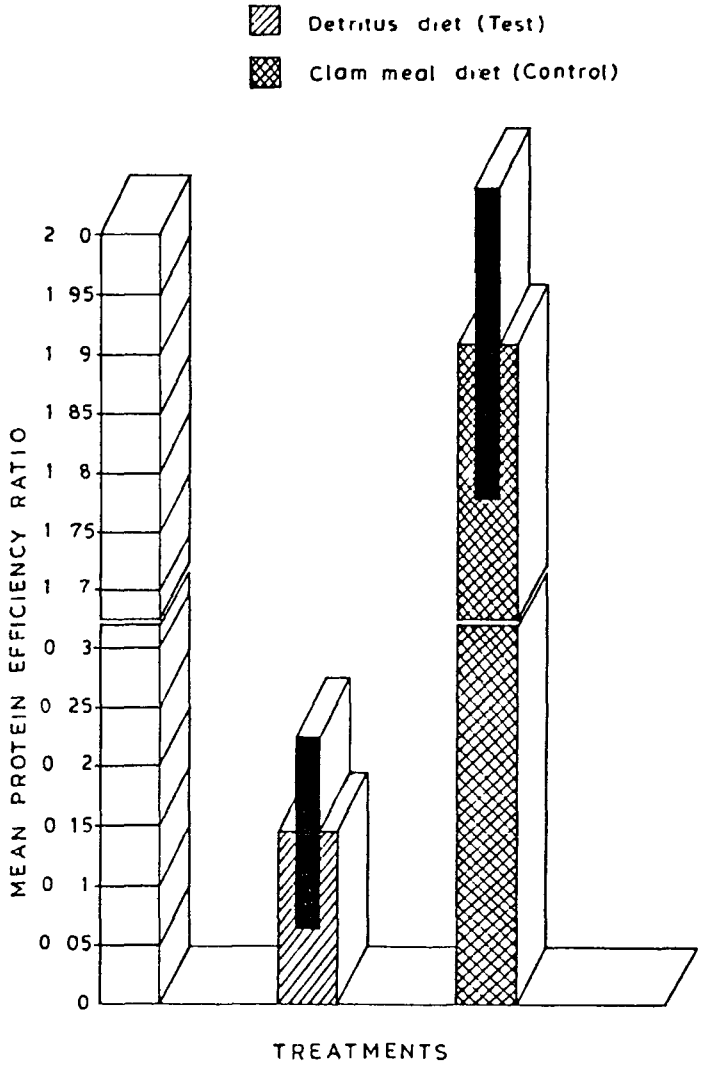


Fig.13 Protein efficiency ratio obtained for P. indicus juveniles fed wit
detritus diet and clam meal diet

Table 14. Apparent digestibility of the detritus diet (test) and the clam meal diet (control)fed to *P. indicus* juveniles.

Diet	Replication	Total food consumed (g)	Total excreta produced (g)	Apparent digestibility (%)	Mean (%)
Detritus (Test)	1	3.369	1.039	69.160	
	2	3.209	1.082	66.282	
	3	3.287	1.029	68.695	
	4	3.275	1.306	60.122	
	5	2.408	0.909	62.251	64.515
	6	2.307	0.925	59.904	
	7	3.755	1.307	65.193	
Clam meal (control)	1	7 919	0.954	87.953	
	2	5.074	0.791	84.411	
	3	6.697	0.856	87.218	86.859
	4	5.997	0.691	88.478	
	5	5.060	0.690	86.363	
	6	6.616	0.922	86.064	
	7	7.080	0.883	87.528	

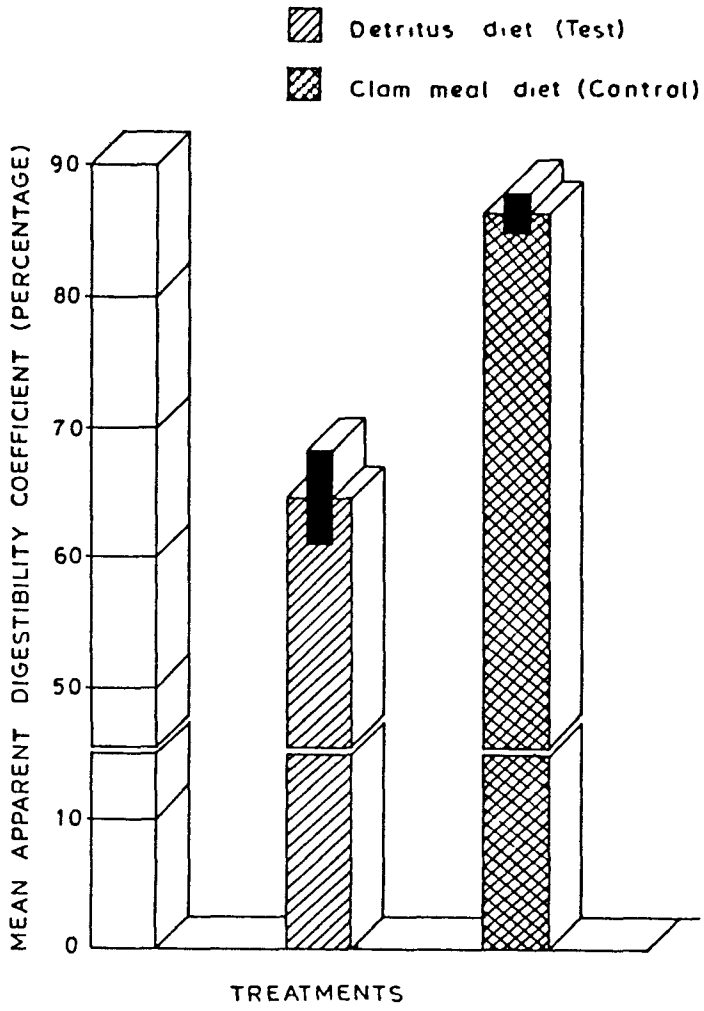


Fig.14 Apparent digestibility coefficient of detritus diet and clam meal diet fed to P. indicus juveniles.

4.3.7 Apparent Protein Digestibility.

The results of apparent protein digestibility value obtained for the test and control diets are given in table 15. The mean apparent protein digestibility value obtined for the detritus diet was 71.540% and for the clam meal diet, it was 94.750% (Fig. 15).

Table 15. Apparent protein digestibility coefficient of the detritus diet (test) and clam meal diet (control) fed to *P. indicus* juveniles

Treatments	* Food consumed	*Excreta produced	%Protein in food	%Protein in Excreta	Protein ingested (g)	Protein digested (g)	Protein digestibility Coefficient
Detritus	3.087	1.085	24.59	19.95	0.759	0.543	71.54
Clam	6.349	0.827	24.92	10.05	1.582	1.499	94.75

* Av. of seven values

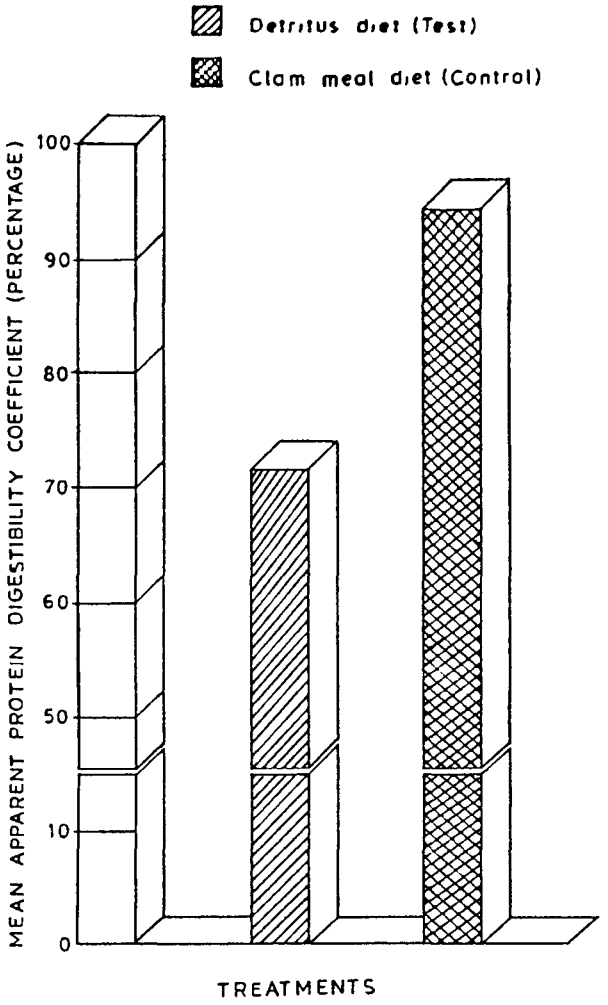


Fig.15 Apparent protein digestibility coefficient of detritus diet and clam meal diet fed to P. indicus juveniles.

4.4 Experiment to Evaluate the Feasibility of Using Plant Detritus as Partial Substitute for Animal Protein Source in the Diet for *P. indicus* juveniles

Eight diets formulated, incorporating plant detritus at various levels (0 to 100%) replacing the conventional clam meal in a standard diet (Sherief, 1987), were evaluated in terms of survival, growth, food conversion ratio, protein efficiency ratio, and protein digestibility of the prawn *P. indicus*.

4.4.1 Survival Rate.

The rate of survival of the prawns fed with 8 different diets having different levels of detritus did not vary significantly ($P>0.05$) as seen from the data given in the table 16 and represented in figure 16. Highest percentage of survival (100%) was obtained for the diets FD1 (with 0% detritus) and FD8 (100% clam meal replaced with detritus) while the diet FD2 (with 10% of clam meal protein was replaced with detritus) was having the lowest survival rate (90%).

4.4.2 Growth.

Of the eight diets tested, the FD2 apparently gave the best growth of prawns (table 18) ranging from 2.92 to 3.12 cm and 0.149 to 0.161 g (Av. 3.02 cm, 0.153 g). The average increment of growth obtained with respect to other diets were 2 9 cm and 0.146 g in FD1, 2.87 cm and 0.138 g in FD3, 2.97 cm and 0.138 g in FD4, 2.92 cm and 0.133 g in FD6, 2.89 cm and 0.124 g in FD5,

2.64 cm and 0.102 g in FD7 and 2.27 cm and 0.056 g in FD8 (vide table 18), generally showing a decreasing trend in growth with increase in level of detritus in the diet.

The average net gain in length and weight was highest for the prawns fed with FD2 diet (10% detritus), and the lowest for those fed with FD8 diet (100% clam meal replaced with detritus), the values being 0.943 cm; 0.114 g and 0.313 cm; 0.052 g respectively. Table 18 provides the mean net gain in length and weight of prawns fed with all diets.

There was no significant difference (P>0.01) in length and weight increments of the prawns fed with diets FD1,FD2, FD3, FD4,

Table 16. Survival rates (%) obtained when diets containing different levels of plant detritus were fed to *P. indicus* juveniles

Treatments	Survival Rate (%) Replications 1	2	3	Mean Survival Rate (%)
FD1	100	100	100	100
FD2	90	90	90	90
FD3	90	100	100	96.67
FD4	90	100	90	93.30
FD5	100	90	90	93.30
FD6	90	90	100	93.30
FD7	100	100	90	96.67
FD8	100	100	100	100

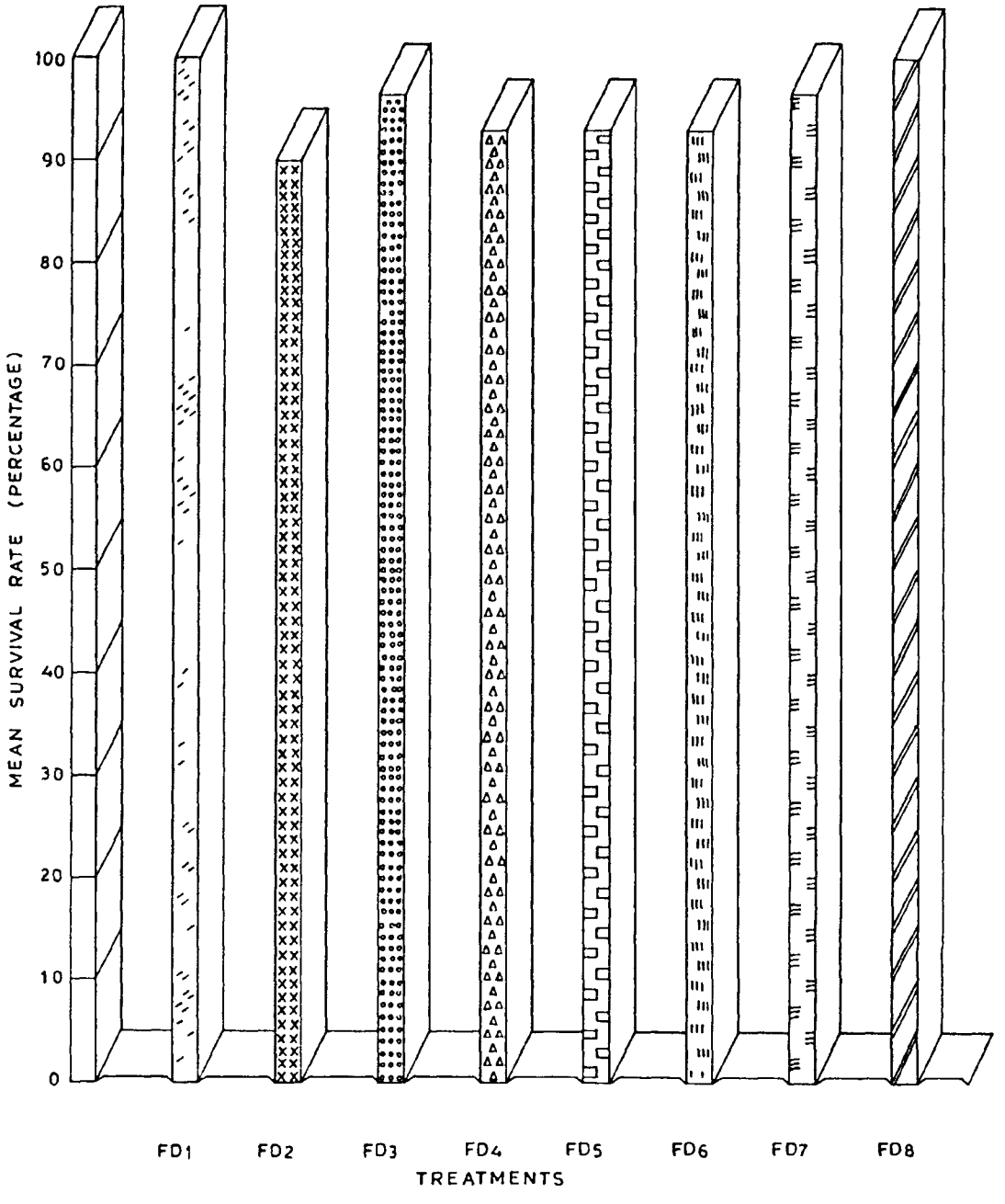


Fig.16 Survival rate of P. indicus juveniles fed with the eight diets in feeding experiment - II.

Table 17. Analysis of variance of the data on survival rate of P. indicus juveniles fed with diets containing different levels of plant detritus

Source of Variation	Degrees of freedom	Sum of Squares	Mean sum of Squares	F value computed	F value Tabular
Bet. diets	7	891.620	127.314	1.799	2.66
Error	16	1132.217	70.764		
Total	23	2023.838			

FD5 and FD6 having clam meal replaced with detritus at 0, 10, 20, 30, 40 and 50% levels respectively. The length and weight increments of prawns fed with the diets FD7 and FD8 were found to be significantly lower ($P<0.05$) than that achieved by feeding with the other six diets. As seen from the tables 19 and 20, between FD7 and FD8, there is no significant difference in length increment ($P>0.05$) whereas significant difference exists with regard to weight ($P<0.01$).

The increase in length and weight of prawns during different time intervals are shown in figures 17 and 18, respectively.

The percentage of length and weight increment recorded for all the eight treatments are provided in table 18 and depicted in figures 19 and 20 respectively. The highest average increase in length was recorded in those prawns fed with FD2 diet (45.48%) while the highest percentage weight increment was obtained in the FD1 treatment (303.65%) and the lowest values (16.15% and 61.89% respectively) were recorded for the prawns fed with FD8 diet

Table 18. Average length (cm) and weight (g) increment of *P. indicus* fed with diets containing different levels of plant detritus

Diets	Replications	Days: 0 day l	0 day w	10 days l	10 days w	21st day l	21st day w	Growth (%) l	Growth (%) w
FD1	1	2.08	0.039	2.60	0.160	3.12	0.184	50.00	371.79
	2	1.95	0.033	2.37	0.109	2.79	0.132	43.08	300.00
	3	2.02	0.036	2.40	0.111	2.78	0.122	37.62	238.89
	Av.	2.02	0.036	2.46	0.127	2.90	0.146	43.57	303.56
FD2	1	2.05	0.037	2.59	0.118	8.12	0.161	52.20	335.14
	2	2.08	0.040	2.55	0.140	3.02	0.149	45.19	272.50
	3	2.10	0.041	2.51	0.139	2.92	0.150	39.05	265.85
	Av.	2.08	0.039	2.55	0.129	3.02	0.153	45.48	291.16
FD3	1	2.07	0.038	2.43	0.109	2.80	0.126	35.27	231.58
	2	2.10	0.041	2.66	0.145	3.22	0.188	53.33	346.34
	3	2.05	0.037	2.32	0.097	2.59	0.105	26.34	183.78
	Av.	2.07	0.038	2.47	0.117	2.83	0.138	38.31	253.70
FD4	1	2.12	0.044	2.56	0.134	3.01	0.142	41.98	222.73
	2	2.11	0.043	2.49	0.136	2.88	0.137	36.49	218.60
	3	2.09	0.040	2.55	0.108	3.02	0.134	44.50	235.00
	Av.	2.11	0.042	2.53	0.126	2.17	0.138	40.99	225.44

contd.

FD5	1	2.06	0.038	2.56	0.135	3.06	0.137	48.54	260.53
	2	2.18	0.045	2.49	0.116	2.80	0.117	28.44	160.00
	3	2.15	0.042	2.48	0.119	2.80	0.117	30.23	178.57
	Av.	2.13	0.042	2.51	0.123	2.89	0.124	35.74	199.70
FD6	1	2.12	0.041	2.52	0.112	2.93	0.133	38.21	224.39
	2	2.10	0.040	2.58	0.121	3.06	0.153	45.71	282.50
	3	2.10	0.040	2.43	0.098	2.77	0.112	31.90	205.00
	Av.	2.11	0.040	2.51	0.110	2.92	0.133	38.61	237.30
FD7	1	2.10	0.040	2.36	0.096	2.62	0.110	24.76	175.00
	2	2.00	0.038	2.31	0.090	2.61	0.099	30.50	160.53
	3	2.16	0.042	2.42	0.092	2.69	0.096	24.54	128.57
	Av.	2.09	0.040	2.36	0.093	2.64	0.102	26.60	154.70
FD8	1	1.95	0.035	2.15	0.056	2.30	0.054	17.95	62.86
	2	1.90	0.032	2.19	0.053	2.30	0.054	21.05	68 75
	3	2.01	0.037	2.17	0.057	2.20	0.057	9.45	54.05
	Av.	1.95	0.035	2.18	0.055	2.27	0.056	16.15	61.89

Table 19. Analysis of variance of the data on gain in length of P. indicus juveniles fed with diets containing different levels of plant detritus

Source of variation	Degrees of freedom	Sum of squares	Mean sum of squares	F value Computed	F value Tabular (1% level)
Bet. diets	7	0.906	0.129	4.907	4.03
Error	16	0.422	0.026		
Total	23	1.328			

Standard error of treatment means = 0.133

Critical difference t0.05 = 0.282

Comparison of means based on critical difference

FD2	FD1	FD4	FD6	FD3	FD5	FD7	FD8
0.943	0.880	0.863	0.813	0.797	0.757	0.553	0.313

Underscored means are not significantly different

Table 20. Analysis of variance of the data on gain in weight of P. indicus juveniles fed with diets containing different levels of plant detritus

Source of Variation	Degrees of freedom	Sum of squares	Mean sum of squares	F value Computed	F value Tabular (1% level)
Bet. diets	7	0.919	0.0027	6.75	4.03
Error	16	0 006	0.0004		
Total	23				

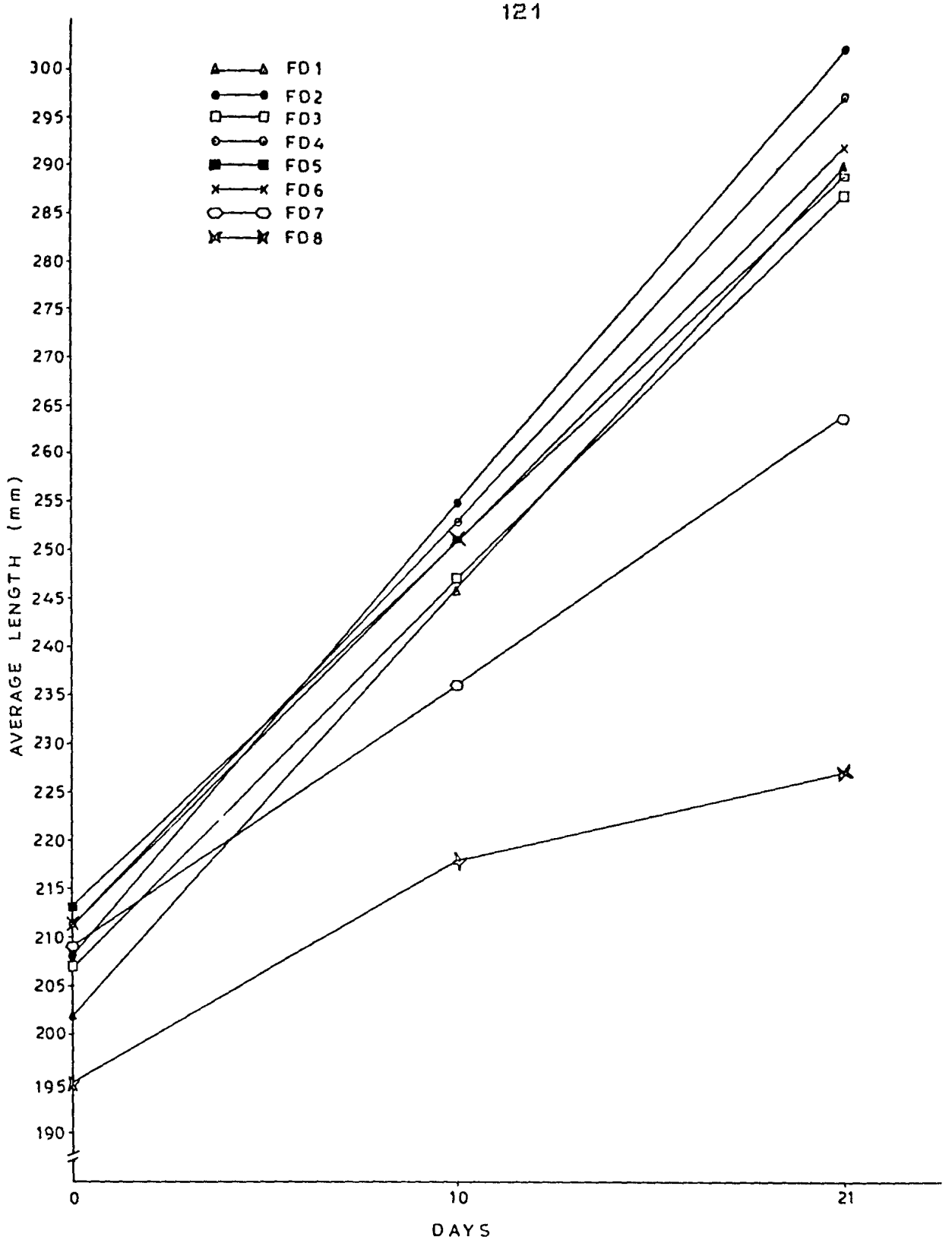


Fig.17 Length increment of P. indicus juveniles fed with the eight diets in feeding experiment - II.

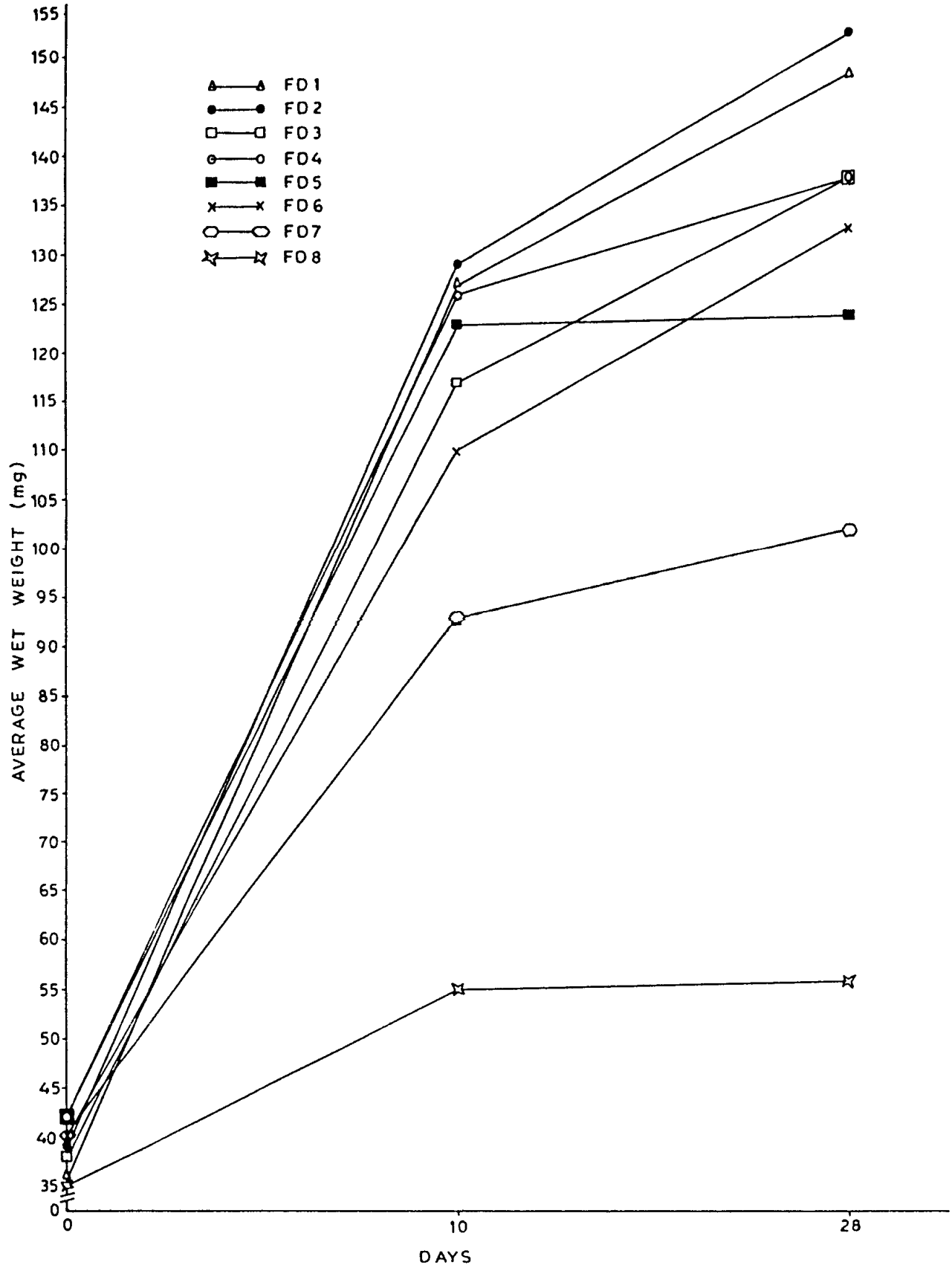


Fig.18 Weight increment of P. indicus juveniles fed with the eight diets in feeding experiment - II.

Standard error of treatment means = 0.016

Critical difference t0.01 = 0.282

Comparison of means based on critical difference

FD2	FD1	FD4	FD6	FD3	FD5	FD7	FD8
0.114	0.110	0.0993	0.0957	0.0953	0.0820	0.0617	0.0213

Underscored means are not significantly different

4.4.3 Specific Growth Rate.

The prawns fed with the diets FD1, FD2, FD3, FD4, FD5 and FD6 showed significantly higher ($P<0.01$) specific growth rates than those fed with the diets FD7 and FD8. The highest mean value was obtained for those fed with diet FD1 (6.60%), followed by FD2 (6.48%), FD3 (5.93%), FD6 (5.77%) and FD4 (5.62%) (table 21) The specific growth rate recorded for the prawns fed with FD8 was the lowest (2.29), and was found to be significantly lower ($P<0.01$) than all other treatments (table 22). The specific growth obtained for the treatment FD7 was significantly better than FD8 and lower than others. Figure 21 illustrates the specific growth rates of prawns fed with the different diets.

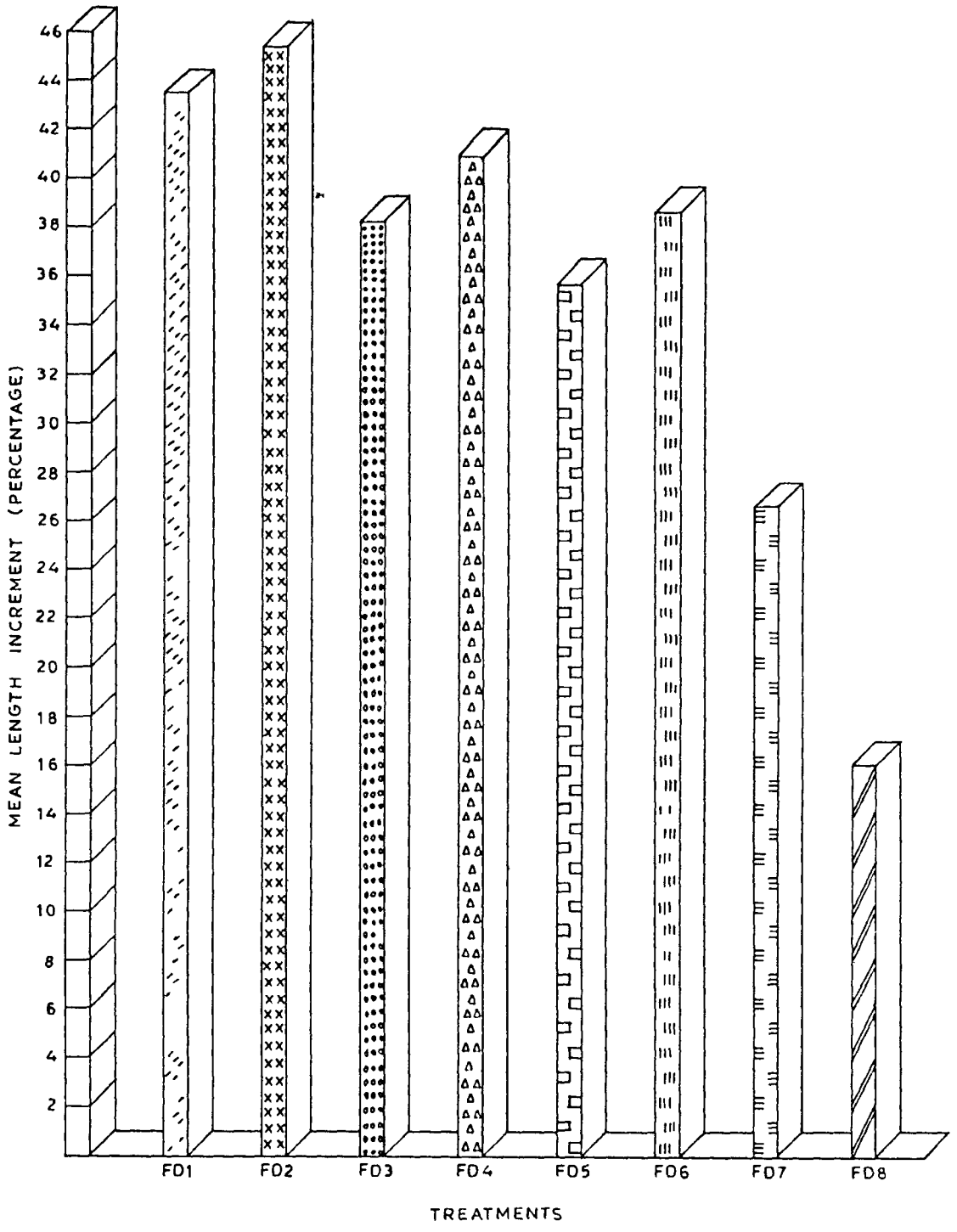


Fig.19 Percentage length increment of P. indicus juveniles fed with the eight diets in feeding experiment - II.

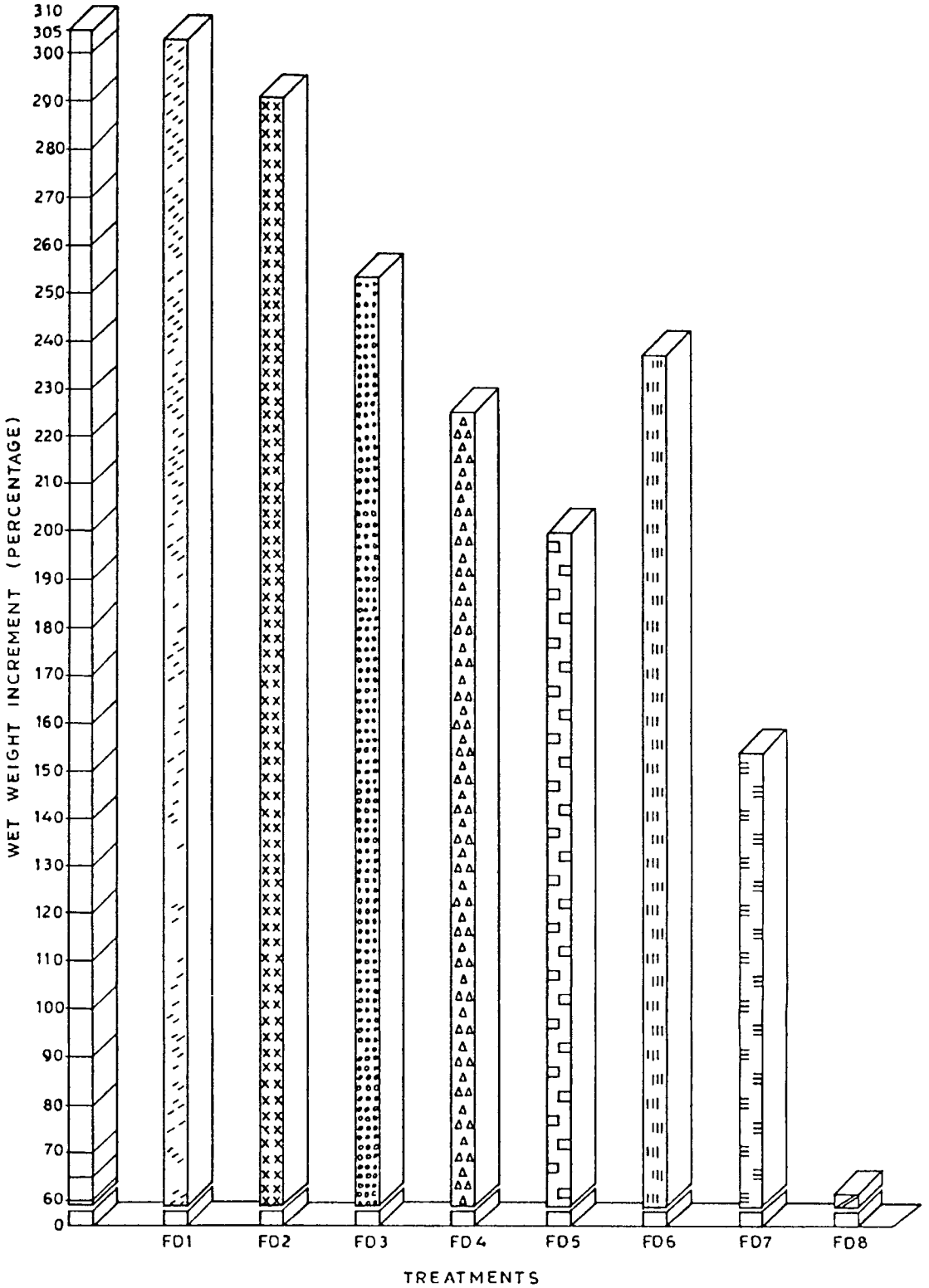


Fig.20 Percentage weight increment of P. indicus juveniles fed with the eight diets in feeding experiment - II.

Table 21. Specific growth rate (%) of P. indicus juveniles fed with various test diets in feeding experiment-II

Diets	Replication	Av. initial weight (g)	Av. final weight (g)	sp. Gr. rate (%)	Mean (%)
FD1	1	0.039	0.184	7.387	
	2	0.033	0.132	6.601	6.60
	3	0.036	0.122	5.812	
FD2	1	0.037	0.161	7.002	
	2	0.040	0.149	6.262	6.48
	3	0.041	0.150	6.176	
FD3	1	0.038	0.126	5.708	
	2	0.041	0.183	7.123	5.933
	3	0.037	0.105	4.967	
FD4	1	0.044	0.142	5.579	
	2	0.043	0.137	5.518	5.618
	3	0.040	0.134	5.757	
FD5	1	0.038	0.137	6.107	
	2	0.045	0.117	4.550	5.179
	3	0.042	0.117	4.879	
FD6	1	0 041	0.133	5.604	
	2	0.040	0.153	6.388	5.767
	3	0.040	0.122	5.310	

contd.

FD7	1	0.040	0.110	4.817	
	2	0.038	0.099	4.560	4.438
	3	0.042	0.096	3.937	
FD8	1	0.035	0.057	2.322	
	2	0.032	0.054	2.492	2.291
	3	0.037	0.057	2.058	

Table 22. Analysis of variance of the data on specific growth rate of P. indicus juveniles fed with diets containing various levels of plant detritus

Source of variation	Degrees of freedom	Sum of squares	Mean sum of squares	F value Computed	F value Tabular
Bet. diets	7	83.990	11.999	9.198	4.03
Error	16	9.999	0.625		
Total	23	93.989			

Standard error of transformed treatment means = 0.645

Critical difference $t_{0.05}$ = 1.108

Comparison of transformed means based on critical difference

Diets	FD1	FD2	FD3	FD6	FD4	FD5	FD7	FD8
Transformed mean values	14.87	14.74	14.06	13.88	13.71	13.13	12.15	8.69

Underscored means are not significantly different.

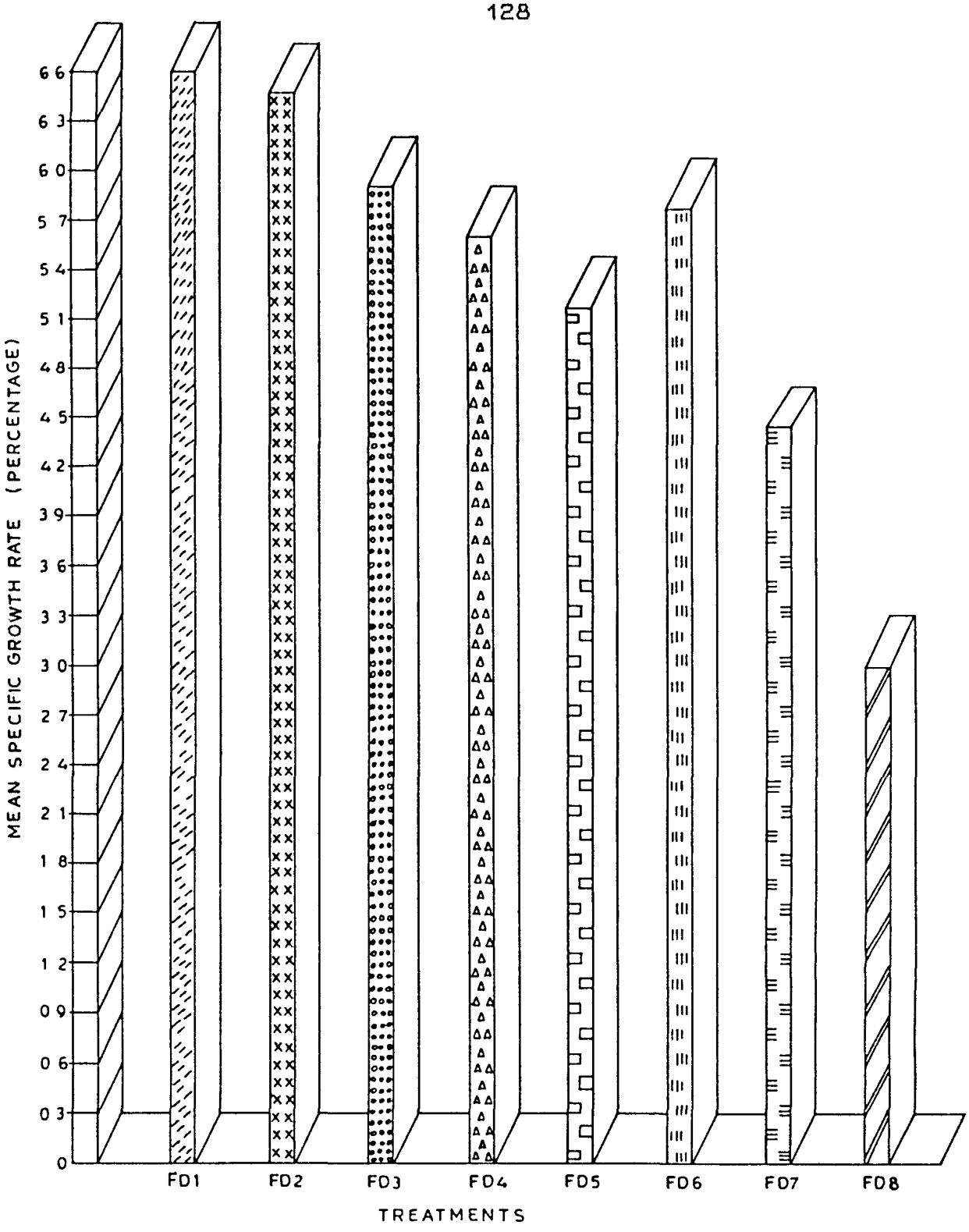


Fig.21 Specific growth rate of P. indicus juveniles fed with the eight diets in feeding experiment - II.

4.4.4 Food Conversion Ratio (FCR).

The best average food conversion ratio was given by the diet FD2 (2.60). This was followed by FD1 (2.86), FD4 (3.27), FD3 (3.33), FD6 (3.9), FD5 (4.00), FD7 (4.85) and FD8 (14.70) (table 23).

Statistical analysis of the data revealed that the food conversion ratios (FCR) obtained for the different treatments FD1, FD2, FD3, FD4, FD5 and FD6 are significantly ($P<0.01$) better than those obtained for the treatments FD7 and FD8 (table 24). The variation in food conversion ratio (FCR) of the diets FD5, FD6 and FD7 is found to be insignificant ($P<0.05$). So also the variations in FCR values of the treatments FD1, FD2, FD3 and FD4 are also found to be insignificant ($P>0.05$). Treatment FD8 recorded the highest food conversion ratio (14.697). The FCR values obtained for various treatments are showin in Figure 22 .

Table 23. Food conversion ratio obtained for *P. indicus* juveniles fed with diets containing different levels of plant detritus in feeding experiment II

Diets	Replication	Initial biomass (g)	Total wet wt. gain (g)	Net wt. gain (g)	Total food consumed (g)	FCR	Mean FCR
FD1	1	0.390	1.843	1.453	3.130	2.154	
	2	0.329	1.315	0.986	2.979	3.021	2.863
	3	0.360	1.219	0.859	2.932	3.413	
FD2	1	0.372	1.601	1.229	2.500	2.034	
	2	0.395	1.490	1.095	3.141	2.868	2.604
	3	0.408	1.499	1.091	3.174	2.909	
FD3	1	0.383	1.256	0.873	3.270	3.746	
	2	0.406	1.826	1.420	3.689	2.598	3.325
	3	0.374	1.049	0.675	2.451	3.431	
FD4	1	0.436	1.394	0.958	3.046	3.180	
	2	0.431	1.366	0.935	3.237	3.462	3.274
	3	0.395	1.328	0.933	2.967	3.180	
FD5	1	0.380	1.366	0.986	3.632	3.684	
	2	0.450	1.162	0.712	3.037	4.265	4.060
	3	0.422	1.161	0.739	3.127	4.231	
FD6	1	0.414	1.310	0.896	3.607	4.026	
	2	0.402	1.491	1.089	3.600	3.306	3.900
	3	0.403	1.116	0.713	3.113	4.366	

contd.

FD7	1	0.402	1.102	0.700	3.072	4.389	
	2	0.376	0.992	0.616	3.458	5.614	4.856
	3	0.416	0.950	0.534	2.438	4.566	
FD8	1	0.350	0.570	0.220	3.247	14.759	
	2	0.317	0.543	0.226	3.066	13.566	14.697
	3	0.368	0.572	0.204	3.216	15.765	

Table 24. Analysis of variance of the data on food conversion ratio of P. indicus juveniles fed with diets containing various levels of plant detritus

Source of variation	Degrees of freedom	Sum of squares	Mean sum of squares	F value Computed	F value Tabular (1% level)
Bet. diets	7	217.909	31.129	79.412	4.03
Error	16	6.269	0.392		
Total	23				

Standard error of treatment means = 0.511

Critical difference $t_{0.05}$ = 1.084

Comparison of treatment means based on critical difference

Diets	FD2	FD1	FD4	FD3	FD6	FD5	FD7	FD8
Mean values	2.604	2.863	3.374	3.325	3.900	4.060	4.850	14.697

Underscored means are not significantly different.

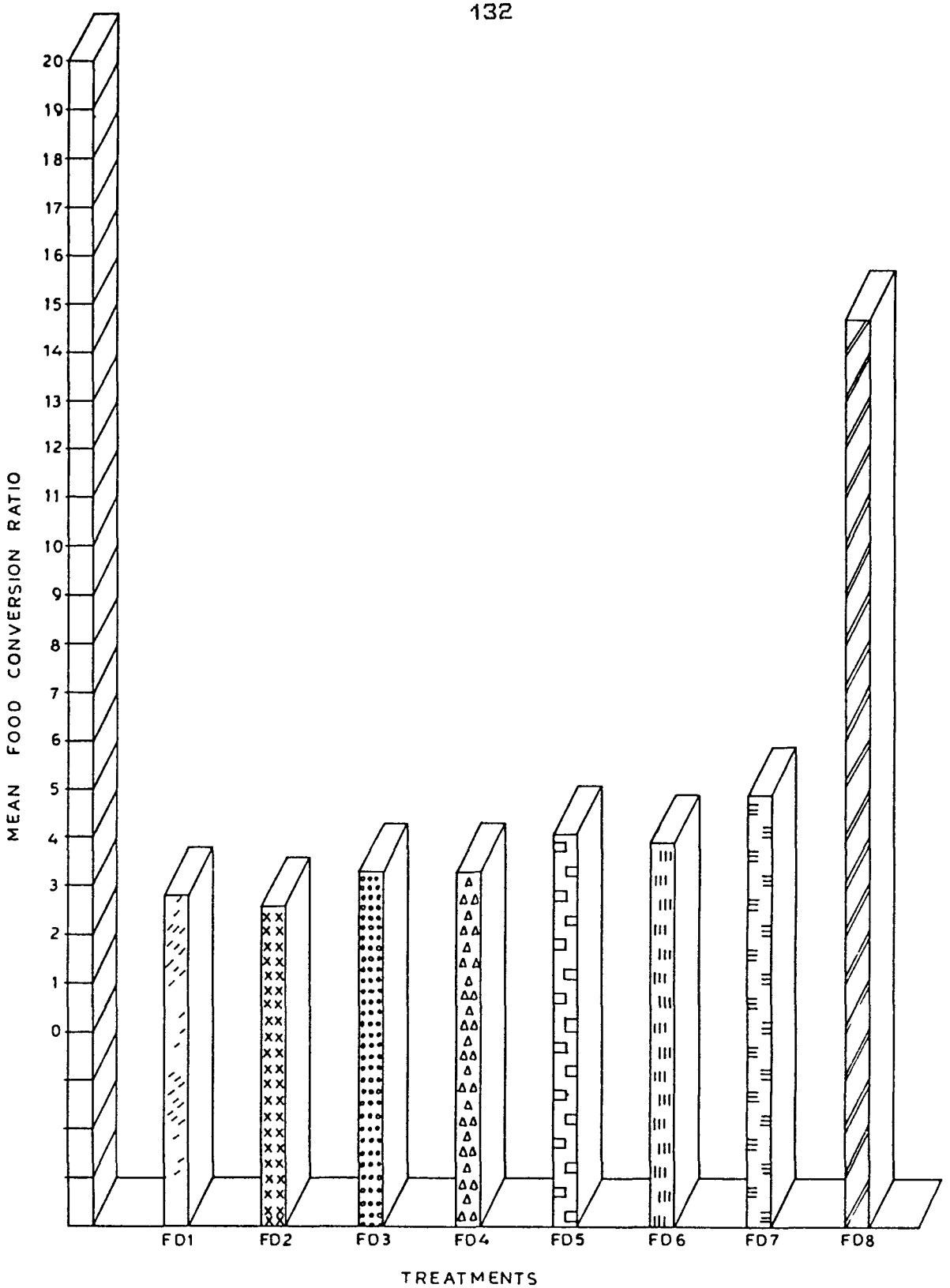


Fig.22 Food conversion ratio obtained for P. indicus juveniles fed with the eight diets in feeding experiment - II.

4.4.5 Protein Efficiency Ratio.

It was observed that the prawns fed with the diet FD2 gave the best protein efficiency ratio (1.29) and the lowest value was obtained for those fed with diet FD8 (0.354). Protein efficiency ratios recorded for other treatments were 1.157, 1.087, 1.107, 0.996, 0.986 and 0.936 for the diets FD1, FD3, FD4, FD6, FD7 and FD5 respectively (table 25). Analysis of variance of the data revealed that the protein efficiency ratio obtained for the diet FD8 was significantly lower ($P<0.01$) than those obtained for the other treatments. The variation in protein efficiency values among the seven treatments was also found to be insignificant ($P>0.05$) as could be seen in table 26. The protein efficiency ratios observed for different treatments are shown in figure 23.

Table 25. Protein efficiency ratio obtained for *P. indicus* juveniles fed with diets containing different levels of plant detritus in feeding experiment II

Diets	Replication	Initial biomass (g)	Total wet wt. gain (g)	Net wt. gain (g)	Total protein consumed (g)	PER	Mean PER
FD1	1	0.390	1.843	1.453	0.981	1.481	
	2	0.329	1.315	0.986	0.934	1.056	1.157
	3	0.360	1.219	0.859	0.919	0.935	
FD2	1	0.372	1.601	1.229	0.765	1.607	
	2	0.395	1.490	1.095	0.961	1.139	1.290
	3	0.408	1.499	1.091	0.971	1.124	
FD3	1	0.383	1.256	0.873	0.930	0.939	
	2	0.406	1.826	1.420	1.049	1.354	1.087
	3	0.374	1.049	0.675	0.697	0.968	
FD4	1	0.436	1.394	0.958	0.842	1.138	
	2	0 431	1 366	0.935	0.894	1.046	1.107
	3	0.395	1.328	0.933	0.820	1.138	
FD5	1	0.380	1.366	0.986	0.961	1.026	
	2	0.450	1.162	0.712	0.803	0.887	0.936
	3	0.422	1.161	0.739	0.827	0.894	
FD6	1	0.414	1.310	0.896	0.942	0.951	
	2	0.402	1.491	1.089	0.940	1.159	0.996
	3	0.403	1.116	0.713	0.813	0.877	

contd.

FD7	1	0.402	1.102	0.700	0.649	1.079	
	2	0.376	0.992	0.616	0.731	0.843	0.986
	3	0.416	0.950	0.534	0.515	1.037	
FD8	1	0.350	0.570	0.220	0.626	0.351	
	2	0.317	0.543	0.226	0.591	0.382	0.354
	3	0.368	0.572	0.204	0.620	0.327	

Table 26. Analysis of variance of the data on protein efficiency ratio of P. indicus juveniles fed with diets containing various levels of plant detritus

Source of Variation	Degrees of freedom	Sum of squares	Mean sum of squares	F value Comp ed	Tabular (1% level)
Bet. diets	7	1.646	0.235	7.291	4.03
Error	16	0.516	0.032		
Total	23				

Standard error of treatment means = 0.147

Critical difference $t_{0.05}$ = 0.429

Comparison of means based on critical difference

Diets	FD2	FD1	FD4	FD3	FD6	FD5	FD7	FD8
Mean values	1.290	1.157	1.107	1.087	0.996	0.936	0.986	0.354

Underscored means are not significantly different.

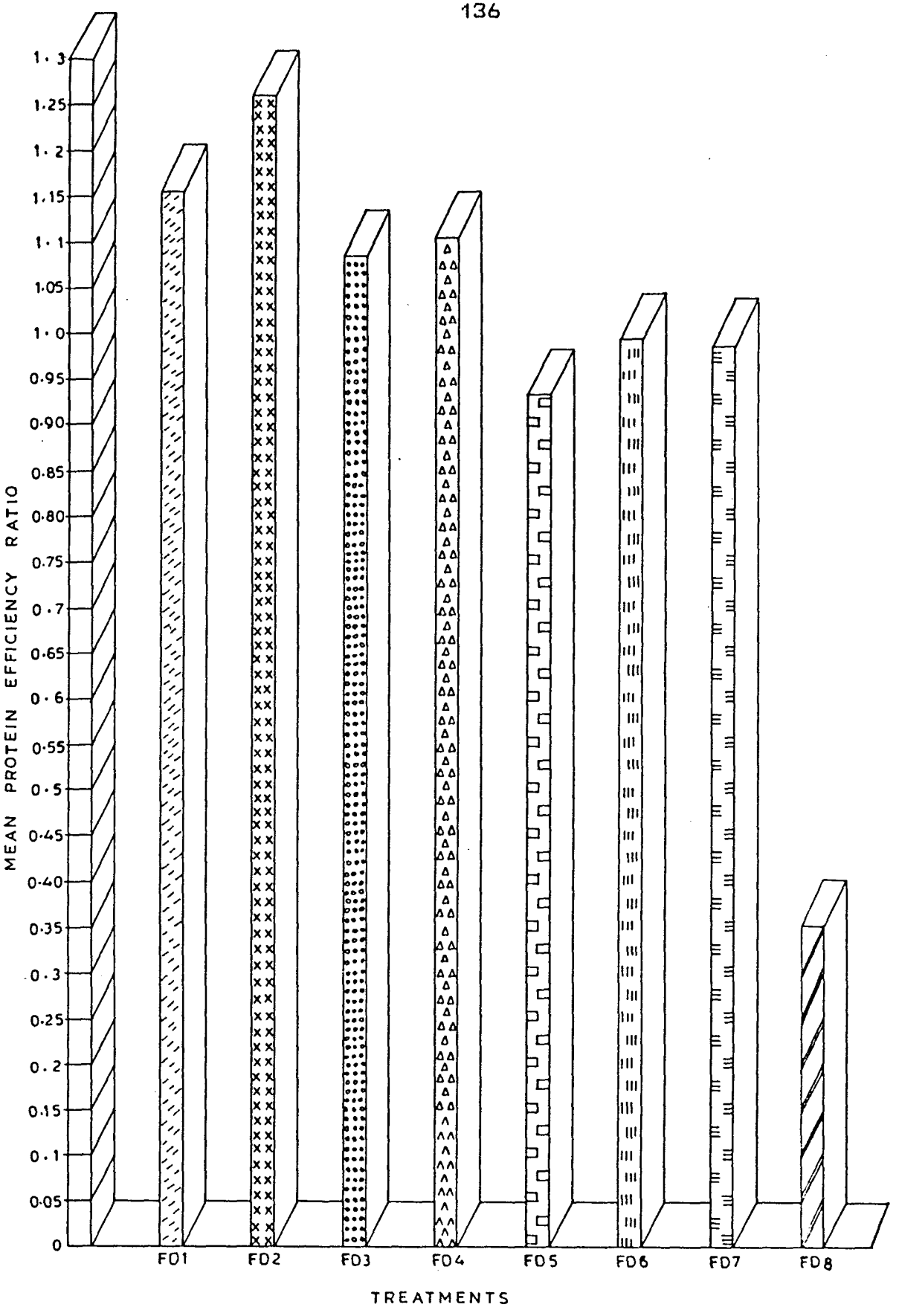


Fig.23 Protein efficiency ratio of P. indicus juveniles fed with the eight diets in feeding experiment - II.

4.4.6 Apparent Digestibility Coefficient.

Apparent digestibility coefficient values obtained for the various test diets employed are provided in table 27. The highest mean apparent digestibility coefficient was obtained for the diet FD2 (76.186%) and the lowest for the diet FD8 (54.392%).

Statistical analysis of the data showed that there exists significant difference ($P<0.01$) in apparent digestibility values of various test diets (table 28). The diets FD1 and FD2 showed significantly better ($P<0.01$) apparent digestibility values than rest of the diets. It was also observed that the difference in apparent digestibility of the diet FD3 from the diet FD1 is insignificant ($P>0.05$), while the diets FD3, FD4 and FD5 show insignificant differences ($P>0.05$) in digestibility values among themselves. The diets FD6 and FD7 also showed no significant difference ($P>0.05$) in apparent digestibility value, while the diet FD8 showed a significantly lower value ($P<0.01$) than the rest of the diets. Figure 24 illustrates mean apparent digestibility values obtained for the eight diets employed in this experiment.

Table 27. Apparent digestibility coefficient of the diets containing various levels of plant detritus fed to P. indicus juveniles in feeding experiment-II

Diets	Replication	Total food consumed (g)	Total Excreta produced (g)	App. Digestibility (%)	Mean (%)
FD1	1	3.130	0.772	75.326	
	2	2.979	0.755	74.642	74.016
	3	2.932	0.819	72.080	
FD2	1	2.500	0.518	79.280	
	2	3.141	0.799	74.556	76.186
	3	3.179	0.804	74.722	
FD3	1	3.270	0.910	71.911	
	2	3.689	0.994	73.050	71.853
	3	2.451	0.721	70.600	
FD4	1	3.870	1.100	71.576	
	2	3.237	0.959	70.358	70.639
	3	2.967	0.891	69.983	
FD5	1	3.632	1.151	68.337	
	2	3.037	0.983	67.646	69.014
	3	3.127	0.905	71.059	
FD6	1	3.607	1.227	65.986	
	2	3.600	1.103	69.356	68.298
	3	3.113	0.948	69.553	

contd.

FD7	1	3.072	0.997	67.539	
	2	3.458	1.237	64.239	65.755
	3	2.438	0.841	65.488	
FD8	1	3.247	1.460	55.189	
	2	3.006	1.376	55.134	54.392
	3	3.216	1.516	52.854	

Table 28. Analysis of variance of the data on apparent digestibility of the various test diets fed to *P. indicus* juveniles in feeding experiment-II

Source of variation	Degrees of freedom	Sum of squares	Mean sum of squares	F value Computed	F value Tabular (1% level)
Bet. diets	7	344.779	49.254	40.076	4.03
Error	16	19.662	1.229		
Total	23	364.441			

Standard error of transformed treatment means = 0.905

Critical difference $t_{0.05}$ = 1.918

Comparison of transformed means based on critical difference

Diets	FD2	FD1	FD3	FD4	FD5	FD6	FD7	FD8
Transformed mean values	60.815	59.361	57.962	57.191	56.181	55.740	54.188	47.52

Underscored means are not significantly different.

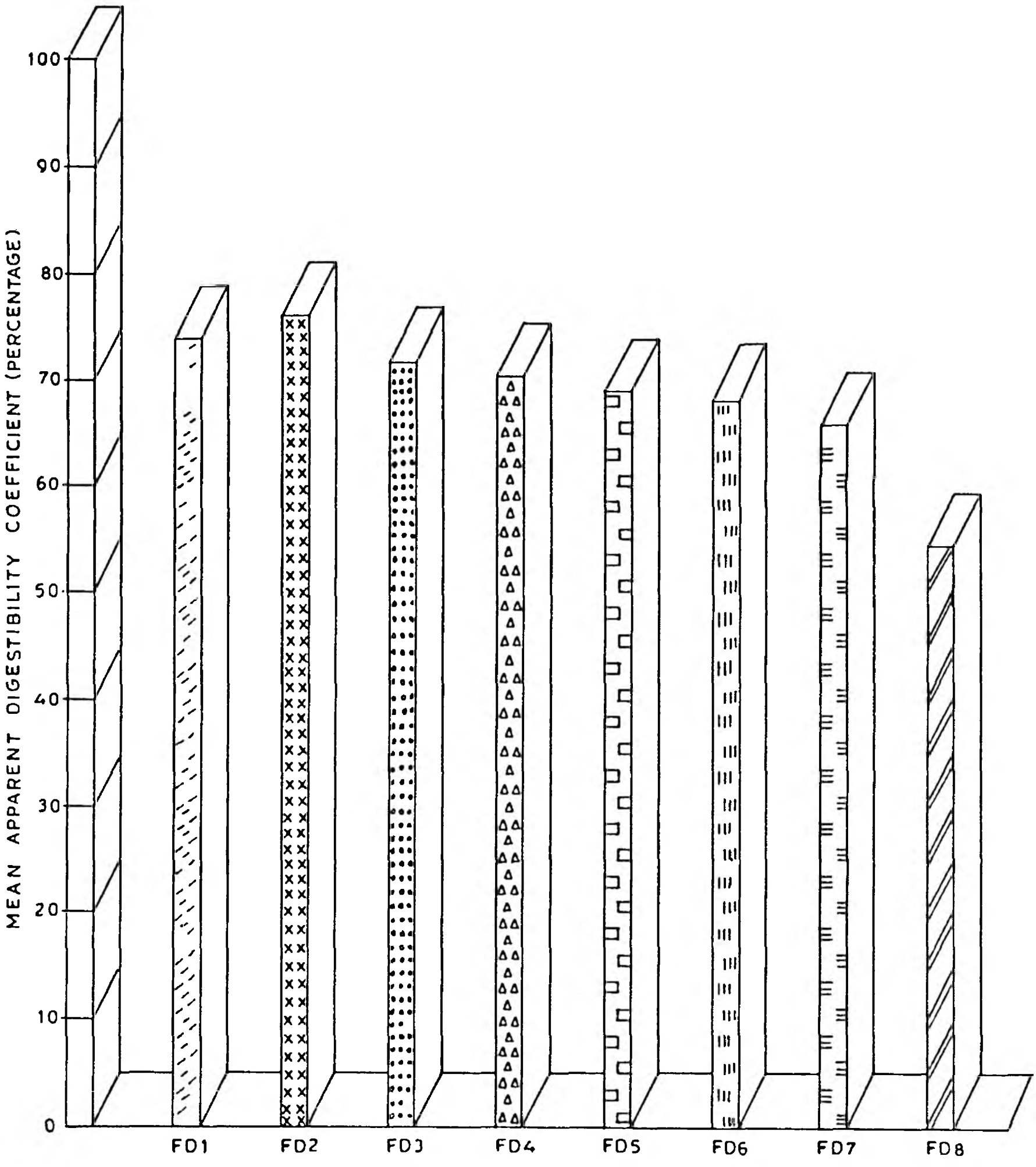


Fig.24 Apparent digestibility coefficient of the various test diets fed to P. indicus juveniles.

4.4.7 Apparent Protein Digestibility Coefficient.

Table 29 gives apparent protein digestibility values of all the eight diets employed in this experiment. It was observed that the test diet FD2 gave the highest apparent protein digestibility (87.319%) and FD8 the lowest (57.353%). The apparent protein digestibility values obtained for the treatments FD1, FD3, FD4, FD5, FD6 and FD7 were 86.243%, 84.080%, 82.866%, 80.533%, 79.696% and 71.519% respectively (Fig. 25).

Table 29. Protein digestibility coefficient of the diets containing different levels of plant detritus fed to P. indicus juveniles

Diets	Food consumed	Excreta produced	%Protein in food	%Protein in excreta	Protein ingested	Protein digested	Protein digestibility coefficient(%)
FD1	3.014	0.782	31.35	16.62	0.945	0.845	86 243
FD2	2.940	0.707	30.60	16.15	0.899	0.785	87.319
FD3	3.137	0.880	28.45	16.72	0.892	0.750	84.080
FD4	3.358	0.983	27.63	16.22	0.928	0.769	82.866
FD5	3.265	1.013	26.45	16.59	0.863	0.695	80.533
FD6	3.440	1.093	26.42	16 70	0.899	0 716	76.696
FD7	2.989	1.025	21 14	17.52	0.632	0.452	71.519
FD8	3.176	1.451	19.27	17.99	0.612	0.351	57.353

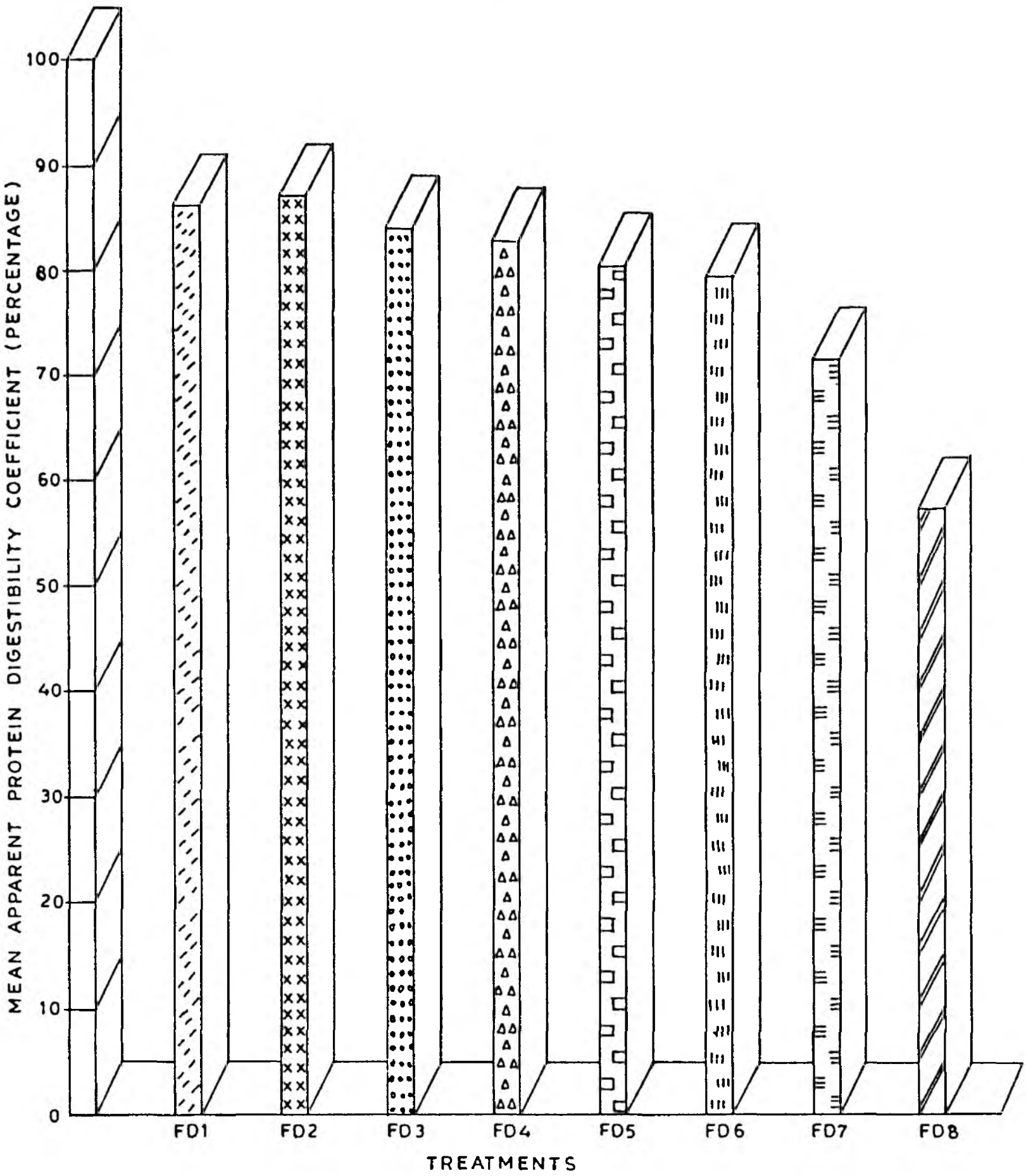


Fig.25 Apparent protein digestibility coefficient of the various test diets fed to P. indicus juveniles.

4.5 Water Quality Parameters Recorded

The different water quality parameters recorded during the feeding experiment are given below.

4.5.1 Temperature.

In feeding experiment-I, the temperature of the rearing medium ranged between 26.8 and 27.8°C in the morning (8 AM) and between 28.0 and 30.2°C in the evening (6 PM).

During the feeding experiment II, the water temperature varied from 26.8 to 27.5°C (morning) and 28.5 to 30.3°C (evening).

4.5.2 pH.

All the cisterns registered neutral to alkaline pH throughout the experimental period. In experiment I and II the pH values ranged between 7.0 and 8.5.

4.5.3 Dissolved Oxygen.

During the first experiment, the average value of dissolved oxygen ranged from 5.04 to 8.32 ppm, while in the second the values ranged between 4.97 and 7.67 ppm.

DISCUSSION

V DISCUSSION

5.1 Evaluation of the Preference of *Penaeus indicus* Juveniles towards Different Plant Detritus Sources as Food.

The experiment conducted to evaluate the preference of *P indicus* juveniles towards the different detritus food sources like *Rhizophora apiculata* leaves, *Chromolaena odorta* leaves, *Pistia stratiotes* plants, and Paddy (*Oryza sativa*) straw, which were provided in a tank, has revealed that *R. apiculata* leaf detritus is the most preferred one. It was found that 49.87% of the prawn juveniles in the tank congregated and fed this source. But in the initial stage (10-15 minutes), no distinct preference to any of the decayed plant material was exhibited by the prawns, which could be due to the time lag usually taken by prawns to reach the food source. Later on, more and more prawns started congregating towards the preferred sources, clearly demonstrating the preference to a particular food source.

Of the four different plant detritus sources provided majority of the prawns(49.87%) preferred the *R. apiculata* leaf detritus (vide table4). This kind of preference to *Rhizophora*, the mangrove plant available in the estuarine areas, which are the nursery grounds of penaeid prawns, is understandable.

Sambasivam and Krishnamurthy (1986) reported that mangrove

foliage was well accepted by P. indicus. Similarly in the case of Metapenaeus monoceros, Sumitra-Vijayaraghavan and Ramadhas (1980) and Sumitra-Vijayaraghavan and Wafar (1983) have reported that the diets prepared from Rhizhopora detritus were quite acceptable to the prawns. Goswami and Goswami (1979;1982) also evaluated the acceptability of diets containing mangrove foliage, as one of the ingredients, to P. indicus M.affins, M. monocers and reported that diets containing high levels of mangrove leaves and wheat flour produced better growth.

According to Mohamed and Rao (1971), in nature, P. indicus resides for about six months in estuarine areas having mangroves during their juvenile phase and move progressively off-shore when they become sub-adults. Leh and Sasekumar (1980) found that 11-59% of the plant matter consumed by penaeid prawns collected from Selanger waters was constituted by mangrove detritus. Thus it could be seen that P. indicus juveniles do exhibit a distinct preference towards mangrove detritus. The exact reason for preferring mangrove detritus over the other sources could not be stated clearly; it could be that the prawns find the 'taste' to their liking and possibly the unique 'odour' of the decaying mangrove leaves has got some special attraction to prawns, which make use of chemo-sensory and tactile senses to detect their food

The capacity of the prawn P. indicus to utilize the wax

coating of the mangrove leaves is yet to be studied. The wax coating present on the surface of the leaves remains intact even after the decomposition of the leaf. P. indicus juveniles were found not to utilize this. In the case of P. stylirostris, Von Prahl (1978) reported that the first stage post-larvae could digest this wax, while the later post-larvae and juvenile stages lack this ability. The detritus from Chromolaena odorata, which was preferred next to R. apiculata leaf detritus, has got a very soft texture and was found to decay uniformly. This probably would have contributed to its higher level of acceptance by the prawns, in comparison to Pistia and paddy straw detritus.

Low acceptability recorded for the Pistia detritus might be due to the fibrous nature and the presence of roots which are not degraded properly. Hence pretreatment may be required to make it acceptable as detritus food source. Mechanical (soaking, milling, grinding), chemical (lime) and biological (with yeast) treatments are reported (Anon, 1980) to be necessary for proper digestion and utilization of such aquatic weeds.

Acceptability of decayed paddy straw was found to be significantly less when compared to Rhizophora and Chromolaena and almost similar to that of Pistia. It may be due to its coarse and fibrous nature.Srinivasan(1987) reported that paddy and wheat straw have large amounts of ligno-cellulosic residues, which are

not easily degraded by microorganisms, unless they are pretreated using special techniques. Fan et al. (1981), after studying the biodegradation of wheat straw, reported that both physical and chemical pretreatment methods are necessary to decompose these types of plant materials. Thus poor degradation of this lignocellulose rich agricultural by-product makes it unacceptable to juvenile prawns.

The increased prawn production from rice fields with decaying straw reported by many could be owing to the nutrients leaching out from decaying paddy straw, as pointed out by Gopalan et al. (1982), making the system more organic rich. Kirchman and Ducklow (1987) reported that bacteria can utilize dissolved organic matter leached from the detritus and inturn offer themselves as food sources for those organisms feeding on detritus. Thus the attached periphyton and the 'scum' developed from the decaying paddy straw might have contributed to the better productivity reported from these fields. The comparison of prawn fields with regard to productivity has often been made with the perennial fields, where the prawns normally do not get adequate organic material and seasonal paddy fields, where paddy is grown during monsoon season and utilized for traditional prawn culture during summer season. In these seasonal fields, the major food the prawns could utilize is the decaying straw. Although not acceptable, to

the same level as Rhizophora and Chromolaena, paddy straw could be regarded as a good food for prawns in traditional prawn fields, due to the high level of organic enrichment by bacterial and periphyton growth. Decaying paddy straw was suggested to contribute to the productivity of traditional prawn culture fields by Menon (1954) and George (1974).

5.2 Experiment to Find the Improvement in Protein Levels of Rhizophora and Chromolaena

The experiment to find the improvement in protein levels of the two plant materials revealed that in Chromolaena there is a substantial improvement during the course of decay (vide table 7) wherein the level has improved from an initial average of 20.5 to a level of 25.7% by the 15th day.

Many workers have reported that the bacterial degradation brings about an improvement in protein level (Venkataramiah et al., 1978; Sumitra-Vijayaraghavan and Ramadhas, 1980; Schroeder, 1987). Although an improvement in protein level was noted in both the plant materials used for the present experiment, there is a marked variation in the levels, it being substantially high in the case of Chromolaena (a difference of 5.064% from the original) compared to that of Rhizophora detritus (a difference of 1 778%)

The higher final protein level achieved in the case of

Chromolaena may be due to the better availability of readily digestible energy substrate and nitrogen source to the bacteria that build up on the decaying material, as suggested by Lopez et al. (1977) and Tenore et al. (1982). Rice and Hanson (1984) have pointed out that the concentration of proteins and amino acids in the parent plant matter directly influences the protein and amino acid concentration of subsequent detritus; protein-rich plants making protein-rich detritus. Thus better protein content of the fresh plant material might be the reason for the better final protein level observed for Chromolaena detritus. As pointed by Moriarty and Pullin (1987), the growth of bacteria on the decaying plant material is influenced by food supply and, the bacterial build up on the plant material depends not only on the organic carbon and nitrogen in it but also on the nutrient composition, ie., the availability of readily digestible energy and nitrogen sources in the parent plant material.

In the case of Rhizophora apiculata, as could be seen from the present study, low availability of nitrogen (evident from low initial protein value) could be one of the reasons for the lower level of nutrient enrichment achieved. According to Srinivasan (1987), carbohydrates, one of the major energy substrates, in the Rhizophora leaf is constituted mainly of ligno-cellulose which is very resistant to bacterial degradation unless the plant material

is pretreated. This could be one of the reasons for the lower difference in protein level obtained for Rhizophora detritus. In the present study, the plant material was subjected to one of the physical pretreatments (cutting) but no chemical methods employed to make the plant material more susceptible to bacterial degradation thus resulting in lower increase in the protein level.

The decomposition rate of waxes present in plant materials, especially in leaves, is estimated to be very low, about 25% per year. Retention of the wax coating, observed in the present study, on the chopped plant material, even after several days of decomposition in the digester, might be another reason for reduced microbial 'processing' and protein improvement in the case of Rhizophora.

The substantial increase in protein level in the decaying Chromolaena, observed in the present study, could be attributed to the bacterial degradation of organic matter and resulting bacterial enrichment of the plant detritus. An initial lag in improvement followed by a pronounced rise in protein level, then a plateuing and finally a decline in levels could be seen (Vide Fig 5). The lag phase could be noted up to the day 10, followed by a steep increase upto the 15th day, then a stagnation upto the 20th day and finally the decline starts at the 20th day. This observation clearly agrees with those by Robinson et al. (1982)

and Biddlestone and Gray (1987). Robinson et al. (1982) reported that the conversion efficiency of bacteria during degradation of kelp (Laminaria) was 45% for the first 2-3 days of degradation but declined to about 20% after 20 days, as percentage of refractory detritus increased, with the depletion of readily digestible matter. Such decline in protein level has been observed by Biddlestone and Gray (1987), who pointed that prolonged microbial colonization could lead to formation of recalcitrant carbon and nitrogen complexes. Pullin (1987) stated that there is a limit for bacterial enrichment in a decaying substratum as the bacteria will not go on increasing in biomass; rather there would be death/turn over, resulting in an upper limit of about 10^{8}-10^{9} bacteria/g.

Since there is decline in protein level after reaching a maximum, the appropriate time of harvesting of the material used for decay is to be determined so as to get the maximum protein enrichment. In the present study, the maximum average protein level of Chromolaena was observed on the 15th day, and as such the Chromolaena plant material decayed for a period of 15 days was used for the feeding experiments.

5.3 Experiment to Evaluate the Feasibility of Using Plant Detritus as Exclusive Protein Source in the Diet for *P. indicus* Juveniles

The results of the feeding experiment to evaluate the suitability of using *Chromolaena* detritus as the exclusive protein source, given in table 10 and fig. 8 have demonstrated that detritus cannot be used as the exclusive protein source for the prawn. The survival and growth obtained for the juvenile *P. indicus* was significantly low when fed with the diet prepared exclusively with *Chromolaena* detritus. Further, the food conversion value and the protein digestibility of the diet were not up to the mark.

The average survival rate obtained for the juveniles fed with detritus diet was only 24.29%, whereas it was 78.57% for the iso-nitrogenous control diet, having a protein level of 25%. This suggests that plant detritus sources of protein at 100% level cannot form a viable alternative to the animal protein for incorporation in feeds of penaeid prawns. Similar observations regarding the difficulty in replacing an animal protein completely with plant protein have been reported by many workers Thus Venkataramiah *et al*. (1978) observed that *P. aztecus* fed with pellets made out of decomposed grass *Spartina patens* produced a survival of only 26% after a 45 day rearing period in comparison

to 92% obtained with an animal protein source. Primavera and Gacutan (1989) observed that P. monodon fed with decaying Najas graminea had given a survival rate of only 30.60% after a 30 day feeding experiment, in comparison to 90% survival obtained with Mytilus edulis as feed. So also Stern et al. (1976) observed that M. rosenbergii fed with Azolla, Elodea, Cladophora, and Lemna had a survival rate of only 53, 33, 30 and 27% respectively, in comparison to 90% survival observed for purina ration (control) over a period of 28 days.

The low survival rate obtained in all cases reported so far including the present study, indicates that plant detritus protein source is lacking in some nutrients which are vital to the prawns. Many workers, such as Swaminathan (1967), Fetuga et al. (1973) and Felkar and Bendurski (1977), have reported that most of the plant protein sources lack amino acids like methionine, cystine, lysine and tryptophan which are very essential for growth and survival of prawns.

It is the composition of the protein, rather than the total quantity of protein, that is important in deciding the quality of the diet. Rice (1982) and Hanson (1982) had pointed out that the parent plant matter directly affects the amino acid concentration of subsequent detritus and the detritus produced from plant sources lack many essential amino acids. Even though protein rich

plants could make protein rich detritus, due to the inherent shortage of many amino acids in these plant materials (Bowen, 1987), the quality of plant detritus as far as omnivorous or carnivorous groups of animals are concerned, is low.

As could be seen from the table 10, juvenile prawns fed with detritus (test) showed poor performance when compared to that of the prawns fed with the clam meal diet (control). The average percentage increase in length and weight for those fed with the test diet was only of the order of -6.7 and 17.45% respectively whereas it was 57.68 and 393.14% for those fed with control diet, clearly establishing the low quality of the test diet.

Venkataramiah et al. (1978), using feed pellets made from decayed Spartina patens, got only a lower length and weight increment of 2.9 and 35.7% respectively in P. aztecus when compared to 28.6 and 96.8% obtained with the control diet made of fish meal. Sumitra-Vijayaraghavan and Ramadhas (1980), on the other hand, reported 160% increase in weight for Metapenaeus monoceros fed with diets prepared with Rhizophora leaf detritus while the control registered a growth increment of 118.0%.

Most of the plant proteins, when used as exclusive protein sources were reported to produce poor growth rate in prawns by

Kanazawa et al, (1970), Sick and Andrews (1973), Deshimaru and Shigueno (1972) and Balazs et al. (1973). Prawns require diets that are rich in basic amino acids like lysine, histidine and arginine (Deshimaru and Shigueno, 1972 ; Shigueno, 1984) but many of the plant protein sources lack these basic amino acids (Swaminathan, 1967).

Although there was an increase in protein level of the plant material, contributed by the bacterial build up on the decaying material, the improvement in quality of the protein may only be marginal, as pointed out by Schroeder (1978) and Phillips (1984). They reported that bacteria developed on the detritus do generally lack sterols, long chain polyunsaturated fatty acids and amino acids like methionine, which are highly essential for the growth of penaeids (New, 1976). Moreover there are reports regarding the deterioration in quality of protein owing to prolonged decay. Thus Rice (1982) reported that there is a possibility of transformation of nitrogen during the process of decomposition by interacting with lignin and other lignin like compounds, resulting in the formation of relatively refractory complexes

In the present experiment the average growth rate of (12 2mg/day) obtained for P. indicus juveniles fed with control diet, though much higher than that of the prawns fed with test diet (0.57mg/day), was found to be lower when compared to that

obtained for this species by Colvin (1976); ie., 105-107mg/day and Ahamad Ali (1982); ie., 23mg/day. The low growth rate obtained in the present study even for the clam meal based diet could be attributed to the lower protein content (25.0%), when compared to the higher protein levels made use of (43-46%) by the above workers. Colvin (1976) observed the best growth rate of P. indicus at a protein level of 40%, beyond which it declined. So also Ahamed Ali (1982) observed a progressive increase in live weight gain for P. indicus with increase in crude protein level upto 42.9% and it declined there after.

Very high food conversion ratio for the prawns fed with detritus diet (Av. 35.88), in comparison to the value obtained for the prawns fed with the control diet (2.11) clearly indicates the low efficiency of the detritus diet. This is in conformity with the observation of Colvin (1976) that P. indicus produced high food conversion ratios when fed with protein sources that are deficient in essential nutrients. He obtained comparatively high food conversion values for the diets based on fish meal as the major protein source. This high value was attributed to the deficiency of lysine, histidine and arginine in the protein source. Similarly for plant detritus, where the major sources of protein are the parent plant matter (which is deficient in many essential amino acids required for prawns) and the microbial load

that develops on the decaying material (which also lack many essential amino acids and polyunsaturated fatty acids), a deficiency of required nutrients could produce inefficient food conversion by prawns. The indigestible refractory compounds that might be produced during the decomposition process (Rice, 1982) could also increase the food conversion ratio.

The better food conversion ratio (2.11) obtained for the prawns fed with clam meal protein might be due to the improved protein quality of the source, when compared to that of plant detritus. Colvin (1976) obtained a food conversion value of 2.59 when the prawns were fed with a diet based primarily on prawn meal and this was attributed to the similarity of the amino acid profile of the animal protein source with that of prawns Ahamed Ali (1982) obtained a food conversion ratio of 1.46 for P indicus juveniles when fed with a diet based primarily on clam meal powder as the major protein source.

Diets containing low quality proteins are likely to give only low protein efficiency ratio. As such, in the present experiment, the low protein efficiency ratio obtained with the test diet is due to the low protein quality of the detritus when compared to that of the control diet comprising of clam meal. The plant detritus consisting of plant and microbial protein has a low protein value and is deficient in many amino acids as pointed by Phillips (1984).

In addition, detritus may contain large proportion of indigestible organic matter like cellulose, lignin and other refractory products that are generally low in both energy and amino acids (Bowen, 1987).

The microbial portion of the detritus protein is easily assimilated by animals (Newell, 1965) but its contribution is only marginal (Bowen et al., 1984; Findlay et al., 1984).

As could be seen from the data (table 14), apparent digestibility coefficient of the detritus based diet(64.515%) was significantly low when compared to that of control diet (86.859%). This could be correlated to lower protein digestibility and the high content of cellulosic material in the detritus based diet. An unfavourable amino acid composition of the diet is known to impair protein digestion (Nose, 1964).

Although many penaeid prawns are known to consume large quantity of detritus, their capacity to digest the detritus protein is very low. But certain fishes like Oreochromis mossambicus (having acidic pH in the stomach) and larvae of insects like Tipula abdominalis (having very high pH of 11) in the gut) are known to have a capacity to digest the detritus protein very efficiently (Bowen, 1981; et al., 1980).

The control diet made of clam meal has a very high protein digestibility of 86.859%. This could be due to the better quality of the protein when compared to that of detrital protein.

5.4 Experiment to Evaluate the Feasibility of Using Plant Detritus as Partial Substitute for Animal Protein Sources in the Diet for *P. indicus* juveniles.

The results of the experiment conducted to find out the possibility of incorporating plant detritus in a standard prawn diet, by replacing the clam meal protein at eight levels (0% - FD1, 10%-FD2, 20%-FD3, 30%-FD4, 40%FD5, 50%-FD6, 75%-FD7, 100%-FD8) showed that plant detritus could be used upto a level of 50% in the diet without producing any adverse effect on survival, growth and food conversion efficiency of the prawns.

Apparently, the best performance was given by the diet FD2, where 10% animal protein was replaced with plant detritus and the poorest by the diet FD8, where 100% of the animal protein was substituted with detrital protein. There is no significant difference in the performance, when plant detritus was incorporated upto a level of 50% of the animal protein in the feed, indicating that plant detritus source could be utilized for the preparation of prawn diets whereby the cost of production can be reduced substantially.

There was no significant variation in survival rate of prawns fed with the test diets. The diet containing no detritus (100% clam meal as animal protein source -FD1) and the diet containing no clam meal protein source (100% animal protein replaced with detritus - FD8) gave 100% survival rate, although in the latter case the growth obtained was negligible,, indicating that the absence of animal protein in the diet may not affect survival rate. The 100% survival rate obtained for the prawns fed with FD8 diet could be due to the fact that the other ingredients of the diet together with C. odorata leaf detritus could provide the energy required for maintenance, but not for tissue growth. The diet FD8 containing 19.27% protein would have provided the maintenance level of protein for the prawns, though it did not contribute significantly to the growth. This is in agreement with the observation of Ahamad Ali (1982) who reported that P. indicus requires a level of 15% protein for maintenance. Further, incorporation of plant material is reported to improve the survival rates (Venkataramiah et al., 1975). Venkataramiah et al. (1975) reported that addition of vegetable matter in the diet increased the survival rate of P. aztecus. Similar report on the improvement of survival rate of M. rosenbergii has been given by Herpaz and Schmelbach (1986), when plant materials were added to the prawn diet.

Growth rate of prawns fed with diets FD1, FD2, FD3, FD4, FD5 and FD6 did not significantly vary from one another which indicated that plant detritus could be added to the diet of prawns to a level of 50% without impairing the growth. The protein level of these diets (FD1 - FD6) which ranged from 26.12 to 31.35% is comparatively lower than the optimum protein level reported to be required for the species by Colvin (1976). This could be the reason for the lower mean growth rate(1.52-5.43 mg/day) obtained in the present study. Colvin (1976) and Ahamad Ali (1982) have reported that the optimum growth of P. indicus could be achieved by feeding with diets containing 35 to 40% protein. Ahamad Ali (1982) observed that there was only gradual increase in growth of prawns when fed with diets having protein levels varying from 20.6 to 35% .

The best growth rate was produced by the diet FD2 having 10% detritus, though the level of protein in the diet was lower than that of FD1. This observation is in agreement with that of many earlier workers such as Venkataramiah et al.(1976), Herpaz and Schmalbach (1986) who reported that addition of a small amount of plant material could improve the growth rate of prawns. Lee (1970) also reported that plant protein sources produced superior growth rates when mixed with animal protein sources. Forster and Gabbot (1971) reported that cellulose could be assimilated by the prawn to a small extend when fully ground.

The diets containing 75% detritus and 100% detritus produced very poor growth of P. indicus juveniles. This could be due to the reduced amount of animal protein in the former diet and its complete absence in the latter. It is known that diets which are not balanced, as far as the amino acid requirement of the prawns are concerned, would result in poor growth of prawns (Deshimaru and Shigueno, 1972).

Thus Stern et al.(1976) and Primavera and Gacutan (1989) did not obtain promising results when diets based exclusively on plant protein sources were fed to the prawns.

In the present study, it could be seen that as the level of incorporation of detritus increased beyond 50% there was significant increase in the food conversion ratio and reduction of protein efficiency value (Av. 0.354). This could be due to lack of many essential amino acids in the plant proteins (Fetuga et al , 1973; Felker and Bandurski, 1977) and the bacterial protein (Phillips, 1984), which are the major contributors of detrital proteins So also Schroeder (1978) reported that single cell proteins like bacteria are low in many essential amino acids and sulphur containing amino acids, which inturn could affect the efficiency of the protein (Penaflorida, 1989)

The digestibility obtained for the test diets FD7 and FD8 was considerably low, when compared to that of the other test diets indicating that incorporation of detritus beyond a level of 50% of the animal protein source impairs the digestibility. Better food conversion ratio and protein efficiency of a diet results from better protein digestibility and absorption. The higher values obtained for the above two parameters (Vide tables 23 and 25) for the diet FD2 directly imply that the protein digestibility and absorption were significantly better for this diet.

Maynard and Loosli (1978) have pointed out that difference in digestibility arises from incomplete digestive action or lack of complete absorption. Thus incomplete or inefficient digestion of the exclusively plant based diet together with the inherent deficiency of several essential amino acids in the plant sources could have resulted in the unsatisfactory performance of these diets.

The diet FD2 which incorporated 10% plant detritus produced apparently the best conversion ratio (2.604) and protein efficiency ratio (1.29), even better than a diet which was completely devoid of detrital protein (FD1). Many authors (Williams, 1958; Lee, 1970; Balazs et al ., 1973, Goswami and Goswami, 1982) have shown that diet based on a combination of animal and suitable plant protein sources could produce better

conversion efficiencies and protein utilization in prawns, than diets based purely on animal protein sources which in turn is attributed to better amino acid balance achieved by the mixing of different protein sources. Herpaz and Schmalbach (1986) attributed the better efficiency of the diet supplemented with plant protein source like leaves, to the better availability of nutrients like vitamin C to the prawns.

SUMMARY

VI SUMMARY

1. The objective of the present study is to evaluate the feasibility of using plant detritus as a sole food source for Penaeus indicus juveniles and to find out the level of its incorporation in a diet for the prawn, in place of animal protein source.

2. The experiment to find the preference of P. indicus juveniles towards a particular plant detritus from any four different items provided in a tank, was conducted in one ton oval FRP tanks, containing 300 litres of 20ppt brackish water, with 20 prawns in each tank.

3. The juvenile prawns, acclimated at 20 ppt salinity having a size of 25-32mm and 110-150 mg, were simultaneously provided with decayed plant materials such as Rhizophora apiculata leaves, Chromolaena odorata tender twings and leaves, whole plant of Pistia stratiotes and paddy (Oryza sativa) straw. Prawns showed better preference for R. apiculata detritus and C. odorata detritus, as indicated by the higher number of animals (49.8 and 36.86% respectively) found feeding on these sources, while decayed Pistia and paddy were found to be less acceptable to the prawns (only 7.18 and 5.83% respectively)

4. The two plant materials found better preferred were selected for further studies, subjected to bulk digestion in a digester;

specially designed for this purpose. The improvement in protein value of the decaying plant material was found out.

5. R. apiculata plant material showed only a slight improvement in protein level (max. average value 7.528% from the original level) while C. odorata registered comparatively better protein level (max, av. value 25.716%) Hence the latter source was selected for incorporation in a diet for P.indicus juveniles, as exclusive food source and partial animal protein substitute.

6. In order to evaluate the feasibility of using C. odorata detritus as exclusive protein source and animal protein substitute, two sets of feeding experiments were conducted in fibre glass tanks, having 55cm diameter and 35 cm height with 50 litres of 20 ppt water, keeping 10 prawns in each tank.

7. In the first feeding experiment, juvenile prawns of 21-29mm and 80-105 mg were reared for 28 days, while in the second set of feeding experiment, prawns of 18-21mm and 32-45mg size were reared for 21 days.

8. In the first feeding experiment, to assess the suitability of using C. odorata detritus as exclusive protein source, two isonitrogenous diets (25% protein) were formulated, one made of the plant detritus and other with clam meal compounded as pellets using tapioca powder as binder in both the cases.

9. In the second feeding experiment to find the level at which C. odorata detritus could be used to replace animal protein (clam meal) source, eight diets were formulated by substituting 0(FD1), 10 (FD2), 20 (FD3), 30 (FD4) 40(FD5), 50 (FD6), 75 (FD7) and 100% (FD8) clam meal in a standard prawn diet.

10. The prawns in both the feeding experiments were fed daily with the prepared feed, ad libitum. The feed remnants and the excreta collected, dried at 60°C and later used for estimation of food intake and growth efficiency.

11. Water in the experimental tanks was aerated through-out the culture period and complete water exchange done once in a week. Survival rate and biomass were assessed every 10 days in both the experiments.

12. Survival, growth, food conversion ratio, protein efficiency ratio and apparent digestibility values were found out in both the feeding studies to judge the performance of the diets.

13. Statistical analysis of the data was carried out using Student's-t test in the case of experiment-I and analysis of variance (after angular transformation of percentage values obtained) in the second set of experiment.

14. After 28 days of rearing, in the first feeding experiment, the prawns fed with diet made exclusively of plant detritus

produced poor survival (Av. 24.29%) and growth (Av. net gain in length and weight, -0.17cm and 0.016 g respectively) compared to the survival (78.57%) and growth (Av. net gain 1.48 mm and 0.343 g) obtained for those fed with clam meal (control) based diet.

15. The food conversion ratio obtained for the prawns fed with plant detritus based diet was significantly higher (Av. 35.883) when compared to the value observed for those fed with clam meal based diet (2.111).

16. The prawns fed with detritus based diet showed very low protein efficiency ratio (Av. 0.144) while those fed with clam meal based diet showed a high protein efficiency ratio (1.905).

17. The apparent digestibility and protein digestibility values obtained for the test diet (detritus based) were only 64.515 and 71.540% respectively while they were 86.859 and 94.750% for the clam meal based diet.

18. The second feeding experiment, to evaluate the feasibility of substituting plant detritus for animal protein source in a standard prawn diet at different levels, has shown that plant detritus could be successfully incorporated in the diet upto a level of 50% of the animal protein source with out producing any adverse effect on growth and survival.

19. The survival of the prawns fed with the eight diets (containing detritus at different levels) did not show any

significant difference. The difference in growth of the prawns was not significant upto level where the diet contained 50% detritus. The diet FD2 containing 10% plant detritus produced the highest growth rate (Av. net gain 0.94 cm and 0.114 g) among all the eight different diets tested, while the diet containing no clam meal protein (FD8) gave the lowest growth (Av. net gain 0.313 cm and 0.032g).

20. The food conversion ratio obtained for the prawns did not vary significantly upto a level of 50% plant detritus (Av. ranged from 2.604 to 4.06) while the diets containing very high level of detritus (75% and 100% of animal protein source substituted with detritus ie. FD7 and FD8) provided very high FCR value (4.85 - 14.69). The diet FD2 containing 10% plant detritus, gave the lowest food conversion ratio (2.604).

21. Incorporation of plant detritus upto 75% of the clam meal protein did not produce any marked variation in protein efficiency ratio (ranged from 1.157 - 0.986), but the 100% plant based diet (FD8) gave very low protein efficiency ratio.

22. The apparent digestibility of the diet FD1 and FD2 was significantly better than the other six diets. The diet FD2 gave the best apparent digestibility and protein digestibility, 76.180 and 87.319% respectively, while the lowest values were observed for the prawns fed with an exclusively plant based diet (FD8), 54.352 and 57.353% respectively.

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VII REFERENCES

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DETRITUS OF PLANT ORIGIN AS A FOOD SOURCE FOR *PENAEUS INDICUS* H. MILNE EDWARDS

By
UNNIKRISHNAN. R

ABSTRACT OF A THESIS

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ABSTRACT

The objective of the present study was to evaluate the feasibility of using plant detritus as an exclusive food source for the juveniles of Penaeus indicus and also to find out the level of its incorporation in a standard diet for the prawn in place of animal protein sources.

When four plant detritus were simultaneously presented to P. indicus juveniles of size 25-32 mm and 110-150 mg, they exhibited best preference for detritus from Rhizophora apiculata, followed by Chromolaena odorata, Pistia stratiotes and paddy detritus.

Two better preferred plant detritus sources viz. R. apiculata and C. odorata, were subjected to bulk digestion and the improvement in protein level by way of microbial growth during the process of decay was recorded. Since C. odorata showed a better protein level (Max. av. 25.716%) on the fifteenth day than R. apiculata (Max. av. 7.528%) on the twentieth day, C. odorata detritus was used for the next two feeding experiments: the first to find whether it could be used as exclusive protein source and the second to find the level at which this could be used to replace animal protein source in a standard diet for P. indicus.

The first feeding experiment, for a period of 28 days, to evaluate the feasibility of using plant detritus as sole protein source revealed that an exclusively detritus based diet is not

suitable for P. indicus juveniles. The detritus based diet produced lower survival, growth, protein efficiency ratio, protein digestibility and high food conversion ratio when compared to that of control diet prepared with clam meal.

The second experiment done with eight diets for a period of 21 days revealed that plant detritus could be used for substituting upto a level of 50% of the animal protein source in a standard prawn diet, without producing any adverse effect on growth and survival. While, a diet containing 10% plant detritus fared even better than a diet which was totally devoid of detrital protein.

The growth, food conversion ratio, protein efficiency, apparent digestibility and protein digestibility values obtained for various diets did not vary significantly upto a stage where 50% of the animal protein was substituted with detrital protein, beyond which the values declined. The best values were obtained for the diet FD2 and the lowest for the diet FD8.