DISCUSSION

Freshwater prawns are well distributed throughout the tropical and sub-tropical zones. But only some species are of commercial value. The potential species for culture practice in India are *M. rosenbergii*, *M. malcolmsonii*, *M. lamarrei* and *M. biramanicum*. But intensive and extensive culture practices are followed only for giant freshwater prawn *M. rosenbergii*. The second largest prawn is *M. malcolmsonii*. It is distributed almost in all the rivers that drain into the Bay of Bengal and the Arabian Sea (Kanaujia and Mohanty, 1996).
Many researchers have already worked on the distribution, biology, fisheries and culture history of \textit{M. rosenbergii} but only very limited research has been carried out on \textit{M. malcolmsonii}. Prakash (1989) observed a small percentage of \textit{M. malcolmsonii} in the Ganga river at Lalgola and its abundant distribution was observed in the rivers draining in the East Coast and specially in the Mahanadi, the Godavari, the Krishna, the Cauvery and to some extent in the Hooghly (Kurian, 1976; Ahmed and Jamil, 1984; and, Prakash, 1989).

The Fishery and biology of \textit{M. malcolmsonii} from the river Godavari was investigated by Ibrahim (1962). Its distribution in the Hooghly and the Godavari rivers was investigated by Rajyalakshmi (1975) and George and Suseela (1982) and its availability in various parts of India was investigated by Tripati (1992).

The present study was carried out to collect data about the availability of \textit{M. malcolmsonii} in Jederpalayam and to assess the feasibility of culturing the same in and around Jederpalayam. Most of the ponds present in and around Jederpalayam are being rainfed and because of this, generally, the small ponds are not used for aquaculture. To counter this, the introduction of fast growing freshwater prawn \textit{M. malcolmsonii} could be thought of for production from all types of water areas i.e. seasonal or perennial and small or big.

In the present study the number of juveniles collected from the check dam across the river Cauvery at Jederpalayam, Namakkal is given
in Table 1. These juveniles were used for culture by various fish farmers. The highest collection of juveniles was reported in 1988 (77398 juveniles/y). It decreased by 43.59 percent in 1989 and the decrease could be due to over-fishing and also due to the catching of the berried females. In 1990 the number of juveniles collected showed a 30.25 percentage increase and it decreased by 54.72 percent in 1991. In 1992 it increased by 25.00 percent and in 1993 and 1994 also the number slightly increased. However during 1995 to 1998, it has again decreased. There was no collection during 1995 to 1998. Unless measures are taken to stop the capture of the berried females it will be highly difficult to get the juveniles from the natural sources. Though factors like availability of food, climatic change, disease etc. play a role in their occurrence, regular over-exploitation seems to be the main factor responsible for the decrease.

The details of the collection of juveniles of M. malcolmonil in Jederpalayam during the different months in the year 1979 - 1998 are given in Table 2. The maximum collection of juveniles was observed during November-December months. Ibrahim (1962) observed a peak collection of juveniles during December to January in the Dowleieshwaram Anicu, across the river Godavary. George and Suseela (1982) observed the peak periods during August-November in the Godavari estuary. In the Hooghly-malta estuary it was during July-October (George and Suseela, 1982). Rao (1982) observed that the M. malcolmonii had a peak occurrence during December to March and also in July to September in Lake Kolleru in Andhra Pradesh.
John et al. (1998) observed the same condition, i.e. December to January in Upper Anicut, Grand Anicut and Lower Anicut of the Cauvery river in Tamil Nadu. Raman (1967) revealed that the peak season for the collection of 21 to 32 mm size juveniles was October to December in the river Cauvery. From the data collected it is clear that November to January is the peak period for collecting the juveniles at Jederpalayam. Unless measures are taken to stop over-fishing of the berried females, the availability of the juveniles from the natural resources will dwindle. Since May to June is the period during which the berried females are available in plenty, fishing should be stopped during this season to protect the natural stock.

The fishery of *M. malcolmsonii* in the Cauvery river system is not scientifically managed. There is no organised fishery for this species in the entire stretch of the river system. Only the fishermen who are mainly engaged in finfishing catch the prawns and bring it to the market. The fishery could be generated using the juveniles which are now caught prematurely in the river Cauvery. More awareness is to be created among the fishermen about the importance and potential of this fishery in the Cauvery river system.

Observation made in the present study showed the breeding season of *M. malcolmsonii* to be from May to October with a peak in August to September in the Cauvery river at Jederpalayam. Similarly John et al. (1998) observed berried females of *M. malcolmsonii oX* the Lower Anicut in the Cauvery river in the later fortnight of May. From June to September, 63 percent of females observed at all collection
centers were breeders. The occurrence of breeders in the commercial catch is high during October also.

Some experimental trial cultures were earned out and the aquaculturists achieved impressive results by the introduction of *M. malcolmsonii* in their aquaculture system around Jederpalayam. This has created widespread awareness about the economic potentialities of its culture and the collection of its juveniles from the rivers among the fishermen and other farmers.

One of the most important factors limiting the economic success in any commercial culture of a species is its food requirement. The determination of the nutritional requirement for the growth of any cultured organism will greatly reduce and streamline the expenditure of fish farmers in terms of the amount and type of feed given and also the period and utilization of manpower. But research work related to the nutritional requirement is very scarce.

Protein is an essential but expensive component of any formulated feed. But it is a very important component for growth and maintenance and it may also be catalyzed as a source of energy by crustaceans. The nature and quality of the dietary protein, the level of protein intake and the ability of the organism to utilize other dietary components as sources of energy affect the utilization of protein.

Optimum requirement of dietary protein level of prawn differs from species to species. Optimum dietary protein requirement in the feed for culturing freshwater prawns has been proposed using diets of
varying protein sources by various workers, but most of the work carried out are on *M. rosenbergii* which showed high rate of growth and survival in the protein level ranging from 14 to 45 percent (Bartlett and Enkerline 1983, Balazs *et al.*, 1974; Fujimura and Okomota, 1972; New, 1980; Clifford and Brick, 1979; D'Abramo and Reed, 1988; Law *et al.*, 1990; Koshio *et al.*, 1992; Balazs and Ross, 1976; Mukhopadhayay and Das, 1994; and, Nair and Sherief, 1993).

In the case of *M. malcolmsonii*, Das *et al.* (1995) observed good growth rate when they were fed on feed containing 35 percent protein level. Better growth was observed in *M. lamarrei* when they were fed on diet containing 33.09 and 33.48 percent protein levels than when they were fed on diets containing 16.17 and 17.35 percent protein levels (Chakarborty and Qureshi, 1994).

In the present study, to estimate the level of protein requirement for juveniles of *M. malcolmsonii* ten experimental feeds were compounded with protein level ranging from 18 to 36 percent at 2 percent interval and tested for physico chemical analyses. Observation showed that the pellet stability decreased with increase of protein level in the feed because of the presence of more percentage of raw materials like fishmeal and prawnmeal in the high protein feed. These raw ingredients disintegrate faster because of their poor binding capacity than the vegetable ingredients like wheat flour, sesame oil cake, groundnut oil cake and tapioca (Ali, 1987). But the level of incorporation of vegetable ingredients gets decreased in the high level protein feeds.
Observation showed that the weight gain increased with an increase of protein level up to 30 percent and beyond that it decreased. The highest growth was achieved at 30 percent protein level followed by 32 percent. The study proves that 30 to 32 percent is the optimum protein level for culturing juveniles of *M. malcolmsonii*. It was supported by the observation made by D'Abramo and Reed (1988), Ang (1987), Ellis *et al.* (1987), Tripati (1991), Tidwell *et al.* (1993), Corbm *et al.* (1983) and Das *et al.* (1995), in *M. rosenbergii*. A protein range of 25 to 35 percent was found suitable for culturing this species.

In the present study protein levels lower than 30 percent decreased the growth in *M. malcolmsonii* and similar observations were made by certain other workers. Gomaz *et al.* (1988), Bartlett and Enkerlin (1983) and Balazs *et al.* (1974) observed the same result in freshwater prawns *M. rosenbergii*. Protein levels higher than 32 percent did not further increase the growth and that could be due to the stress caused on digestion, absorption and excretion of the excess of nitrogenous materials. Continued feeding on such high protein feed will lead to more stress on the organisms, thus affecting their growth and efficiency. Significant difference was not observed in the weight gain in *M. malcolmsonii* fed on feed containing a protein level between 30 and 32 percent protein. Hence increasing the level of protein beyond 30 to 32 percent will only result in unnecessary increase of feed cost which will lead to loss of income. Hence 30 percent protein level is selected as the optimum protein level for preparing feed for juveniles of *M. malcolmsonii*. 
The rate of consumption depends upon the availability of feed, feeding time, appearance, flavour, taste and texture of the feed. Flavour and taste depend upon the chemical composition of the components used in the preparation of the compounded feed, their combination and the processing techniques involved.

The rate of consumption decreased with the increase of protein level in the diet. It is to be noted that the feed with increased level of protein had increased level of energy. The protein energy ratio varied from 52.75 in Feed 1 to 100 in Feed 10. Protein energy ratio also plays a major role because the crustaceans like prawns consume feed primarily to satisfy energy requirement and hence the amount of dietary protein must be balanced with proper amount of dietary energy in order to achieve optimum protein intake and feed conversion. Required levels of dietary protein also may be influenced by the amount of dietary energy present and also the form in which it is supplied like lipids or starches.

Present observation showed a gradual increase in the rate of consumption with a decrease of protein energy level in the feed and it indicated that the organisms consumed more feed in order to get the required quantity of protein energy.

Though a high level of protein was provided in feeds 8, 9 and 10 (feed with 32, 34 and 36 percent protein) the organisms did not show higher level of growth with these high protein feeds. It indicated that there is a limit beyond which the organisms did not use the protein for the purpose of growth because it reduces the amount of energy available through non-protein sources. The insufficient nonprotein components in
the feed can lead to metabolism of dietary protein for the energy (Capuzzo and Lancaster, 1979 and Capuzzo, 1979). Hence a protein level beyond 30 percent in the feed for *M. malcolmsonii* is uneconomical. Such increase will only result in stress or it may be used for metabolism.

The best rate of consumption, production and protein efficiency ratio was observed when the prawns were fed with feed with protein and carbohydrate in the ratio of 1:1. It is known that any quantity of protein above optimum will go for yielding energy. Therefore it is necessary to limit the protein to the optimum (30 percent) and incorporate starch to meet the energy demand. Similarly Gomez *et al.* (1988) observed the highest survival and growth in the group of organisms fed with the feed containing protein and starch in the ratio (P/S) of 1:1 in *M. wstenbergii*. In the juveniles of *Penaeus monodon*, protein utilization was improved by increment of the available energy in the diet (Clifford and Brick, 1979). Feed efficiency was improved by dietary carbohydrate supplementation in *Penaeus indicus* (Bautista, 1984). As dietary energy increased, growth and feed efficiency became better and the maximal value of growth was obtained in feed with 3.81 kcal/g. Gomez *et al.* (1988) also observed the best PER among prawns (*M. wstenbergii*) fed on feed with 3.84 kcal/g.

In the present study the FCR decreased with an increase of protein and energy level in the feed. It was 5.61 to 3.42 in feeds 1 to 10. Boonyaratpalin and New (1980) and Balazs and Ross (1976) observed similar trend in *M. rosenbergii* when they were fed on feeds containing 15, 25 and 35 percent protein. In this study a lower FCR was observed
among the organisms fed on feed containing 30 percent protein. Beyond 30 percent protein level the FCR decreased, but such feeds are not economical and the decrease of the FCR was not very significant. Similarly Unnikrishnan et al. ("1992) also observed a low FCR when M. rosenbergii was fed on feed containing 33 percent when spirulina was used as a protein source. Behanan et al. (1992) observed an FCR of 4.18 and 5.79 among M. rosenbergii fed on diet containing 33 and 44 percent protein respectively. James et al. ("1992) achieved an FCR of 6.82 in M. rosenbergii when they were fed on feed containing 41 percent protein and it may be because of the less availability of energy sources and the dietary protein might have been diverted to metabolic pathway for energy production. Such activity would create stress for the animal.

In the present study gross growth efficiency and protein efficiency ratio showed an increase with an increase of protein in the feed from 18 percent up to an optimum level of 30 percent in the feed. The highest protein efficiency ratio was observed in 30 percent protein feed. Boonyaratpalin and New (1980) observed a protein efficiency ratio of 1.13 among M. rosenbergii fed on 35 percent protein feed.

The protein efficiency ratio decreased beyond the 30 percent protein level. Similarly Koshio et al. (1992) achieved a PER of 1.57 at 27 percent protein level, 1.6 at 30 percent protein level and 1.51 at 36 percent protein level for M. rosenbergii, Unnikrishnan et al (1992) achieved a PER of 0.62 and 0.67 with two different diets both containing 40 percent protein level and James et al. (1992) observed a PER of 0.42 at 40 percent protein level.
In the present study, low protein feeds as well as high protein feeds showed a low PER. The high PER was observed only when the animals were fed on feed with optimum protein level. This is similar to the observations made by Behanan et al. (1992) in *M. rosenbergii*.

Hence to maximise both growth and protein efficiency ratio in prawns, sufficient quantity of energy sources should be added in the feed in addition to the required proteins. Energy production from protein oxidation is both nutritionally and economically wasteful. The protein sparing action and utilization of other dietary constituents must be optimized to maximise the growth and protein efficiency ratio of the animals (Capuzzo and Lancaster, 1979 and Clifford and Brick, 1979). In the present study the relation between protein energy ratio and protein efficiency ratio showed that the PER increased with an increase of P/E ratio up to the optimum protein level, beyond which the PER decreased. When the ratio of total energy to protein is too high it may result in the restriction of the consumption of protein and growth retardation. On the other hand, a feed too low in total energy may require protein to be diverted along catabolic pathways to compensate the deficiency resulting again in poor growth and low protein efficiency ratio. Hence at the optimum protein and protein energy ratio, the protein efficiency ratio would be high (Sedgewick, 1979).

In the present study the highest growth was achieved in the diet containing 30 percent protein and a protein energy ratio of 84.12 and an energy value of 3.89 kcal/g. It was followed by the feed containing 32 percent protein which also had a protein energy ratio of 89.42 and an energy value of 3.92 Kcal/g. It reveals that the optimum protein and
protein energy value for the cultivation of *M. malcolmsonii* is 30 percent and 84.12 respectively.

Similar type of observations were made by Summerlin (1988) who evaluated the weight gain and survival response of juvenile freshwater prawns in different P/E ratios in feeds containing four levels of crude protein (25, 30, 35 and 40 percent). In his study the energy was expressed as total energy calculated from caloric equivalents of protein, carbohydrate and lipids and the energy levels were adjusted with lipids and carbohydrates. The highest weight gain was observed among the juvenile freshwater prawns fed on feeds containing 35 percent protein and protein energy of 130 to 158 mg protein/kcal.

Based on the experiments conducted at present, a 30 percent protein level is found to be suitable for culturing the juveniles of *M. malcolmsonii* and the same was followed as the optimum protein level for compounding feed for other experiments in this study.

The success of the formulation of prawn feed depends on its nutritional value, consistency, water stability, sinking rate and flavour attractants.'Proper balance among these factors leads to optimum acceptance and the best growth rates of culture organisms in the shortest period of time. The presentation of feed in its most suitable physical form is the key to the successful performance of the feed.

The physical shape of a feed should be in accordance with the feeding habits of the culture organisms and should not be an impediment to their feeding activity. In the case of prawns the larvae are filter
feeders and require particles with good suspension quality. Postlarvae, juveniles and adult, prawns can conveniently hold the feed with the help of pleopods and nibble. Feeds in pellet form with appropriate diameter only are suitable for cultured prawns.

The artificially compounded pellets must be uniform in size and shape. In the present study eleven pellets were prepared with different diameters to find out the optimum pellet size suitable for culturing prawns of various sizes. The benthic nature of prawns imposes the additional requirement of rapid sinking of the pellets in addition to good water stability to enable maximum utilization of the feed pellet. Also it should be possible to follow inexpensive storage methods and easy means of dispensing.

Since 1970, several kinds of aquaculture feeds are manufactured. Flaked feed was developed by Meyers and Brand (1975) and it was optimized by Boonyaratpalin and Lovell (1977) and Hastings (1982). Microencapsulated feed (Jones and Gabbot, 1976) and pelleted/extruded feed (AH, 1987; Raj, 1989; Daniel and Chandrasekaran, 1993; and, Daniel et al, 1997) are some of the other kinds of feeds used for aquaculture. Each type of feed has certain advantages as well as disadvantages that restrict its application.

Flaked feeds easily degenerate because of their large contact area with water. The microencapsulated feeds, which have slow leaching of nutrients and low disintegration rates influence the rate of digestion and hence they are not economical. Hence pelleting is the most popular form
of producing crustacean feed due to its technological and economic advantages.

Different kinds of pelleted feeds have been developed and they are dry, wet, expanded and hard pellets. The moist pellets need cold storage facilities which are very expensive and cumbersome. Hence preparation of dry pelleted feed appears to be more practical for prawn culture.

The knowledge of the preparation of the diet in the dry pellet form is sure to help in our efforts in developing prawn culture. The factors which influence the physical characteristics of pelleted feed are the quality of raw materials and processing methods of the raw materials.

To obtain a homogeneous mixture of the feed, the raw materials should be powdered individually to a specific particle size. Grinding of ingredients generally improves the digestibility, because the surface exposed to enzyme activity will be increased. Fine powdered ingredients also help the pelletability of the feed. The feed mix should be thoroughly homogenized. This is important to avoid selective feeding of a particular ingredient in the feed and also to achieve good pellet stability. Hence, in the present study, the ingredients were finely powdered separately and then mixed as per the formula.

The physical instability of feed pellets and 'leaching out' of specific hydrosoluble nutrients are serious problems' in crustacean cultures since most of these species are continuous feeders and grasp
feed pellets with pincer-like appendages and masticate externally (Forster, 1971; Zein-Eldin and Meyers, 1973; Provasoli, 1976; and, Farmanfarmainan and Lauterio, 1982).

An efficient binder, if it is highly expensive would make the final cost of the feed uneconomical. So it is essential to consider these facts while selecting a binding agent. Meyer et al. (1972) discussed the range of substances available for binding aquatic feeds and Forster (1972 a and b) examined the effect of different binders on the assimilation efficiency of the feeds for prawns. The water stability of prawn feeds had been studied by Meyers and Zein-Eldin (1972), Goswamy and Goswamy (1979), Farmanfarmaian and Lauterio (1982), Ali (1988), Forster and Gabbot (1971) and New (1976) in relation to different binders.

In the present study, tapioca is used as a binder. The stability of feed in water shows that tapioca powder is a suitable binder for prawn feed. In addition to providing stability it also forms a good source of energy. When compared to other chemical binders, it will help in bringing down the final cost of the feed. Hence tapioca is a potential binder cum energy supplier for prawn feed. Starch was found to be a good source of binder for penaeid prawns (Abdel-Rehman et al., 1979). At 40 percent level it produced faster growth rate (Ali, 1982) in Penaeus indicus.

The water stability of an aquatic feed plays an important role in determining the overall performance of the feed. In the present study the observations made on the relation between the pellet size and pellet stability of eleven types of feed pellets with different diameters (viz
0.25, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5 and 5.0 mm) show that the stability of the pellet increased with an increase of pellet size. The stability of pellet influences the rate of consumption, for the feed pellets which get disintegrated faster facilitate rapid leaching of nutrients, especially the micronutrients, leading to non-availability of such nutrients if they are not consumed immediately after dispersion to the animal. Rough ingredients like prawnmeal and fishmeal disintegrate faster because of their poor binding capacity than the smooth ingredients like wheat flour, sesame oil cake, groundnut oil cake, tapioca etc.

Observation made in the present study reveals that the rate of consumption is maximum only at a particular level of stability of the pellet for prawns of each size. When the ingredients are loosely blended, the pellet will disintegrate faster and that will lead to water pollution and ultimately to economic loss. If the pellet is too hard it is difficult for the animals to ingest and hence a balance between the two should be struck.

The observation made in the present study shows that the rate of sinking increases with the increase of the diameter of the pellet. The sinking rate of the pellets play a major role in the consumption rate in the experimental animals. The rate of consumption increased along with an increase of sinking rate but beyond the optimum point it did not increase. The sinking rate of pellets is directly related to the hardness of the pellet. Hence the optimum level of sinking rate was directly proper**! to the size of the prawn and it revealed that large, *, pmwns can handle the hard pellets without any difficulty compared to the smaller ones.
Experiments were carried out to find out the relationship between the pellet size and prawn size using eleven types of feed viz feeds with different diameter like 0.25, 0.50, 1.00, 1.50, 2.00, 2.50, 3.00, 3.50, 4.00, 4.50 and 5.00 mm on *M*. *malcolmsonii* of four different sizes (1.2 ± 0.2, 3.2 ± 0.2, 5.1 ± 0.1 and 7.1 ± 0.3 cm), because the size of the feed pellets has direct influence over the rate of consumption and in turn the rate of growth of aquatic organisms. Optimum pellet size is a prerequisite for the best growth rate of prawns and hence the size of the pellet should be suitable for the mouth size and the size of the appendages which help in holding and manoeuvring the feed pellet.

Observations made in the present study show that 1.2 ± 0.2 cm size prawns consumed more when they were fed on feed pellets with 1.00 ± 0.02 to 1.50 ± 0.04 cm diameter. Prawns of 3.2 ± 0.2 cm size showed maximum feed consumption when they were fed on the feed pellets with 2.00 ± 0.05 to 2.50 ± 0.07 cm diameter. The prawns of 5.1 ± 0.1 cm size showed the highest feed consumption when they were fed on pellets of 3.00 ± 0.01 to 3.50 ± 0.03 cm diameter and the prawns of 7.1 ± 0.3 cm size consumed more feed when the organisms were fed on feed pellets of 4.00 ± 0.02 to 4.50 ± 0.04 cm diameter.

The rate of consumption and the rate of production were found to be closely related to the size of the pellet. Observation showed that the large size prawns handle large sized pellets more rapidly and efficiently than the small sized pellets. The smaller prawns either rejected large sized pellets or spent more time in breaking the pellets and that reduced the rate of consumption and that in turn affected the rate of production. Although the larger prawns consumed smaller pellets, they required
more time to fill their stomach and ultimately spent more energy to capture equivalent amount of smaller pellets which also in turn reduced the rate of consumption and production. In the present study the maximum growth rate was observed only when they were fed on pellets of the optimum size. The pellets which are either larger or smaller than the optimum size resulted in reduced growth rates because most of the food energy was spent on capturing or manipulating the feed pellets. Wankowski and Thorpe (1979), Knights (1983), Tabachek (1988) and Godlen et al. (1997) made similar observations in fish. The optimal pellet size is not only related to the size of the prawn but also to the length of prawn appendages and size of the mouth (Fowler and Burrow, 1971; Wankowski and Thorpe, 1979; and, Tabachek, 1988). Ali (1987) states that pellets with 1, 3 and 5 mm diameter size are suitable for postlarvae, juveniles and adult prawns respectively.

The net energy available for growth as a consequence of feeding on pellets depends on the size of the pellet. Hence it is reasonable to assume that energy expenditure is closely associated with the size of the pellet and the size of the animal that feeds on the pellet. The net energy gain decreases with decrease of the size of the pellets and increases with increase of the size of the pellets from the optimum. When supplied with large size pellets, the success of capture and ingestion becomes critical for smaller organisms.

Macarthur (1972) and Wankowski (1979) made similar observations in fish. The pellets should have sufficient energy to be expended in capture, ingestion and digestion of the feed particles, viz. sufficient enough to meet the metabolic requirements of prawns for at
this level only the maintenance requirements of the prawns are being met and below the optimum size would fail to satisfy their requirement.

The optimum pellet size increased directly in proportion to the size of the prawns, size of the mouth and also the size of the appendages which were larger in the large sized prawns and smaller in the small sized prawns. The large sized prawns handled large sized pellets more easily than their corresponding small sized prawns.

The effect of pellet size on the weight gain of prawns depends on the pellet size, which is chosen by the culture organisms. Usually the pellet size that resulted in the maximum increase in weight and length gain was the optimum for the mouth size of the prawns. The maximum growth observed in fish was generally with pellets of 25 percent of their mouth size (Wankowski and Thorpe, 1979). Pellets of 40 - 60 percent of the mouth size (Knights, 1983) and pellets of 11 to 38 percent of the mouth size (Tabachek, 1988) were also found to be optimum for different fish species. Increase in the feeding opportunity and likelihood of successful ingestion is observed when they are fed on pellets of the optimum size.

In the present study the maximum production was observed only when the prawns were fed on pellets of the optimum size and feeding on pellets of larger or smaller size than the optimum resulted in a reduced rate of consumption and growth.

Feed is one of the most costly items associated with the culture of freshwater prawns where supplementary feeding is usually offered to
Incorporate the production. While under-feeding limits growth, excess feeding not only pollutes the environment but also increases the cost of production. Hence it is important to find out the optimum feeding frequency to be followed in order to bring out the best growth without wasting the feed.

Freshwater prawns are known to have a relatively short digestive tract and also to be engaged in frequent feeding activity and, due to this, the rate of passage of feed through the gut is rapid. Since only limited amount of time is available for the nutrients to get absorbed in the body (Hanson and Goodwin, 1977), increasing the feeding frequency from one time to two or more times per day may help to increase the total consumption. Also this practice will reduce the leaching of nutrients from the feed. The prawns also show variation in feed consumption during the various hours of the day. Some species consume more feed during dawn and dusk and some species consume more feed during the night hours while others consume more during the day hours.

According to Forster (1972) prolonged immersion of feed in water can lead to loss of 20 to 30 percent of dry matter content including the loss of water soluble nutrients. In addition to that the feed which has been depleted of nutrients may not attract the organisms and may ultimately get ignored (Provasoli, 1975). This type of problems may be resolved by the presentation of the diet to the prawns in a way which ensures rapid consumption during suitable feeding hours. This concept requires administration at a rate compatible with the natural behaviour of the species.
In intensive culture, where artificial feeds often of high quality are presented in large amount at infrequent intervals, the prawns find it difficult to cope with the system of feeding. They are metabolically incapable of consuming daily requirements within a short spell of time. These difficulties may be overcome by the simple expedient of more frequent feeding. However the frequency of feeding to be administered and quality of feed to be administered at various hours of the day need to be standardised before starting the commercial culture.

Frequent feeding has been reported to improve the growth among fishes (Kono and Nose, 1971; Andrews and Page, 1975; Grayton and Beamish, 1977; and, Chua and Teng, 1978), among shrimps (Sampath and Srither, 1987; and, Kutty and Jose, 1996) and among prawns (Marian et al, 1989; Koshio et al, 1992; Ang, 1987; and, Heinen and Mensi, 1991).

In the present study, to find out the effect of feeding frequency on the feed intake and production, four feeds were used. The weight gained showed an increase as the feeding frequency was raised. However increase in weight was not observed beyond a certain feeding frequency. The maximum weight gain was observed among prawns of 1.1 ± 0.2 cm size when they were fed four times a day. However prawns of 3.2 ± 0.2, 5.1 ± 0.1 and 7.1 ± 0.2 cm sizes showed a maximum weight gain when they were fed three times a day. This type of variation may be due to variation in age and in the size of the stomach. Kono and Nose (1971) conducted studies in fishes and reflected the same type of response. They have established a relationship no
between the size of the stomach and the optimum feeding frequency for a number of species.

Sedgewick (1979) found that when *Penaeus merguiensis* were fed four times a day, the weight increased more rapidly and the organisms utilized their feed more efficiently than when they were fed once a day. Kutty and Jose (1996) observed the highest weight gain, feed consumption and survival in *Penaeus monodon* when they were fed thrice a day. Marian *et al.* (1989) observed three times a day as the optimum feeding frequency for the destalked organisms of *M.lamairei* to obtain maximum growth rate while it was six times a day for the control prawns i.e., intact specimens. Koshio *et al.* (1992) obtained the highest mean value of growth rate from unilateral eye stalk ablated prawns (*M rosenbergii*) as well as in the control prawns when they were fed twice a day.

In the present study the rate of consumption and the rate of production showed an increase as the feeding frequency was raised from once a day to four times a day in 1.1 ± 0.2 cm size prawns and three times a day among prawns of 3.2 ± 0.2, 5.1 ±0.1 and 7.1 ± 0.2 cm size. A further increase in feeding frequency did not influence these parameters. Sampath and Srither (1987) observed maximum food consumption, absorption and production in *P.monodon* when the feeding frequency was increased from once in five days to once a day, twice a day and thrice a day and further increase in the frequency of feeding did not affect those parameters. They observed a rate of consumption of 3.5 mg/g/d at a feeding frequency of once in five days, 8.91 mg/g/d at thrice a day and 15.10 mg/g/d at four times a day. The
rate of production observed by them was 1.75, 4.38, 6.27, 7.05 and 6.35 mg/g/d at 1/5, 1/1, 2/1, 3/1 and 4/1 frequency of feeding respectively. Sheleser (1974) found reduced growth when the feeding rate was less than once daily. Sick et al. (1913) however, found that the rate of feed ingestion in *P.setiforus* when given an artificial diet was inversely related to the period of exposure to the feed. A decline in feed efficiency may be incurred through the potential deterioration in nutritive quality if feed is left exposed in water for a long period before ingestion. Artificial dried feeds are particularly at risk because of the possible leaching of soluble components.

In the present study the total feed intake increased with an increase of feeding frequency. However total feed intake increased only up to an increase of three meals a day and thereafter the total feed intake did not change much. In the case of prawns which were fed twice a day, the total feed intake was higher when compared to the prawns fed on a feeding frequency of once a day. The highest total feed intake was observed when the organisms were fed three times a day. But further increase in feeding frequency (4/1, 5/1 and 6/1) did not influence the total feed consumption. It revealed that the feed consumed during the previous meal was not digested completely and the ingestion of materials hampers the development of appetite which leads to low efficiency of consumption and production.

Observation made on the feeding activity of the prawns in the present study showed that *M.malcohmonii* consumes more feed during early morning, evening and night hours than during late morning and afternoon hours. Hence the evening and night feeding schedules are
better suited for *M. malcolsonii* during their rearing period. Premvera *et al.* (1979) also observed intensive feeding among fish during dusk hours (18.00 hrs) when compared to the morning and afternoon hours. According to Pascual (1989) and Kutty and Jose (1996) the best feeding time for *P. monodon* is late afternoon and evening hours because the organisms are more active during these hours.

In the present study it was also observed that the meal size increased with a decrease of feeding frequency. The maximum amount of feed per meal was consumed by the prawns fed at the lowest feeding frequency viz once a day. According to Sampath and Srither (1987) *P. monodon* increased the meal size, elevated the efficiency of absorption and production and reduced the metabolic loss when the frequency of feeding was decreased. This finding lends support to previous findings on fish by Tylar and Dun (1976). Marian *et al.* (1989) have reported that at low feeding schedules the test fish increases the meal size as compensation.

The feed conversion ratio observed in the present study among the organisms of four different size fed on six different feeding regimes is shown in fig 26. The feed conversion ratio decreased with the increase of the feeding frequency upto 4/1 in 1.1 ± 0.2 cm size prawns and 3/1 in 3.2 ± 0.2, 5.1 ± 0.1 and 7.1 ± 0.2 cm size prawns and further increase of feeding frequency did not affect this parameter. The lower FCR was observed in the organisms fed on four times a day in 1.1 ± 0.2 cm size prawns and three times a day in 3.2 ± 0.2, 5.1 ± 0.1 and 7.1 ± 0.2 cm size prawns and further increase of feeding frequency did not affect the FCR. Since maximum consumption and production were
achieved at the optimum feeding frequency, further increase would only result in wastage. Koshio et al. (1992) observed greater FCE and lowest FCR with the unilateral eye ablated prawns than among intact prawns among the six feeding frequencies tested. But within the same treatment, the highest FCE (lowest FCR) was observed when *M. rosenbergii* were fed two times a day. In the present study the lowest FCR was observed in 4/1 for 1.1 ± 0.2 cm size prawns and 3/1 for 3.2 ± 0.2, 5.1 ± 0.1 and 7.1 ± 0.2 cm size prawns and further increase of frequency did not influence the FCR very much.

The gross growth efficiency was directly related to the quality of feed, feed intake and growth. The gross growth efficiency increased as the frequency of feeding increased up to 4/1 among 1.1 ± 0.2 cm size prawns and 3/1 among 3.2 ± 0.2, 5.1 ± 0.1 and 7.1 ± 0.2 cm size prawns and further increase of frequency did not show much increase in their gross growth efficiency, because, beyond the optimum feeding frequency the rate of consumption and production did not improve. Among *P. monodon* low feeding regimes helped in better feed conversion than frequent feeding regimes because they adopt themselves to increase the meal size when fed on low feeding regime. But such type of adaptation to the level to bring out better feed conversion was not observed among *M. malcolmsonii* in the various sizes tested.

Protein efficiency ratio is one of the most important factors in the formulation of feed because it is directly related to the level of protein arid feed intake. The PER increased as the feeding frequency was raised Upto 4/1 for 1.1 ± 0.2 cm size prawns and 3/1 for 3.2 ± 0.2, 5.1 ± 0.1 and 7.1 ± 0.2 cm size prawns.
From the observations made in the present study it is clear that four times a day feeding frequency is the optimum for prawns of 1.1 ± 0.2 cm size and three time a day frequency is optimum for prawns of 3.2 ± 0.2, 5.1 ± 0.1 and 7.1 ± 0.2 cm size, for the cultivation of *M. malcolmsonii*.

Increased demand for freshwater prawns (*Macrobrachium*) as food has increased the development of prawn culture. But viable monoculture techniques mainly depend on the application of high quality feeds which are nutritional and economical. Semi-intensive and intensive prawn farming depends on supplementary feed. The supplementary feeds may consist of animal and vegetable protein sources and the suitability of the ingredients is an important factor to be considered for the formulation of feed for prawns. Nutritional deficiency tends to result in moult failure and reduced growth.

In order to know about the ingredient acceptance of freshwater prawn *M. malcolmsonii*, several raw materials were used for compounding feed for this species in order to give suitable recommendation for feed formulation. Such raw materials should be available in sufficient quantity, have stable price, be available round the year, and be adequately nutritional and cost effective. Much effort has been directed towards substitution of fishmeal with soybean meal or a combination of feedstuffs in freshwater prawn feeds.

Several animal protein sources like prawnmeal and mussel meat (Mukhopdhdyay and Das, 1994), beef liver (Graces and Ifcincn. 1W>., silkworm pupae (Das et al., 1995), blood meal (Chakraborn and
Qureshi, 1994), crab protein concentrates (Koshio et al, 1992 and Balazs et al, 1976), clam meal (Nair and Sherief, 1993), insect meal, prawn flesh, tadpoles and mollusks meat (Ovie, 1991), carp meal (Jeyalakshmi et al, 1997) and shrimp meal and tuna (Balazs and Ross, 1976 and Koshio et al, 1992) were used by various authors. In addition to that, vegetable protein sources such as corn silage (Moore and Stanley, 1982), fresh leaves (Harpaz and Schmalbach, 1984 and Aquacop, 1976), moist pressed brewers grains (Kohler and Kreuger, 1985), leaf protein concentrates (Jeyalakshmi and Irwin, 1996 and Jeyalakshmi et al, 1997), spirulina (Jeyalakshmi et al, 1995 a and b), orange flesh, peeled sweet potato, peeled bananas, turnip greens, carrot top, different varieties of fruits and vegetables (Graces and Heinen, 1993) and groundnut oil cake and mustard oil cake (Chakraborty and Qureshi, 1994) have also been tried in the feed for Macrobrachium species.

Nutritional requirement of prawns has been reviewed by New (1976, 1980 and 1987), Biddle (1977) and Sick and Millikan (1983). Prawn feeds are comparatively cheaper than shrimp feeds because the former requires less dietary protein (New, 1990).

In the present study ten different feeds were formulated in order to find out the acceptance of certain ingredients like prawnmeal, fishmeal, pila meal, carp meal, groundnut oil cake, sesame oil cake, ricebran, tapioca, bajra, ragi, greengram, soybean meal and spirulina meal in various composition as shown in Table 11 and tested on M.malcolmsonii (feeds 26 to 35). Fishmeal and prawnmeal are high quality animal protein sources which are rich in essential aminoacids and
minerals and *Pila globosa* is a locally available inexpensive animal protein source. Bajra and ragi are the locally available small millets rich in minerals; greengram (*Phaseolus aureus*) is a locally available economic legume rich in protein and soybean meal is a high quality vegetable protein source. Spirulina has the highest plant protein content as compared to other algal forms and it contains B-carotene, B-complex, vitamins and minerals. Groundnut oil cake and sesame oil cake are commonly used vegetable protein sources. Ricebran is used for its carbohydrate and fibre content. All these ingredients were mixed in various percentages to get isoproteinaceous feeds and they were tested for their acceptance by *M. malcolmsonii*.

The feed conversion ratio among the test animals ranged from 3.02 to 3.87 and the percentage of growth varied from 42.20 to 83.07 in feeds 26 to 35 (Table 13). The best growth was observed in feed 26 which contained 27 percent of prawnmeal in addition to groundnut oil cake, sesame oil cake, ricebran and tapioca. This observation indicates that prawnmeal is a very good growth promoter for *M. malcolmsonii*. A percentage growth of 79.49 was observed in feed 31 which contained 10 percent fishmeal, 10 percent prawnmeal and 15 percent soybean meal in addition to groundnut oil cake, sesame oil cake, ricebran and tapioca. Soybean meal also appears to be a suitable protein source for the cultivation of *M. malcolmsonii*. The difference in the percent of growth between feed 27 and feed 31 is narrow, but feed 31 contained much lesser quantity of prawnmeal than feed 27 and hence the cost of feed 31 would be lesser than feed 27.
The highest percentage of growth was observed in feed 27 incorporated with prawnmeal as the only animal protein source at 25 percent level. It may be because that the prawnmeal fulfills the essential aminoacid requirement of *M. malcolmsonii*. Das *et al.* ("1995) also observed maximum growth in *M. malcolmsonii* when they were fed with prawnmeal incorporated diets. Deshimaru and Shigueno (1972) observed best growth performance in penaeid prawns that were fed on diet having aminoacid composition with close resemblance to that of its body tissue.

The next highest growth was observed in feed 32 which contained fishmeal, prawnmeal and soybean meal in equal proportion in addition to other ingredients. Here fishmeal and prawnmeal are partially replaced by soybean meal. It shows that soybean meal is a suitable vegetable protein source for the cultivation of freshwater prawns. Similarly Balazs *et al.* (1973) carried out a trial with *M. rosenbergii* where the organisms fed on diet based on soybean meal as an all vegetable protein source resulted in better growth than soybean - fishmeal diet but inferior to fish soybean - shrimp based diet. This observation indicates that soybean meal contains comparatively better essential aminoacid composition for *M. malcolmsonii*.

The percentage of growth in feeds 26, 29, 30 and 32 shows that all these four feeds are suitable for the cultivation of *M. malcolmsonii*. Feed 30 contained bajra and ragi as the main vegetable protein source. Bajra and ragi are rich in energy and micronutrients in addition to limited quantity of protein and the addition of these two small millets has enhanced the growth of the test animals.
The percentage of growth observed in feeds 26 and 32 were equal (76.41 percent). The animal protein level was high in feed 26 wherein prawnmeal and fishmeal were the protein sources; where as in feed 32, the animal protein level was 10 percent lesser than feed 26 and that 10 percent was compensated by the incorporation of spirulina algal meal in place of 5 percent fishmeal and 5 percent prawnmeal.

A few reports are available regarding the use of spirulina meal as a component of fish feed (Stanley and Jones, 1976; Daniel and Kalavalli, 1991 and 1992; and, Matty and Smith, 1979). Thomas and Raja (1980) opined that spirulina has promising future in rural pisciculture. Soong (1980) and Fox (1980) reported spirulina as an excellent feed for fry and juveniles of milk fish and tilapia respectively. Tsai (1981) reported a satisfactory weight gain in *Penaeus japonensis* when they were fed on feed containing *Spirulina pkitensis* and fishmeal as protein sources. Jeyalakshmi et al. (1995 a and b) found spirulina meal can replace the fishmeal fully or partially in the prawn feed. The observations made in the present study indicate that spirulina meal can partially take the place of prawnmeal and fishmeal in freshwater prawn feed.

Feed 29 contained greengram, a locally available legume as the main vegetable protein source and the rate of growth was also better in this feed. It shows that greengram is an alternate protein source for oil cakes in the feed of *M.malcolmsonii*, It is rich in some essential aminoacids and minerals and that could have enhanced the growth rate of *M.malcolmsonii*. 


The next level of growth performance was observed in feed 28 and 33. Feed 28 contained fishmeal as the exclusive source of animal protein while in feed 33 fishmeal was partially replaced by spirulina algal meal. Both these feeds did not contain prawnmeal and that could have been the reason for the reduced rate of growth.

The feeds which contained pila meal (feed 34 and 35) as animal protein source resulted in very poor growth when compared to other feeds. This shows that pila meal is not suitable for formulating feed for *M. malcolmsonii*. It could be because of lack of essential aminoacids in the pila meal or difficulties in the digestion and absorption of the protein of the same.

The highest rate of production and gross growth efficiency was observed in feed 27 and it was followed by feed 31, 29 and 32 and the lowest rates of production were observed in feed 34 and 35.

The overall observation showed that prawnmeal is an essential ingredient in the feed for *M. malcolmsonii*. Soybean and spirulina can replace the animal protein source to a certain extent and greengram can be used as a vegetable protein source.

In the present experiment greengram *Phaseolus aureus*, a locally available legume, is used as a vegetable protein source in place of oil cakes for the cultivation of *M. malcolmsonii*. It is a known fact that legumes possess a number of undesirable substances and antinutritional factors like oligosaccharides, enzyme inhibitors, flavanols, alkaloids, organic acids, glycosides, phenolic substances etc. Drying, soaking,
autoclaving, roasting, germination, fermentation etc. are some of the methods generally practiced to reduce these antinutritional factors.

Various scientists have used a number of locally available inexpensive non-conventional protein sources as feed ingredients in the feed for aquaculture. Some of the substances are corn silage (Moore and Stanley, 1982), fresh leaves (Harpaz and Schmalbach, 1984), moist pressed brewers grains (Kohler and Kreuger, 1985), orange flesh, peeled sweet potatoes, peeled bananas, turnip greens, carrot tops and different types of fruits and vegetable sink (Graces and Heinen, 1989), black gram, greengram and cow pea (Desilva et al., 1988), lupin seed meal (Higuera et al., 1988), Phaseolus aureus (Desilva and Gunasekara, 1989 and Jeyalakshmi and Daniel, 1997) and Clitoria leaf (Raj, 1989). Some of the ingredients have also been subjected to various treatments like drying, soaking, popping and thermal treatment in order to make the substance more acceptable (Luquet and Bergot, 1976; Boonyaratpalin and Lovell, 1977; Capper et al., 1982; Wee and Wang, 1987; Higuera et al., 1988; Palacios et al., 1988, and, Olverae? al., 1988).

Soaking provides more chance for the elimination of soluble antinutritional factors. Jood et al. (1988) have suggested 24 h soaking of the legumes for the reduction of flatus producing substances like raffinose, stachyose and verbascose. Soaking the seeds in water inactivates the lectins and digestive enzyme inhibitors in dry bean cultivars. Granted/. ( 1982) observed the efficiency of heat treatment (above 75 °C) after soaking the Phaseolus vulgaris.
Autoclaving is a process in which the legumes are subjected to wet heat treatment with plenty of water and then drained, washed and processed to eliminate the antinutritional and undesirable factors. In this processing technique minerals and some carbohydrates are washed away and that in turn brings about a loss of dry matter resulting in an increase of the percentage of other components like protein and fat. It efficiently eliminates most of the undesirable and antinutritional components but Ologhobo and Fetuga (1983) observed that a careful control of processing condition is essential to prevent the loss of functional aspect of the protein as well as nutritional damage to protein. But the existence of heat-resistant and growth inhibiting substance is possible as observed by Durigan et al. (1987) in dry bean cultivar. In Phaseolus vulgaris certain antinutritional factors are stable to dry heat but could be completely destroyed by autoclaving as observed by Tan et al. (1983).

Roasting is a process which retains the nutrients and inactivates growth inhibitors and also the contaminating microorganisms. It also changes the bioavailability of proteins, carbohydrates and vitamins. Ayatse et al. (1983) observed a loss of moisture, ash and fibre and a relative increase of ether extract (fat), protein, carbohydrate and calories after roasting. In addition to these changes, roasting also reduces the hardness and improves the flavour of the seed. Increase in protein digestibility was observed in bengal gram, maize and soybean after roasting by Srivastav et al. (1990) and that might have been due to the destruction of protease inhibitors; but there is a possibility of the existence of certain antinutritional factors which are resistant to dry
heating as reported by Tan et al. (1983) in winged bean *Psophocarpus tetragonolobus*.

Germination is considered to be a useful method to produce nutritious food (Rahman, 1983). In the process of soaking prior to germination, minerals and other soluble components are leached out and dry matter gets reduced. During the process of germination the unsaturated fatty acids and unsaponifiable matters are broken down by hydrolysis and that results in the increase of saturated fatty acids (El-Sebaiy and El-Mahdy, 1983). The stored compounds in the seed undergo oxidative breakdown because of increase of metabolic activities of the germinating seed. During such metabolic activity, undesirable compounds like raffinose and stachyose responsible for flatulence problem are hydrolysed, phytates are decomposed, trypsin inhibitor activities are reduced and amylase inhibitors are eliminated. The functional properties of the protein get improved resulting in increased protein solubility, digestibility, flavours and texture over the ungerminated seed.

Since it is an economical method to correct deficiencies and to produce a more nutritious food, people consume many legumes after germination. Germinated seeds show a reduction in carbohydrate and they apparently increase the protein, fat and ash values (Daniel, 1992). Loss of water soluble compounds and ultimate reduction in the dry matter and metabolic changes inside the seed are the reasons for such changes observed in the chemical constituents of the seeds. Rao and Belavady (1978) have observed a decrease in oligosaccharides in
Cajamis cajan, Cicer arietinum, Phaseolus aureus and Phaseolus mungo by germination.

As observed in the present study it is well known that the rate of consumption of feed by the cultured animals depends upon the availability of feed, appearance, flavour, taste and texture of the feed. Flavour and taste depend upon the chemical composition of the components used in the preparation of the compounded feed. The factors affecting the flavour and taste are the saponins, flavanols, alkaloids, organic acids, glycosides and phenolic substances which are common in legumes. Their level of availability differs in different seeds and so also in different parts of the seeds and it is influenced by processing techniques.

The present study shows a reduction in the rate of consumption of the feed incorporated with the raw whole seeds of greengram. It could be due to the presence of off-flavour and sharp taste substances, which are common in raw legumes. The rate of consumption significantly increased in the feed containing autoclaved greengram (feed 40) and that could be due to the reduction of the off-flavour and sharp taste substances and also the changes brought about in the texture of the seed matter and the improvement of the meal quality. Daniel (1992) and Jeyalakshmi and Daniel (1997) observed a similar trend in fish while feeding them on the diets incorporated with autoclaved seed meal.

Feed incorporated with germinated greengram meal also showed higher rate of consumption than the raw seed meal and that is also due to the reduction of undesirable compounds present in the seeds. The process
of germination improves the functional properties of proteins which results in the increase in flavour, texture and protein digestibility as observed by Jood et al. (1988) and Rajyalakshmi and Gervani (1990). This could be the reason for the increased rate of consumption in feed 42, which contained germinated greengram.

The rate of consumption was also high in the feed which contained roasted greengram (feed 41) than that of the control feed as well as which contained raw seeds and soaked seeds. The increase in the rate of consumption could be due to the elimination of the off-flavour and sharp taste substances and also due to improvement in the flavour and taste of the roasted seed powder. Capper et al. (1982) observed such increase in the rate of consumption in carp when fed on feed containing roasted mustard seed cake.

Even the feed which contained the seeds subjected to mere soaking for 24 h, showed a better rate of consumption than the feed which contained raw whole seeds. Soaking helped in the elimination of soluble antinutritional factors. Jood et al. (1988) have suggested a 24 h soaking of legumes to reduce the flatus producing substances.

The rate of production directly depends upon the quality of the feed consumed which in turn depends upon the ingredients used, their combination and processing technique. The rate of production in the present experiment was more or less similar to the control (groundnut oil cake) and the feed incorporated with raw whole greengram. It was slightly higher in the feed which contained soaked greengram.
The best rate of production was observed among the organisms fed on feed incorporated with autoclaved greengram (feed 40). The observation indicates that autoclaving has helped in eliminating the antinutritional factors. Henderson et al. (1985), Semino and Cerletti (1987) and Tan et al. (1984) have observed a reduction of enzyme inhibitors, lectins, oligosaccharides and phytates by autoclaving. Improvements in the protein utilization (Khan et al., 1979) and enhancement of digestibility are also observed due to autoclaving.

Equally higher rate of production was observed when the organisms were fed on feed incorporated with roasted greengram (feed 41). That is because of the elimination of antinutritional factors and improvement of the seed meal. Barroga et al. (1985) and Ayatse et al. (1983) have made similar observations in their studies. Roasting also improves the protein digestibility of seed meal (Srivastav et al., 1990). Similarly Capper et al. (1982) observed an increase in the rate of production among carps when they were fed on the feed incorporated with 20 percent of roasted mustard cake over that of the unroasted cake.

The rate of production observed in feed containing germinated greengram (feed 42) is not encouraging. It indicates the possible presence of thermolabile substances in the seeds. These factors get degraded only on subjecting the seeds to such treatments as autoclaving or boiling for a considerable period of time. Viola et al. (1983) observed similar property in soybean meal. Though germination improves the nutritional status of the seeds there always exist a problem of thermolabile undesirable factors.
The highest gross growth efficiency, highest protein efficiency ratio and lowest feed conversion ratio were observed in feed 40 (autoclaved greengram) and in feed 41 (roasted greengram) and it was followed by feed 42 (germinated) and feed 39 (soaked). Autoclaving and roasting efficiently eliminates most of the undesirable antinutritional components and improves the quality of protein present in greengram and also its digestibility. Soaking removes the soluble toxins and germination improves the nutritional status of the seeds but there always exists the problem of thermolabile factors.

The overall observation shows that oil cakes (groundnut oil cake and sesame oil cake) can be replaced by greengram. Relatively better performance was observed when the feed was incorporated with greengram subjected to heat treatment, either wet (autoclaving) or dry (roasting). These treatments improve the quality of the feed which in turn helps to enhance the growth performance of *M. malcolmsonii*.

In the present experiment tapioca and ricebran were replaced by small millets *Eleusine coracana* (ragi) and *Permisetum americanum* (bajra). Since these small millets are rich in energy and minerals; inexpensive and widely available in rural India they are chosen as sources of energy for formulating feed for *M. malcolmsonii*.

Heat treatments are known to eliminate antinutritional factors and to improve the quality of the meal. But the success of the treatment depends upon the standardisation of the time required for the treatment. Variation in the duration of heat treatment helps to reduce greater or lesser quantities of antinutritional factors and hence two different
timings were given for each of the heat treatments. Autoclaving was performed for 10 and 20 min and roasting was carried out till the plant ingredients turned golden yellow and brown in colour.

Ologhobo and Fetuga (1983) observed that a careful control of processing conditions is essential to prevent functional as well as nutritional damage to protein. Bressani et al. (1982) reported that cooking black beans for 10 to 30 min at 121° C improved their protein utilization as compared to raw beans. However, longer cooking caused a drop in the nutritive value of the beans. Khan et al (1979) observed 10 to 20 min cooking at 121° C to be adequate to improve the meal of chick peas, mash beans, mung beans and cow peas and also to improve their protein utilization as compared to raw beans.

In the present study the rate of consumption observed among the organisms fed on the feed containing autoclaved plant materials for 10 min was 41.71 mg/g/d and it was 43.23 mg/g/d in 20 min autoclaving. The rate of production was 13.14 mg/g/d in 10 min autoclaving and it was 13.16 mg/g/d in 20 min autoclaving. From this it is clear that 10 min is sufficient to eliminate the thermolabile antinutritional factors and to improve the protein utilization.

Similarly roasting also has helped in eliminating antinutritional factors. The variation in the rate of consumption, rate of production, gross growth efficiency and protein efficiency ratio indicates that it is sufficient to roast the plant protein sources till they turn golden yellow in colour. Further increase of time till they turn brown does not improve the growth performance of the cultured animals. Higher duration of
roasting seems to reduce the quality of the feed and thereby the digestibility, absorption and conversion. Prolonged roasting denatures the protein and ultimately it is not available for effecting better growth. Hence roasting for lesser duration of time viz. till the ingredients turn golden yellow in colour is advisable for processing the plant protein sources for *M. malcolmsonii* culture.

Ibiyemi *et al.* (1989) observed 120° C to be most suitable roasting temperature for obtaining beans (*Pakia filicodae*) of highest quality. Srivastav (1990) has observed an increase in the digestibility of bengalgram, maize and soybean after roasting, indicating the possible destruction of protease inhibitor and opening of the protein structure. Barroga *et al.* (1985) observed a 17 percent reduction of polyphenol in mung bean on roasting. Kato *et al.* (1981) observed that roasting soybean at 200° C for 10, 20 and 30 min resulted in the improvement in the flavour from beany or objectionable to desirable by sensory evaluation.

In the present study also roasting helped in improving the flavour of the plant protein sources and that could be the reason for higher rate of consumption than in the control. Increased rate of production and conversion indicates improved rate of digestibility of the protein components and their absorption and utilization for growth. From this observation it is clear that the plant protein sources shall be subjected to roasting before incorporating them in the compounded feed for *M. malcolmsonii*. 