# Chapter Five

# NUTRITION

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Through supplemental feeding of prawns, higher stocking densities and a shorter culture period are possible. Increase in production per crop and in the number of croppings per year results in higher return on investment. Thus fish farmers find feeding artificial diets to prawns to be profitable even if operational cost, which is mainly due to feed, increases by 50-60% over that of the traditional method. There is therefore a need to develop an economical and biologically effective diet for prawns.

In the development of artificial diets for prawns, the practical approach is to simulate their food in the natural environment especially when no data on nutrient requirements are available. Dietary requirements of prawns can be obtained from food intake studies in the natural habitat, since available food in ponds is limited and differs from food in the wild. A study of the nutritional needs of the species is necessary. Based upon experience in the poultry and livestock industry, success in these industries came with acquisition of knowledge of nutrient requirements and the development of feeds that met the nutritional needs of the species.

## FOOD AND FEEDING HABITS

Prawns are omnivorous during their early stage of growth. From zoea to mysis they prefer phytoplankton, mainly algae, and shift to zooplankton and crustaceans such as *Artemia* and rotifers from the mysis to post-larval stages (Villaluz et al 1969). At the juvenile stage, crustaceans like small crabs and shrimps, molluscs, fish, polychaetes, ophiuroids, sand and silt, and even debris have been found in their gut. Marte (1980) reported that around 85% of the ingested food of *P. monodon* caught from the wild in Makato, Aklan consisted of crustaceans mainly small crabs, shrimps, and molluscs. Polychaetes, ophiuroids, fish debris, sand and silt composed the remaining

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15%. The transport time for food (95%) from the foregut is around five hours. Prawns feed on slow-moving benthic organisms and crustaceans appear to be the "staple" food while molluscs contribute the largest bulk. Significant monthly variations in feeding activity were shown by the wild prawns caught from the Makato area (Marte 1982).

*P. monodon* juveniles caught along the Sudanese Red Sea coast were found to feed mainly on algal materials while adults fed on crustaceans, annelids, algae, mud, and unidentified matter (El Hag 1984). Furthermore, El Hag (1984) classified adults as omnivorous but they prefer animal protein. Likewise, the gut of *P. monodon* from the Korapuzha estuary, India had been found to contain crustaceans, molluscs, polychaetes, fishes, and vegetable matter (Thomas 1972).

Nezaki (unpubl. 1986a) obtained similar results in a study conducted in the northern coast of Panay Island, Philippines. A monthly survey and monitoring of prawn broodstock showed the gut content to contain crustaceans, molluscs, polychaetes, and detritus as main food items. Development of the ovaries was strongly influenced by the abundance of these prey organisms. Studies on prawns caught from the wild show that they tend to be carnivorous as they grow older (Marte 1982).

During the peak spawning months - March, April, June, August, and December - molluscs occur in the gut more frequently than crustaceans. While in other months (January, March, August) fish remains occur in more prawns. This finding suggests that certain nutrients derived from molluscs and fish may be needed for gonad development.

Prawns are nibblers and slow eaters. They take food with their pincers, bring this to their mouth, and slowly chew on the food. If the feedstuff in the pellet is not homogeneous enough, larger particles are spit out. If the whole pellet is small enough for their mouth, the whole pellet is consumed (Pascual, pers. observation). Cannibalism is caused by factors such as insufficient feed, crowding, poor quality of feed or a nutritionally inadequate ration. Healthy prawns attack and feed on the weak ones. Exuviae are ingested but causes for such are still to be determined. Although they have been found to feed continuously all day, they seem to consume more food at night than during the day.

Apud et al (1980) have observed that *P. monodon* in ponds eat anytime of the day but prefer to bottom-feed when there is light. The prawns move around the perimeter of the pond in the late afternoon and evening, hence the suggestion to give more feed at such time of the day.

## NUTRIENT REQUIREMENTS

Very little information on the nutrient requirements of *P. monodon* is available at present. Likewise, there is scarcity of data on the biological availability and apparent digestibility of protein, fats, and carbohydrates. For practical purposes, and in the absence of hard data, prawn feeds have been formulated from what little information there is and values derived from other species. Supplementary feeds in the form of chicken entrails, frog meat, mussel meat, trash fish, worms, and snails are available but problems related to mass production, storage, unpredictable availability, and quality have led to the search for other feedstuff to be incorporated in artificial feed or dry pellets.

### Protein and Amino Acids

Protein is primarily necessary for growth, and when there is not enough energy from fat and carbohydrates, it is used to supply heat and energy before it is utilized for growth. High protein diets like algae and *Artemia,* apparently required by larvae for growth and survival, seem to suggest that high amounts of protein are required by the larvae. Alava and Lim (1983) found that *P. monodon* juveniles need around 40% protein. For broodstock, diets containing 50% protein seem to be necessary (Millamena et al 1986). In a recent study by Bautista (1986), protein between 40 and 50% gave the best growth and survival in the presence of 20% carbohydrates and 5-10% lipid. Nezaki et al (1986b) found that 55% protein with 15% carbohydrates in grow-out diets gave the best growth. However, when carbohydrate content is increased to 25% content, a 45% protein diet can give results comparable to those of diets containing 55% protein.

Studies by Wilson (1984) have shown that the closer the essential amino acid pattern of the diet is to that of the species being studied, the more effective is the diet for growth. Amino acids are building blocks for protein formation and when one essential amino acid is insufficient in the diet, protein synthesis is hampered, resulting in diminished utilization and efficiency of the diet. Not only the amount but also the quality of protein has to be considered.

Ten amino acids have been found essential and have to be included in the diet. The essential amino acids for *P. monodon* are similar to those defined by Deshimaru and Kuroki (1974) for *P. japonicus* and by Shewbart et al (1972) for *P. aztecus.* Several investigators have analyzed the amino acid pattern of *P. monodon* (Catedral and Penaflorida 1977, Kanazawa and Teshima 1981, Coloso and Cruz 1980). Penaflorida (pers. comm.) found that except for arginine, the essential amino acid pattern was similar throughout the life cycle of *P. monodon.*

Coloso and Cruz (1980) found by $^{14}C$ labelling that *P. monodon* can not synthesize arginine, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, valine, threonine, and tryptophan. Moreover, Pascual and Kanazawa (1986) showed that by following the amino acid pattern of the prawn, a semi-purified type of complete diet provided for good growth and survival. Nezaki et al (1986b) also determined that various diets containing 55% protein were formulated with the use of three sources of protein: defatted prawn flesh, casein, and gelatin. One diet simulated the amino acid profile of *P. monodon* juveniles. The prawns fed the diet that had the most similar amino acid pattern to the prawn muscle, gave the highest percentage weight gain and feed efficiency. Preliminary results on the required amount of arginine and histidine in the diet showed that a level close to the amount found in the tissues of *P. monodon* postlarvae gave the best results (Pascual, in prep.). These studies confirm the results of other researchers that the closer the essential amino acid pattern of the diet, the more effective it is for growth.

Since protein sources are one of the most expensive items in a practical diet, it is necessary to search for locally available potential plant and animal sources. Although semi-purified diets are used for the determination of required nutrient levels, results from such studies have to be translated into practical-type diets for commercial use.

Alava and Lim (1983) used squid meal, fish meal, shrimp meal, casein, and soybean meal as protein sources in diets with protein content ranging from 25 to 60% protein and found 40% protein diet to give the best growth rate. However, comparable results were obtained with shrimps fed 30, 35, and 45% protein diets. In another study by Pascual (1985), diets containing approximately 40% protein from shrimp head meal, fish meal, soybean meal, earthworm meal, and squid meal gave good results.

## Lipids and fatty acids

Lipids or fats are necessary for their energy value, polyunsaturated fatty acids (PUFA) and phospholipid content, and vitamin (A, D, E & K) value. Millamena and Quinitio (1985) have shown that for prawn larvae, PUFA are important for growth and enhancement of metamorphosis. In view of the limited capacity of prawns to biosynthesize PUFA, these essential fatty acids have to be provided in the diet to ensure survival and development.

The fatty acid composition of postlarvae is generally related to the fatty acid composition of the diets (Yashiro 1982). Mendoza (1982) found that a diet containing 11.7% lipid gave maximum growth, efficient feed conversion and protein efficiency ratio, and good survival rate in *P. monodon* juveniles. Bautista (1986) also showed that a 10% lipid content in the diet was effective in assuring good growth and survival as long as protein content was between 40 and 45% and carbohydrate was 25%. Catacutan (unpubl.) showed that the best growth of *P. monodon* juveniles was attained with lipid source containing high amounts of highly unsaturated fatty acids of the n-3 series in semi-purified diets for juvenile prawns; thus, 10-11% of this type of lipid may be required.

In a related study by Catacutan and Kanazawa (1985), juvenile *P. monodon* (0.2 to 0.5 g) were fed various types of dietary fatty acids for a period of 35 days. The neutral lipid and polar lipid fractions were analyzed and found to contain high levels of certain polyenoic acids (20:4 n6, 20:5 n3, 22.6 n3), and the sum of n3 series was high in the polar lipid fraction. The component fatty acids of the prawns were correlated with the dietary fatty acid content.

The fatty acid profile of the ovaries, hepatopancreas, and tail muscle of wild *P. monodon* broodstock indicates that there is a predominance of higher long chain polyunsaturated fatty acids --arachidonic (20:4*w*5), eicosapentaenoic acid (20:5*w*3), and docosahexaenoic acid (22:6*w*3) in prawn broodstock (Millamena et al, in press). She further reported (unpubl.) that the inclusion of 5% cod liver oil together with 4% soya lecithin in the diet improved fecundity and egg hatching rate.

Other types of lipids needed by the prawn are cholesterol (Nalzaro 1982) and phospholipids (Pascual 1986). A total cholesterol level of about 1% required for maximum growth, high feed conversion, high protein efficiency and survival rate, and maintenance of a constant level of body cholesterol in prawn juveniles was reported by Nalzaro (1982). However, a practical formulated diet was used and therefore the control diet also contained some cholesterol. Whether 1% cholesterol in the diet would give similar results remains to be confirmed. In addition, Ubal et al (1986) indicated that a level of 0.6 to 1.0% cholesterol in a semi-purified diet containing 6% refined cuttlefish liver oil and soya oil in 3:1 ratio was necessary for good weight gain and feed efficiency in prawn juveniles.

Lecithin which contains 62% phospholipids, phosphatidyl choline, phosphatidyl inositol, and phosphatidyl-ethanolamine has been found necessary in prawn grow-out at around 3% in the diet (Pascual 1986). Furthermore, Nezaki et al (1986c) showed that soybean lecithin levels at around 4% gave the best results compared to those fed greater than 4.6% soybean lecithin levels. Percentage weight gain and feed efficiency increased significantly in prawn juveniles and decreased with increasing lecithin levels beyond 4%. Millamena et al (1986) reported a level of 4% lecithin was necessary for broodstock diets.

## Carbohydrates

Carbohydrates in prawn diets are not only useful for their energy value and protein-sparing function but also for their binding properties. Among the carbohydrates that have been studied are sucrose, dextrin, maltose, molasses, cassava starch, cornstarch, sago palm starch, trehalose, glucose (Pascual et al 1983, Alava and Pascual 1987). Sucrose and sago palm starch at 10% of the diet gave better survival rates than the other carbohydrates tested at the same level. However, histopathological changes in the hepatopancreatic cells were observed (Pascual et al 1983). On the other hand, molasses at 10% of the diet caused mortality within 10 days of culture. In another study by Alava and Pascual (1987), sucrose and trehalose proved to be the better sugars compared to glucose. At 20% of the diet, glucose, a simple sugar, is easily assimilated and remains in the hemolymph for as long as 24 hours and therefore is detrimental to *P. japonicus* (Deshimaru and Yone 1978).

Fourteen-day old postlarvae (2 mg mean body weight) were fed diets containing 10% lipid, protein levels of 25, 35, 45, and 55%, and starch at 10, 20, 30, and 40% to determine the effects of dietary protein and starch levels on growth and survival of *P. monodon.* Growth was not affected by starch levels in the diet but was proportional to the amount of protein content. Survival was affected by the protein/starch ratio (Bages and Sloane 1981).

*Energy.* The study of Bautista (1986) indicates that prawn juveniles need energy values between 2850 and 3700 Kcal/l kg of diet depending on the protein, carbohydrate, and fat content. The best growth, survival, and feed conversion ratio (FCR) were obtained with 40-50% protein, 5-10% lipid, and 20% carbohydrates.

## Vitamins and Minerals

Vitamins and minerals are important for regulating body processes. The B vitamins are necessary for proper utilization of proteins, carbohydrates, and fats while vitamins A and C are important in building resistance to infection. Vitamin D together with minerals, calcium, and phosphorous is necessary for the formation of the exoskeleton or shell. All of these nutrients although needed in minute amounts are necessary for the proper utilization of food by the prawns. It is therefore important that these nutrients be included in complete diets for prawns in their proper amounts. However, up to the present only exploratory, preliminary work on vitamins and minerals have been done on *P. monodon.* Hence, we rely on published data for other species like *P. japonicus* (Deshimaru and Kuroki 1974). Preliminary studies with juveniles under laboratory conditions showed that in practical formulated diets some vitamins may be omitted without decreasing growth and survival. Efficiency of the diets was comparable to the growth obtained for prawns fed the complete diet (Pascual, unpubl.). Catacutan and Kanazawa (1985) also found similar results with the use of purified diets.

Bautista (in prep.) pointed out the importance of calcium: phosphorous ratios in diets, indicating a 1:1 ratio for *P. monodon* grow-out. A dietary Ca/P ratio of 1:1 was found to be effective in hardening the exoskeleton and preventing soft-shelled disease.

## DIET DEVELOPMENT

With some knowledge of the nutritional requirements of the prawn, it is possible to formulate an artificial diet using local indigenous feedstuff and those commonly used in the livestock and poultry industry. Aside from nutritional requirements and sources of the nutrients, there are other factors that have to be considered. There are practical problems related to the physical features of the diet: water stability, attractability, size, shape, density, and texture. The physical characteristics of the diet and factors to be considered would differ from one stage of the life cycle of the prawn to another -- from larval stage to grow-out to broodstock.

### Larval Diets

Larvae are pelagic and swim continuously in the water column; hence, this characteristic has to be taken into consideration in the development of larval diets. The diet needs to be suspended in water for a certain period. There are so called microparticulate diets which are either microbound or microcapsulated or microcoated. Bautista et al (unpubl.) have formulated a microbound diet that is presently under study. Commercial microencapsulated diets are available in the market for *P. monodon* larvae. The use of non-live feeds is associated with problems of water pollution. With proper management techniques, however, microparticulate diets for larvae offer a potential substitute for traditional algal food.

Quinitio et al (1983) found that soya bean meal is a good substitute for algal food in the larval stages. Likewise, frozen, fresh, and dried *Acetes* sp. were fed to larvae and found to give good survival (Kungvankij et al 1986).

**Grow-out and Broodstock Diets**

Several formulations have been screened under laboratory conditions and there are four diets that are recommended for different culture or rearing methods (Pascual, in press). The best have been tried under pond conditions and at a stocking density of 25 000 per hectare. There are also several commercial diets imported from Taiwan and Germany.

Knowledge of the characteristics of a good broodstock diet is scanty. Millamena et al (1986) are studying broodstock diets and have used a pelleted feed in bringing prawn to maturity. However, frozen squid or mussel meat has to be fed in combination with this pellet. They reported that the PUFA present in the diet are important for good fecundity, high hatching rate, and healthy larvae (Millamena et al 1986). Food sources like marine worms, molluscs, and crustaceans, used traditionally in shrimp maturation diets, contain high level of PUFA (Millamena et al 1986). The study of Marte (1982) indicated that there are certain nutrients in molluscs and fish which are required for gonad development because during the appearance of spawners, these feeds are found abundantly in the gut of the prawns. Primavera et al (1979) fed broodstock with mussel meat alone or in combination with pellets compared to those that were not offered any mussel meat.

## PHYSICAL CHARACTERISTICS OF PELLETS

All types of diets have to be properly bound and attractive to the organism. Hence, finely ground feedstuff and a good binder with an attractant are necessary in the development of a feed. Antioxidants and anti-mold agents may also be necessary especially in the tropics where relative humidity is generally high during the rainy months. A good packaging material also has to be developed to avoid fungal growth.

Sweet potato starch, cassava starch, extract of shark fins, *Gracilaria,* gum arabic, alginate, glutinous rice, carboxymethylcellulose, carrageenan, corn starch, polymethylolcarbamide, and sago palm starch (Pascual et al 1978; Pascual and Tabbu 1979; Murai et al 1981; Pascual and Sumalangcay 1982; Pascual, unpubl.; Lim and Destajo 1979) have all been studied for their possible use as binders in both practical and semi-purified diets. Sweet potato starch at 5% has poor binding capacity and allows growth of molds easily. Other binders are either too expensive or not commercially available. Sago palm starch, cornstarch, alpha potato starch, and carboxymethylcellulose are good but relatively expensive binders for commercial use in the Philippines. Polymethylolcarbamide at 0.5 to 1% has been found to be of help in practical diets but not in semi-purified diets that do not contain gelatin (Pascual, unpubl.). Steaming the diet has been found to further increase water stability of the pellet.

Attractiveness is another characteristic of a prawn diet that has to be considered. Several attractants have been tested by incorporating shrimp, mussel, squid, fish and mussel extracts in purified diets (Pascual 1980, Murai et al 1983) while krill meal, earthworm meal, glycine, sucrose, and mussel water have been used as attractants in a practical diet. Addition of krill meal, earthworm meal, and sucrose improved attractability to a certain extent while glycine supplement and mussel significantly improved attractability. Furthermore, dietary groups supplemented with any type of attractant showed better mean weight gain than those fed the diet without attractants. Prawns fed the diet with earthworm meal gave the best growth rate and feed conversion (Murai et al 1983). Hence diet attractability, per se, may be a vital factor in determining the quality of compounded feed for prawn.

## ANTI-NUTRITIVE FACTORS

The efficiency of raw feedstuffs is improved by processing. Pascual (1985) found that earthworm meal when incorporated in the diet in the fresh-frozen state rather than in the dried meal form gave poor survival. According to Stafford and Edwards (1983) there is a heat-labile toxic substance in the coelomic fluid excreted by the choriogenic cells of the worms.

Heat-labile trypsin inhibitors are found in soybean meal therefore the latter has to be cooked before it is incorporated in the diet. Defatted soybean meal with low content of trypsin inhibitor should be the choice meal (Akiyama 1988).

*Leucaena* (ipil-ipil) leaves are a potential source of protein but because of the mimosine content, can not be used unless the mimosine is removed. Vogt et al (1986) found that the hepatopancreatic cells (R-cells in particular) are damaged in the presence of mimosine. Damage to new cells occurs before growth, and survival is affected. Soaking ipil-ipil leaves in fresh water for 24 hours and air drying thereafter removes around 95% of the mimosine (Pascual and Penaflorida 1979). However, the method is not practical for commercial use.

The use of electron microscopy as a method for detecting early pathological changes in the midgut gland of *P. monodon* fed various types and levels of nutrients, protein, fats, and carbohydrates has been demonstrated by Storch et al (1984) and Vogt et al (1985, 1986). Starved prawns showed pathological changes which were irreversible when starvation lasted for 5 days (Vogt et al 1985).

## FEED AND FEEDSTUFF RESOURCES

A diet is generally composed of protein source--animal and plant; lipid source--animal and plant; carbohydrate source; binder; attractant; vitamins; minerals; additives such as attractants; antioxidants; fungicides; and sometimes hormones, etc. The amino acid pattern of the protein source and fatty acid profile in lipid source are important considerations in choosing the feedstuff to be incorporated in the diet.

### Protein Sources

Feedstuffs considered as protein sources usually contain more than 20% protein on a dry matter basis. There are two principal sources of protein: animal and vegetable. Squid meal, shrimp meal, mussel meat, fish meal, shrimp head meal and earthworm meal have been found to be good animal protein sources (Lim et al 1979, Pascual and Destajo 1979, Pascual 1985).

Shrimp, earthworm, squid, and mussel meals are not only excellent sources of protein but also provide attractants and contain essential amino acids and fatty acids needed by the prawn. Shrimp meal and other crustacean meals contain astaxanthin that gives the bright red color to the prawn when cooked (Benjamin 1982). Generally, a combination of two or more protein sources is better than just one. Ipil-ipil leaf meal of not more than 10% in the diet may substitute for part of the animal protein source (Pascual and Catacutan, unpubl.). Recently, Pascual et al (unpubl.) found that soybean meal at 35 to 45% of the diet gave similar results in terms of growth and survival to those of diets with lower soybean content (15 or 25%) when fed to prawn juveniles for a period of four months in earthen ponds.

The amino acid pattern of the protein source is an important factor in the choice of protein sources. Penaflorida (unpubl.) who is screening for other potential animal and vegetable protein sources found that the common limiting amino acid in both types of feedstuffs is arginine.

## Lipid Sources

The effect of various oils like corn oil, soybean oil, beef tallow, pork lard and fish oil on growth of *P. monodon* juveniles has been studied by Mangalik (1979). Fish oil is the best, followed by beef tallow, soybean oil, copra oil, and pork lard, in descending order. Likewise, Mangalik (unpubl.) tried different lipid sources in prawn diets and found that cod liver oil followed by beef tallow and pork fat gave good growth and survival. Structure of hepatopancreatic cells of prawns fed cod liver oil was similar to the control. A 1:1 ratio of cod liver oil and soybean oil, preferably the crude degummed soya oil if available, is suggested (Pascual 1986). Coconut oil does not contain the essential polyunsaturated fatty acids needed by the prawn, hence has not been used in prawn diet.

Some carbohydrate sources are wheat flour (bread flour), rice flour, cassava flour, potato starch, sago palm starch, "tiki-tiki" or the very fine type of rice bran, corn meal, and copra meal.

In the absence of hard data on the vitamin-mineral requirements of *P. monodon,* a vitamin-mineral premix recommended for *P. japonicus* by Deshimaru and Kuroki (1974) and by Catacutan and Kanazawa (1985) are used in both practical and semi-purified diets.

### Apparent Digestibility

Apparent digestibility of the feedstuff is important for it is useless if it is not digestible and utilized by the prawn. Catacutan has analyzed the apparent digestibility of some protein sources for male *P. monodon* with weights of approximately 30 grams. Both full fat and defatted soybean meal were equally digestible while fish meal was poorly digested. Further work has to be done to confirm these results (Catacutan, unpubl.).

## FEEDING PRACTICES

Feeding trays are used under pond conditions to be able to see whether the prawns are feeding or not. Automatic and semi-automatic feeders are available. However, under Philippine conditions where labor is relatively cheap and where unemployment is high, food could be broadcast around the pond twice, thrice, or even five times a day. About 10% of the total daily feed ration is placed in trays in order to observe if the animals eat.

A feeding scheme for grow-out is in the chapter on culture techniques.

### Feed Storage Requirements

Feeds have to be properly stored to prevent bacterial and fungal growth. The presence of these in feeds can cause diseases and mass mortality. Rancidity and destruction of nutrients can be caused by improper storage. Feeds should be stored in a cool, airy but not humid environment. Waterproof sacks prevent moisture from spoiling the feed. Aflatoxin, a carcinogen, is present when *Aspergillus* molds grow in the feed. Hence, feeds should be stored properly. Rodents and cockroaches should be avoided. Plastic-covered containers kept in a cool place will help prevent rodents from attacking the feed.

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