Milkfish, *Chanos chanos* 13

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Introduction

Milkfish (*Chanos chanos* Forsskal), the only species known in the family of Chanidae, is an important food fish in the Indo-Pacific regions (Chen, 1976). In some countries, milkfish fingerlings are also used as bait for the tuna fishing industry. This species is best suited for culture in the tropics because of its fast growth, efficient use of natural foods, herbivorous food habit, propensity to consume a variety of supplemental feeds, resistance to disease and handling and tolerance to a wide range of environmental conditions. Milkfish are euryhaline and can thrive in waters of 0 to 150 p.p.t. salinity (Crear, 1980).

Milkfish is cultured on a large scale only in the Philippines, Indonesia and Taiwan. Small-scale or experimental production is being practised in a few other Asian countries, such as Thailand, Malaysia, Vietnam and Sri Lanka, and in Hawaii, Guam and Kiribati. Milkfish farming is believed to have begun in Indonesia some 700 years ago (Ronquillo, 1975) and was introduced into the Philippines and Taiwan more than 300 years ago (Ling, 1977). In 1983, milkfish was the single most important species produced through aquaculture in these countries, using more than 500,000 ha of brackish-water and freshwater areas to produce over 365,000 t (Lee and Banno, 1990). In 1990, the cultured area decreased to 410,000 ha but the production increased to about 460,000 t (Lee, 1995; Bagarinao, 1999). In Taiwan, approximately 12,850 ha of ponds were used for milkfish production in 1990 and yielded an average of 7.0 t ha^{-1}. The Phillippines produced 210,900 t of milkfish from 156,177 ha of brackish-water ponds and 19,000 t from about 10,000 ha of freshwater pens, at an average yield of 1.3–1.9 t ha^{-1}. In 1990, Indonesia devoted the largest pond area (231,000 ha) for milkfish production but the average yield was only 0.6 t ha^{-1}.

The discrepancy between the yield in these countries is mainly attributed to differences in culture technology, skill and management inputs, such as stocking rate, size, pest and predator control, fertilization, feed and feeding and water management. For example, the multiple-size stocking method used in the Philippines yielded an annual production of 2.2–2.7 t ha^{-1} (Pamplona and Mateo, 1985). The deep-water culture practised in Taiwan with the use of high stocking rates and formulated diets produced 8–10 t ha^{-1} $year^{-1}$ (Liao and Chen, 1986). This chapter reviews information on nutrient requirements, feeds and feeding practices of milkfish.

Nutrient Requirements

Protein and amino acids

Milkfish, like other fish, do not have an absolute protein requirement *per se*, but require a balanced mixture of essential and non-essential amino acids. The minimum amount of dietary protein required for the optimum growth, good feed efficiency and survival of 40 mg milkfish fry has been reported to be about 40% (Lim *et al.*, 1979). However, it has been reported that the protein requirements of fish vary with species, size or age, protein quality, dietary level of energy, water quality, presence of natural food and feeding and culture management (NRC, 1983).

Milkfish require the same ten essential amino acids (arginine, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan and valine) as other species (Borlongan and Coloso, 1993). The quantitative requirements of juvenile milkfish for these essential amino acids, determined by breakpoint analysis of the growth curve, are presented in Table 13.1. It has been

Table 13.1. Essential amino acid requirement of juvenile milkfish (from Borlongan and Coloso, 1993).

Amino acid	Requirement (% of dietary protein)*
Arginine	5.2
Histidine	2.0
Isoleucine	4.0
Leucine	5.1
Lysine	4.0
Methionine†	2.5
Phenylalanine‡	4.2 or 2.8
Threonine	4.5
Tryptophan	0.6
Valine	3.6

* The basal diets contained 40–45% protein.
† In the presence of cystine at 0.75% of dietary protein.
‡ In the presence of tyrosine at 1.0% and 2.6% of dietary protein, respectively.

suggested that arginine, leucine and lysine may be the first limiting amino acids since they occurred at high concentrations in the amino acid pattern of protein from the whole body of milkfish juveniles (Coloso *et al.*, 1988). More recent studies, however, showed that the requirement levels of these three essential amino acids and those of tryptophan and valine were lower than those found in milkfish body proteins, but those of the other essential amino acids were similar to the values of the tissue proteins (Borlongan and Coloso, 1993).

The non-essential amino acids can be adequately synthesized by fish but their presence in the diets has a sparing effect in that it reduces the need for fish to synthesize them. Two special examples of sparing action are the conversion of phenylalanine to tyrosine and methionine to cystine. These non-essential amino acids can only be synthesized from the essential amino acid precursor (NRC, 1993). Milkfish actually have a requirement for aromatic amino acids (5.22% of dietary protein), which can be met by either phenylalanine alone or a proper mixture of phenylalanine and tyrosine. In the presence of tyrosine at 1.0% of dietary protein, the phenylalanine requirement was estimated to be 4.22%. The phenylalanine requirement decreased to 2.80% of dietary protein when the tyrosine level was increased to 2.66%. Dietary tyrosine was found to replace up to 46% of the total aromatic amino acid requirement for milkfish (Borlongan, 1992a; Borlongan and Coloso, 1993). Since most practical diets contain adequate levels of phenylalanine and tyrosine, the sum of these two amino acids normally exceeds the dietary needs of most fish (NRC, 1993). A similar relationship exists between sulphur-containing amino acids (methionine and cystine). The presence of cystine in the diet will reduce some of the requirement for methionine (NRC, 1993). The methionine requirement of milkfish was estimated to be 2.7% of protein at 0.28% dietary cystine. In the presence of 1.48% cystine, the methionine requirement was reduced to 1.50% of dietary protein (Sastrillo, 1980).

Milkfish appear to have the ability to utilize crystalline amino acids. Supplementation of 0.5% L-tryptophan to a vitamin-free casein diet provided better growth of young milkfish than a diet containing a combination of casein and gelatin (Lee and Liao, 1976). Chiu *et al.* (1986) reported that supplementation of 2.8% lysine hydrochloride to a maize-gluten meal-based diet significantly improved the growth and feed efficiency of milkfish fry.

Milkfish use proteins of animal origin better than plant proteins. Among animal proteins, fish meal and meat and bone-meal have higher nutritive value than shrimp-head meal. Among plant proteins, soybean meal was superior to copra and *Leucena leucocephala* leaf meals (Samsi, 1979). Borlongan and Coloso (1994) showed that leaf meals from swamp cabbage (kangkong, *Ipomea reptans*), sweet potato (kamote, *Ipomea batatas*), ipil-ipil (*L. leucocephala*) and cassava (kamoteng kahoy, *Manihot esculanta*) can be used to replace 15% of fish-meal protein in a basal diet containing 53% Peruvian fish-meal and 15% soybean meal without affecting the growth performance of milkfish. The true protein digestibility of casein, gelatin, fish-meal, soybean meal and *L. leucocephala* leaf meal by three sizes of milkfish held in fresh water or sea water is given in Table 13.2. Gelatin had the highest digestibility regardless of fish size and water salinity.

Table 13.2. Apparent protein digestibility of some feedstuffs by three sizes of milkfish in fresh water (F) and sea water (S) (from Ferraris *et al.*, 1986).

		Apparent protein digestibility (%)		
Feed ingredient	Water	2 g	60 g	165 g
Casein	F	58	83	87
	S	73	49	65
Gelatin	F	94	94	94
	S	96	98	97
Fish-meal	F	45	65	73
	S	71	62	71
Soybean meal (defatted)	F	53	69	94
	S	74	54	58
L. leucocephala leaf meal	F	47	41	42
	S	61	31	–10

The digestibility of other feedstuffs increased with fish size and tended to be lower for fish held in sea water than in fresh water. *Leucena leucocephala* leaf meal was the least digestible (Ferraris *et al.*, 1986).

Energy

Providing the optimum energy in the diet is important because a deficiency in non-protein energy means that part of the protein will be used to meet the energy requirement. Except for a study of Pascual (1984), no studies have been conducted to determine the energy requirements of milkfish. For milkfish juveniles weighing 0.5–0.8 g, poor growth was observed in fish fed diets containing below 2500 kcal of metabolizable energy kg^{-1} diet. However, increasing dietary energy levels beyond 3500 kcal kg^{-1} did not further improve weight gain. A dietary protein-to-energy ratio of 118–127 mg $kcal^{-1}$ was suggested. Lim *et al.* (1979) obtained maximum growth of milkfish fry (40 mg) with a 40% protein diet having 2740 kcal of digestible energy kg^{-1} diet. In a study to evaluate different supplemental feeds for milkfish in brackish-water ponds, Sumagaysay *et al.* (1991) reported that a diet containing 27.4% protein and 4236 kcal of gross energy kg^{-1} resulted in a maximum increase in profit. In the absence of clear-cut information on energy requirement, data available for tilapia and common carp are suggested.

Lipids and fatty acids

Lipids are important sources of highly digestible energy and are the only source of essential fatty acids needed by fish for normal growth and development. Milkfish fed lipid-free or 7% lauric acid (LA) diets grew significantly less than those fed diets containing 6% LA plus 1% linoleic (18:2n-6), or 0.5% linoleic and 0.5% linolenic (18:3n-3) acids. The diet supplemented with 1% 18:3n-3 provided the highest weight gain but was not significantly different from those fed the diet with 1% 18:2n-6. Based on these results, it appears that milkfish have a dietary requirement for both linoleic (n-6) and linolenic (n-3) acids (Bautista and de la Cruz, 1988). Borlongan (1992b), however, showed that the n-3 rather than the n-6 series fatty acids were essential for the growth and survival of milkfish juveniles, because supplementation of 2% 18:3n-6 to the tristearin-based diets did not enhance milkfish growth as effectively as diets supplemented with n-3 series fatty acids. Signs of essential fatty acid deficiency in milkfish were growth depression, fin erosion, darkening of the upper pigmented body surface, high mortality, increased levels of monoenoic acids, decreased levels of polyunsaturated fatty acids and liver abnormalities, such as lipid infiltration in the blood-vessels and cellular swelling (Bautista and de la Cruz, 1988; Borlongan, 1992b). However, juvenile milkfish grew well and did not exhibit essential fatty acid deficiency signs when fed diets containing at least 1% 18:3n-3 and/or 1.0% of the long-chain polyunsaturated fatty acids (PUFA) 20:5n-3 and 22:6n-3 (Borlongan, 1992b).

Because of the presence of significant amounts of PUFA in the livers of milkfish, despite their absence in the natural food, milkfish may have the ability to bioconvert short-chain n-6 and n-3 unsaturated fatty acids into long-chain n-6 and n-3 PUFA (Benitez and Gorricita, 1983). Kanazawa (1985), however, observed that milkfish grew better on a diet containing 20:4n-6 than on a diet containing 18:2n-6. The growth-promoting effect of 20:5n-3 and 22:6n-3 has also been observed to be superior to that of 18:3n-3 (Borlongan, 1992b). Thus, the ability of milkfish to bioconvert 18:2n-6 and 18:3n-3 to longer-chain PUFA, as has been suggested by Benitez and Gorriceta (1983), may be insufficient to meet their physiological needs.

Milkfish do not tolerate as high a level of dietary lipid as do salmonids. In studies using cod-liver oil (Alava and de la Cruz, 1983) and the combination of a 1 : 1 ratio of cod-liver oil and maize oil (Camacho and Bien, 1983), a lipid level of 7–10% has been reported as optimum for milkfish fingerlings. This level was sufficient to maintain liver structural and cellular integrity. Lipid levels below 7% resulted in decreased granulation and loss of nuclei of liver cells. Dietary lipid levels exceeding 10% caused minor disruption of hepatocytes from the formation of large lipid vacuoles, the loss of hepatic cord with development of fibrous tissues and the occurrence of pyknotic nuclei (Alava and de la Cruz, 1983).

Carbohydrates

Milkfish, like other finfish, do not have a specific requirement for carbohydrates. However, carbohydrates are always included in fish diets because they are the least expensive source of energy, function as a pellet binder and serve as precursors for the formation of various metabolic intermediates essential for growth. Carbohydrates have also been shown to have a sparing effect on the utilization of dietary protein in several aquaculture species. Milkfish can probably utilize carbohydrates as an energy source very efficiently, as do tilapia and common carp. Purified diets containing up to 35% dextrin have been used successfully in various nutritional studies. Practical diets in Taiwan currently used for pond feeding contain 45% or more of total carbohydrate.

Vitamins and minerals

The importance of vitamins and minerals in milkfish diets has been recognized as these nutrients have normally been included in experimental or production diets. Except for the study of Minoso *et al.* (1999), which demonstrated the dietary essentiality of phosphorus and iron, no information is available on milkfish vitamin and mineral requirements. However, milkfish probably require the same vitamins and minerals as do other aquaculture species. Various vitamin and mineral mixes designed for cold-water and warm-water fishes have been used by different workers in milkfish nutrition research with satisfactory results. Thus, in the absence of information on these subjects, vitamin and mineral allowances established for other tropical species, such as tilapia and common carp, are recommended.

Practical Diets

Newly hatched milkfish fry use their yolk as a source of nutrients. As soon as the yolk-sac is absorbed, they begin to swim up and search for food. Live foods such as rotifers (*Brachionus* sp.) are used as the first food up to day 14. Newly hatched brine shrimp (*Artemia*) nauplii are commonly used from day 15 to harvest (usually day 21). However, wild-caught milkfish fry or 15-day-old hatchery-produced milkfish larvae have been reared successfully to adult stages with artificial diets. Before the development of compounded diets, during 1- to 2-week holding periods, wild-caught milkfish fry were fed mashed boiled egg-yolks, good-quality rice bran or wheat flour. Such agricultural products or by-products as rice bran, leaf meal, breadcrumbs or soybean meal are occasionally used for fish grown in nursery or grow-out ponds when there is insufficient growth or depletion of natural foods.

In recent years, efforts have been made to develop prepared diets for milkfish using available information on milkfish nutrient requirements and information derived from other species. Microbound larval diets using carrageenan as a binder were developed. These diets have been used successfully for milkfish larvae in combination with rotifers from day 2 to 14 and solely from day 15 to 21 as a substitute for *Artemia* (Borlongan *et al.*, 2000). Diets for fry have been formulated and used for fish grown in fresh water (Santiago *et al.*, 1983, 1989) and sea water (Alava and Lim, 1988). An example of a practical diet formula for milkfish fry is given in Table 13.3.

During the grow-out phase, milkfish are regarded as a herbivore. Compounded diets containing 23%–27% crude protein have been used successfully for deep-water pond culture of milkfish in Taiwan (Liao and Chen, 1986). Since the milkfish is an efficient feeder and feeds at the bottom of the food chain, natural pond foods make a valuable contribution to its nutrient requirements. Thus, these diets are assumed to be sufficient for satisfactory milkfish growth. A model formula of a practical pond diet for milkfish is presented in Table 13.4.

Adult milkfish, known in the Philippines as *sabalo*, are considered to be omnivores. However, little is known about the diets and feeding of milkfish brood-stock. Milkfish that matured and spawned naturally in floating cages at the SEAFDEC (Southeast Asian Fisheries Development Center) Aquaculture Department in the Philippines were fed with shrimp pellets containing 42%

Table 13.3. Model formula of a practical diet (40% protein) for milkfish fry (modified after Lim, 1991).

Ingredient	Per cent in diet
Fish-meal	30.0
Soybean meal	20.0
Squid meal or shrimp meal	15.0
Wheat flour	25.45
Marine fish-oil	8.0
Vitamin mix*	1.0
Trace mineral mix†	0.5
Antioxidant‡	0.05

* Complete vitamin mix for warm-water fish (NRC, 1993).
† Trace mineral mix should provide the following minerals (mg kg^{-1} diet): manganese, 25: zinc, 80; iron, 60; copper, 5; iodine, 5; cobalt, 0.05; and selenium, 0.04.
‡ Butylated hydroxyanisole or butylated hydroxytoluene.

Table 13.4. Model formula of a practical pond feed (27% protein) for milkfish (modified after Lim, 1991).

Ingredient	Per cent in diet
Fish-meal, anchovy or menhaden	10.0
Soybean meal, 48% protein	34.5
Grains or grain by-products	48.0
Pellet binder*	3.0
Oil	2.0
Dicalcium phosphate	1.5
Vitamin mix†	0.5
Trace mineral mix‡	0.5

* Pellet binder may be hemicellulose or lignin sulphonate.
† Vitamin mix for supplemental diets for warm-water fishes (NRC, 1993).
‡ The same trace mineral mix as that used in practical diets for milkfish fry (Table 13.3).

protein (Lacanilao and Marte, 1980). At present, a 36% protein and 8% lipid with 1% lecithin diet has been developed for milkfish brood-stock. Fed to breeders at the onset of the spawning season, this diet was found to improve the reproductive performance of milkfish (FDS, 1994). At Tung Hsing Hatchery, Pingtung, Taiwan, pond-reared brood-stock were fed with a variety of diets, including rice bran, wheat meal, soybean meal and eel diet (Lin, 1985). At Tungkang Marine Laboratory, Taiwan, a diet consisting of 70% eel diet, 14.75% wheat-germ meal, 14.75% soybean meal and 0.5% vitamin E was used during the spawning season (Chang *et al.*, 1993). Purina trout chow or laboratory-prepared diets containing 32–46% protein have been used successfully at the Oceanic Institute in Hawaii (Kelley and Lee, 1986). In Japara, Indonesia, a 36% protein diet, in which 50% of the protein was supplied by fish-meal, has been used successfully for maturing brood-stock reared in tanks (Poernomo *et al.*, 1985). Thus, in the absence of information on milkfish brood-stock nutrient requirements, the diets for brood-stock should contain a high level of good-quality protein. Also, marine fish-oil rich in PUFA should be included. In addition, the diets should be fortified with extra vitamins and trace minerals. An example of a milkfish brood-stock diet is given in Table 13.5.

Milkfish accept a variety of diets, in meal form and in moist, sinking or floating pellets. Crude feedstuffs are offered in meal form, whereas the compounded diets are usually processed into sinking pellets. Milkfish can use meal-form diets effectively. However, compounded diets should be pelleted to minimize dissolution and separation of nutrients and subsequent waste. Crude diet sources may be uneconomical when pelleted for pond feeding.

Pelleted diets must have desirable physical characteristics, especially water stability and pellet size. The diets must remain water-stable long enough to minimize nutrient loss and diet wastage. Hard and durable pellets are necessary when diets are to be crumbled for feeding smaller fish. The most common pellet

Table 13.5. Model formula of a brood-stock diet (36% protein) for milkfish (modified after Lim, 1991).

Ingredient	Per cent in diet
Fish-meal, anchovy or menhaden	25.0
Soybean meal	34.0
Wheat flour	15.0
Rice bran	20.9
Pellet binder*	3.0
Fish-oil	2.5
Dicalcium phosphate	1.0
Vitamin mix†	1.0
Trace mineral mix‡	0.5

* Pellet binder may be hemicellulose or lignin sulphonate.
† Complete vitamin mix for warm-water fishes (NRC, 1993).
‡ The same trace mineral mix as that used in practical diets for milkfish fry (Table 13.3).

size used for feeding milkfish to marketable size (400 to 500 g) is approximately 4–5 mm in diameter and 6–8 mm long. Diets in meal or crumbled forms of different particle sizes are used for fry and fingerlings.

Feeding Practices

Feeding rates for milkfish are affected by size, water quality (such as temperature, salinity and dissolved oxygen), feeding frequency, and nutrient density of the diets, especially energy content. As with other fish, the feed consumption rate of milkfish is inversely related to fish size. For example, with a diet containing 40% protein and 3450 kcal of metabolizable energy (ME) kg^{-1}, a daily feeding rate of 20% of the biomass is optimum for 7.7 mg milkfish fry reared under laboratory conditions (Lim, 1978). For fish averaging 0.60 g, feeding at 9% of the body weight resulted in a 130% increase in weight gain over the 5% feeding rate (Chiu *et al.*, 1986). In pond environments where natural food is present, milkfish grown to marketable size are fed with commercial pellets containing 23–27% protein at a daily rate of 3–4% of body weight (Benitez, 1984).

Milkfish, like most other species, benefit from multiple daily feedings. The growth and feed efficiency of 0.6 g fingerlings fed at 5% or 9% of body weight increased by about 20% when the feeding frequency was increased from four to eight times daily (Chiu *et al.*, 1986). Under pond conditions, milkfish are normally fed two to three times daily (Liao and Chen, 1986). Diets are offered to fish by hand or by automatic feeders. The latter are commonly used in Taiwan and in intensive culture in the Philippines. Automatic feeders equipped with one or two pipes extending toward the pond are installed on the dikes. The feeders contain devices that can be adjusted to deliver measured quantities of diets at given time intervals. The pond bottom of the feeding area is checked 1 h after feeding for the purpose of adjusting diet allowances.

References

Alava, V.R. and De la Cruz, M.C. (1983) Quantitative dietary fat requirement of *Chanos chanos* fingerlings in a controlled environment. Paper presented at the Second International Milkfish Aquaculture Conference, Iloilo, Philippines, 4–8 October 1983.

Alava, V.R. and Lim, C. (1988) Artificial diets for milkfish, *Chanos chanos* (Forsskal), fry reared in sea water. *Aquaculture* 71, 339–346.

Bagarinao, T. (1999) *Ecology and Farming of Milkfish*. SEAFDEC Aquaculture Department, Tigbauan, Iloilo, the Philippines, 171pp.

Bautista, M.N. and de la Cruz, M.C. (1988) Linoleic (ω6) and linolenic (ω3) acids in the diet of fingerling milkfish (*Chanos chanos* Forsskal). *Aquaculture* 71, 347–358.

Benitez, L.V. (1984) Milkfish nutrition. In: Juario, J.V., Ferraris, R.P. and Benitez, L.V. (eds) *Advances in Milkfish Biology and Culture*. Island Publishing House, Manila, pp. 133–143.

Benitez, L.V. and Gorricita, I.R. (1983) Lipid composition of milkfish grown in ponds by traditional aquaculture. In: Cho, C.Y., Cowey, C.B. and Watanabe, T. (eds) *Finfish Nutrition in Asia – Methodological Approaches to Research and Development*. IDRC-233e, Ottawa, Canada, pp. 145–151.

Borlongan, I.G. (1992a) Dietary requirement of milkfish (*Chanos chanos* Forsskal) juveniles for total aromatic amino acids. *Aquaculture* 102, 309–317.

Borlongan, I.G. (1992b) The essential fatty acid requirement of milkfish (*Chanos chanos* Forsskal). *Fish Physiology and Biochemistry* 9, 401–407.

Borlongan, I.G. and Coloso, R.M. (1993) Requirements of juvenile milkfish (*Chanos chanos* Forsskal) for essential amino acids. *Journal of Nutrition* 123, 125–132.

Borlongan, I.G. and Coloso, R.M. (1994) Leaf meals as protein sources for milkfish, *Chanos chanos* (Forsskal). In: De Silva, S.S. (ed.) *Fish Nutrition Research in Asia, Proceedings of the Fifth Asian Fish Nutrition Workshop*. Asian Fisheries Society Special Publication No. 9, Asian Fisheries Society, Manila, the Philippines, pp. 63–68.

Borlongan, I.G., Marte, C.L. and Nocillado, J.N. (2000) Development of larval diet for milkfish (*Chanos chanos*). *Journal of Applied Ichthyology* 16, 68–72.

Camacho, A.S. and Bien, N. (1983) Studies on the nutrient requirement of milkfish *Chanos chanos* (Forsskal). Paper presented at the Technical Symposium on Aquaculture, University of the Philippines in the Visayas, Iloilo, the Philippines, 19 February 1983.

Chang, S.L., Su, M.S. and Liao, I.C. (1993) Milfish fry production in Taiwan. In: Lee, C.S., Su, M.S. and Liao, I.C. (eds) *Fish Hatchery in Asia, Proceeding of the Finfish Hatchery in Asia '91*. Oceanic Institute, Honolulu, Hawaii, pp. 157–171.

Chen, T.P. (1976) *Aquaculture Practice in Taiwan*. Fishing News Books, Farnham, Surrey, England, 162 pp.

Chiu, Y.N., Sumagaysay, N.S. and Sastrillo, M.A.S. (1986) Effect of feeding frequency and feeding rate on the growth and feed efficiency of milkfish *Chanos chanos* Forsskal juveniles. *Asian Fisheries Science* 1, 27–31.

Coloso, R.M., Benitez, L.V. and Tiro, L.B. (1988) The effect of dietary protein-energy levels on growth and metabolism of milkfish (*Chanos chanos* Forsskal). *Comparative Biochemistry and Physiology* 89A, 11–17.

Crear, D. (1980) Observations on the reproductive state of milkfish populations *Chanos chanos* from hypersaline ponds on Christmas Island (Pacific Ocean). In: Avault, J.W. Jr (ed.) *Proceedings World Mariculture Society*, Vol. 21. Louisiana State University, Baton Rouge, Louisiana, pp. 548–556.

FDS (Feed Development Section) (1994) *Feed and Feeding of Milkfish, Nile Tilapia, Asian Sea Bass, and Tiger Prawn*. Aquaculture Extension Manual No. 21, SEAFDEC Aquaculture Department, Tigbauan, Iloilo, the Philippines, 97 pp.

Ferraris, R.P., Catacutan, M.R., Mabelin, R.L. and Jazul, A.P. (1986) Digestibility in milkfish, *Chanos chanos* (Forsskal): effects of protein source, fish size and salinity. *Aquaculture* 59, 93–105.

Kanazawa, A. (1985) Nutritional factors in fish reproduction. In: Lee, C.S. and Liao, I.C. (eds) *Reproduction and Culture of Milkfish*. Oceanic Institute, Waimanalo, Hawaii, pp. 115–125.

Kelley, C. and Lee, C.S. (1986) Artificial propagation. In: Lee, C.S., Gordon, M.S. and Watanabe, W.O. (eds) *Aquaculture of Milkfish (*Chanos chanos*): State of the Art*. Oceanic Institute, Waimanalo, Hawaii, pp. 83–116.

Lacanilao, F.L. and Marte, C.L. (1980) Sexual maturation of milkfish in floating cages. *Asian Aquaculture* 3, 4–6.

Lee, C.S. (1995) *Aquaculture of Milkfish (*Chanos chanos*)*. Oceanic Institute, Hawaii, 141 pp.

Lee, C.S. and Banno, J. (1990) Milkfish culture and production in Southeast Asia – present and future. In: *Proceedings, Regional Workshops on Milkfish Culture and Production in Southeast Asia – Present and Future*. Tarawa, Kiribati, pp. 43–65.

Lee, D.L. and Liao, I.C. (1976) A preliminary study on the purified test diet for young milkfish, *Chanos chanos*. In: *Proceedings, International Milkfish Workshop Conference*. Tigbauan, Iloilo, the Philippines, pp. 104–120.

Liao, I.C. and Chen, T.I. (1986) Milkfish culture methods in Southeast Asia. In: Lee, C.S., Gordon, M.S. and Watanabe, W.O. (eds) *Aquaculture of Milkfish (*Chanos chanos*): State of the Art*. Oceanic Institute, Honolulu, Hawaii, pp. 209–238.

Lim, C. (1978) Effect of feeding rate on the survival and growth of milkfish (*Chanos chanos*) fry in a controlled environment. In: *SEAFDEC Aquaculture Department Quarterly Research Report II (4)*. Tigbauan, Iloilo, the Philippines, pp. 17–19.

Lim, C. (1991) Milkfish, *Chanos chanos*. In: Wilson, R.P. (ed.) *Handbook of Nutrient Requirements of Finfish*. CRC Press, Boca Raton, Florida, pp. 97–104.

Lim, C., Sukhawongs, S. and Pascual, F.P. (1979) A preliminary study on the protein requirements of *Chanos chanos* (Forsskal) fry in a control environment. *Aquaculture* 17, 195–201.

Lin, L.T. (1985) My experience in artificial propagation of milkfish – studies on natural spawning of pond reared broodstock. In: Lee, C.S. and Liao, I.C. (eds) *Reproduction and Culture of Milkfish*. Oceanic Institute, Waimanalo, Hawaii, pp. 185–203.

Ling, S.W. (1977) *Aquaculture in Southeast Asia – a Historical Overview*. University of Washington Press, Seattle, Washington, 108 pp.

Minoso, M.G., Borlongan, I.G. and Satoh, S. (1999). Essentiality of phosphorus, magnesium, iron, zinc and manganese in milkfish diets. *Fisheries Science* 65, 721–725.

NRC (National Research Council) (1993) *Nutrient Requirements of Warmwater Fishes and Shellfishes*. National Academy Press, Washington, DC, 102 pp.

NRC (National Research Council) (1993) *Nutrient Requirements of Fish*. National Academy Press, Washington, DC, 114 pp.

Pamplona, S.D. and Mateo, R.T. (1985) Milkfish farming in the Philippines. In: Lee, C.S. and Liao, I.C. (eds) *Reproduction and Culture of Milkfish*. Ocean Institute, Honolulu, Hawaii, pp. 141–163.

Pascual, F.P. (1984) The energy-protein requirement of *Chanos chanos* fingerlings. Poster paper presented during the International Symposium on Feeding and Nutrition in Fish, 10–13 July 1984, University of Aberdeen, UK.

Poernomo, A., Lim, C., Vanstone, W.E., Daulay, T. and Anindiastuti (1985) Maturation of captive milkfish (*Chanos chanos*) in tanks. In: Lim, C. (ed.) *Fish Nutrition and Feed Technology Research in Indonesia*. Research Institute for Freshwater Fisheries, Central Research Institute for Fisheries, Agency for Agricultural Research and Development, Jakarta, Indonesia, pp. 78–103.

Ronquillo, I.A. (1975) Biological studies on bangos (*Chanos chanos*). *Philippine Journal of Fisheries* 9, 18–37.

Samsi, S. (1979) Effects of various protein sources on the growth and survival rates of milkfish (*Chanos chanos* Forsskal) fingerlings in a controlled enviroment. MSc thesis, University of the Philippines in the Visayas, Iloilo, the Philippines.

Santiago, C.B., Banes-Aldaba, M. and Sungalia, E.T. (1983) Effect of artificial diets on growth and survival of milkfish fry in fresh water. *Aquaculture* 34, 247–252.

Santiago, C.B., Pantastico, J.B., Baldia, S.F. and Reyes, O.S. (1989) Milkfish (*Chanos chanos*) fingerling production in freshwater ponds with the use of natural and artificial feeds. *Aquaculture* 77, 307–318.

Sastrillo, M.A. (1980) Methionine requirement of milkfish (*Chanos chanos* Forsskal) juveniles. MSc thesis, University of the Philippines in the Visayas, Iloilo, the Philippines, 38 pp.

Sumagaysay, N.S., Marquez, F.E. and Chiu-Chern, Y.N. (1991) Evaluation of different feeds for milkfish (*Chanos chanos*) reared in brackishwater ponds. *Aquaculture* 93, 177–189.