GENERAL INTRODUCTION

The need for substantial increase in the world's supply of animal protein has generated greater interest in aquaculture of finfish, shrimps and other aquatic organisms. Fish ranks first among the farm animals in terms of protein yield per unit food intake. The rearing of fish at high stocking levels necessitates a detailed study of their nutritional requirements in order to produce feeds that, besides being cost-effective, are nutritionally adequate for their growth. In recent years, therefore, much attention has been focussed on finfish nutrition and considerable efforts have been expanded to the development of formula feeds for a number of cultivable species as evidenced by increasing amount of literature in the form of published papers and reviews (Castell, 1979; Cowey, 1979; Cowey and Sargent, 1972, 1979; Cowey and Stevenson, 1979; Halver, 1979a,b; Nose, 1979; Nose and Arai, 1979; Ogino, 1979; Chow, 1982; NAS-NRC, 1981, 1983; Jauncey, 1982a; Ketola, 1982; Millikin, 1982a; Watanabe, 1982; Cowey and Luquet, 1983; Takeuchi et al., 1983; Robinson and Lovell, 1984a; Cho et al., 1985; Cho and Kaushik, 1985; Halver, 1985; Kanazawa, 1985; Tacon and Cowey, 1985; New, 1986; Wilson and Halver, 1986; Yamada, 1986; Bowen, 1987; Halver, 1989; Kaushik et al., 1989; Lall, 1989a; Lovell, 1989; Piper et al., 1989; Sargent et al., 1989; Wilson, 1989; and Tacon, 1990).
Since protein constitutes in fish culture the single most expensive item in artificial feeds, it is logical to incorporate only that much which is necessary for normal maintenance demand and growth. Any excess is considered wasteful, biologically as well as economically. Diet development for particular species therefore, requires a precise assessment of its protein needs which determines, to a large extent, the overall success of its production. Halver and his colleagues (DeLong et al., 1958), working on chinook salmon with diet containing casein, gelatin and crystalline amino acids, simulating the amino acid profile of whole egg protein, were the first to give the definition of optimum protein requirement as minimum protein needed by the fish for maximum weight gain. The pioneering work of Halver and his colleagues provided the basic model for subsequent studies on the protein nutrition of a number of fish species like channel catfish, Ictalurus punctatus (Lovell, 1972; Page and Andrews, 1973; Prather and Lovell, 1973; Lovell, 1975; Garling and Wilson, 1976), coho salmon, Oncorhynchus kisutch (Zeitoun et al., 1974); common carp, Cyprinus carpio (Ogino and Saito, 1970; Takeuchi et al., 1979); estuary grouper, Epinephelus salmoides (Teng et al., 1978); gilthead bream, Chrysophrys aurata (Sabaut and Luquet, 1973); grass carp, Ctenopharyngodon idella (Dabrowski, 1977); largemouth bass, Micropterus salmoides (Anderson et al., 1981); milkfish, Chanos chanos (Lim et al., 1979); plaice, Pleuronectes platessa.
(Cowey et al., 1972); puffer fish, Fugu rubripes (Kanazawa et al., 1980); rainbow trout, Salmo gairdneri (Halver et al., 1964; Zeitoun et al., 1973; Satia, 1974; Austreng and Refstie, 1979); red sea bream Chrysophrys major (Yone, 1976); smallmouth bass, Micropterus dolomieu (Anderson et al., 1981); snakehead, Channa micropeltes (Wee and Tacon, 1982); sockeye salmon, Oncorhynchus nerka (Halver et al., 1964); striped bass, Morone sexatilis (Millikin, 1982; Berger and Halver, 1987); tilapia, Tilapia aurea (Davis and Stickney, 1978; Winfree and Stickney, 1981; Toledo et al., 1983); Tilapia nilotica (Santiago et al., 1982; De Silva and Perara, 1985; Teshima et al., 1985; Wang et al., 1985; Wanningama et al., 1985); Tilapia zillii (Teshima et al., 1978; Mazid et al., 1979); Tilapia mossambica (Jauncey, 1982); yellowtail, Seriola quinqueradiata (Takeda et al., 1975); grey mullet, Mugil capito (Papaparesekeva- Papoutsoglou and Alexis, 1986); catfish, Clarias batrachus (Chuapoehuk, 1987; Khan and Jafri, 1990); Heteropneustes fossilis (Akand et al., 1989); white sturgeon, Acipenser transmontanus (Moore et al., 1988); Japanese eel, Anguilla japonica (Nose and Arai, 1972); and European eel, Anguilla anguilla (Higuera et al., 1989). Recently, the least-cost dietary protein requirement for four different species of young tilapia have been evaluated by De Silva et al. (1989). Although the approach used by various workers has changed little, if at all, the use of maximum tissue protein retention or nitrogen balance in preference to weight gain as criterion of requirement has been suggested by few (Ogino,
A critical review of the methods used for estimating dietary protein and amino acid requirements in fish has been made by Tacon and Cowey (1985) and Kaushik (1988). Several protein sources, natural (fish meal, soybean meal) or purified (casein, albumin and gelatin), either alone or supplemented with free amino acids, have been used for evaluating the dietary protein requirements of fish, since no single protein is considered ideal in satisfying all the requirements of the animal.

Results of most protein requirement studies indicate that fish need relatively high (35 - 55%) protein for their growth (NAS-NRC, 1981, 1983; Tacon and Cowey, 1985; Wilson and Halver, 1986; and Moore et al., 1988). This high dietary protein requirement in fish is generally attributed to preferential use of protein over carbohydrate as a dietary energy source (Cowey, 1975). The optimum level of protein in the diets is, however, influenced by factors such as the balance of essential amino acids, protein digestibility and protein:energy ratio in the diet, besides temperature of water, salinity, stage of growth of the fish and species, and availability of natural food, etc. (Mertz, 1969; Ringrose, 1971; Lee and Putnam, 1973; Zeitoun et al., 1973; Satia, 1974; Cowey and Luquet, 1983; and De Silva and Perara, 1984, 1985).

Information on the amino acid requirement constitute an equally important aspect in nutrition and feed formulation of a species.
The quantitative amino acid requirement is the minimum amount of amino acid that gives the maximum growth rate. An excess supply of essential amino acids over the optimum required by fish may not necessarily increase its utilization (Halver et al., 1957). Fish, like other animals, have a requirement for a well-balanced mixture of essential and non-essential amino acids. A proper balance and quantity of essential nitrogen in the form of essential amino acids may reduce the requirement of non-essential nitrogen component, thereby, reducing the overall nitrogen requirement in fish. A deficiency in one or more essential amino acids may cause poor growth and lack of appetite (Mertz, 1972).

Development of first successful amino acid test diet for chinook salmon by Halver (1957) enabled a number of workers to study the essentiality of various amino acids in other fish species (Halver and Shanks, 1960; Shanks et al., 1962; Dupree and Halver, 1970; Arai et al., 1972; Nose et al., 1974; and Mazid et al., 1978). Later studies on quantitative amino acid requirements were mostly based on the test diets in which the nitrogen component consisted either of all crystalline amino acids or a mixture of amino acids with selected whole protein source, commonly casein and gelatin (DeLong et al., 1962; Chance et al., 1964; and Halver, 1965), zein (Dabrowski, 1981) or gluten (Halver et al., 1958; Ketola, 1983), the amino acid profile of the total protein component of the diet being controlled so as to simulate the amino acid pattern of
a specific reference protein. To assure the maximum utilization of the amino acids, such diets contained protein at or slightly below the optimum requirement. Measurements of essential amino acid requirement has largely been based on dose-response curve obtained by feeding graded levels of each amino acid in the test diet. On the basis of observed growth response plotted over this curve, dietary requirement is usually taken at the 'break-point'. In newer techniques, free amino acid levels within specific tissue pools, whole blood, blood plasma or muscle (Kaushik, 1979) or oxidation of radio-active labelled amino acids administered orally or by injection (Walton et al., 1982) were used as criteria for estimating the dietary amino acid requirements of fish. Using diet containing a whole protein source of high biological value, Ogino (1980) determined the quantitative essential amino acid requirement of fish on the basis of the daily deposition of individual amino acids within its carcass. Tacon and Cowey (1985) referred to a similarity between the relative proportions of individual amino acids required in the diet and that of the same 10 essential amino acids present within the fish carcass. Wilson and Poe (1985) obtained a strong regression coefficient when essential amino acid requirement of the channel catfish was regressed against the whole body essential amino acid profile.

Although quantitative essential amino acid requirements have been worked out for many fish species (Halver, et al., 1958; Halver,
Aquaculture nutrition is concerned with the supply of dietary nutrients to fish either directly in the form of an artificial diet or indirectly through the increased production of natural live food organisms. Within the intensive culture systems, the natural food organisms play little or almost no role in the nutrition of the farmed species. This necessitates feeding fish with artificial diet which becomes the single most critical and expensive commodity in the entire culture operation. Lovell (1989) has exhaustively
reviewed the importance of diet in fish husbandry. The use of compounded feeds in fish culture has been attempted and emphasized by several workers in the past who have tested the efficacy of such diets for various fish species (Reinitz et al., 1978; Reinitz and Hitzel, 1980; Bryant and Matty, 1981; Dabrowski and Kozlowska, 1981; Jafri et al., 1981; Viola et al., 1981; 1982, Higgs et al., 1982; Jackson et al., 1982, 1984; Dabrowski et al., 1983; Hardy and Sullivan, 1983; Santiago et al., 1983; Tacon et al., 1983\textsuperscript{a,b}; Viola and Arieli, 1983\textsuperscript{a,b}; Abel et al., 1984; Akiyama et al., 1984; Charlon and Bergot, 1984; Niamat and Jafri, 1984\textsuperscript{a,b}; Ofozekwu and Ejike, 1984; Robinetti, 1984; Robinson et al., 1984; Winfree and Stickney, 1984; Alexis et al., 1985; Asgard and Austrang, 1985, 1986; Campbell, 1985; Cho et al., 1985; Crampton, 1985; Cuzon, 1985; Dabrowski and Kaushik, 1985; Robinson et al., 1985; Uys and Hecht, 1985; Merola and Comtelmo, 1987; Hossain and Jauncey, 1989; Piper et al., 1989 and Nandeesha et al., 1991).

A balanced formula for fish diet must include an energy source plus sufficient indispensable amino acids, fatty acids, specific vitamins, and minerals to sustain life activities and promote growth (Halver, 1976\textsuperscript{b}. The available energy level in feed is of prime importance. Too much energy in feed is wasteful and may result in excess fat deposition in fish and limit feed consumption. When feed is deficient in energy, protein and other nutrients are not utilized to their fullest potential for growth. The information on proximate
composition and energy content of feed ingredients is, therefore, essential to formulate nutritionally balanced diets.

With increase in the knowledge of the nutritional needs of the species, cost-effective dietary formulations can be developed, provided the information regarding the cost, nutrient content and its availability to the fish and minimum-maximum restrictions on levels of various ingredients are known. For a successful diet development strategy, the nutrients contributed by each feedstuff should be identified to ensure a meaningful purpose of its selection. Any nutrient in a particular feedstuff, such as an amino acid, is just as valuable as the same nutrient in any other feedstuff and this allows the interchange of one feedstuff with the other as cost and availability change. Feedstuffs are compared with one another on the basis of cost per unit protein, energy or amino acid. Thus, there is no ideal formulation but rather an almost infinite number of possible feed formulations that can effectively meet the nutritional needs of the fish. Better production and increased growth performance of fish is, however, tied up with proper selection and combination of feed ingredients, so as to meet the requirement of essential dietary nutrients. Although cheap availability and nutritional richness of several feedstuffs and many agricultural byproducts facilitate fish diet formulation, the presence of anti-nutritional factors and toxins in some plant origin feedstuffs may depress fish growth, if not properly inactivated. Ingredients
used in fish feed formulations are both of animal and plant origin, the former includes byproducts of fish, shrimp, meat and poultry industries and wastes from slaughterhouse, and the latter feedstuffs of plant origin. With the exception of fish meal, which has a well-balanced essential amino acid profile, majority of protein sources exhibit amino acid imbalances that make them unsuitable as a sole dietary protein. Feedstuffs are, therefore, mixed to obtain the desired essential amino acid profile.

Although fish cultivation in India is an age-old practice, basic nutritional studies on fish are relatively few. Some information is available on the gross protein requirement of Indian major carps and catfishes (Jayaram, 1978; Sen et al., 1978; DARE, 1984; Renukaradhya and Varghese, 1986; Singh and Bhanot, 1988; Swami et al., 1988; and Akand et al., 1989). Niamat (1985) has worked out the essentiality of arginine, lysine and tryptophan in purified diets for the catfish, Heteropneustes fossilis. However, no published data is available on the quantitative amino acid requirements of these fishes, hampering efforts to translate the information to least-cost practical diets. Efforts of several organizations, including some of governmental agencies, were directed towards developing nutritionally adequate fish feeds and scanning new economical feed ingredients (DARE, 1984). The need for initiating diet development program, using locally available ingredients, for carp polyculture in India was stressed

The present study was undertaken with a view to obtaining information on the protein and amino acid requirements of some Indian cultivable finfish species, and testing the efficacy of formulated feeds on these fishes.

The study is presented in the thesis in two parts.

Part I deals with the protein and amino acid requirements of the Indian major carps and a cultivable catfish.

Part II embodies information on the efficacy of the feeds formulated using locally available feedstuffs.

The study provides basic information which could be of interest to fish nutritionists in undertaking diet development programme for these fishes.