CHAPTER ONE

GENERAL INTRODUCTION AND REVIEW OF LITERATURE
1. **GENERAL INTRODUCTION AND REVIEW OF LITERATURE**

Fish production is a direct function of survival and growth (Rounsefell and Everhart, 1966). Intensive fish culture aims at realising these objectives. It has been well recognised that feeding forms an integral part of the management measures resorted to attain higher productions in fish culture. Natural fish food production being limited inspite of efforts to increase the inherent fertility of the pond, the need to supplement the energy required for growth to the large number of fishes introduced per unit area in intensive fish culture is imperative.

Energy required for growth, both somatic and gonadal, has to come through the food ingested. Energy for growth is channelised only after meeting the sustenance demand. While undernourishment leads to depression in fish growth, overnourishment leads to wastage of food. Hora and Pillay (1962) have stated that while an austerity diet keeps the fish stunted providing only sustenance energy, a richer diet favours rapid growth. Therefore, proper feeding at not only optimum levels but also optimum in quality is essential in artificial feeding. Hence the need to provide complete and 'balanced' feed assumes importance.
Evolving a 'balanced' feed has to be through an evaluation of the requirements of the food constituents which vary with the species, size and stages in the life cycle. Devaraj (1976) has outlined the role played by balanced feeds in increasing fish production in intensive fish culture. Furukawa (1976) opined that development of feeding facilities and formulation of diets of reasonable price and high efficiency is one of the technical problems facing the future development of aquaculture in Japan (see also Dillon, 1976). Bhanot and Gopalakrishnan (1973) have highlighted studies on basic nutrition and physiology as of primary importance. Lovell (1976a) has indicated that information on nutrient requirements of the animal as one of the factors for determining the minimum cost feed formulations. Sneed et al. (1972) have opined that with the need to increase fish production, feeds must be designed for realising maximum growth which has to take cognizance of the nutritional requirements.

Studies made in this direction have been principally through assessment of the actual requirements using purified test diets by varying the particular component desired to be known, and through compounding of ingredients of vegetable and animal origin and testing their relative efficiencies correlating proximate composition with fish growth (Shell, 1968).
There have been attempts at evolving and evaluating cheap and 'balanced' artificial feeds (Lakshmanan et al., 1968; Chakraborty et al., 1973; Devaraj, 1976; Devaraj and Keshavappa, 1980, 1983; Devaraj et al., 1981, Singh and Sinha, 1981) for use in fish culture ponds in India. The studies related mostly to mixing ingredients of both plant and animal origin and ascertaining the effects of protein, carbohydrate and fat on growth of test fishes. Such formulations were not based on an initial understanding of the nutrient requirements of carps. Sen et al. (1978), Verghese et al. (1976) and Singh and Sinha (1981) later worked out the requirements of protein and carbohydrates for the fry and fingerlings of carps in India. While the former used purified test diets, the latter experimented with formulated diets. The merits of components of plant and animal origin singly and in combination were not, however, dealt with.

During the present studies, it was intended, therefore, to study the growth trends in fry and fingerlings of two selected Indian major carps, rohu (Labeo rohita Ham.) and mrigal (Cirrhinus mrigala Ham.) and the exotic common carp (Cyprinus carpio Ham.) fed on casein-based purified diets in experiments conducted in cement cisterns, initially to assess the basic requirements of protein at the gross level (the experiments restricted to fry of common carp and mrigal, and fingerlings of common carp and rohu) under the local temperature regime which was different from that recorded in the
earlier work. Formulated diets using ingredients of plant and animal origin exhibiting varying levels of protein were to be tested keeping growth as the index. The optimum level of feeding in realising the maximum growth in fry of rohu was also intended to be ascertained.

Lovell (1980a) has stated that purified diets are moist diets stored frozen. Indicating the specifications of research diets, he emphasized the need for all research diets to be purified, alike in all respects, palatable, feedable, nutritionally complete and as far as possible made from purified ingredients. Purified diets have been used for ascertaining the nutritional requirements of salmon and trouts (Halver, 1972, 1980), channel catfish (Jewell et al., 1933; Nail, 1962; Dupree, 1960; Krishandhi and Shell, 1965; Tiemeier et al., 1964, 1965), Japanese eel (Arai et al., 1971; Nose and Arai, 1972), tilapia (Jauncey and Ross, 1982) and Indian major carps (Sen et al., 1978; Mahajan and Yadave, 1974).

Krishandhi and Shell (1965) in their studies, have demonstrated the superiority of casein over purified soybean protein. Work carried out at the South-easterly Fish Cultural Laboratory in North America has also indicated the superiority of casein over soybean protein or gluten in promoting growth in channel catfish (Shell, 1966). Lovell (1980a) indicated casein and gelatin (5:1) as a good protein combination for
purified diets, vitamin-free casein for vitamin studies, blood fibrin for mineral studies and suggested that egg protein could be used in experiments where quantitative protein requirements have to be varied. Mahajan and Yadave (1974) formulated synthetic diet with casein as the base in their studies on the growth of three-week old common carp till the ninth week of their early part of life. Sen et al. (1978) prepared purified test diets showing varying levels of protein by suitable manipulation in the casein-dextrin ratio and tested on spawn, fry and fingerlings of rohu, mrigal and common carp for the first time in India.

Hickling (1971) and Jhingran (1975) have enumerated that ready acceptability and easy digestibility are qualities required in a feasible fodder.

Ingredients such as mill by-products, oil extractions, animal by-products, brewer's yeast have been variously used in fish feed manufacture in the United States (Raven and Walker, 1980). Shell (1968) considers the use of mixtures of animal and vegetable products in feeding gold fish as early as 1946 in North America as the beginning of experimentation in nutrition of warm-water fishes. Hora and Pillay (1962) reviewing the practices of feeding fish in the Indo-Pacific region stated that artificial foods are of vegetable or animal origin depending on the feeding habits of the fish and the training given to accept a particular type of food.
Oil cakes of peanut and soybean, soybean milk, bean meal, barley, oats, wheat, wheat flour, wheat bran, rice bran as feeds of vegetable origin and fresh, dried, defatted silkworm pupae, flesh of snails, mussels, clams, shrimps, fish meal, slaughter house wastes as feed of animal origin are used in the region.

The principal nutrient factors that determine the quality of the supplementary feed favouring growth of fishes are proteins, carbohydrates, fats (lipids), vitamins, minerals and trace elements. The first three form the food sources of energy required for metabolic activities. Besides the quality, the level of these constituents in the feed, decide their usefulness (Halver, 1976).

Proteins help in the tissue building activity in animals. They are large, complex molecules containing either all or majority of the amino acids. Fish, like other animals, has to depend on the food for the supply of the amino acids required. As such, proteins form the most important component of the food. Protein ingested is broken down into amino acids through hydrolysis and these are distributed by the blood to the various tissues of the body where they are reconstituted into proteins. Inadequacy of protein in the diet reduces growth rate leading to cessation or results in loss of weight because of withdrawal of protein from other tissues for maintaining more vital functions of the fish.
Excess protein might result in its being used as a source of energy (Steffens, 1981). Protein is the costliest ingredient of the feed and its use for purposes other than tissue building is not desired if economic fish productions are to be obtained in culture fishery operations. Maximum utilization of protein by fish depends, among other factors, on the levels of other food components present in the diet which serve as sources of energy. The most economical source of protein is from natural feedstuffs. Though both plant and animal protein are efficiently converted into fish flesh by fish, animal proteins in general are more easily digestible. Nose and Toyama (1966) and Nomura et al. (1973) have shown that protein types differ from one another.

Nutritionally, the 23 amino acids isolated from natural proteins are divided into dispensable and indispensable amino acids (Halver, 1972, 1980). Fish requires all the ten indispensable (essential) amino acids which they cannot synthesise and gross deficiency in any one of these results in poor growth even if protein level is high. Fishes exhibit a relatively higher need of amino acids (Mertz, 1972) and hence require higher levels of dietary proteins (Steffens, 1981). Ogino and Saito (1970) showed this to be true for common carp. The presence of dispensable amino acids in the diet reduces the need for the fish to synthesise them (National Research Council, 1983).
Fish require a well balanced mixture of dispensable and indispensable amino acids. Precisely for this, proteins from different sources are mixed while formulating practical diets for fish. To correct the amino acid inadequacies in feed formulations, either proper combination of protein sources are selected to meet the recommended amino acid composition or the diet is supplemented with synthetic amino acids or excessive amounts of protein are provided.

Singh et al. (1979, 1980) recorded higher growth rate in mrigal and rohu fingerlings and observed that both quantity and quality of proteins are important for the growth of rohu. They also showed the influence of temperature on protein synthesis in rohu where the growth nearly doubled at 28°C from the rate at 20°C.

Fish utilize carbohydrates available in the diets as either easily digestible sugars or as complex cellulose molecules as source for energy. It is the least expensive form of dietary energy and helps in pelleting quality of practical fish diets. In fact, optimal levels of carbohydrate spares protein and this is referred to as the 'protein sparing action' of carbohydrates (Tiemeier et al., 1965). Higher levels of dietary digestible carbohydrate may lead to death through accumulation of glycogen in the liver as shown by Phillips et al. (1948) in trout. Carbohydrates are absorbed as simple sugars. Common carp utilize higher
levels of dietary carbohydrates (Ogino et al., 1976; Shimano et al., 1977; Sen et al., 1978; Takeuchi et al., 1979; Furuichi and Yone, 1980; Likimani and Wilson, 1984). This was also true for the fry and fingerlings of rohu (Sen et al., 1978). Diets containing over 40 per cent dextrin resulted in low feed efficiency and growth retardation in common carp (Furuichi and Yone, 1980).

Utilization of dietary carbohydrate in fishes appears to differ with their complexity. Being a partially hydrolysed polysaccharide, dextrin is shown as more digestible than starch in warm-water fishes (Singh and Nose, 1967). Lovell (1980a) observed to the contrary. Anderson et al. (1984) stated that with addition of assimilable carbohydrate, growth increases in juvenile tilapia (Aureochromis niloticus). Common carp has higher digestibility for rice and wheat bran (Bondi et al., 1957). Rohu and mrigal fingerlings exhibit high digestibility of carbohydrates (Singh et al., 1986).

It is felt that fish species that can readily adopt to high carbohydrate diets and convert the excess energy into lipids are much more efficient in carbohydrate utilization than those that lack that ability.

Fat calories help spare protein for growth, improving net protein utilization (NPV). Steffens and Albrecht (1973, 1975) and Steffens (1977) have shown in trout that increasing dietary fat level would improve the growth rate and protein
utilization when fed on a diet of reduced protein content. Sneed et al. (1972) reviewing the work on the requirement of various feeds for channel catfish, stated that fats are better utilized by fishes in warm waters than carbohydrates.

Dietary lipids are fatty acid esters of glycerol. These would help in the absorption of fat-soluble vitamins and decide the flavour and textural properties of the feed. Fish fat contains numerous poly-unsaturated fatty acids belonging to the linolenic (w3) group. Environmental factors like temperature and salinity, seasonal variation, maturity and diet composition affect the essential fatty acid (EFA) composition of fishes.

Watanabe et al. (1981) attributed lowest growth rate in carp (Cyprinus carpio) receiving the diet without supplement of lipid to lower calorie content and the absence of EFA. The best conversion and weight gains are observed in fish receiving a diet containing both 1 per cent 18:2 w6 and 1 per cent 18:3 w3 fatty acids. Dietary lipids affect more through muscle, plasma and erythrocyte fatty acid compositions in common carp. Factors important in evaluating a dietary lipid are digestibility, the presence of any toxic material in a particular oil, the degree of oxidation present, or the possibility of auto-oxidation in the case of unsaturated oils, the content of fatty acids essential for the particular species and the level of fat the animal can tolerate.
Vitamins are organic compounds required in trace amounts in the function of most forms of life but which some organisms are unable to synthesise. Natural food provides the required vitamins to fishes in extensive fish culture. But, where large numbers are involved, as in intensive culture, vitamins are to be provided as premix for proper growth of fishes along with the supplementary feed. The levels of each of the vitamins in the pelleted diet should be higher than the required level to overcome the loss of certain vitamins (oxidation of ascorbic acid) during feed manufacture and storage and to overcome the problem of reduced availability of vitamins due to the presence of anti-nutritional factors in the feed.

The quantitative and qualitative requirements of vitamins for warm-water fishes have been experimentally determined. Factors affecting vitamin requirements are size, age and rate of growth of fishes, environmental factors and nutrient relationships. Vitamins essentially needed in the diets of common carp if not available result in fin congestion, nervousness, loss of colour, skin and fin haemorrhages, exophthalmia, warped operculum, muscular dystrophy and mortality.

Vitamins are broadly grouped as water-soluble and fat-soluble. The former group includes vitamins of B-complex and vitamin C, while the latter has vitamins A, D, E and K.
Water-soluble vitamins are metabolized readily and excreted when intake exceeds storage capacity. As such, hyper-vitaminosis of water-soluble vitamins does not occur while it may happen with fat-soluble vitamins. Deficiency of vitamin C in rohu grown in ponds leads to bone diseases (Singh and Radheshyam, Ms). Both water-soluble and fat-soluble vitamins are shown as required for healthy growth of mrigal fry and fingerlings by Singh and Sinha (1981). Addition of multi-vitamin tablets to the conventional feed mixture of groundnut oil cake and rice bran increased the food intake, feed conversion and growth in rohu fingerlings. Survival and growth of spawn and fry of Indian major carps increased when provided with vitamin B complex and yeast. This is attributed by Singh et al. (1980) to greater acceptability and conversion of feeds.

Minerals are essential for tissue formation, for various metabolic processes and also to maintain the isotonic equilibrium between the medium and the tissues of the organism. Ogino and Kamizono (1975) feeding diets containing graded levels of salt mixture to young trout (Salmo gairdneri) and carp (Cyprinus carpio) observed that dietary levels of salt mixture exerted a strong influence on growth and mortality of trout and growth in common carp. Keotala (1975) showed that addition of ash prepared from fish protein concentrate or dicalcium phosphate alleviated the soybean deficiency in rainbow trout. Some minerals such as calcium
are directly absorbed by the fish through gills or skin or both. Marine fish derive minerals by swallowing considerable quantities of sea water (Smith, 1930). Freshwater fish take in comparatively less water (Simkiss, 1974). Important among the essential minerals for body functions in fish are calcium, phosphorus, sodium, potassium, molybdenum, magnesium, iron, selenium, iodine, manganese, copper, cobalt, zinc, chlorine and chromium. The levels of these minerals in tissues of fish are determined by their functional roles.

Calcium and phosphorus are required for bone formation and in fish, the skeleton accounts for the bulk of calcium present, scales being another place of deposition (Arai et al., 1975; Watanabe et al., 1980). Calcium is also essential for blood clotting, muscle function, proper nerve impulse transmission, osmoregulation and as a co-factor in enzymatic processes. Phosphorus is involved in energy transformations, cellular membrane permeability, genetic coding and general control of reproduction and growth (National Research Council, 1983). It also serves as a buffer in maintaining normal pH in body fluids and cells (Wasserman, 1960).

The minimum requirements of common carp for dietary calcium is very low. Fortification of phosphorus in the form of mono- and di-basic calcium phosphates increased the growth of common carp fingerlings and adults as also tilapia in Israel (Hapher and Sandbank, 1984).
Magnesium deficiency leads to poor growth, sluggishness, convulsions and high mortality in common carp (Ogino and Choice, 1976).

Iron deficiency in the medium causes hypochromic microcytic anaemia in common carp (Sakamoto and Yone, 1978).


Most fish diets contain substantial amounts of sodium, potassium and chlorides. Freshwater contains moderate levels of these ions. Salts are directly absorbed by fish through gills.

Das (1959) experimented with cobalt nitrate on the survival rate of major carps during the first three weeks of life. Sen and Chatterjee (1979) screened several micro-nutrients and observed that manganese and cobalt promoted growth and enhanced survival of spawn, fry and fingerlings of catla, rohu and mrigal.

In the light of the above literature, during the present studies, it was planned to undertake work on experimental nutritional requirements of fry and fingerlings of the selected carp species, to ascertain the composition of the diets based on their origin and the optimum level of feeding.
required for realising maximum growth.

The studies conducted have been arranged in the following manner:

Chapter 1 deals with the background information through review of literature highlighting the objectives of the present study against the lacunae existing.

Chapter 2 details the materials used and methods employed for conducting experimental work and also analyses the results.

Chapter 3 highlights the results of experimental work conducted for ascertaining the nutritional requirements and growth of test fishes in relation to purified diets.

Chapter 4 analyses growth of fishes with formulated diets.

Chapter 5 examines the growth of fry of rohu in relation to feeding level.

Chapter 6 incorporates a general discussion of the results against the background of existing literature.

The results have been summarised and conclusions drawn besides referring to the literature cited separately.

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