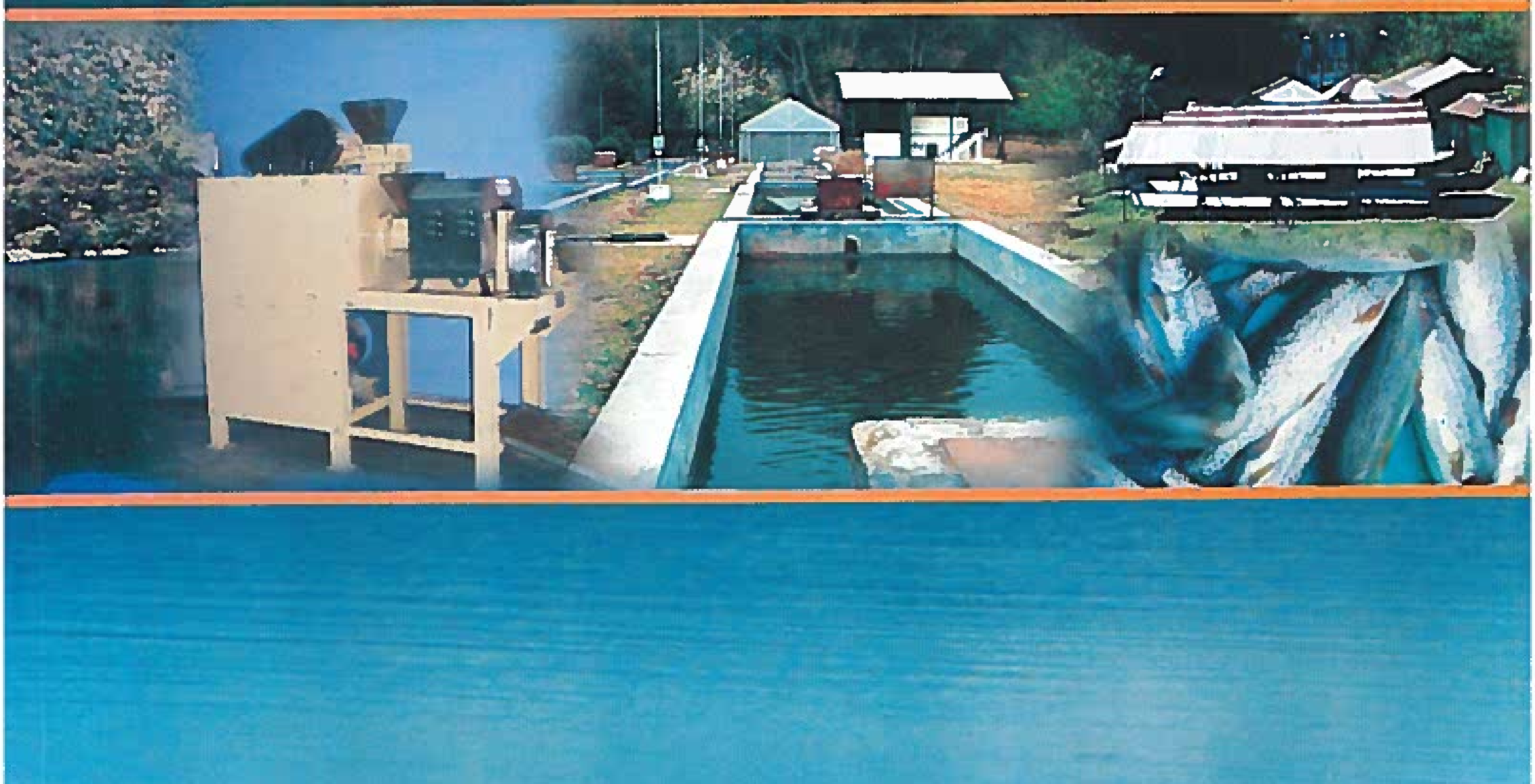
Coldwater Fish Nutrition

Madan Mohan
Yasmeen Basade



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Foreword

Coldwater fisheries is spread over the Himalayan and Peninsular regions of India. The coldwater aquatic resources are diverse in nature includes the streams, rivers, lakes and reservoirs, which extend from the high altitudes to the foothills. These resources hold considerable population of food, sport and ornamental fish species. A few decades ago, these resources were considered to be inexhaustible and enough to sustain the population living in upland regions. However, from the middle of the last century, there has been a population growth, income growth and urbanization, which have not left the hill regions unaffected. The large-scale developmental activities have resulted in degradation of ecology of coldwater streams. lakes and reservoirs and there has been a sharp decline in availability of fishes from these ecosystems. Taking into consideration the importance of coldwater fisheries resources available in the Himalayan and Peninsular regions of India, it was necessary to provide proper thrust in the development of coldwater fisheries.

Aquaculture has been the fastest growing food production sector, while capture fisheries have experienced a declining trend. Aquaculture therefore, can contribute significantly to food security and poverty alleviation in parallel with the development of profit-oriented entrepreneurship. Though, the magnitude of resources in coldwater sector is small in comparison to tropical waters but the fact remains that they have received low priority and investment, thus has remained under developed in comparison to warm water sector. Coldwater fisheries contribute meagerly to the inland fish production of India though the coldwater region has tremendous potential and its share can be improved to a greater extent through various fisheries development strategies like by conserving fishery resources including habitats, developing suitable fish species combination for fish farming at different altitudes of Himalayan region and by adopting new aquaculture technologies.

In aquaculture, feed accounts a major portion of operational cost, depending upon the management practices followed. As a result, feed continues to dominate aquaculture needs. It is under this scenario, Directorate of Coldwater Fisheries Research, Bhimtal has taken up initiative to work on the nutritional aspects of coldwater fishes in particular the exotic trout and carps and the indigenous mahseer and snow trout. In anticipation that less expensive formulations could results in an equivalent economic performance, emphasis on understanding the nutrient composition of local, commercially available ingredients, and their inclusion levels in feed formulation has also been attempted.

Of late, in India, considerable work has been done in the field of coldwater fish nutrition, but the information is scattered. An attempt has been made by the authors to bring together all the available information under one volume. This publication gives an extensive description of the research work done in the field of coldwater fish nutrition in India, covering the aspects of nutritional requirements, feeding of coldwater fishes and nutritional deficiency diseases along with the constraints, recommendations and future areas of work. This book will be beneficial to the students, teachers, researchers and planners and will go a long way in promoting coldwater fisheries in India.

(S. Ayyappan)

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Preamble

Coldwater fisheries of India extend along the uplands in Himalayan and Peninsular regions. Sizeable population of food, sport and ornamental fishes exist in the coldwater, which can contribute to large extent to food security and poverty alleviation by development of profit-oriented trade through aquaculture. Previously cold waters of the country could not be brought under the purview of aquaculture development owing to various inherent problems such as, majority of the coldwater fishes do not occur in great abundance, they are invariably slow growing, environmental degradation of the aquatic habitats due to anthropogenic pressure, lack of scientific investigation pertaining to the species, etc. Recently, culture of fish in the coldwater regions of India is gaining momentum. In the high altitude zones culture of exotic trout and in the mid-altitude regions exotic carp culture. Among the indigenous species attempts are being made to promote the culture of mahseer and snow trout.

Nutrition is an important and expensive component of fish farming. Consequently, the need for complete and supplementary feeds to provide the required nutrients for growth and development becomes necessary. The nutrient quality of aquaculture feeds affects the growth performance and health of cultured species; hence, nutritional adequacy and cost-effectiveness of feeds are critical to the growth of the fish-farming sector. The development of an economical and palatable feed with optimized nutrient content is therefore desirable.

In view of the above desired needs Directorate of Coldwater Fisheries Reserach, Bhimtal have taken initiative to develop feeds for the commercially important coldwater fishes. Studies were undertaken to develop feeds for the various grow stages of these fishes. Trout being highly carnivorous can be cultivated intensively with complete artificial diets. Whereas, exotic carps and mahseers are benefited by pond fertilization and supplementary feeding, depending upon the intensity of culture operations. As a result feeds have been developed for trout, golden mahseer and exotic carp, which have been experimentally tried with very encouraging results.

This book provides an exhaustive account of the research work done in the field of coldwater fish nutrition in India and will serve as a guideline to all those who are fascinated and concerned about the strengthening of coldwater fisheries configuration as it is one of the promising up-and-coming sector.

P.C. Mahanta

Preface

Aquaculture is undergoing an exponential development due to progressive reduction in natural fish stocks and catch fishery, coupled with an increasing demand for food fish. Freshwater aquaculture represents approximately one third of the total world aquaculture production. The introduction of new fish species, translocation of commercially important indigenous fishes to aquatic habitats and new innovations in culture technique have helped to achieve the substantial increase in fish production in inland sector. In view of the limitations of capture fisheries production and stagnation of warm water aquaculture, cold water aquaculture is being given the highest priority in the fisheries development plans.

In India, until recently there has been no information on the actual volume of aquaculture production, particularly from the coldwater sector. Although the information available now is that of the total fish production from the Indian Himalayan States, which includes both the production from the upland regions as well as from the plains. The total fish production from the Indian Himalayan States is presently 2.76 lakh tonnes, that constituted about 7.34% of total inland fish production which stands at 3.76 million tonnes.

In the coldwater sector the culture of exotic trout (rainbow trout) has increased rapidly in the recent past and many programms have been formulated for its promotion. Presently, cultured trout holds a major portion of the total output. With the introduction of improved management practices, the use of artificial feeds is becoming a foremost priority almost everywhere. Feed cost is estimated to vary between 60-80%, depending on the type of feed used and the intensity of other management practices.

Exotic carp culture in the mid-altitude regions is gaining popularity in several places both in the Central Himalayas as well as in the North East Himalayas with the practical demonstration by the farmers of the region of its potential. Supplementary feed forms an important component in the culture of exotic carps. Depending on the intensity of the culture operation, the cost of the feed has been reported to be between 50-70%. Hence, feeds remain one of the dominant needs.

Although attempts are being made to promote the culture of indigenous mahseer fishes, *Tor* spp., but this is still in a very early stage and is mainly attempted for polyculture with exotic carps. Hatcheries have been setup in the States of Uttarakhand, Arunachal Pradesh and in the Peninsular region of India to cater the seed demands of the regions for culture and rehabilitation in the open water bodies. The other indigenous fish of the upland regions of Himalayas, the snow trout, *Schizothoraichthys* spp. and *Schizothorax* spp., is not much sought after due to its slow growth rate.

For proper growth fish requires diets that meet their nutrient and energy demands. Nutrition plays a pivotal role in aquaculture of coldwater fish species. Against this backdrop, to address these needs of nutrition of coldwater fishes the present publication embarks on fish nutritional research work done in India with the aim to develop cost-effective feeds for coldwater upland fishes. This publication is an attempt to make available to the various users the research work done and the feeds been developed for the culturable coldwater fish species. It gives a comprehensive account on the nutritional requirements, feeding of coldwater fishes and nutritional deficiency diseases along with the constraints, recommendations and future areas of work. We believe that the present volume will be useful to students, researchers and planners interested in coldwater fishery sector.

Madan Mohan
Yasmeen Basade

1 COLDWATER FISHERIES SCENARIO OF INDIA

The term coldwater is by and large referred to the aquatic ecosystems, which maintain ameliorative thermal regime for the well being of the members of the family Salmonidae. In India there are a large number of indigenous and few exotic fish species, which inhabit streams, lakes and reservoirs at an altitude > 900 m asl having a water temperature < 20°C, that are brought under this definition. Coldwater fisheries is spread over the Himalayan and Peninsular regions of India. The coldwater aquatic resources are diverse in nature includes the streams, rivers, lakes and reservoirs which extend from the high altitudes to the foothills. These resources hold considerable population of food, sport and ornamental fish species. Few decades ago, these resources were considered to be inexhaustible and enough to sustain the population living in upland regions. However, from the middle of the last century, there has been a population growth, income growth and urbanization, which have not left the hill regions unaffected. The large scale developmental activities have resulted in degradation of ecology of coldwater streams, lakes and reservoirs and there has been a sharp decline in availability of fishes from these ecosystems. Taking into consideration the importance of coldwater fisheries resources available in the Himalayan and Peninsular regions of India, it was necessary to provide proper thrust in the development of coldwater fisheries.

There are 258 fish species indigenous and exotic, belonging to 76 genera of which 203 are recorded from the Himalaya while 91 form Deccan plateau. The important ones are snow-trouts (*Schizothorax* spp. and *Schizothoraichthys* spp.), mahseers (*Tor* spp.), minor carps (*Labeo dero, L. dyocheilus, Crossocheilus* spp. and *Garra* spp.), lesser barils, minnows, catfishes and loaches among indigenous species and trouts and Chinese carps among exotics. These fishes do not form fisheries of appreciable magnitude, the reasons attributed to this situation are many but most important one being, first due to slow growth and small size the fishes fetch less price, second is the cast net used as gear which is basically a one man unit so community fishing is hardly prevalent, thirdly the terrain in hill areas having meager transport facilities make difficult to access the markets to sell the production. Though, the magnitude of resources in coldwater sector is small in comparison to tropical waters but the fact remains that they have received low priority and investment, thus has remained under developed in comparison to warm water sector. Hill states contribute only 3-4% to the inland fish production of India though the region has tremendous potential and its share can be enhanced to about 8-10% through fisheries development activities like by developing suitable fish species combination for fish farming at different altitudes of Himalayan region and by conserving fishery resources including habitats.

ECOLOGICAL SCENARIO

The occurrence and distribution of coldwater fishes apart from other habitat factors is largely governed by the temperature and altitudinal variations which dials other water quality parameters to sustain these fish species.

The temperature tolerance of coldwater fishes lies at lower levels of the thermal scale, which is of critical significance and play a crucial role in their dispersal in the uplands. The thermal regime limits the very existence of fish species and other aquatic life, which greatly alters the composition of biota in upland streams and wetlands. Aside from various biotic communities, it is the upper level of tolerance limit that determines the survival, occurrence and distribution of the fish species in time and space. Good growth performance for most of the coldwater fishes is between the temperature range of 15-25^{0}C with lower limits to 10.0^{0}C. The trouts and snow-trouts, however, have lower thermal limits to 5.0^{0}C

Coldwater fishes are adapted to living in highly oxygenated water available in torrential streams in the mountains. Such oxygen-rich environment has induced structural modifications in the respiratory organs such as reduced gills with narrow gill opening, thus the coldwater fishes of torrents cannot survive for long in the water poor in oxygen. The upper limits of oxygen for exotic trouts and indigenous snow-trouts is 8 mg/l and above, whereas for carp and mahseer it is about 6.0 and 7.0 mg/l, respectively. The lower limits of oxygen for these coldwater fishes normally is 5-6 mg/l except for common carp which can survive at 3 mg/l oxygen concentration also.

As regard to altitudinal adaptations most of the coldwater fishes inhabiting in the torrential waters have morphological modifications such as development of hold fast and suckers, dorso-ventral flattening of body, reduction of scales, eyes, bladder, size of barbels and ventral or dorso-ventral position of mouth. The majority of fishes of mountain torrents do not grow to large size and hence cannot be exploited for commercial venture. However, these fish species can be valued as ornamental for aquariums and can be lucrative for export to the ornamental fish markets, fetching good returns to the society.

FISHERY RESOURCES

The aquatic resources holding coldwater fisheries are estimated as under.

Water bodies	Area
Steams/ Rivers	10,000 km
Natural lakes	20,500 ha
Reservoirs	50,000 ha
Brackish water lakes	2,500 ha

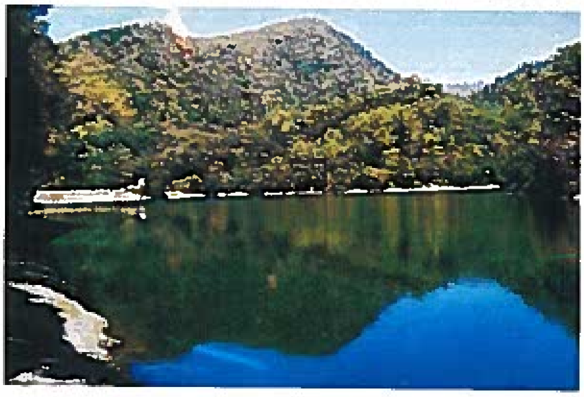

Fig. 1a. Lake Sattal in Kumaon Himalayan region.

The Himalayas are the main watersheds in the Indo-Gangetic region, having numerous rivers, streams, lakes and reservoirs. The Himalayas are drained by 19 major rivers, of which the Indus, Ganga and Brahmaputra are among the largest rivers in the world. Five rivers belong to the Indus system (Ravi, Beas, Jhelum, Sutlej and Chenab); nine

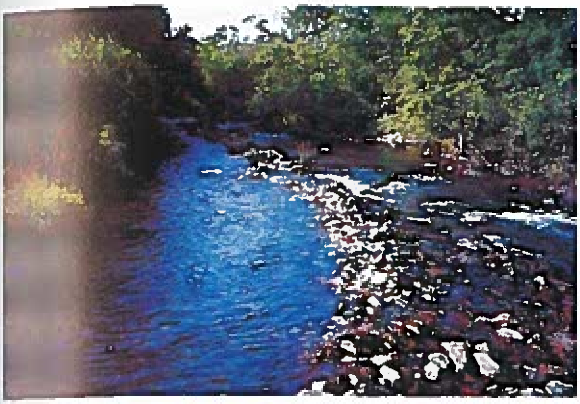

Fig. 1b. River Kosi in Kumaon Himalayan region

(Ganga, Yamuna, Ram Ganga, Kali-Sharda, Karnali, Rapti, Gandak, Bhagmati, Kosi) belong to the Ganga system, and three (Tista, Raidak, Manas) belong to the Brahmaputra system. Most of these rivers flow in deep valleys until they exit the mountains.

Fig. 1c. Lake Kupup Tso in Sikkim

The retreat of glaciers resulted in the creation of many lakes in Kashmir, Uttarakhand and Sikkim, while landslides and tectonic movements caused the formation of other lakes. Lakes are present at high altitude in the Great Himalaya and Trans-Himalaya, some of them being brackish or saline. Freshwater lakes in Kashmir Valley are believed to have originated as oxbow lakes of the Jhelum River.

The largest floodplain lakes in the Kashmir Valley are Wular, Dal and Manasbal. Twelve high-altitude lakes are located in Kashmir.

Fig. 1d. Lake Memenchu in Sikkim

Lakes Nainital, Bhimtal, Naukuchiatal, Khurpatal and Sattal are situated in Uttarakhand at low altitude. Four lakes are situated in Western Ghats (Ooty, Kodaikanal, Devicolam and Elephant).

From the fishery point of view, Gobindsagar and Pong are the two most important reservoirs of the Himalayan foothills in Himachal Pradesh.

FISHERIES

The fish species distribution in the Himalayan streams depends on the flow rate, nature of substratum, water temperature and the availability of food. In torrential streams the headwater zone is inhabited by rheophilic species of loaches and catfishes (*Nemacheilus gracilis, N. stoliczkae* and *Glyptosternum reticulatum*); the large stream zone is inhabited by *Diptychus maculatus* and *Nemacheilus* spp. While in the upper reaches rheophilic species of the snow trouts *Schizothoraichthys esocinus, S. progastus, Schizothorax richardsonii* and *Schizopygopsis stoliczkae* occur, middle stretches are frequented by *Schizothoraichthys longipinnis, S. planifrons* and *S. micropogon* and the least rapid reaches are occupied by *Garra gotyla gotyla, Crossocheilus latius diplocheilus, Labeo dero* and *L. dyocheilus*; slow moving

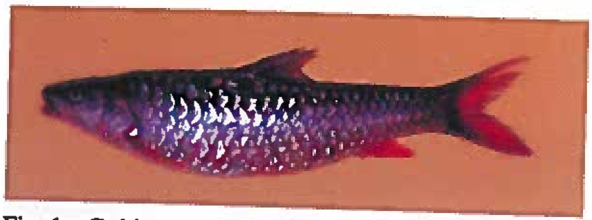

Fig. 1e. Golden mahseer, *Tor putitora*

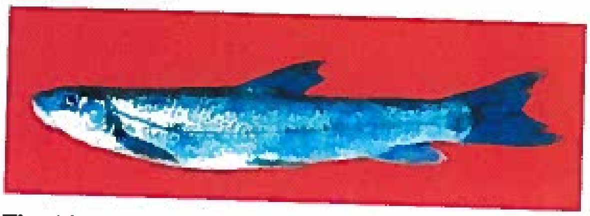

Fig. 1f. Snow trout, *Schizothorax richardsonii*

Fig. 1g. Rainbow trout, *Oncorhynchus mykiss*

Fig. 1h. Common carp, *Cyprinus carpio*

Fig. 1i. Silver carp, *Hypophthalmichthys molitrix*

Fig. 1j. Grass carp, *Ctenopharyngodon idella*

meandering zone are inhabited by a large number of cold- to eurythermal species such as *Barilius* spp., *Tor* spp. cat fishes, homalopterid fish (*Homaloptera* spp.) and snakeheads (*Channa* spp.). Among the exotic fishes are the exotic trout and the Chinese carps- common carp, grass carp and the silver carp.

The eastern Himalaya drained by the Brahmaputra has a greater diversity of coldwater fish than the western Himalayan drainage. Fisheries in the Himalayan rivers can be divided into (a) subsistence fishery; and (b) sport/recreational fishery. The subsistence and commercial fisheries exploit carps (*Labeo* and *Tor* spp.), lesser barils (*Barilius* spp.), schizothoracines (*Schizothorax* and *Schizothoraichthys* spp.), garrids (*Garra* spp.) and sisorids (*Glyptothorax* and *Glyptosternum* spp.). The other genera are small-sized and of low economic value.

Fish production in mountain streams is low and therefore any commercial fishery is on a very limited scale. The low biological productivity results in the prevalence of small-sized fish, except in pools where fish have some shelter and resting place. The fishing methods using nets, traps and poison are simple but well-suited to the turbulent nature of the streams. Cast nets are the most common gear used. The sinkers allow rapid settling of the net at the bottom, thus preventing it from being carried downstream by the rapid current. The fisherman upturns the stones on the stream bed covered by the net, which makes the fish come out of their hideouts below the stones and get trapped in the peripheral pockets of the net. The other types of nets used are: drag nets operated in conjunction with stake net (*kadh*), seines, stake nets, bag nets (*kochbi*), and some other types. The traps (*chip* and *urli*) are typical for Himachal Pradesh, the whole stream is usually diverted into this trap. The various poisons used are lime, sap of *Euphorbia rogleana*, powdered seed of *Xanthoxylum alatum* and *Cascaria tormentosa*, boiled tea leaves, etc. In addition, spears, horse hair nooses, harpoons with 4-5 barbed points and grain fishing are also used in different waters of the Himalayas.

Sport and recreational fishery

In India angling has remained a favourite pursuit of the British in the first half of this century, and it was mainly for this reason that brown trout and rainbow trout were introduced in the upland waters. In India sport fishing is now a very popular outdoor recreational activity, which has given boost to tourism in the Himalayas. The best sport fish are *Tor putitora*, *Tor tor* and *Salmo trutta fario*. One can expect that with fast increasing urbanization in the country, recreational fishery will become even more popular as a means of escaping the crowded conditions of towns.

Trout

The trout, which is now acclimatised in the streams of Jammu and Kashmir, Himachal Pradesh and to a lesser extent in the central and eastern Himalayas, is permitted to be caught on rod and line using both artificial and live baits. Special bylaws have been formulated under the Indian Fisheries Act in the states of Jammu and Kashmir and Himachal Pradesh. They regulate the fishing season, bag limit and prescribed baits. Organised brown trout fishing is confined mainly to the streams of Kashmir and Himachal Pradesh in the northwestern Himalayas. In Kashmir all trout streams are divided into fishing beats, each with a stream length of 3-5 km. The number of anglers to be permitted in each beat is fixed on a daily, weekly or seasonal basis. The fishing season extends from March to October every year. The minimum legal size of trout to be caught from any of the Himalayan streams in Kashmir and Himachal Pradesh ranges from 25-30 cm. The bag limit ranges from 5-7 fish of 25 cm and above in length.

Mahseers

The principal species of mahseers which contribute to the sport fishery are *Tor putitora*, *T. tor* and *T. mosal*. These species have wide-range distribution in the Himalayan rivers. They are caught on a stiff fibreglass rod of 3-4 m in length which has an adjustable brake system reel and a 4.5-5.4 kg strength line. Five principal ways of fishing for mahseer are: spinning, fly fishing, live-bait fishing, gram fishing, and paste fishing. In the past there was a sharp decline in catches of the mahseers, which are declared endangered

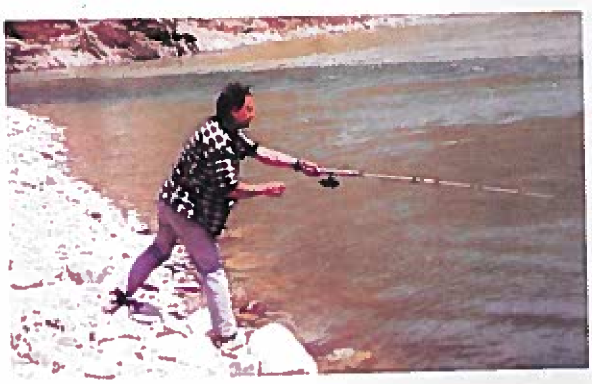

Fig. 1k. Angling for mahseer in an upland Himalayan river

fish in India. However, a number of angling associations have made an effort to create awareness among the fishing community and devoted anglers in particular, to conserve the threatened genetic material in the Himalayas.

Ornamental fishery

The water resources both the streams and lakes hold sizable population of ornamental fishes. In the western Himalayas streams and tributaries of river Ganga and Indus Systems, namely Alaknanda, Yamuna, Ganga, Bhagirathi, Kali, western Ramganga and Saryu drainages in Uttarakhand, Yamuna, Beas, Sutlej, Ravi, Tawi and Chenab drainage in Himachal Pradesh and Indus, Jhelum, Chenab and Ravi drainages in Jammu and Kashmir. The valley lakes and mountain lakes of these states are important resources of ornamental fishes. More than 100 varities of fishes are known for their ornamental value. The important ornamental fishes are the barils (*Barilius* spp.), danios (*Danio devario*, *Brachydanio rerio*, *Esomus danricus* and *Rasbor* spp.), barbus (*Puntius* spp.), catfishes (*Channa* spp.), loaches (*Botia* spp., *Nemacheilus* spp.), minor carps (*Crossocheilus latius latius*, *Garra* spp., *Labeo* spp.) and sisorids (*Glyptothorax* spp.).

At present NEH region is the stakeholder in the trade of ornamental fishes with 85% of the market share of India. In the western Himalayan states, Jammu and Kashmir, Himachal Pradesh and Uttarakhand, the ornamental fish trade is virtually absent. On the other hand, these states have great potential for development of this trade. To develop an organized ornamental fish trade proper strategies have to be devised beginning from identification of the potential resources, selection of suitable species for artificial propagation and undertaking biological investigations of these species in regards to their food and feeding, growth, maturity, fecundity and reproduction.

2 NUTRITIONAL REQUIREMENTS

Inland fish aquaculture has made tremendous progress world over particularly in Asian countries like China and India. The increase in yield has been manifold during last few decades. The success of this venture can be judged from the fact that a great number of people have accepted and taken up fish production as their main means of livelihood and source of additional income. New technologies have been developed for fish rearing in different agro-climatic and physico-chemical conditions for various life stages of different fish species. In most condition, they are provided with man made diets to hasten their growth and in turn for quick production of fish biomass. These diets are prepared from the good quality materials yet cost are kept at minimum level as 60-70% of the total fish culture expenses are incurred of fish food. Hence, it becomes mandatory to know the nutritional requirement of these fishes particularly which are produced in upland regions.

For any successful aquaculture programme, one of the major problem is to formulate a relatively cheap diet which can ensure the rapid growth of fish from juvenile to table size with the higher survival. Providing a nutritionally balanced diet which supports the maintenance, growth, reproduction and health of the fishes are important objectives of feed formulation in finfish aquaculture. The feed ingredients should facilitate the manufacturing process to produce a diet with the desired physical properties with least impact on water quality in the culture system. It is a well known that formulation of balanced diet depends on sound and precise knowledge of nutrient requirements of fish at various stages of its development keeping in mind the health, well being and optimization of growth potential of the respective fish species.

Their nutritional requirements mainly depend on their aquatic environment, which generally has great impact on energy utilization. Many coldwater fish species require good amount of energy for maintaining their up right position against water current in riverine environment particularly during monsoon season. But these factors get minimized during fish rearing in aquaculture farms as fishes may rarely face these conditions. While formulating fish diets, protein is generally given first priority, which is required for growth and maintenance and is more expensive than other energy producing components. The protein must be balanced for essential amino acids. The quantity of carbohydrate may differ from species to species, which mainly depend on the ability of fish species to utilize its maximum quantity to their maximum advantage. Since lipid is the primary non-protein energy source for almost all the fish species, its type and amount to be used are decided to provide essential fatty acids. Vitamins and minerals are generally provided as premix as their availability in the feeds generally remains uncertain. In the following paragraphs, an attempt is made to enlist and describe the nutritional requirements of coldwater fishes based on the researches carried out in India and elsewhere.

PROTEIN

Protein is the very important constituent of fish diet as major portion of expenditure in feed preparation is incurred on protein sources. The studies on several fish species have revealed that feeding fry, fingerlings and subsequently adult ones require correct knowledge of their protein demand as protein requirement are maximum during fry stage and it decreases with the increase in fish size. This higher demand of protein at fry stage can be attributed to rapid increase of majority of tissues in small fishes as growth shows positive allometry and even metabolic turnover is also higher. Based on several investigations conducted at Directorate of Coldwater Fisheries Research, Bhimtal the young ones of golden mahseer contains about 58.27% of total body protein. In experimental conditions, these young ones evinced very good growth at 45-50% dietary protein level. As mahseer grows, its protein requirements decreases in a gradual manner. Natural feed provide about 70% of their calories in the form of protein wherein some portion is used as source of energy for metabolic activities. For example, as is known that rainbow trout in the wild feed on aquatic and terrestrial invertebrates which provide quite high (37-66%) protein in their natural food. But during culture process, the amount of protein is reduced up to the level which will be sufficient for growth as quick fish production is the main target. But lipids and carbohydrates are provided as energy sources which compensate for less protein. It is important to include sufficient energy from non-protein sources in artificial diets.

Almost throughout the world, in fish farm protein from animal and plant sources are extensively used. While fish meal is the main protein source of animal origin, soybean being from plant kingdom. Due to its high protein content and balanced essential amino acid profile, fish meal is widely accepted in fish farming. Fish meal is also an excellent source of essential fatty acids, digestible energy, minerals and vitamins. Hence, fish meal is the most expensive protein source in aquaculture feeds. Fishmeal prepared from good quality whole fish is one of the best quality protein sources. Fish meal prepared from fish parts, such as waste from fish processing and canning plants, has a lower percentage of good quality protein than that of whole fish. It is also high in ash and should be used cautiously in fish diets as it can produce mineral imbalances. Other animal protein sources are by products such as meat and bone meal and poultry by-product meal, that contain about 45-55% crude protein but its quality is inferior to that of whole fish meal as the ash contents is usually high because a good amount of the material is derived from bone and non muscle tissues. Flash or spray dried blood meal is rich in protein (80-86%) but low in methionine and unbalanced in branched chain amino acids.

Fig. 2a. Soybean, used in fish feed as a protein source

Wherever soybean is available in good quantity, it is used as good source of protein in fish aquaculture industry. A considerable amount of fish meal in the diet can be replaced with soybean meal in omnivorous freshwater species, such as carp, tilapia and catfish. Investigations with rainbow trout, have

Fig. 2b. Mustard oil cake, used in fish feed as a protein source

revealed that soybean meal is also a viable source of protein for carnivorous fishes. Soybean meal is the best plant protein source in terms of protein content and essential amino acid profile. However, it is limiting in sulfur containing amino acids (Methionine, Lysine and Cystine) and contains many endogenous antinutrients including protease (tripsin) inhibitor, phytohaemagglutinin and anti-vitamins. Many of these factors can be destroyed or inactivated during thermal processing. The contradiction among research worker regarding the use of soybean meal as a protein source for fish can be related to the quality and processing of soybean meal, fish species and size and culture systems. It has been observed that the processing method of soybean meal has a significant effect on its nutritive value. It has been found that the germination and defattening of soybean meal reduced the activity of protease inhibitors. Heating soybean meal helps rupture the cellulose membrane surrounding the cell and release the cell contents making them more available. Heating also inactivates and destroys the antinutritional factors in soybean meal. It has been found that the quality of full fat soybean meal boiled at 100° C for one hour was improved and trypsin inhibitor activity decreased in fish.

CARBOHYDRATES

It is a well known fact that coldwater fishes do not utilize carbohydrates as energy sources so well as warm water species although dietary requirement for carbohydrates has not been documented in fish yet it is very important that a suitable quantity of carbohydrates may be provided in the diet of the fish. As carbohydrate is the least expensive source in the diet, the maximum tolerable quantity can be used depending on the various fish species. Cereal grains serve as inexpensive sources of carbohydrates for warm water fish, but their use in cold-water fish feeds is limited. Starch is also important for the binding properties for pelleted feeds. Whole grains contain 62 to 72 percent starch, which are 60 to 70 percent digestible by warm water fish but markedly less digestible by salmonids. Enzymes for carbohydrate digestion are available in fish digestive system. The enzymes for the major carbohydrate

Fig. 2c. Finger millets, used in fish feed as a carbohydrate source

metabolic pathways, such as, glycolysis, tricarboxylic acid cycle, pentose-phosphate shunt, gluconeogenesis and glycogen synthesis have been demonstrated. Studies have revealed that the hormonal and metabolic-regulation of carbohydrate and energy metabolism varies among fish and may be somewhat different than in mammals. Feeding high concentrations of digestible carbohydrates have been reported to result in an increase in liver size and glycogen content in salmonids.

LIPIDS

It is very essential to include lipids in the diets of the fishes as they are very important sources of energy and essential fatty acids required for normal growth and development. They are very helpful in the absorption of fat soluble vitamins. Dietary lipids mainly in the form of triacylglycerols, are hydrolysed by digestive enzymes to a mixture of free fatty acids and 2-monoglycerides. These compounds are then absorbed and either used for the synthesis of various cellular components or catabolised for energy. Dietary lipids contain both saturated and unsaturated fatty acids. The essential fatty acids function as components of phospholipids in all bio-membranes and as precursors for eicosanoids that fulfill a variety of metabolic functions. Biomembranes must be in a fluid state to function properly at various temperatures. Membrane fluidity depends on the proper balance of saturated and unsaturated fatty acids as components of membrane phospholipids. During acclimation to cold water temperatures the total amount of phospholipids in the fish bio-membranes does not change, however, changes occur in the relative proportions of individual phospholipids, in the fatty acid composition of the phospholipids, and in the distribution of fatty acids within the phospholipid molecules.

There is no definite percentage of dietary lipids required in fish diets without considering the type of lipid as well as the protein and energy content of the diet. Lipid concentrations of upto 20 percent give optimum results with some species. It has been found that the protein content of rainbow trout diets could be reduced from 48 to 35 percent without any reduction in weight gain if the lipid concentration was increased from 15 to 20 percent. This indicates that all diets should be formulated not only to meet the optimum ratio of energy to protein for that species, but also to contain an sufficient amount of lipid. However, too much dietary lipid may result in an imbalance of the DE/CP ratio and in excessive fat deposition in the visceral cavity and tissues which would adversely affect yield, product quality and storage. The fatty acid composition of the dietary lipid has a significant influence on the tissue fatty acid composition of the fish.

MINERALS

Mineral supplements are essentially required for achieving nutritionally balanced diets. They are absorbed by fishes not only from their diets but also from their outside aquatic environment. Minerals such as calcium (Ca), magnesium (mg), sodium (Na), potassium (K), iron (Fe), zinc (Zn), copper (Cu) and selenium (Se) are generally derived from the water to satisfy the part of the nutritional requirements of fish. Phosphates and sulphates are more effectively obtained from feed sources. The main functions of minerals are formation of skeletal structure, electron transfer, regulation of acid-base equilibrium and osmoregulation. Minerals are also important components of hormones and enzymes and they activate enzymes.

Mineral mixtures are available in the market from which best quality mixture must be selected and added in feed. The individual requirement of each important mineral has not been investigated for mahseer so far which will be taken up. But it must be assured that mineral mixture must contain enough quantity of calcium and phosphorus which is essential for skeleton formation and other important metabolic functions.

Calcium and Phosphorus

Calcium and phosphorus are two most required and well studied minerals. They are very important as they are directly involved in the development and maintenance of the skeletal system and participate in several physiological processes. Calcium also plays an important role in muscle contraction, blood clot formation, nerve impulse transmission, maintenance of cell integrity and acid base equilibrium and activation of several important enzymes. Generally fish absorb calcium directly from their environment. The uptake of calcium occurs through gills, fins and oral epithelia, however, gills are considered the most important site for calcium regulation in fresh water conditions. The calcium requirement is affected by water chemistry and species differences. A low concentration of calcium (0.34% or less) is required in the diet of carp for optimum growth. Calcium deficiency has not been detected in carp or catfish in fresh water. Generally calcium from the natural ingredients of the diet supplies sufficient calcium to meet the requirements of most fish species. For golden mahseer, 750 mg/kg of feed of calcium carbonate in a mineral premix has given good results.

It is known that phosphorus is an important constituent of nucleic acids and cell membranes, and is largely involved in all energy- producing cellular reactions. The role of phosphorus in carbohydrates, lipid and amino acid metabolism as well as in various metabolic processes involving buffers in body fluids, is also well established. Feed is the main source of phosphorus for fish because the concentration of phosphorus is low in natural waters. Rainbow trout and carp require 0.5 to 0.8 percent phosphorus while Atlantic salmon in fresh water needs 0.6 percent of the diet. The dietary supply of phosphorus is more critical than that of calcium because fish must effectively absorb, store, mobilize and conserve phosphorus in both freshwater and seawater environments. In most fishes, the main phosphorus deficiency sign include poor growth, feed efficiency and bone mineralisation. Other sign of deficiency in carp include increase in the activity of certain gluconeogenic enzymes in liver, increase in carcass fat with increase in carcass water content, reduced blood phosphate levels, deformed head and deformed vertebrae. Wide differences in the availability of phosphorus from various sources have been reported. The availability of phosphorus in fishmeal is significantly lower for carp than for rainbow trout. The difference in the availability of phosphorus to salmonids and to carp is probably due to the limited secretion of gastric juices by warm water fishes. Feed stuff that originate from seeds contain phosphorus primarily as the calcium-magnesium salt of phytic acid known as phytin. Phytin phosphorus is unavailable to animals with simple stomachs because they lack the enzme phytase in the gastrointestinal tract. Phytic acid also forms insoluble salts with free calcium in the digestive tract. Therefore, the availability of phosphorus from most plant products is low; for example, in soybean meal it is between 29 and 54 percent.

Magnesium

Magnesium is an essential cofactor in many enzymatic reactions in intermediary metabolism. These enzymes include phosphokinases, thiokinases, phosphatases and amino acyl synthetases. Magnesium plays an important role in the respiratory adaptation of freshwater fish. It is also required in skeletal tissue metabolism, osmoregulation and neuromuscular transmission. The quantitative dietary requirements of rainbow trout, carp have been estimated to range from 0.04 to 0.06 percent of the diet. The magnesium requirement of fish can be met either from the diet or water. It has been found that in fresh water, a concentration of 46 mg per liter was sufficient to meet the requirement of rainbow trout fed a magnesium free diet. The investigation on nutritional requirements of golden mahseer fry revealed that 30 mg/kg of feed is good enough.

Sodium, Potassium and Chloride

The minerals like sodium, potassium and chloride are the most abundant electrolyte in the body. Sodium and chloride are the principal cation and anion, respectively in the extra cellular fluid of the body, whereas, potassium is the major monovalent intracellular cation. Chloride ion is the major anion of gastric juice and blood. The deficiency sign of these elements are difficult to produce because fish really absorb these elements from the surrounding aquatic medium. The abundance of these elements in common feed stuffs used in fish diets means they need not be supplemented in most natural ingredient diets. Juvenile chinoock salmon reared in fresh water required 0.8 percent potassium in their diet for maximum growth, and the whole body potassium saturation was reached at a potassiun concentration between 0.6 and 1.2 percent of the diet. Supplements of 1 to 4 percent of sodium chloride in natural ingredient diets had no beneficial effect on the growth of rainbow trout. However, higher supplements of salt adversely affected growth and feed efficiency of rainbow trout. An amount of 750 mg/kg of sodium chloride, and 2 mg/kg of feed of potassium iodide added in the diet of fry of golden mahseer gave good results.

Iron

Iron is an essential element in the cellular respiratory process through its oxidation – reduction activity and electron transfer. It is found in the body mainly in the complex form bound to proteins, such as heme compounds (haemoglobin and myoglobin), heme enzymes (cytochromes, catalase, peroxidase, etc.) and nonheme compounds (transferrrin, ferritin) and iron containing flavoproteins (ferredoxins, dehydrogenases). Feed is considered the major source of iron for fish because natural waters usually contain low amounts of soluble iron. Fish can absorb soluble iron from the water through the gills because the addition of ferrous sulphate to water enhanced growth and hemoglobin level in platyfish. Iron is absorbed from the peritoneal cavity in rainbow trout and stored in the liver, spleen and anterior kidney. Among salmonids Atlantic salmon require 60 mg/kg of diet. In golden mahseer fry feed, 50 mg/kg of feed of ferrous sulphate gave good growth. Iron deficiency causes microcytic anaemia in brook trout. The normal liver colour changed to yellowish white during iron deficiency in carp. Dietary iron toxicity signs develop in rainbow trout when fed more than 1380 mg Fe/kg. The major effects of iron toxicity include reduced growth, increased mortality, diarrhoea and histopathological damage to liver cells.

Copper

High concentration of copper is found in the heart, liver, brain and eyes. The dietary copper requirement of rainbow trout is 3 mg/kg. In golden mahseer diets, the addition of 6 mg/kg of feed of copper sulphate is good enough. Carp fed diets containing high ash fishmeal without copper supplement showed reduced growth and cataract formation. Fish appear to be more tolerant of copper in the diet than of dissolved copper in the water. Concentrations of 0.8 to 1.0 mg copper per litre as copper sulphate in water are toxic to many species of fish. There is no deleterious effect of feeding rainbow trout diets containing 150 mg copper/kg for 20 weeks.

Zinc

In rainbow trout, zinc deficiency caused growth suppression, mortality, lens cataract, erosion of fins and skin and short body dwarfism. When zinc supplement (40 mg/kg) were added to rainbow trout diets containing white fishmeal, dwarfism and cataract problems were alleviated. The zinc requirement of young rainbow trout and carp has been estimated from 15 to 30 mg/kg of diet and of golden mahseer as zinc sulphate as 70 mg/kg of feed. The gills in rainbow trout play a major role in excretion of zinc. The bio-availability of zinc in fishmeal is inversely related to the tricalcium phosphate content. Rainbow trout and common carp can tolerate 1700 to 1900 mg Zn/kg of diet without adverse effects on growth or survival. When rainbow trout were fed with higher concentration of zinc to 1000 mg/kg diet exhibited reduced haemoglobin, haematocrit and hepatic copper concentrations.

Iodine

The deficiency of iodine can cause thyroid hyperplasia in fishes. Thyroid hormone deficiency has been induced by glucosinolates in the diet. It has been reported that higher iodine occurred in fingerlings due to increased thyroid activity during smoltification and relatively high concentrations of iodine and fluorine (4.5 mg/kg of diet of each) were essential to protect Atlantic salmon from bacterial kidney disease infections. The total uptake of iodine depends on the iodine content of the feed and water. It has been proved by experiments, that rainbow trout derive 80 percent of their iodide from water, 19 percent from diet, and less than 1 percent by recycling iodide from thyroid hormone degradation.

Manganese

Manganese functions as a cofactor in a number of enzyme systems, including superoxide dismutase and those involved in amino acid, fatty acid and glucose oxidation. Manganese deficient diets caused depressed growth in common carp and rainbow trout, and abnormal growth and shortening of the body in the rainbow trout. Supplementation of the diet with manganese up to 13 mg/kg improved growth in both species and prevented abnormalities in rainbow trout (Lovell, 1998).

Selenium

Selenium functions as a component of the enzyme glutathione peroxidase, which reduces hydroperoxides, which are strong pro-oxidants and thus protects polyunsaturated phospholipids in cellular and subcellular membranes from oxidation damage. Selenium also act as cofactor in glucose metabolism. Selenium deficiency causes reduced growth rate and suppressed plasma glutathione peroxidase activity. Selenium deficiency alone does not produce pathological signs in fish, but selenium and vitamin E deficiency combined causes nutritional muscular dystrophy. Maximum plasma glutathione peroxidase activity occurred in rainbow trout fed diets containing 0.38 mg of selenium/kg (Lovell, 1998). Fish feed containing predominantly plant ingredients should contain a selenium supplement.

Chromium

Less is known about chromium requirements of fish. They apparently have a dietary requirement and metabolic need.

Vitamins

These organic compounds in trace amounts are very essential from an exogenous source for the normal growth, reproduction and health. They can be classified as water soluble and fat soluble. Eight of the water soluble vitamins are required in relatively small amounts, have primarily coenzyme functions and are known as the vitamin B complex. Three of the water soluble vitamins, choline, inositol and vitamin C are required in large quantities and have function other than coenzymes. Vitamin A, D, E and K are the fat soluble vitamins that function independent of enzymes or in some cases such as vitamin K may have coenzyme roles.

Fat Soluble Vitamins

They are absorbed in the intestine along with dietary fats and are stored by animals if dietary intake exceeds metabolic requirements. Fishes have the capacity to store enough fat soluble vitamins in their tissues to produce a toxic condition (hypervitaminosis) which has been observed in trout for vitamin A, D and E which may not occur in practical conditions.

Vitamin A

This vitamin is essential for proper growth, reproduction, resistance to infection and the maintenance of differentiated epithelia and mucus secretions. Its deficiency in rainbow trout can cause anaemia, twisted gill opercula and haemorrhages in the eyes and base of fins. Brook trout exhibited poor growth, high mortality, and eye lesions when fed a vitamin A deficient purified diet from first feeding. Its high dietary intake (2.2 million IU/kg diet) caused slow growth, anaemia and severe necrosis of the caudal fin in brook trout at 8.3°C. Feeding up to 2.5 million IU retinyl palmitate to trout at 12.4°C also reduced body fat and liver size. This vitamin is added in fish feeds as the acetate, palmitate or propionate ester in the form of free flowing beadlets in a multivitamin premix.

Vitamin D

This vitamin is very essential and is required for facilitating mobilization, transport, absorption and use of calcium and phosphorus along with the actions of parathyroid hormone and calcitonin. Rainbow trout fed with a vitamin D-deficient diet exhibited poor growth, elevated liver lipid content, impaired calcium homeostasis manifested by tetany of white skeletal muscles. The two major natural sources of vitamin D are ergocalciferol (vitamin D_2, which occurs in plants) and cholecalciferol (vitamin D_3, found in animals). Vitamin D_3 is added in the fish feeds either as a beadlet with vitamin A or as a spray or drum-dried powder in a multivitamin premix.

Vitamin E

This vitamin functions as a very good antioxidant. Vitamin E and selenium function as part of a multi component antioxidant defense system which protects the cell against the adverse effects of reactive oxygen and other free radical initiators of the oxidation of polyunsaturated membrane phospholipids, essential proteins and sometimes both. Its deficiency has been studied in Atlantic salmon and rainbow trout whose signs include muscular dystrophy involving atrophy and necrosis of white muscle fibres, edema of heart, muscle and other tissues due to increased capillary permeability, impaired erythropoisis and depigmentation. If high concentration of dietary polysaturated fatty acids are included in the feeds of common carp and rainbow trout, the requirement of vitamin E is increased. High dietary concentration of vitamin E (5000 mg /kg of diet) has shown to cause reduced concentration of erythrocytes in trout blood. This vitamin is added in fish feed as a dry powder.

Vitamin K

This vitamin is required for stimulation of prothrombin activity in plasma and synthesis of blood clotting factors VII, IX and X. The three major forms of vitamin K include vitamin K_1, or phylloquinone which can be isolated from plants; vitamin K_2 or the menaquinones which are synthesized by bacteria and vitamin K_3 or menadione which is a synthetic product. It has been seen that many animals do not require vitamin K in the diet because of bacterial synthesis in the intestinal tract, but intestinal vitamin K synthesizing microflora have not been described in fish. High concentration of this vitamin (2400 mg/kg of diet) had no adverse effect on growth, survival, blood coagulation or the number of erythrocytes of young trout. Vitamin K is added to the fish feeds as a menadione salt-menadione sodium bisulfite (50 percent K_3), menadione sodium bisulfite complex (33 percent K_3), or menadione dimethylpyrimidinol (45.5 percent K_3).

Water Soluble Vitamins

In some warm water fish species, intestinal synthesis of microorganisms supplies the requirement for certain vitamins. These vitamins except two water-soluble growth factors (choline and myoinositol) and ascorbic acid have unique coenzyme functions in cellular metabolism. As these vitamins are not stored in fish body tissues, their constant supply is essential.

Thiamin

The deficiency of this vitamin can create neurological disorders such as hyperirritability in salmonids. It is available in coenzyme form which is thiamin pyrophosphate which functions in the oxidative decarboxylation of α -keto acids, such as pyruvate and α -ketoglutarate. It is added in fish feed as thiamin mononitrate which is 91.9% thiamin.

Riboflavin

The sign of riboflavin deficiency appears in the eyes and include photophobia, cataracts, corneal vascularisation and haemorrhages in salmonids. Riboflavin deficient common carp exhibited haemorrhages in various parts of body, nervousness and photophobia but no evidence of cataract development. It has been observed that the riboflavin requirement was not affected by temperature or by genetic differences in growth rate. It has been reported that feeding quite high concentrations of riboflavin (up to 600 mg/kg diet) had no adverse impact on the growth of rainbow trout. This vitamin is generally added in fish feed as a dry powder in a multivitamin premix.

Vitamin B_6 (Pyridoxine)

The deficiency of this vitamin appears as anorexia and poor growth which appears in fish within 3 to 6 weeks after being fed with this vitamin deficient diet as well as creates histopathological changes in rainbow trout liver. This vitamin is added as pyridoxine hydrochloride in a dry form as part of a multivitamin premix in the fish feeds.

Niacin

This vitamin is essential for several oxidation reduction reactions involving the transfer of hydrogen and electrons in carbohydrate, lipid and amino acid metabolism. Tryptophan can be metabolically converted to niacin in many animals but not in certain salmonids. Its deficiency in trout and salmon exhibits anorexia, poor growth, poor feed conversion, intestinal lesions, muscular weakness and increased mortality. In common carp, its deficiency showed skin and fin lesions, high mortality, skin haemorrhages, anaemia and deformed jaws when fed with niacin deficient feed for 2 to 6 weeks. Its high dietary intake (10,000 mg/kg diet) can increase liver fat, decrease body fat and reduce growth rate in fingerlings of brook trout. This vitamin is added in fish diets as nicotinic acid or niacinamide in multivitamin premix.

Pantothenic Acid

The only known function of pantothenic acid is as a component of coenzyme A (CoA), which is involved in transfer of acetyl (2-carbon) units in numerous reactions in the metabolism of proteins, carbohydrates and lipids. Deficiency causes dietary gill disease in several fish species, which is characterized by clubbed, exudates-covered gill lamellae, fused gill filaments, and swollen operculums. Lesions on skin and fins, anaemia, anorexia and poor growth are also found in fish deprived of pantothenic acid. Supplemental pantothenic acid, as calcium d-pantothenate (92% vitamin activity) or calcium DL-panthenate (46% activity), is recommended for commercial fish feeds (Lovell, 1998).

Biotin

Biotin functions as a coenzyme in carboxylation (transfer of carbon dioxide) reactions. Enzyme systems containing biotin are acetyl-CoA carboxylase, propionyl-CoA carboxylase, and pyruvate carboxylase. Metabolic functions requiring biotin are many and include synthesis of fatty acids, oxidation of energy yielding compounds, synthesis of purines, and deamination of certain amino acids. A reliable indicator of biotin status that has been used in fish is pyruvate carboxylase or acetyl-CoA carboxylase activity. Fish vary in sensitivity to biotin deficiency. Rainbow trout are highly sensitive, young rainbow trout required only 4 weeks to show deficiency signs under optimum environment for growth. Rainbow trout showed poor growth, degeneration of gill lamellae and epithelium, and enlarged, pale livers. Subclinical signs in fish are reduced carboxylase activities in liver and, in trout abnormal synthesis of glycogen and fatty acids, degeneration of acinar cells of pancreas, and glycogen deposition in kidney tubules. Bioavaliability of biotin in many feedstuffs is limited. Biotin availability in corn and soybean meal, however, is higher. Supplemental biotin is not required in practical corn-soybean meal or corn-soybean meal – fishmeal diets for normal growth and pyruvate carboxylase activity. The dietary requirement for fish is low, about 0.25 mg/kg diet, so practical fish diet do not usually need supplemental biotin (Lovell, 1998).

Folic Acid

The deficiency of folic acid exhibits anorexia, reduced growth, poor feed conversion and megaloblastic anaemia which can be seen as pale gills. The number of erythrocytes are found to decrease when rohu are fed folic acid deficient diet. Folic acid is added as dry powder in a multivitamin premix.

Vitamin B_{12}

This vitamin is required for normal maturation and development of erythrocytes, for the metabolism of fatty acids and for the normal recycling of tetrahydrofolic acid. When salmon and trout are fed with low quantity of this vitamin, a high variability in numbers of fragmented erythrocytes and in hemoglobin value. Whenever necessary, this vitamin is added as dry powder in multivitamin premix.

Choline

The deficiency of choline in rainbow trout diets may cause light coloured livers, protruded eyes, anaemia and extended abdomen. In lake trout, when fish were fed with choline deficient diets for 12 weeks, a depressed growth rate and increase in liver fat content was observed. This is added in fish diets as a 70% choline chloride solution or a 25 to 60% dry powder.

Vitamin C

This vitamin is a very strong reducing agent and is oxidized to dehydroascorbic acid which can be reduced back to ascorbic acid by enzyme actions. Ascorbic acid allows the absorption of iron and prevents anaemia. Ascorbic acid also functions with vitamin E and minimizes peroxidation of lipids in fish tissues. Its deficiency in salmon and trout can create body deformity such as scoliosis, lordosis and abnormal support cartilage of the eye, gill, and fins and internal haemorrhaging usually produced by nonspecific signs such as anorexia and lethargy. Deformities such as scoliosis and lordosis due to this vitamin deficiency have been observed in Indian major carps and common carp. Reduced reproductive performance has also been reported in rainbow trout fed with vitamin C deficient diets. The decrease in this vitamin's levels has been reported during embryonic and larval development of fish which indicates that its requirements during early life stages may be higher than for fingerlings or adults. This vitamin is not generally added in multivitamin premix in fish feeds. Several coated forms of this vitamin e.g. fat coated are used to increase retention capacity of this vitamin in fish diets. Its form also depends on the manufacturing process as its good amount is generally lost during feed formulation.

3

FEEDING EXOTIC TROUT

Trout are of importance as sport and food fish. Rainbow trout, *Oncorhynchus mykiss* is the best-suited salmonid for farming as it is fast growing, have shorter incubation period, accepts artificial feed, withstands higher temperatures (20-22°C and even up to 24°C for a short duration) and low dissolved oxygen levels and is more resistant to diseases. Various hill states of India are promoting aquaculture of trout, namely, Himachal Pradesh, Jammu & Kashmir and Uttarakhand in northwestern and central Himalayan region; Arunachal Pradesh, Sikkim and Meghalaya in northeast Himalayan region and Tamil Nadu and Kerala in peninsular region. There are altogether about 23 trout culture farms/ hatcheries in India spread in these states. Earlier trout seed was produced in government controlled farms primarily to stock the streams and lakes for angling purposes. Only after 1990's in the states of Jammu & Kashmir and Himachal Pradesh two pilot scale farms were established with foreign collaboration, namely EEC and Norway, to raise trout to table size and to introduce the fish in market, as a commodity, on a small scale. These initial attempts were successful and now these states undertake sale of rainbow trout through government controlled outlets. Recently Government of Himachal Pradesh has involved private farmers in the rainbow trout farming activity. The trout farming practices involves the maintenance of brood stock in ponds/ raceways at a density of 6-8 numbers m² having a weight of 1kg/

Fig. 3a. Rainbow trout, *Oncorhynchus mykiss*

fish with proper feeding. Breeding is done by stripping of the spawners for the sex products, fecundity of rainbow trout ranges from 1650-1850 eggs/kg body weight. The fertilized eggs are incubated in the hatchery. The incubation period varies with water temperature from 31 days at 10°C to 48 days at 7.2°C. In another 15 days three-fourth of the yolk sac is absorbed and at this stage initial feeding is started. Feed having 50-55% protein is given at every half hour interval from morning to mid-night at a rate of 10% of the body weight. The fish after attaining 0.5g weight are shifted to rearing tanks (rectangular: 6x0.6x0.5m or circular: 1m diameter; 0.4-0.6m depth) and stocked at rate of 10,000 numbers/m². Good maintenance of brood stock on a nutritious diet, careful handling of fertilized eggs, prophylaxis against fungus, providing enhanced water supply, thinning of hatchlings at eyed ova and alevian stages has resulted in 95% survival from green eggs to swim-up fry stage. By adopting proper farm management practices the table fish can easily be produced in a period of 1+ year. To promote trout farming, the Directorate of Coldwater Fisheries Research, Bhimtal has also initiated farming of rainbow trout at its Experimental Fish Farm, Champawat in Kumaon, Uttarakhand with the objective to raise brood stock for seed production and to raise table size fish for sale. The results of rearing trials revealed that fish can attain an average growth of one kg (750-2100g) by third year when fed on formulated diet having about 47-57% protein level. The attempt has proved a success and opened a new possibility of commercial farming of trout in the Kumaon Himalayan region.

FOOD HABITS

The fishes inhabiting the mountain streams have undergone remarkable modifications in their morphology to procure their food while maintaining upright position in fast-flowing waters. Brown trout, *Salmo trutta fario* has been reported as sight feeder and prey upon the most preferred food items repeating the act again and again without taking the risk of being washed away in turbulent waters (Sehgal et al., 1984). These authors further observed that the feeding pattern of brown trout in Kashmir streams change with increase in size. Fish of 101-200 mm size group foraged on nymphs of Ephemeroptera in largest density (74.2%) followed by larvae of Trichoptera (13.7%) and larvae of Diptera (7.9%). The remaining percentage was constituted by larvae and adults of Coleoptera (0.7%) and aerial insects (3.5%). With increase in size brown trout in the 201-300mm size group had a changed feeding spectrum. The fish switched on predominantly to caddis larvae (54.6%) followed by nymphs of Ephemeroptera (14.1%), larvae of Diptera (4.8%), adults and larvae of Coleoptera (4.2%), nymphs of Plecoptera (1.5%) and aerial insects (20.8%). In case of lake fish, chief food components were Crustaceans dominated by Copepods and Cladocerans as high as 90-95%, while rest was a mixture of benthic naididae, chironomids and trichopterans as compared to the fish from stream area which recorded 80-90% benthic insects in their gut (Raina, 1992). Rainbow trout (*Oncorhynchus mykiss*) are opportunistic feeders that rely on a wide variety of food items ranging from small insects to crayfish. Trout inhabiting streams with a significant amount of riparian vegetation often feed heavily on terrestrial insects, such as grasshoppers and ants, that fall into the stream. Rocky stream riffles produce bottom-dwelling aquatic invertebrates, such as insects and crustaceans, that are also fed upon. In lakes and streams, invertebrates such as plankton, crustaceans, snails, and leeches, as well as small fish and fish eggs also serve as food for trout.

FEEDS AND FEEDING

Feeds and feeding practices for trout culture in the country has been chronological accounted by Jhingran and Sehgal (1978), the authors have lucidly explained that the artificial feeds play a vital role in production in trout farms. The cost, extent of utilization of artificial feeds by the fish and its conversion rate ultimately determine the economic viability of a particular trout-farming unit. For many years it was believed that bovine liver constituted a complete diet for the trout and the same was continued to be used in greater quantity than any other food. Often the bovine liver, given to trout was infested with trematodes which transmitted infectious diseases and disabilities. As trout culture spread far and wide in the world, the trout farmers started supplementing bovine liver diet with by-products like cattle lungs, hearts and spleens obtained from slaughterhouses and meat packing factories. Early trout culturists in the USA even kept heads of freshly killed bovine animals hanging over the ponds so as to obtain sustained supply of maggots, which would grow over the carrion. These maggots would fall into the pond and form supplementary diet. Products like powdered marine and freshwater fish; by-products from fish canneries and cereals were also used to supplement trout diets.

Types of artificial feeds

During the early period of trout culture, naturally occurring organisms were the only food that was available to the trout. Such organisms were, however, available only in a limited quantity and augmentation of their production by artificial means was not an easy task. This approach was hence abandoned and it resulted in greater use of other animal and vegetable products from extraneous sources which were available in abundance during that period. Artificial diet for trout can be divided into conventional or 'wet' feeds and pelleted or 'dry' feeds.

Wet feeds

Conventional or wet feeds, such as glandular parts of farm animals, were amongst the first artificial feeds used to supplement or replace natural trout food. To increase the poundage of glandular parts, vegetable products like cereals, cottonseed, wheat bran, etc. were then begun to be mixed with them. With the emergence of trout farming as an industry in USA, barring hide, hooves and horns, every part of the farm animal was utilized for trout feeding. In India, goat and sheep meats supplemented with their livers and fresh fish were the principal kind of wet feeds used in trout farms. However, due to sharp rise in the cost of goat and sheep meats and their livers, the trout farmers switched over mainly to raw fish. Raw fish, when used without eviscerating, possess a thermo labile enzyme, called thiaminase, which is responsible for causing deficiency of thiamin chloride (vitamin B_1) in trout. As a result of deficiency of vitamin B_1, trout shows symptoms of 'whirling' (a disease in which fish performs cork screw movement) accompanied by melanotic appearance (darkening of the skin) of the body (Sehgal and Joshi, 1975). The authors also demonstrated that partial cooking of fish flesh, supplemented with sheep or goat liver and wheat bran, reduced the incidence of 'whirling' to almost nil. Even eviscerating and washing of raw fish before feeding the trout helped to reduce the onset of the disease.

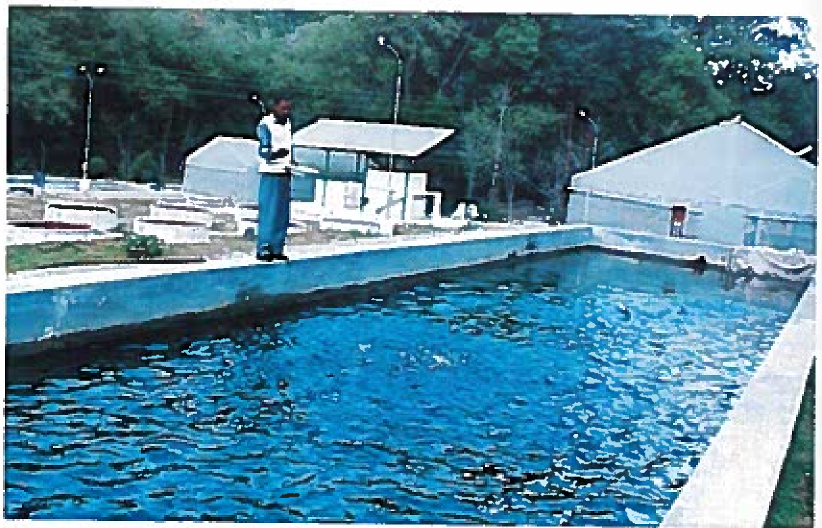

Fig. 3b. Feeding of rainbow trout in raceways of experimental fish farm, Champawat

Dry feeds

With the advancement of knowledge of trout nutrition dry compound pelleted feeds were also formulated by combining various ingredients in different proportions to provide balanced diet to the trout. Wet feeds were virtually eliminated with the evolution of dry feeds as dry feeds were simpler to use through automatic feeders, easy to store, maintain hygienic condition in pond, better utilization and high conversion rate. At the Srinagar Research Centre of the Central Inland Fisheries Research Institute, attempts to evolve the pelleted feed for trout were crowned with success for the first time in India in 1974 (Sehgal et al., 1976). The procedure for experimental pelleting followed at this center involved several steps viz., procurement of ingredients, crushing, sifting, conditioning, granulation, drying, crumbling and screening.

Four feeds were formulated by combinations of the ingredients in different proportions (Table 1). The dry ingredients were crushed, sifted through 0.2 mm mesh sifter and mixed with wheat starch (maida). Thereafter, hot water was added to the mixture to make dough, which was allowed to remain for 20-30 minutes for conditioning. During conditioning hydrolysis of wheat starch increased both the stability and digestibility of pellets. Compression of the conditioned dough

Table 1. Ingredients and chemical composition of four formulations of pellets at Srinagar Research Centre, Central Inland Fisheries Research Institute.

	Formula I	Formula II	Formula III	Formula IV
Ingredients (g)				
Brown fish meal	380	485	600	700
Soybean	150	200	100	100
Brewer's yeast	100	50	100	100
Dried skimmed milk	55	50	-	-
Bone meal	50	50	-	-
Wheat bran	220	120	-	-
Wheat starch	-	-	150	50
Shark liver oil	30	30	30	30
Vitamin mixture[1]	15	15	20	20
Chemical composition (%)				
Crude protein	28.00	35.00	39.16	37.63
Crude fibre	00.60	0.80	2.15	0.76
Ether extract	7.53	7.94	5.34	5.34
Nitrogen free extract	27.53	14.56	13.33	8.13
Ash	26.54	32.60	37.20	43.74
Moisture	9.80	9.10	2.82	4.40

[1] Modified Halver's vitamin mixture
(Source: Jhingran and Sehgal, 1978)

as performed in a hand operated macaroni machine. The dried pellets were crumbled and screened through different meshed screens according to the size of the trout to be fed (Table 2).

Table 2. Pellet types used for different fish size groups

Type	Size No.	Pellet diameter (mm)	Fish size (g)
Crumbles	1	0.25-0.70	0.12-0.25
Crumbles	2	0.70-1.30	0.25-2.80
Crumbles	3	1.30-2.20	2.80-10.00
Pellet	4	2.2	10.0-35.00
Pellet	5	3.0	35.00-80.00
Pellet	6	4.5	80.00-210.00

(Source: Jhingran and Sehgal, 1978)

In India, however, the diet given varies from hatchery to hatchery. It is done according to availability of the feeds. The newly emerged swim-up fry are often fed on a liquid diet comprising either chicken egg yolk or goat or sheep liver or dried skimmed milk. The fingerlings and yearlings are fed either on minced liver or dried silk-worm pupae and powdered locally available dried fish. Two years old and above are fed on chopped mutton and fillets made from local fish.

Trout is readily adaptable to intensive artificial feeding. The daily ration depends on water temperature, size of the fish and type of the feed. With experimental formulation of dry feeds at the Srinagar Research Centre of the Central Inland Fisheries Research Institute in 1974, efforts have been made to evolve feeding schedules for different stages of brown and rainbow trout based on water temperature and fish length (Table 3). Fry to yearling size trout were fed every two hourly from sunrise to sunset, while the older fish were fed twice a day at an interval of 6-8 hours.

In India, trout feeding is done manually by broadcasting the feed from the edge of the pond, such a method is time consuming. If the farm is large mechanical and automatic methods of feeding have be adopted.

The economics of trout feeding depends largely on cost of feed, its utilization and conversion ratio. Sehgal and Joshi (1975)

Table 3. Feeding schedule for trout developed for Laribal and Harwan hatcheries in Kashmir (in relation to fish length and water temperature)

Fish size (mm)	Pellet size (mm)	Water temperature (°C)									
		2.0	4.0	6.0	8.0	10.0	12.0	14.0	16.0	18.0	20.0
Up to 25	Mash	2.7	3.0	3.6	4.1	5.0	6.1	7.0	8.2	8.8	10.0
25-50	Mash	2.2	2.5	3.0	3.4	4.2	5.2	5.8	6.7	7.2	7.9
50-75	0.25-0.70	1.8	2.0	2.4	2.8	3.3	4.1	4.7	5.5	5.9	6.4
75-100	0.70-1.30	1.3	1.5	1.8	2.1	2.5	3.1	3.5	4.2	4.6	5.1
100-125	1.30-2.20	1.0	1.2	1.4	1.6	1.9	2.3	2.6	3.2	3.5	4.0
125-150	2.2	0.8	0.9	1.2	1.3	1.8	2.1	2.5	2.7	2.9	3.6
150-175	3.0	0.7	0.8	0.9	1.1	1.3	1.5	1.8	2.1	2.2	2.2
175-200	4.5	0.6	0.7	0.8	0.9	1.1	1.3	1.5	1.7	1.9	2.0

Note: This schedule is subject to change depending on the species of trout, water quantity etc.
(Source: Jhingran and Sehgal, 1978)

found the conversion ratio of 11.8 when fresh fish was given to brown and rainbow trout at Harwan, Srinagar. Trials conducted with dry palletized feed, developed by the Srinagar Research Centre of the Central Inland Fisheries Research Institute in 1974 (Table 1), at Harwan and Laribal trout farms in raceways gave a conversion ratio ranging from 1.4-2.0 for feeds I-IV having crude protein level between 28-40% (Sehgal et al., 1976).

Swim-up fry to fingerling stage

Brown trout

Investigations conducted on brown trout (*Salmo trutta fario*) rearing from green egg to table size fish by Sunder et al. (1986) revealed that the swim-up fry of brown trout (80-100 mg) were initially fed on boiled and finely minced hen's egg yolk and skimmed milk in the ratio of 1:1 with a pinch of common salt @ 6% body weight every two hourly from sun rise to sun set during the first 30 days when the stock was still in the hatching troughs. In the second month, they were transferred to the nursery ponds and fed on 1:1 mixture of wet feed and dried feed mash and subsequently from third month onwards, the fry were exclusively fed on laboratory prepared artificial dried feeds (Table 4). The results showed that with 48% protein diet the final weight attained (15mg), survival (30-35%) and FCR (1.8) were better compared to fish fed with 35% and 31% protein diet in which the respective values for final weight attained (10mg and 7.5mg), survival (31-35% and 20-20%) and FCR (2.0 and 2.2) were not encouraging.

Rainbow trout

For rainbow trout (*Oncorhynchus mykiss*), initial feeding for the young ones is done at the rate of 10% of fish body weight.

Table 4. Ingredient (g) and chemical composition (%) of the formulated feeds

	Feed No. 1	Feed No. 2	Feed No.3
Ingredients (g)			
Fish meal	500	400	-
Bone meal	-	-	-
Soybean meal	200	-	-
Wheat bran	50	150	150
Wheat starch	50	-	-
Mustard oil cake	-	100	-
Silk worm pupae	-	200	700
Brewer's yeast	35	40	70
Shark liver oil	30	40	10
Dried skimmed milk	40	50	50
Vitamin mixture	15	10	10
Mineral mixture	30	10	10
Chemical composition (%)			
Crude protein	31.06	35.00	48.12
Crude fibre	1.89	0.51	1.92
Ether extract	5.38	6.54	10.62
Nitrogen free extract	21.44	29.55	24.74
Ash	28.22	23.97	11.04
Moisture	12.04	4.43	2.76

(Source: Vass et al., 1981)

Fig. 3c. Rainbow trout juveniles

They must be fed several times a day and feeding to be carried out from daybreak to midnight. Care must be taken to avoid long intervals between feeding, as it may cause minor to major mortality. As fry/fingerling grow quite fast at this stage, their feed must have 50-55% protein. For very effective feeding, enough light must be arranged inside hatchery so that young fry can see food particles.

When ¾th of the yolk is absorbed, the newly emerged fry are fed with emulsified hen's egg yolk for three days and are switched over to minced goat liver, which is continued for the next seven days. From eleventh day onwards-formulated feed containing about 50% protein is given. After one month rearing the fry grow to 18-24mm in length corresponding to 0.20-0.80g in weight. This feed is well accepted by the fish and the fish grew to 50-75 mm in total length with 2-5g body weight in three months.

The results of various trials conducted at DCFR Experimental Fish Farm, Champawat revealed that growth performance, feed efficiency and survival of fry was better in fish fed at the rate of 10% of body weight, three times a day and stocked at a density of 50 fish per 200l of water.

This feed was further refined and a new formulation was prepared, for fry to fingerling stages, with the ingredients- fish meal, soybean meal, wheat middling, starch, Brewer's yeast, shark liver oil, linseed oil, dried skimmed milk, vitamin pre-mix, mineral pre-mix, choline chloride and mono calcium phosphate. This feed was prepared through a single screw extruder. Proximate composition of the extruded rainbow trout feed is given in table 5.

Table 5. Proximate composition of the extruded rainbow trout feed

Proximate composition (g/100g)	
Moisture	2.76
Crude protein	48.12
Crude fat	19.62
Crude fibre	1.92
Ash	11.04
NFE	24.74

The overall performance of feed was good. Survival of more than 90% was achieved in the first two months. But due to scarcity of water in the summer months of May and June at the farm there was some mortality during third month (Table 6).

In the first five months a cumulative survival of 62.35%, FCR of 1.47 and SGR of 3.19% day^{-1} was achieved, in spite of lot of stress due to shortage of water.

Fingerling to table size

This aspect was studied by Sunder et al. (1986) with the view to assess the possibility of raising brown trout fingerling to table size in the farms within a reasonable rearing period. The fingerlings were fed with 28% and 47% protein diets (Table 7) of 3-6 mm size @ 2-

Table 6. Growth performance and survival of rainbow trout fry fed with the extruded feed from hatching to first five months.

Parameters	Initial	1 month	2 months	3 months	4 months	5 months
Average length (mm)	12	20	35	30	50	80
Average weight (g)	0.10	0.30	0.50	2.0	3.0	12
Survival (%)	90.14	96.10	96.20	73.43	72.10	62.35

8% body weight by broadcasting 3-4 times a day. To the 47% protein diet was once or twice in a month sheep/goat meat was substituted to counteract the ill effects, if any, of dry feed and in addition to regular ingredients in the dry palletized feed periodically terramycin @ 5,000-10,000 units/kg was administered as antibiotics to control diseases and help in growth. The authors observed that with high protein feed (47%) the fish production could be around 8-9 tonnes per hectare while it estimated only 2-3 tonnes per hectare with low protein feed (28%).

Table 7. Ingredient (g) and chemical composition (%) of the formulated feeds

	[1]Feed No. 1	[2]Feed No. 2
Ingredients (g)		
Fish meal	380	-
Bone meal	50	-
Soybean meal	150	-
Wheat bran	220	130
Wheat starch	-	-
Mustard oil cake	-	-
Silk worm pupae	-	800
Brewer's yeast	100	50
Shark liver oil	30	-
Dried skimmed milk	55	-
Vitamin mixture[3]	15	10
Mineral mixture	-	10
Chemical composition (%)		
Crude protein	28.00	47.47
Crude fibre	0.60	1.37
Ether extract	7.53	15.85
Nitrogen free extract	27.53	17.89
Ash	26.54	8.40
Moisture	9.80	9.02

(Source: [1]Sehgal, et al., 1976 and [2]Sunder et al., 1982)

Fig. 3d. Rainbow trout produced at experimental fish farm, Champawat

Feed mill and feed manufacturing

During 1984, fast growing variety of rainbow trout (*Oncorhynchus mykiss*) was introduced in Kokernag trout farm, district Anantnag in Kashmir with the assistance of EEC (European Economic Community) and the required infrastructure facilities in the form of hatcheries, farm, laboratory, storage house, office building, feed mill, etc. have been established on modern lines. Production started in March 1992 (Sardar and Wani, 2002).

Kokernag trout feed mill imported from Holland based 'Ottevanger' Company was installed in 1987 and has a capacity to produce feed @ 0.5 t/ hr. the trout feed has been standardized with a low cost of production. According to Sardar and Wani (2002), seven types of pelleted feeds for different growing groups of trout viz., starter 1, starter 2, fingerling feed, low energy fingerling feed, high energy production feed, new production feed and brood stock feed are being manufactured in this mill. After cooling and drying, feed pellets are put into cement mixer and coated with necessary amount of vitamin C and oil. Various good quality feed ingredients both of plant and animal origin locally available or transported from other regions are added in different ratios and combinations for the manufacture of different types of feeds. The major ingredients used in various trout feeds manufactured at Kokernag feed mill and their proximate compositions are presented in table 8.

Norwegian assisted project "Commercial farming of rainbow trout in Himachal Pradesh" was set up in 1989 at Patlikhul farm, District Kulu, Himachal Pradesh based on the approval of Norwegian Agency for International Development (NORAD). A feed mill having 300 kg hr^{-1} capacity was installed at Patlikuhl farm during 1991 for preparation of different types of feeds viz., starter, on-growing and brood stock. The feed has high stability, appetence and conversion ratio and the protein content varies between 41-53%. Various ingredients used in these feeds are given in Table 9.

Under an ICAR Adhoc Scheme on 'Pilot scale trout feed development' a trout feed mill has been installed at DCFR, Bhimtal during 2005. It has a capacity to produce 100kg/hr.

Table 8. Feed ingredients (%), proximate composition and production cost of different trout feeds

Ingredients	Starter 1	Starter 2	Fingerling feed	Low energy fingerling feed	High energy production feed	New production feed	Brood stock feed
Fish meal	75.00	61.00	56.00	50.00	42.00	44.00	61.00
Soy-meal	-	3.00	7.00	12.00	13.50	18.00	8.00
Whole wheat	11.00	15.50	15.00	15.50	17.00	13.50	15.00
Blood meal	-	5.00	4.00	10.00	6.00	6.00	5.00
Active yeast	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Linseed oil	-	-	-	6.00	15.00	12.00	4.00
Fish oil	7.00	9.00	11.00	-	-	-	-
Vit. premix	2.00	1.50	1.50	1.50	1.50	1.50	2.00
DL methionine	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Choline	0.30	0.30	0.30	0.20	0.20	0.30	0.20
Common salt	0.10	0.10	0.10	0.10	0.30	0.20	0.10
Sod. Alginate	0.50	0.50	0.40	0.50	0.30	0.30	0.50
Proximate composition (%)							
Crude protein	53.70	49.17	47.14	49.08	42.21	45.30	51.58
Ether extract	13.55	14.65	16.32	11.17	19.40	16.69	9.82
Nitrogen free extract	10.35	13.95	15.08	16.39	17.85	16.81	15.26
Crude fibre	3.08	2.89	2.75	2.88	2.47	2.58	3.05
Total ash	11.03	10.31	9.72	10.27	8.79	9.22	10.67
Moisture	6.83	7.16	7.10	7.69	7.13	7.21	7.61
Production cost (Rs.)	18.22	16.77	16.69	17.27	19.83	18.96	18.05

(Source: Sardar and Wani, 2002)

Fig. 3e. Preparation of extruded feed for rainbow trout.

Fig. 3f. Prepared extruded feed for rainbow trout

Table 9. Feed ingredients (%) used in different trout feeds

Ingredients	Starter feed	On-growing feed	Brood stock feed
Fish meal	83.00	60.00	55.00
Whole wheat	5.70	14.20	16.20
Yeast powder	3.00	4.00	4.00
Deoiled soy-cake	-	14.00	17.00
Linseed oil	4.00	5.50	5.50
Shark liver oil	1.00	-	-
Vit. Premix	2.00	1.00	1.00
Sodium alginate	0.10	0.30	0.30
Choline chloride	0.40	0.30	0.30
DL methionine	0.30	0.30	0.30
Mineral mixture	0.30	0.30	0.30

(Source: Anon, 1999)

Rainbow trout feed has been standardized for starter, on-growing and brood stock. The ingredients used in trout feed preparation includes- Fish meal, soybean meal, wheat middling, skimmed milk, yeast powder, lineseed oil cake, shark liver oil, choline chloride, vitamin and mineral premix, etc. The feed is well accepted by different stages of the rainbow trout, it has FCR of 1.8-2.0 and protein content ranges from 47-53%.

4 FEEDING EXOTIC CARPS

Initially monoculture of *Cyprinus carpio* was attempted to create awareness in the hilly region about aquaculture. In Kashmir valley by exploiting the natural productivity of the rural pond and regulating the kitchen refuse and other run-off from the village into the pond, an estimated production in the range of 2.5-3.0 t/ha was achieved in a period of 12 months. In the upland waters the Indian major carps do not grow well due to low thermal regime. Therefore, Directorate of Coldwater Fisheries Research, Bhimtal made trials to culture Chinese carps viz., common carp (*Cyprinus carpio*), silver carp (*Hypophthalmichthys molitrix*) and grass carp (*Ctenopharyngodon idella*). The trial results revealed that eight months period between April to October is the most suitable for growing fish in the temperate climate prevalent in higher reaches of Kumaon. From large number of experimental trials conducted, based on these three species combination stocked in the density range of 2-4 fish/m² with recommended supplementary diet developed from local items like-rice bran/wheat bran/oilcake, soybean flour or kitchen/ livestock/field waste @ 1.5-3.0% and fertilizers like RCD/compost at nominal rate without disturbing aquatic environment enabled to achieve fish production in the range of 0.59-0.69 kg/ m² with moderate practices and 0.926-0.986/ m² with intensive care. A standardized 'Composite Carp Farming Technology' most suitable for mid Himalayan region of the country has been developed (Anon, 2005). The technology is simple to adopt, economical, viable and is capable to recycle the kitchen/farm/agriculture wastes. This technology opens up the possibility of

Fig. 4a. Common carp, *Cyprinus carpio*

Fig. 4b. Silver carp, *Hypophthalmichthys molitrix*

Fig. 4c. Grass carp, *Ctenopharyngodon idella*

promoting exotic carp culture in hills of western and eastern Himalayas where existing production of indigenous fishery is very low.

During the culture practices of grass carp and silver carp it was observed that the growth, maturity and breeding exhibited variations according to the water temperature at different altitudes The induced breeding technique developed for silver carp and grass carp reared in tropical waters was found ineffective in coldwaters. Therefore, a study on induced ovarian development, maturation and spawning of grass carp and silver carp in coldwater was initiated by DCFR Bhimtal. In comparison to their behavior in tropical waters, the fishes grew slower at 4.5-27.0°C, female matured at the age of 7 years and male at the age of 6 years, fecundity was reduced to 0.9 lakh/kg against normal fecundity of 1.2 lakh/kg, required 3-4 times higher doses of spawning agent (Ovaprime/ Ovatide) and needed long spawning and hatching period. Low fertilization (31.7-63.0 %) was recorded. The critical temperatures for breeding and hatching was found 19-24°C and above 21.5°C, respectively. The use of sex hormones with/ without manipulation in environmental factors was found effective in reducing the maturation period from 1-2 years. After a series of trials a standardized 'Induced Breeding Technique of Grass carp and Silver carp in Coldwater' has been developed to produce their seed in large quantities in hills (Anon, 2005). The technique is simple and easy to adopt but differ from the breeding technique followed in warm waters.

The rapid and significant developments now taking place in aquaculture can only be sustained by the provision of adequate inputs, especially those of seed (juveniles for growing)

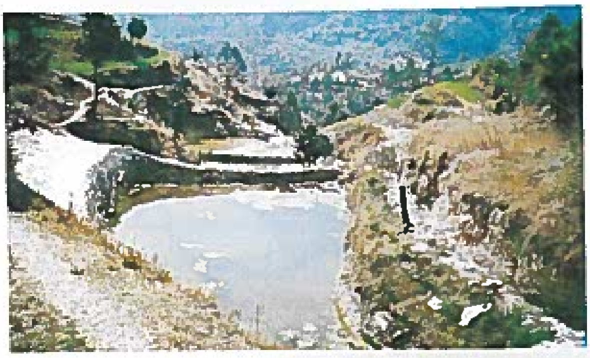

Fig. 4d. Stream belt converted into fishponds

Fig. 4e. Fish farming being practiced by farmers of Kumaon Himalayas

Fig. 4f. Fish farming in NEH region

Fig. 4g. Exotic carps production from a farmer's pond

and feed (Jauncey, 1988). The author envisaged that most future developments would be in the form of semi-intensive or intensive aquaculture systems, which require appreciable inputs of fertilizer and/or artificial feeds. In these systems feed accounts for between 30 and 60% of the production costs. Feed therefore has a major role in the economics of such enterprises. Aquaculture species can obtain the nutrition that they require either endogenously, from natural food present in the culture environment, or exogenously, from artificial food added to the culture environment.

As the stocking density increases the contribution of natural food to overall production decreases whilst that of artificial feed increases. The nature of the artificial feed input will vary with the level of intensification and the contribution made to nutrient requirements by natural food. As the stocking density/yield increases the artificial food has to become increasingly complete, at the highest levels of intensification it has to supply all of the nutrient requirements of the species under culture assuming no contribution from natural food.

For herbivorous, omnivorous or detritivorous species raised in ponds with limited water exchange and at intermediate or low stocking densities natural food production in the pond should be maximized through fertilization. Natural food (phytoplankton, zooplankton, macrophytes, benthic invertebrates, etc.) is generally rich in essential nutrients such as protein (essential amino acids), lipids (essential fatty acids), vitamins and minerals. When, as stocking density increases, natural food (even with fertilization) becomes limiting it is additional food energy input that is required. At this level supplementary foods rich in energy are introduced. At still higher stocking densities, or for carnivorous species, complete feeds must be used.

Among the species cultured in coldwater regions of India, carps are regarded as species that will benefit from pond fertilization and/or supplementary feeding. Trout, however, are very carnivorous and can only be cultivated intensively with complete artificial feeds.

Pond fertilization

Fertilization is performed for the purpose of increasing the production of natural food in a pond. These ponds should have limited or, preferably, no water exchange only make-up for evaporation or seepage. Otherwise the fertilization effects will be lost. The fertilizer is principally required to supply nitrogen, phosphorus and potassium to boost the production of aquatic ecosystem. Fertilizers used in aquaculture ponds are organic fertilizers (animal manure, composted plant waste) and inorganic fertilizers (urea, ammonium salts, nitrates, phosphates, potash). Organic fertilizers are generally preferred because they degrade and release nutrients into the water more slowly and secondly because many aquaculture species

Fig. 4 h. Netting operation in a village pond derive some nutritional value by consuming them directly. While inorganic fertilizers are generally fast in their release of nutrients into the aquatic ecosystem. Hence, are added 'little and often' preferably daily. The recommended levels of input of organic and inorganic fertilizers vary considerably but a typical case for upland ponds (800-1740 m asl) for mixed Chinese carp farming (grass carp 50%, silver carp 25% and common carp 25%) might be; raw cow dung plus oilcake at the rate of 5000 kg + 50 kg ha^{-1} yr^{-1} for organic fertilizer and for inorganic fertilization rates would be urea plus single super phosphate plus potash at the rate of 300+300+50 kg ha^{-1} yr^{-1} or both organic and inorganic fertilizers together; along with liming at the rate of 300 kg ha^{-1} yr^{-1}; with fertilization and liming to be done at every tenth day during the culture period (Anon, 2004).

Supplementary feeds

Supplementary feeds assumes that natural food continues to make a significant contribution to the nutrient requirements of the cultured species, particularly with respect to essential amino acids, essential fatty acids, vitamins and trace elements. Supplementary feed are designed to complement (supplement) the levels of nutrients supplied by natural food. As for pond culture supplementary foods are only of value to pond culture, with limited water exchange, of omnivorous, herbivorous or detritivorous species. Supplementary feeds are predominantly composed of cereals, cereal by-products and oilseed meals; some leguminous crops can also be used. For grass carp the feed can consist simply of chopped fresh green vegetable matter. These types of feed materials can be introduced into ponds either singly or, preferably, as simply balanced

Fig. 4i. Supplementary feed for carp

formulated mixtures. They can be fed in three basic physical forms: (1) as dry meals (or mixes) broadcasted/spread onto water surface; (2) as dough or pastes formed by mixing with water (preferably with a binder) and introduced into the pond as lumps/balls; and (3) as pelleted feeds prepared by using any one of a variety of pelleting techniques.

The first approach is the simplest but will result in considerable wastage since the target species will consume little of it and the remaining will enter the pond ecosystem as an organic fertilizer increasing natural food production. Filter feeding species (like silver carp) will make direct use of some of this feed. The second approach is better as the fish ingests greater proportion of the feed offered. However, feeds of this type have very short storage and water stability; can only be used fresh only and require on site preparation and daily feeding. The water stability can be improved by using binders such as wheat gluten, cassava/tapioca, or any starch material up to 5-10% of dry matter especially if heated/cooked. These dough are well accepted by most fish. The third option, dry pelleted supplementary feed, is the best for culture systems at the upper end of the semi-intensive level. They are easy to store, more water stable, easy to handle and can be formulated to provide a reasonably balanced nutrient profile. The principal disadvantage of such feeds is the cost of manufacture; they should be used where economic analysis has shown them to be viable.

Supplementary feeds are generally not formulated to provide particularly well balanced nutrient profiles, they are usually based on whatever low cost feed materials are available. No attempt would be made in such feeds to balance levels of essential amino acids, essential fatty acids, vitamins and essential minerals. If the feed is to be presented as a dough or dry pellet attention must be paid to the particle size of the feedstuffs used. As this particle size decreases the digestibility and water stability of the pellet will increase. The rate of feeding is expressed as dry matter percentage of live body weight per day. Feeding rate varies with species, age/size, water temperature, expected contribution from natural food and economics.

In all the cases it is assumed that pond water quality will be monitored and maintained. Overfeeding will cause deterioration in water quality, which, if unchecked, will lead to lowered levels of dissolved oxygen and, possibly, mortalities. Poor water quality can be compensated for by reduced feeding and/or water exchange and aeration.

The utilization of exogenous, artificial, feeds is often measured in terms of the food conversion ratio (FCR, kg of food per kg of live weight gain). As supplementary feeds are nutritionally incomplete they would be expected to have poor, high, FCRs. However, this is offset by the contribution made by natural foods. FCRs for supplementary feeds should vary from a high of around 5 (or more) for a simple supplement to 2-3 for a more complete pelleted feed (sometimes as low as 1-2).

In upland fish ponds typical supplementary feed is developed from local items like-rice bran, wheat bran, oil cake, soybean flour, kitchen/livestock/field waste. It is prepared in the form of dough and introduced in the ponds as balls. Feeding rate is @ 1.5-3.0 % of the total fish biomass. For grass carp fresh chopped green grass in given on floating platform @ 10% of biomass or as required (Anon, 2005).

5

FEEDING MAHSEER

Mahseer being a prized fish as a food fish, a sport fish and even in commercial fisheries needs to be well managed and perpetuated. The decline in catches of mahseer across the various ecosystems attracted attention of fishery scientist to re-establish this fish and the mechanism of its restoration was mainly focused on its artificial propagation. The first attempt to breed golden mahseer (*Tor putitora*) met with modest success at Bhimtal with a survival rate of only few hatchlings (Tripathi, 1977). Pathani and Das (1978) used mammalian hormone as well as homoplastic pituitary extract to initiate gonadal development for artificial breeding of fish, however, their attempts were not successful. Joshi (1981, 1988), Joshi and Malkani (1986) and Joshi and Saxena (1992) obtained success in breeding of golden mahseer and rearing of its seed for stocking in natural water bodies. Directorate of Coldwater Fisheries Research, Bhimtal gave thrust to artificial breeding and seed production of golden mahseer and fabricated a flow-through hatchery for its seed production (Sehgal and Malik, 1992). Further, made continued efforts to standardize the breeding techniques and refine the flow-through hatchery system for seed production. The seed production programme of golden mahseer basically involves the efforts to procure mature spawners, their artificial fecundation by dry stripping of the sex products, incubation and hatching of the eggs and rearing of fry in the flow-through hatchery, feeding of fry on formulated artificial feeds, combating diseases by disinfectants and production of fry/ fingerlings for stocking in open waters or culture ponds. The fecundity of golden mahseer ranges from 3000-5000 eggs/kg. Rate of fertilization is 85-90%. The hatching takes place in 80-96 hours at 22-24°C and absorption of yolk sac is completed within 10-12 days. At this stage hatchling measure about 8-10 mm in length and are free swimming tiny fry and are fed on either egg custard or goat liver extract @ 8-10% of body weight for 6-8 times in a day from sun rise to sun set. Water flow in the troughs is maintained at 2-3 l/min. After 15-20 days when fry attain a size of 10-12mm (0.008-0.010g) they are shifted to nursery tanks (2.0m^2 area; 0.45m depth) and stocked at density of 5000-8000 fry/ tank. Water flow in the tanks is maintained at 3-4 l/min. and the fry are fed on artificial compounded feeds having 40-45% protein @ 10-15% of total biomass twice daily. After rearing for about 2-3 months in the flow-through hatchery they

Fig. 5a. Golden mahseer, *Tor putitora*

are either shifted to nursery ponds for stock building or used for ranching open water bodies.

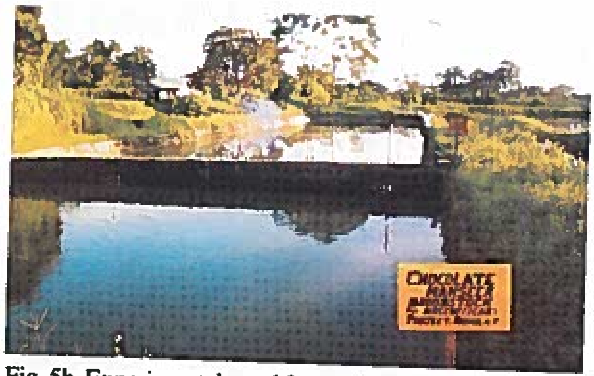

Fig. 5b. Experimental pond for rearing chocolate mahseer at Iduli fish farm, Roying, Arunachal Pradesh.

Among other species of mahseer, Ahmed (1946) stripped and raised the artificially fertilized eggs of pond reared Katli (*Neolissochilus hexagonolepis*) and obtained some advanced fry. In North East Hill Region Directorate of Coldwater Fisheries Research, Bhimtal has made attempts on rearing of juveniles of chocolate mahseer to fingerlings in earthen ponds using conventional supplementary feed at Iduli fish Farm, Roing and a record growth range of 110.0 - 150.0 g/ month was achieved during the summer period. Further, adult fishes of chocolate mahseer were reared in earthen ponds for

Fig. 5c. Experimental cage culture of golden mahseer in a Kumaon Himalayan lake- Bhimtal

raising brood stock for undertaking artificial fecundation under captivity. A modern flow-through hatchery along with stock raising facilities has been established at Iduli Farm of the State Arunachal Pradesh, Roing through Rural Works Division Construction Agency of Arunachal Pradesh. This will help in raising brood stock and producing seed of this species in captivity for culture and ranching to conserve the stocks in wild waters and for providing seeds to other neighboring North East States.

The artificial fecundation of eggs of deccan mahseer (*Tor khudree*) was successfully carried out on a large scale for the first time in 1970 by Kulkarni (1971) at Tata Power Company Fish Farm at Lonavla, Maharashtra. Since then considerable knowledge has been gained on the spawning habits; artificial propagation; hatchery management practices; rearing of fry, fingerlings and brood stock and on success of induced breeding of pond raised stocks of various species of mahseer, namely, *Tor khudree*, *T. mussullah*, *T. tor* and *T. putitora* (Kulkarni and Ogale, 1978; Ogale, 1997).

Attempts have also been made to culture mahseer under pond environment by Directorate of Coldwater Fisheries Research, Bhimtal results indicate that within a years period *Tor putitora* attain a size of 175g (210 mm) in properly managed pond. While *Tor khudree* grew to 600-900g in a year in village ponds near Lonavla. The cage culture of two species of mahseer, *Tor putitora* in lake Bhimtal and *Tor khudree* in Walwan lake gave encouraging results with a overall survival rate of about 70% (Kohli et al., 2005; Anon, 2008). Hence, all the species of mahseer are amenable to artificial breeding and culture under different systems.

FOOD HABITS

Mahseer is an omnivore, feeding on a wide spectrum of materials viz., small shrimp, crustaceans, molluscs, insect larvae, eggs, paddy grains and various seeds. Keshavanath (2000) reported that in pond reared *Tor khudree*, smaller fish mostly feed on zooplankton, while slightly larger fish prefers insects to other food items, so much so that in some cases the gut content mainly consisted of insect remains (nearly 90%). Sehgal et al. (1971) investigated that in the riverine environment food habits of fry and fingerlings of *Tor putitora* includes diatoms (46.98%), decayed organic matter (22.28%), green algae (13.33%), insects (10.27%), blue green algae (1.35%), protozoans (0.70%) and fish (0.41%). Desai (1970) found that food composition gradually varied with increase in the size of *Tor tor* inhabiting R. Narmada. While macrovegetation was least (4.70%), the molluscs (21.90%) followed by insects (53.80%) accounted for a major percentage of the food by volume in juveniles (95-200 mm). As the fish grew in size the animal matter intake decreased (molluscs-14.10%, insects-11.80%) and that of the plant matter increased (macrovegetation-29.20%, algae-13.50%) in the size group 281-440 mm. With further increase in the size (601-760mm) macrovegetation was found to exceed all other food items (44%), algae being 11.40%, while molluscs (7.10%) and insects (5.10%) got reduced. Hence, there is a transition from carnivorous diet in the juveniles to herbivorous diet in the adults. Further Desai (1970, 1992) maintained that *Tor* mahseer has marginal bottom feeding habits and is stenophagic with macrovegetation as its basic food and animal matter as its secondary food. Dasgupta (1988) indicated that the basic food of chocolate mahseer (*Neolissochilus hexagonolepis*) is algal and vegetal matter and animal matter being secondary food and the percentage of vegetal matter was found to increase with increase in length of the fish.

FEEDS AND FEEDING

Nutritional studies on mahseers has been chiefly conducted by Directorate of Coldwater Fisheries Research, Bhimtal (Uttarakhand) to rear early stages of Himalayan golden mahseer (*Tor putitora*); by the College of Fisheries, Manglore (Karanataka) on Deccan mahseer (*Tor khudree*) and at ICAR Research Complex for NEH Region, Barapani (Meghalaya) on chocolate mahseer (*Neolissocheilus hexagonolepis*). To some extent research on mahseer nutrition has been conducted also at Central Institute of Fisheries Education (Deemed University), Mumbai and other organizations.

Tor putitora (Himalayan golden mahseer)

Swim-up fry

Series of experiments were conducted with various artificial compounded test diets (casein based) (Table 8) for rearing the early stages (15-20mm; 60mg) of the species (Raina et al., 1993; Sunder et al., 1998). The diet with about 45% crude protein, 13% ether

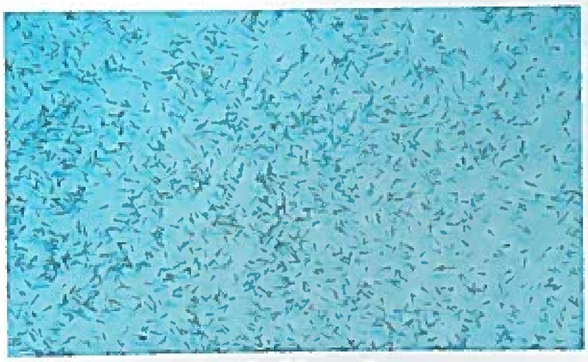

Fig. 5d. Swim-up fry of golden mahseer

extract and 20% carbohydrates gave overall best survival, feed efficiency, conversion ratio and growth performance; this initially formulated diet was named as NRCCWF I. Protein requirement is said to be highest at fry stage and decreases with increasing size (Garling and Wilson 1976; NRC, 1977; Wilson and Halver, 1986). It is recommended that to obtain maximum growth, fish fry must consume a diet containing half of dietary ingredients as protein. The high requirement of the component could be on account of relatively rapid increase of most tissues in smaller fish as they grow with positive allometry and also their generally higher metabolic turn over (Weatherly and Gill, 1987). These authors stated that protein content in practical diets often ranges from 20-60% depending upon the water temperature. Fats being the ready source of energy have the distinct advantage of being almost completely digestible and need to be supplied in diets for

Fig. 5e. Rearing of golden mahseer early fry in flow-through hatchery, Bhimtal

quick growth and maintenance of healthy fish stock. NRC (1981) reported that lipid not less than 10% and not more than 20% can be added to coldwater fish diets with excellent results. Weatherly and Gill (1987) stated that when dietary lipid is generally increased to a certain limit, the feed conversion efficiency of the fish may increase proportionately and further opined that generally in fish diets, the fat level may range from 5-25% without adverse effects on growth and acceptable lipid level should be determined in fish tissues to be able to adjust dietary lipid level accordingly. As per Sunder et al. (1998), based on the analysis of lipid content in the golden mahseer fry tissues (approximately 17%), the diets containing 13-14% crude fat gave best performance. Sunder et al. (1998) also observed that higher values did not prove effective, causing high rate of mortality and low rate of feed efficiency in the test fishes. Carbohydrates to a certain limit can replace the dietary fats to meet the metabolic energy needs of fish. Since carbohydrates are least expensive compared to protein and fat so it could be given in feed formulations besides they also get as binders/fillers in feed preparation. In formulated diets, carbohydrates can vary from 10-50% and efficiency of utilization as energy may range from 40-90% (Hastings, 1979). Feed containing 20-22% carbohydrate suited best for the growth and survival of golden mahseer fry/ advanced fry (Sunder et al., 1998).

Among the various conventional feeds viz., egg yolk emulsion, minced goat liver and rice bran and mustard oil cake mixture, Sunder et al. (1998) observed higher food quotient, survival and feed efficiency when golden mahseer young one's were fed with wet diet of minced sheep/ goat's liver over the dry compounded diets (Table 8). However, the authors felt that this may not be economical and practical as the cost of wet diets have escalated tremendously which may upset the whole aquaculture programme when taken up in a big way besides many a times, the regular supply of such products may not be ensured and also there is the risk of introducing pathogens to the recipient fish stock, if regularly used. Further studies with fishmeal based practical diet (NRCCWF III) with 40% protein revealed that golden mahseer early fry fed with NRCCWF III diet had better growth and feed efficiency compared to those fed minced goat liver (Anon, 2005).

Fig. 5f. Growth response of golden mahseer fry to different feeds- goat liver, trout feed and NRCCWF-III feed.

Table 8. Feed ingredients and chemical composition (%) of formulated diets for golden mahseer

	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6
Ingredients (g/100g)						
Soybean meal (roasted)	60	40	40	40	40	35
Rice starch	25	-	-	-	-	-
Wheat bran	-	-	-	15	5	-
Cod liver oil	5	5	5	10	5	5
Silk worm pupae	-	20	-	-	-	-
Potato starch	-	25	25	-	-	-
Casein	-	-	20	25	40	50
Yeast	-	-	-	5	5	5
Gelatine	4	4	4	-	-	-
Vitamin mix	5	5	5	-	-	-
Mineral premix	1	1	1	-	-	-
Vitamin and minerals mix	-	-	-	5	5	5
Chemical composition (%)						
Dry matter	92.88	91.79	92.65	90.34	89.34	92.12
Crude protein	21.45	27.62	31.94	36.66	45.38	50.21
Crude fat (Ether extract)	24.14	16.44	12.47	17.13	13.69	14.12
Nitrogen free extract	39.80	37.11	38.59	24.78	20.36	22.35
Total ash	4.89	5.28	5.19	7.44	5.98	3.04
Crude fibre	2.60	5.34	4.46	4.33	3.93	2.40
M.E. (K Cal/g)	2.97	2.91	3.25	3.01	2.50	3.32

(Source: Raina et al., 1993; Sunder et al., 1998)

Fry and fingerlings

Based on the trials conducted at Directorate of Coldwater Fisheries, Bhimtal on various nutritional aspects of golden mahseer the following results were obtained.

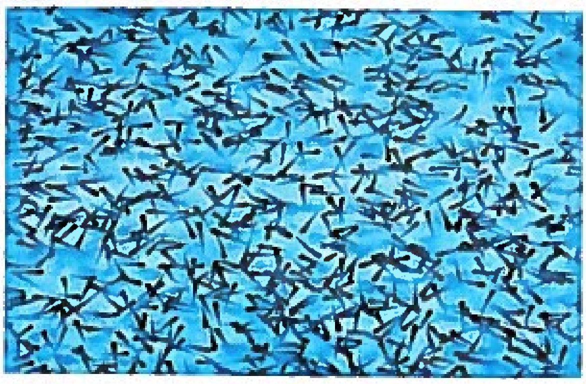

Fig. 5g. Advanced fry of golden mahseer

For rearing fingerlings, the casein present in NRCCWF I diet was replaced with fishmeal to the extent of 50% resulting in NRCCWF II diet and up to 100% in NRCCWF III diet. Further the trout feed and carp feeds were also compared. Among all these diets tried NRCCWF III, a fishmeal-based practical diet was found to be cost effective and better feed in terms of growth performance and feed efficiency (Anon, 2003; Mohan and Basade, 2005).

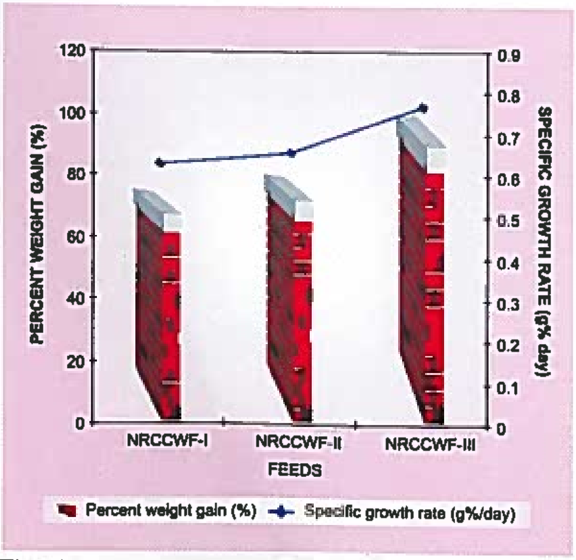

Fig. 5h. Growth response of golden mahseer fingerlings to NRCCWF-I, II and III feeds.

The nutritional requirements for the juveniles of Himalayan golden mahseer have been worked out by conducting experiments with diets having graded levels of protein, lipid and carbohydrates. Based on the best growth performance, digestibility and utilization of feed, the nutrient requirements of the species was assessed to be about 40% protein, 15% lipid and 25% carbohydrates.

Feeding frequency had a significant effect on food consumption and growth of golden mahseer fry. Both food consumption and growth increased with increase in the number of meals per day up to three meals, further increase in number of meals, from

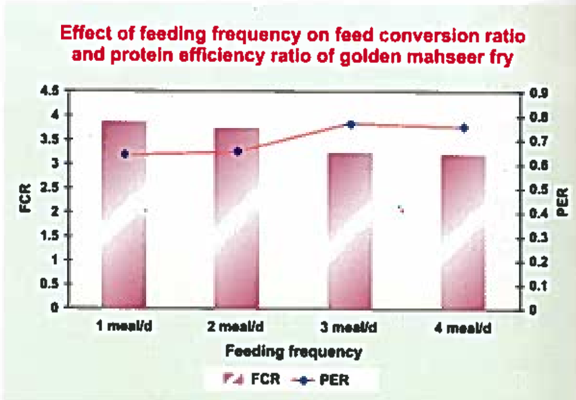

Fig. 5i. Effect of feeding frequency on feed conversion ratio and protein efficiency ratio of golden mahseer fry.

three to four feedings, did not result in greater growth. Since increasing the number of meals from three to four did not significantly enhance the food consumption and growth, hence feeding three times a day seems to be sufficient for maximal growth of golden mahseer fry under rearing conditions (Anon, 2005; Basade and Mohan, 2007).

Feed supplements are known to enhance growth performance of the fish species to which they are fed. Performance of feed supplements was also investigated in case of Himalayan golden mahseer too. Citric acid, an organic acid found in citrus group of fruits can safely be used as feed stimulant at 0.04M concentration in aquaculture of golden mahseer as it is not a chemical which may remain as residue in fish tissue and pose hazards to them and also to the consumers. This safe and cheap ingredient offers immense potential for increase in production (Basade and Mohan, 2006). Chitin is a non-starch polysaccharide and is regarded as component of dietary fiber. Dietary chitin supplementation to the level of 2% had a positive impact on the growth performance of golden mahseer. Chitin can thus be supplemented to the diets of golden mahseer especially to enhance their growth performance which otherwise is very slow (Mohan et al., 2002). For probiotics and immunostimulants, a commercially available product was used as this product contains both the probiotics as well as immunostimulants. The results indicated that probiotics and immunostimulants when incorporated in the diet gave better growth performance, feed efficiency and ADC of dry matter in golden mahseer fingerlings.

In captivity, fish are either fed live (or natural) food items (fish, algae, invertebrates, etc.) or compounded (so-called artificial) feeds. These feeds are mixture of ingredients compounded into water-stable aggregates (pellets, granules). Ingredients entering in the composition of compounded feeds serve as source of nutrients and/or play functional roles (for example, help in the manufacturing process). Ingredients commonly used in fish feeds include fisheries by-products, plant products, animal by-products, as well as various individual nutrients and additives. Fisheries by-products, such as fish meal are produced from low economic value fish species, fisheries by-catches, or by-products from filleting and canning plants. Because they are produced from wild fish catches mostly, fish meal supplies are limited and fluctuating. Fish meal production, and its use in fish feed, is often presented as an unsustainable. Fish meal is an excellent source of nutrients for fish and constitute a significant fraction of the total amount of ingredients used for fish feeds production. Because of its high quality

Fig. 5j. Common buckwheat

Fig. 5k. Finger millet

Fig. 5l. Amaranth

Fig. 5m. Black soybean

Fig. 5n. Horse gram

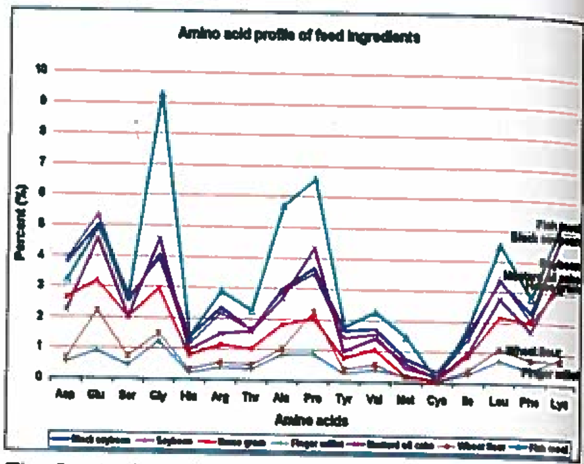

Fig. 5o. Amino acid profile of the indigenous fish feed ingredients

and limited supply, fish meal is a very expensive ingredient. It is therefore, increasingly being replaced in fish feed by more economical protein sources, such as soybean meal, corn gluten meal, etc. A lot of research effort is devoted to replacing fish meal in fish feed formulae.

Survey of the local area/market of Kumaon Himalayan region was conducted and indigenous feed ingredients available in the area were identified and their local names, English name and scientific names were ascertained. The indigenous ingredients identified were- Madira, Barnyard millet, *Echinochloa frumentacea;* Mandua, Finger millet, *Eleusine coracana;* Konee, Foxtail millet, *Setaria italica;* Chena, Proso millet, *Panicum miliaceum;* Ramdana, Amaranth, *Amaranthus sp.;* Ugal, Common Buckwheat, *Fagopyrum esculentum;* Ugal, Tartary Buckwheat, *Fagopyrum tataricum;* Gahat, Horse gram, *Macrotyloma uniflorum;* Bhatt, Black soybean, *Glycine max* and Lai oil cake, Brown mustard oil cake, *Brassica juncea.* Based on their chemical composition it can be concluded that barnyard millet, finger millet, foxtail millet, proso millet, amaranth, common buckwheat and tartary buckwheat can be used as carbohydrate source; horse gram and lai oil cake can be used as protein source and black soybean and soybean can be used as both protein and lipid source (Anon, 2006). The protein sources, horse gram and black soybean can be incorporated in the golden mahseer diets up to 10% and 30% levels, respectively of the total dietary protein. However, it is advantageous to use heat-treated horse gram and black soybean over the raw forms as heat treatment denatures the antinutrients present in them. Among the various locally available indigenous carbohydrate sources assessed for their suitability for inclusion in the diets of Himalayan golden mahseer, it was observed that the control diet having wheat flour as carbohydrate source gave better growth performance, feed efficiency, ADC of dry matter and survivability. Hence, wheat flour is advantageous over mandua, ramdana and ugal as a carbohydrate source in diets of golden mahseer fingerlings.

To conclude, for growth of Himalayan golden mahseer swim up fry to fingerling stage, the feed NRCCWF III was found to be ideal. However, to reduce the cost of feed, fishmeal can be replaced with heat-treated horse gram up to 10% and heat-treated black soybean up to 30% level. Fry can be fed three times a day. To improve the growth and health of the species citric acid and probiotics and immunostimulants can be used.

Tor khudree (Deccan mahseer)

Swim-up fry

The swim-up fry are fed with egg yolk suspension (a pinch for 200-300 fry) and sieved zooplankton (50ml zooplankton for 346 fry; each ml contained 60 numbers) twice daily, morning and evening. This is followed by nursery rearing in manured ponds (stocking density 0.1 million fry/hectare). The fry is fed on a feed containing 25% fish meal, 25% groundnut oil cake, 25% ragi flour and 25% chicken egg yolk (Oliver et al., 2007). While the rearing spawn in fertilized ponds (cowdung @ 100kg/ha) providing a mixture of rice polish and groundnut oil cake powder as supplementary feed resulted in low survival and growth (Keshavanath et al., 2007).

Fry to fingerlings

Investigations carried out in the College of Fisheries, Manglore by Keshavanath (2000) on Deccan mahseer fingerlings showed that diet with 40% protein was better. Artificial wet diet was better utilized compared to dry pellets by the fish. Among the different protein sources tested viz., prawn waste, subabul leaf (*Leucana leucacephala*) and silkworm pupae keeping fish meal as control. Silkworm pupa (raw up to 60% and de-oiled up to 50%) produced the best growth. Further *Spirulina* when used as protein source in pelleted diets either alone or with fish meal/groundnut meal, achieved better growth when used alone. To study the protein sparing effect of sardine oil, sardine oil was fed to deccan mahseer fingerlings through a 40% protein fish meal based diet. The results clearly demonstrated the protein sparing effect of sardine oil, the optimum supplementation being 6%. Dietary administration of 17α-methyltestosterone at 2.5 ppm level had pronounced effect on growth of the fish. Combination of steroid hormones (17α-MT + Diethylstilbestrol (DES); 2+2 ppm) and steroid plus protein hormones (DES + Human chorionic gonadotropin (HCG); 2+10 ppm and 17a-MT + HCG: 2+10 ppm) induced markedly higher growth and FCR, with best results with DES + HCG combination.

For the growth promoters tested Crown Gro-fast, a herbal preparation (Crown Herbal Products Pvt. Ltd., Chennai)at 1.5% level in 40% protein containing fish meal based diet exhibited better growth performance. Other trials on the effect of growth promoters conducted with fry, under laboratory conditions and fingerlings, under farm conditions demonstrated that vitamin D_3, soylecithin, thyroxine and betaine when included in the fish meal based diet containing 37% protein and 10% lipid presented superior growth and feed efficiency to that of the control (Basade, 2001). To reduce the feed input cost, an attempt was made to produce natural food, periphyton, in tanks using different substrates. Fish growth was superior with bamboo substrate than for PVC substrate and the dry matter and protein digestibility of periphyton by the fish were 43% and 64%, respectively. (Keshavanath et al., 2007).

Fig. 5p. Chocolate mahseer, *Neolissochilus hexagonolepis*

Neolissochilus hexagonolepis (Chocolate mahseer)

It has been reported that supplementary feeding of chocolate mahseer fingerlings (20-25g) with rice bran, mustard oil cake, silkworm pupae, fish meal and local herb (*Gymnura crapidoides*) resulted in growth increment to 300-400g recording a survival range of 85-97% in one year while rearing at Barapani fish farm, Meghalaya (Sunder, 2001).

6

FEEDING SNOW TROUT

The scientists of Directorate of Coldwater Fisheries Research, Bhimtal have made significant efforts to artificially propagate various members of Schizothoracids initially in Kashmir during eighties and subsequently in Kumaon Himalaya in nineties and have met with certain degree of success (Vass et al., 1978; Raina et al., 1985a, 1985b and 1986). Through artificial fecundation by stripping of the sex products without any hormonal manipulation the different species of snow-trout (*Schizothoraichthys niger*, *S. esocinus*, *S. micropogon*, *S. curvifrons* and *Schizothorax richardsonii*) inhabiting either lacustrine or riverine systems of the Kashmir valley were bred in the field itself and *Schizothorax richardsonii* in Kumaon Himalaya under pond conditions at the Directorate of Coldwater Fisheries Research, Experimental Fish Farm, Champawat. Rate of fertilization ranged from 65-90%. The fertilized eggs can be incubated under different flowing water conditions, as heavy mortality was registered under still water conditions, either in the hatchery or in the field incubators installed at the stream sites. The incubation period normally ranges from 10-15 days depending upon water temperature. After hatching yolk sac-fry, with a yellowish yolk sac, emerges and remains in semi-quiescent stage for 6-10 days till the yolk sac is completely utilized. After the yolk sac is completely absorbed the free swimming swim-up fry come out which readily accepts the artificial feed. The cumulative survival from fertilized eggs to swim-up fry ranges from 35-60%. The swim-up fry are reared in the hatchery trough to young fry on artificial feeds. The young fry are than shifted outside the hatchery to the nursery/ rearing ponds. At Directorate of Coldwater Fisheries Research, Experimental Fish Farm, Champawat (Uttarakhand) fry were reared in running water cemented raceways (10x3x1m) and fed on artificial compounded diets prepared from both animal and plant sources with oil, vitamin and mineral supplements having 40-50% protein level. Fish grew to 3-5g, 8-12g and 30-40g during first, second and third year, respectively with overall survival rate of 30-50%. The water requirement at various developmental stages for snow-trout under captivity were, for incubation of 3000-5000 eggs, 0.5-1.0 l/min at 8-15°C; for rearing 1000-2000 fry to fingerlings, 2.0-3.0 l/min. at 15-20°C and for rearing 500-1000 fingerlings to yearlings and further, 2.5-3.5 l/min. at <25°C. It is evident that growth of snow-trouts is certainly not very encouraging in captivity, probably due to inherent genetic characters. This could be one of the reasons

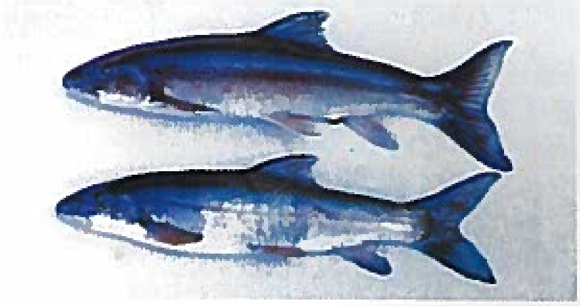

Fig. 6a. Snow trout, *Schizothorax richardsonii*

that culture of this fish has not attracted attention of the entrepreneurs. In nature too, in a period of 7-11 years this fish is known to attain a size of about 500g in colder zones.

At the Directorate of Coldwater Fisheries Research, Experimental Fish Farm, Champawat initial success has been achieved in conducting artificial fecundation, hatching and rearing of young ones from the pond reared *Schizothorax richardsonii.* In Garhwal Himalaya, preliminary breeding experiments through hypophysation using pituitary extract and Ovaprim on *S. richardsonii* are reported to have been conducted with a fertilization rate 81% and 72%, respectively. In Himachal Pradesh too, an experimental trial on the use of homoplastic pituitary extract resulted in complete ovulation in *S. richardsonii* (Sunder 2005).

Hence, the schizothoracine species are easily amenable to breeding either through hypophysation and/ or by stripping method and can be further reared up to the stockable size (>5g) in a period of one year, however, in mud ponds a significant growth could be expected with well balanced artificial diets. The healthy seed thus produced in large numbers can be ranched to rejuvenate the open waters on continual basis besides collection and stocking of natural seed from the drying pools to save the valuable germplasm of these fisheries.

FOOD HABITS

The snow trout, *Schizothorax richardsonii* has a ventrally placed mouth with horny lip well suited to rasping and scraping the epilithic micro-benthic organisms (Sehgal, 1992). The author further reported that the fish like other cyprinids has no well-defined stomach. The juveniles constituting fry and fingerlings (16-65 mm in total length and 32-2500 mg in weight) foraged primarily on soft-bodied insect nymphs and larvae of Diptera (52.7 – 79.7%), Ephemeroptera (10.3 – 40.7%) and Trichoptera (1.2 – 37.0%) in order of preference. The grown-up 101-200 mm size group with distinct ventrally placed mouth and a horny rim along the lower lip made the fish perfect to rasp or scrap the benthic microbiota growing over the rocks, stones, boulders, etc. in its slanting posture. The fish devoured blue-green algae (27.0 – 100.0%), diatoms (33.3 – 90.8%) and green algae (3.8 – 4.0%). With increase in size group 201-300 mm the fish switched on to diatoms (68.5%) followed by blue-green algae (29.5%). In the size group 301-400 mm there was further change in feeding habits. The fish consumed the diatoms to the extent of 91.9% followed by blue-green algae (1.5 – 2.0%). In the size group 401-500 mm the feeding pattern was more or less similar to the earlier size group being diatoms (92.7%) and green algae (1.6 – 5.5%). While Jan and Das (1970) stated that *S. richardsonii* is a bottom feeder and herbivore with 67% plant matter and 24% animal matter. The food spectrum of different Schizothoracids as reported by Jan and Das (1970) specify that *S. niger* and *S. esocinus*, are herbivore surface feeders; *S. curvifrons* is herbivore occasionally resorting to column feeding (Sunder, 1984) and *S. longipinnis* and *S. micropogon* are herbivore bottom feeder (Anon, 1977).

FEEDS AND FEEDING

Initial feeding trials with various feeds prepared both from plant as well as animal origin on various snow trout species conducted in Kashmir farms by Directorate of Coldwater Fisheries Research during early eighties, reveal that the fish can grow to 5g in one year with a survival rate of 75-80%. Later feeding experiments taken up in Kumaon Himalaya (Chirapani Fish Farm, District Champawat, Uttarakhand) on young fry of *Schizothorax richardsonii* collected from nature and fed with artificial diets revealed a net growth increment of about 30 g in about 30 months indicating that the fish is inherently a slow grower. The compounded feeds mainly consists of soyflour, groundnut oil cake, rice polish, fishmeal fortified with Supplevit-M and Agrimin. Even the addition of supplemental vitamins (A, C and E) in the diets during the course of rearing had hardly any significant impact on the growth and survival of fish stocks (Sunder, 2001).

Trials were conducted to determine the effect of dietary protein levels on growth performance of juvenile snow trout. Protein concentration gradation of 400g, 450g and 500g/kg of diet was generated while moving from casein based semi-purified diet to fishmeal based practical diet. Following 90 days feeding trial with graded levels of dietary protein no statistically significant difference was detected for the various growth variables, namely, net weight gain, percent weight gain and specific growth rate. However, feed conversion ratio, protein efficiency ratio and survival was better in fish fed fishmeal based practical diet having 400g/kg of diet protein.

Substituting chitin at 20g/kg of diet to assess its impact on performance of snow trout fingerlings showed that fish fed control diet without chitin had lower growth and poor feed conversion ratio. Accordingly suggesting that chitin can be included at the level of 20g/kg of diet in snow trout feeds.

7 NUTRITIONAL DEFICIENCY DISEASES

Nutritional diseases encountered in coldwater fish culture as discussed by Jhingran and Sehgal (1978) are presented here. The authors expressed that artificial feeding plays an important role in healthy growth of trout. The fish, however, should not be overfed and the diet should be balanced. Lipoid hepatic degeneration, Enteritis, Hepatoma, 'Whirling' and Blue-slime are the principal diseases caused by nutritional imbalance in trout.

Lipoid Hepatic Degeneration is characterized by liver of the fish turning yellow brown in colour. Scrupulous avoidance of over feeding, periodical controlled feeding with fresh bovine liver and resorting to starvation from time to time are some of the prophylactic measures against LHD.

Enteritis is diagnosed by exudation of a yellowish-red fluid from the anus by applying slight pressure on the abdomen of an ailing trout. On dissection, the diseased trout shows inflamed intestine. Avoidance of overfeeding helps to check enteritis.

Hepatoma of rainbow trout shows itself as an external hard tumor behind the pectoral fins. It is believed by American pathologists that hepatoma is caused by over feeding the trout. It is also attributable to an aflatoxin. To prevent the occurrence of hepatoma in rainbow trout Ghittino (1963) has made the following recommendations: (i) feed pellets must be made from aflatoxin free ingredients, (ii) pellets kept under proper storage conditions only are to be used and (iii) feeding of rainbow trout with carcinogenic diets, even for a short period, must be avoided.

'Whirling' due to deficiency of thiamin chloride (vitamin B_1) is a common nutritional disease in hatcheries where raw fish is given as trout food. 'Whirling' movements follow a well-defined pattern attributable to malfunctioning of the nervous system. The following symptoms are described in order of their appearance (Sehgal and Joshi, 1975). To begin with, trout is not able to swim in its normal upright position and shows a tendency to swim at an angle to the vertical plane. As the intensity of diseases increases, the angle to the vertical plane becomes acuter until the fish starts swimming practically on its sides. A sudden disturbance on the pond edge activates the fish and for a second or two it swims normally but then soon relapses to side swimming position. Accompanied by side swimming, the fish loses its equilibrium and performs 'whirling' movements. After a spasm of gyration, the trout falls to the bottom and remains motionless for sometime. During this period the fish does not accept food. The affected fish picks up a mouthful of food and then rejects it. One of the most pronounced symptoms is melanotic appearance of fish. During 'whirling' movement, the trout hits the sides and bottom stones of the pond injuring its snout. As stated earlier raw fish when used without eviscerating possess a thermo labile enzyme called thiaminase, which is responsible for causing deficiency of vitamin B_1 in trout. Sehgal and Joshi (1975) found that partial cooking of fish flesh supplemented with sheep or goat liver and wheat bran reduced the incidence of 'whirling' to almost nil. Danish trout culturists, who use herring to feed trout in commercial farms, also face this deficiency disease (Rasmussen, 1965). As a counter measure, vitamin B_1 blended with coarse-grained wheat flour or calcium carbonate or a combination of the two has proved useful by adding to artificial diet prepared from raw herring. The blended material contains about 600mg of thiamin chloride per gram. As quoted by Rasmussen (1965), the requirement of vitamin B_1 for trout in USA ranges from 0.15-0.186 mg/day/kg of trout.

Blue-slime disease is characterized by a blue-coloured thin film of slime covering the entire body of trout. This film is eventually sloughed off giving a patchy appearance to the body. Accordingly to Davis (1947), biotin deficiency in trout diet is responsible for the incidence of blue-slime. Phillips et al. (1950) indicated that blue-slime is a dietary disease and fingerling brown trout are more susceptible to biotin deficiency than larger fish. He recommended 33% of beef liver and 5% of dried brewer's yeast. Since beef liver and brewer's yeast are both excellent source of the vitamin and when included in the diet in sufficient amounts, will afford complete protection from the disease.

Chopra and Singh (2000) indicated that the intensification of fish culture also produces a number of problems, including the occurrence of fish diseases. Besides this, poor sanitary conditions at many hatcheries and malnutrition or the use of unsuitable diets also cause some diseases. Among these diseases, certain nutritional diseases responsible for heavy mortality of coldwater fishes, especially in confined waters and at hatcheries as per the authors are summarized below.

Dietary gill diseases. The study of Rucker et al. (1952) suggested that it is caused mainly by the deficiency of vitamin pantothenic acid in the diet. The symptoms of the dietary gill disease are quite similar to that produced by bacteria. However, the proliferation of the epithelial cells is not so marked and there is little fusion of the gill filaments. In this disease, Fish (1935) did not observe on the gills of trout the thread-like filaments composed of rod-shaped bacteria, as found in case of bacterial gill disease. However, trout may be affected simultaneously by both bacterial and dietary gill diseases, and deficiency of pantothenic acid in the diet makes trout more susceptible to bacterial infection.

Thyroid tumor or goiter. It attacks trout and is primarily caused by the deficiency of iodine, which is essential to the proper functioning of he thyroid gland. The first external indication of thyroid enlargement is a red line or spot on the floor of the mouth of 2-3 months old fish near the second pair of gill arches. This is followed by an external swelling, appearing as a cone-shaped reddish tumor on the ventral side of the head just below the gills. The tumors do not become externally visible before the fish are about 6 months old. The greatest number of goiters are said to appear in 2-3 year old fish, the thyroid activity decreases and the tumor may decrease in size and disappear. Large tumors may wear away by scraping, and this results in infection by fungus or bacteria.

Adding small quantities of iodine solution to the water can control the disease. The addition of iodine directly to the food is easier and gives good results. A tablespoonful of Lugol's solution (1% iodine dissolved in a 1%

Table 7. Specific vitamin deficiency syndromes

Vitamin	Salmon, trout, carp
Thiamin	Poor appetite; muscle atrophy; convulsions; instability and loss of equilibrium; edema and poor growth.
Riboflavin	Corneal vascularization; cloudy lens; haemorrhagic eyes; photophobia; dim vision; incoordination; abnormal pigmentation of iris; striated constrictions of abdominal wall; dark colouration; poor appetite; anaemia and poor growth.
Pyridoxine	Nervous disorders; epileptiform fits; hyperirritability; ataxia; anaemia; loss of appetite; edema of peritoneal cavity; colourless serous fluid; rapid post mortem rigor mortis; rapid and gasping breathing and flexing of opercles.
Pantothenic acid	Clubbed gills; prostration; loss of appetite; necrosis and scarring; cellular atrophy; gill exudates; sluggishness and poor growth.
Inositol	Poor growth; distended stomach; increased gastric emptying time and skin lesions.
Biotin	Loss of appetite; lesions in colon; colouration; muscle atrophy; spastic convulsions; fragility of erythrocytes; skin lesions and poor growth.
Folic acid	Poor growth; lethargy; fragility of caudal fin; dark colouration and macrocytic anaemia.
Choline	Poor growth; poor food conversion; haemorrhagic kidney and intestine; fatty liver
Nicotinic acid	Loss of appetite; lesions in colon; jerky or difficult motion; weakness; edema of stomach and colon; muscle spasms while resting and poor growth.
Vitamin B_{12}	Poor appetite; low haemoglobin; fragmentation of erythrocytes and macrocytic anaemia.
Ascorbic acid	Scoliosis and lordosis; impaired collagen formation; altered cartilage; eye lesions; haemorrhagic skin, liver, kidney, intestine and muscle.
p-Amino benzoic acid	No abnormal indication in growth, appetite and mortality.
Vitamin A	Photophobia; xerophtalmia, cloudy lens and blindness; poor growth
Vitamin E	Poor growth; pigmented skin; anaemia; ceroid in liver and spleen; fragile erythrocytes
Vitamin D	Bone malformation; disturbed calcium and phosphorus metabolism
Vitamin K	Impaired blood coagulation

(Source: Anon, 1971)

solution of potassium iodide) properly mixed with 50 pounds of ground food is sufficient to protect the fish from this disease.

Anaemia. In many hatcheries, trout become anaemic, showing pale pink or grayish white gills, and may die. The pale appearance of gills is due to a great reduction in the number of red blood corpuscles. Anaemia may be due to various causes. It is characteristic of lipoid degeneration of the liver, and may result from heavy infections with animal parasites. But in many instances anaemia is primarily the result of dietary deficiencies. Tunison et al. (1944) concluded that trout anaemia is caused by the deficiency of several vitamins, and that a combination of riboflavin, pantothenic acid, and pyridoxine is required to restore a normal blood count. Later studies by these workers indicated that folic acid and probably other vitamins should also be added. According to Phillips and Brockway (1947), there are certain hatchery practices in respect of food processing which tend to produce anaemia in trout.

As indicated above, anaemia may be cured by administration of various vitamins of the B-complex group in the usual diet. However, some meats are more effective in preventing anaemia than others. Muscle meats are in general poorer sources of antianaemic factors than the organs commonly used for trout foods, such as liver and spleen (Davis, 1956).

8

CONSTRAINTS

Few cultured species with diverse culture systems

Coldwater aquaculture is precisely dominated by the exotic fishes namely, the trout and Chinese carps. Hence an obvious characteristic of coldwater aquaculture is the diversity of culture systems. The exotic Chinese carps are cultured semi-intensively in earthen ponds, whereas the trout are cultured intensively in cemented raceways.

Fig. 8a. An earthen pond at mahseer hatchery, Bhimtal

This is in turn determined by the diversity of geographical environment of aquaculture, since at higher altitudes the temperature regime is suitable for culture of trout and at mid-altitude the thermal regime suits exotic Chinese carps.

Meager production of coldwater fish

The coldwater fish production is very low compared with the fish production in warm water farming. There are many reasons resulting in this difference in production totals between warm water culture and coldwater culture. The methodologies and models used in warm water culture probably cannot be copied directly to coldwater culture, and most coldwater fish probably cannot be used for culture owing to its small size, slow growth rate, lack of demand from the consumers, etc. Among the indigenous species only mahseer have been artificially spawned, hatched and reared successfully. Additionally,

Fig. 8b. Cemented raceways for rearing juveniles of rainbow trout

Fig. 8c. Cemented raceways for rearing brooders of rainbow trout

there is a much higher investment and risk of high priced, trout, coldwater fish culture, which are inhibiting factors in coldwater fish culture.

Culture systems and the type of feeds

Earth ponds are usually used for the culture of exotic Chinese carps species. There are also a small percentage of cemented tank systems. These systems with higher investment are usually used for species fetching higher prices, such as trout. Most earth pond systems usually use fertilizers (either chemical fertilizers or manure) and directly feed raw materials, such as rice bran, wheat bran, mustard oil cake and soybean meal. However, most cemented tank systems use artificial feeds.

Inadequate research work

Fewer experienced workers and limited studies on aquaculture nutrition and feeds certainly resulted in inconsistent data. Even though species cultured were studied concerning some aspects of their nutrition, these studies are inadequate: there were more general studies than basic studies.

To overcome the constraints the strategies for feed improvement will be -

- Research methodology in aquaculture nutrition should be standardized. There should be proper guidelines for experimental designs. Publishing a guideline book, conducting training courses, and imparting higher education to the aquaculture nutritionists can achieve this purpose.
- Systematic studies should be carried out on the nutrient requirements of the representative, commercially important species cultured, concentrating on a few representative species, rather than attempting to cover all cultured species.
- High quality feeds that are suitable for different farming models and species should be developed to meet the requirement. Special attention should be paid to the development of nutritionally balanced feeds at lower nutrient levels for low priced fishes. Such that, their growth rates and feed costs are acceptable from the economic point of view, and higher profits can be obtained.
- The aquaculture environment is likely to deteriorate in due course; environmental nutrition studies and environmentally friendly feed development should be put on the research agenda.
- Studies on development of feeds with low protein (especially low fish meal) and high energy should be carried out to reduce the pollution of nitrogen and phosphorus from uneaten feeds and feces. To improve the aquaculture environment and the fish health, prebiotics and probiotics should be exploited.
- Studies should be conducted to improve pellet quality and feeding strategies.

9 CONCLUSIONS

In the past, we were always in pursuit of quantity rather than quality. With today's improvement in people's standard of living, those who are better off are now starting to seek after better quality foods. However, quality is not only concerned with food colour, flavour, taste and texture, but also with nutrition hygiene and safety. Consequently, research and development of nutrition and feed for aquaculture should shift from quantity to quality. Studies should be conducted on proper feed formulations, farming strategies and culture environmental management to improve product quality, on immune stimulants or enhancers to reduce the use of antibiotics, other harmful chemicals and their hangover, etc. The feed cost can also be cut down by proper formulation, increasing production scale and reducing management cost.

The future areas of work will be-

- Evaluation of indigenous ingredients and feed supplements for feed formulation
- Evaluation of probiotics and immune stimulants as feed components
- Assessment of role of growth promoters, attractants, antioxidants and feeding stimulants in the diets
- Use of enriched single cell proteins, fish ensilage, etc. as feed components
- Development of encapsulated primer feed
- Ascertaining the amino acid, essential fatty acid, vitamin and trace minerals requirements
- Use of certain cold tolerant substances in feed during low temperature regime
- Reducing use of expensive protein sources through use of non-protein energy sources like lipid and carbohydrates
- Improve and optimize nutrient/energy utilization in order to protect aquatic culture system by reduction of N and P waste
- Economic feasibility of various feeds developed

10

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APPENDIX A: FEED INGREDIENTS AVAILABLE FOR AQUAFEEDS IN INDIA

Feed ingredients of plant origin available for their potential use in aquafeeds in India.

Source: Ayyappan, S. and Ahmad Ali, S. (2007)

Protein Sources

Soybean cake

Groundnut cake

Corn gluten

Cotton seed cake

Seasame cake

Sunflower cake

Rape seed/mustard cake

Linseed cake

Energy (carbohydrate) sources

Coconut cake

Maize

Sorghum

Pearl millet

Other cereals

Wheat

Rice

Rice bran

(including defatted bran 7%)

Wheat bran

Tapioca

Edible oil and fish oil available for aquafeeds in India

Source: Ayyappan, S. and Ahmad Ali, S. (2007)

Soybean oil

Groundnut oil

Seasame oil

Coconut oil

Sunflower oil

Mustard oil/rape seed oil

Cotton seed oil

Palm oil

Soy lecithin

Niger seed oil

Fish oil (Indigenous)

Fish oil (Imported)

Squid oil (imported)

Non-conventional feed ingredients available for aquafeeds in India

Source: Ayyappan, S. and Ahmad Ali, S. (2007)

Animal products/by-products

Meat and bone meal

Poultry offal

Feather meal

Slaughter house waste

Silkworm pupae

Poultry hatchery waste

Single Cell Proteins

Spirulina

Yeast

Yeast extract (from brewery)

Additives and other components used in the aquafeed industry in India

Source: Suresh, A.V. (2007)

Additive/Micro-ingredient

Cholesterol

Mould inhibitor

Antioxidant

Pellet binder

Monocalcium phosphate

Dicalcium phosphate

Limestone powder

Mineral premix

Salt

Potassium chloride

Magnesium sulphate

Vitamin premix

Choline chloride

Vitamin C, coated

Inositol

APPENDIX B: PROXIMATE COMPOSITION OF FEED INGREDIENTS

Ingredients	% Dry matter basis					
	Moisture	Crude Protein	Crude Lipid	Crude Fibre	CHO	Ash
Animal by-products						
Fishmeal (Imported) Grade 1	8.1	70.5	8.5	0.1	Trace	12.8
Fishmeal (Imported) Grade 2	9.1	69.2	6.5	0.1	0.8	14.3
Fishmeal (Imported) Grade 3	5.0	66.6	9.5	0.2	0.2	18.5
Fishmeal (Indigenous)	10.3	64.4	4.7	2.5	2.4	15.7
Fishmeal (Indigenous)	10.8	55.0	5.4	1.7	3.3	23.8
Sergisted shrimp meal	9.8	60.2	6.8	4.4	3.6	15.2
Prawn head meal	9.9	39.8	9.6	16.4	4.1	20.2
Squid meal	8.4	66.5	4.4	3.9	5.9	10.9
Mantis shrimp (*Squilla*)	10.7	44.2	4.4	5.7	4.3	30.7
Clam meat meal	7.7	48.1	13.6	Trace	25.8	5.0
Meat meal	8.0	50.0	4.4	6.8	25.8	5.0
Meat and bone meal	-	51.0	10.0	-	-	16.0
Blood meal	10.0	65.3	0.5	-	-	-
Silkworm pupae	9.8	62.2	7.6	1.3	1.9	17.2
Poultry feather meal	-	85.0	3.2	1.5	-	-
Poultry hatchery waste	-	40.0	-	-	15.2	18.0
Poultry Offal	8.6	60.3	10.1	2.5	6.2	12.3

Contd....

Plant and Plant by-products						
Soybean meal	10.5	51.5	1.0	8.9	19.7	8.5
Corn (maize) gluten	6.8	48.2	2.4	4.8	34.0	3.8
Groundnut cake meal	7.7	48.4	7.6	2.1	28.2	6.0
Groundnut cake meal	13.1	46.9	5.0	8.9	18.0	8.1
Mustard cake	9.2	23.6	9.6	6.3	40.9	10.4
Sunflower cake meal	7.0	26.7	2.0	30.1	26.4	7.7
Sesame cake meal	4.9	34.0	10.8	13.0	24.8	12.5
Sesame cake meal	9.8	38.7	6.0	10.7	15.8	19.0
Rape seed cake meal	11.0	35.9	0.9	13.2	32.1	6.9
Sal seed cake meal	8.6	8.2	2.9	1.7	68.4	10.2
Cotton seed cake meal	7.0	37.0	6.7	13.0	35.3	1.0
Coconut cake meal	8.9	25.9	11.2	17.9	27.2	8.9
Coconut cake meal	8.4	20.3	11.4	16.2	37.5	6.2
Corn meal	10.4	9.5	4.0	3.8	68.7	1.7
Sorghum	10.0	9.0	2.8	3.0	75.1	0.1
Wheat flour	12.5	12.5	2.0	1.8	70.0	1.3
Rice flour	11.5	9.1	0.3	Trace	78.6	0.5
Refined wheat flour	12.3	11.1	0.3	Trace	78.6	0.5
Rice bran	8.7	9.0	4.5	13.2	40.8	23.8
Wheat bran	10.6	10.8	2.5	9.7	6.4	3.0
Tapioca flour	8.5	2.0	0.5	3.5	68.5	2.4
Pistia meal	4.9	19.5	1.3	11.7	37.0	25.6
Leucaena meal	11.8	33.1	4.7	9.0	34.2	7.2
Press mud from sugarcane industry	-	15.4	7.8	23.3	0.8	-
Molasses	-	3.2	-	-	60.8	5.0
Single Cell Protein						
Spirulina	7.8	60.9	9.0	7.5	1.8	13.0
Yeast (bakers)	1.4	56.1	2.1	0.3	30.2	9.9

CHO = Digestible carbohydrate; Blank indicates data is not available
Source: Ayyappan, S. and Ahmad Ali, S. (2007)

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APPENDIX A: FEED INGREDIENTS AVAILABLE FOR AQUAFEEDS IN INDIA

Feed ingredients of plant origin available for their potential use in aquafeeds in India.

Source: Ayyappan, S. and Ahmad Ali, S. (2007)

Protein Sources

Soybean cake

Groundnut cake

Corn gluten

Cotton seed cake

Seasame cake

Sunflower cake

Rape seed/mustard cake

Linseed cake

Energy (carbohydrate) sources

Coconut cake

Maize

Sorghum

Pearl millet

Other cereals

Wheat

Rice

Rice bran

(including defatted bran 7%)

Wheat bran

Tapioca

Edible oil and fish oil available for aquafeeds in India

Source: Ayyappan, S. and Ahmad Ali, S. (2007)

Soybean oil

Groundnut oil

Seasame oil

Coconut oil

Sunflower oil

Mustard oil/rape seed oil

Cotton seed oil

Palm oil

Soy lecithin

Niger seed oil

Fish oil (Indigenous)

Fish oil (Imported)

Squid oil (imported)

Non-conventional feed ingredients available for aquafeeds in India

Source: Ayyappan, S. and Ahmad Ali, S. (2007)

Animal products/by-products

Meat and bone meal

Poultry offal

Feather meal

Slaughter house waste

Silkworm pupae

Poultry hatchery waste

Single Cell Proteins

Spirulina

Yeast

Yeast extract (from brewery)

Additives and other components used in the aquafeed industry in India

Source: Suresh, A.V. (2007)

Additive/Micro-ingredient

Cholesterol

Mould inhibitor

Antioxidant

Pellet binder

Monocalcium phosphate

Dicalcium phosphate

Limestone powder

Mineral premix

Salt

Potassium chloride

Magnesium sulphate

Vitamin premix

Choline chloride

Vitamin C, coated

Inositol

APPENDIX B: PROXIMATE COMPOSITION OF FEED INGREDIENTS

Ingredients	% Dry matter basis					
	Moisture	Crude Protein	Crude Lipid	Crude Fibre	CHO	Ash
Animal by-products						
Fishmeal (Imported) Grade 1	8.1	70.5	8.5	0.1	Trace	12.8
Fishmeal (Imported) Grade 2	9.1	69.2	6.5	0.1	0.8	14.3
Fishmeal (Imported) Grade 3	5.0	66.6	9.5	0.2	0.2	18.5
Fishmeal (Indigenous)	10.3	64.4	4.7	2.5	2.4	15.7
Fishmeal (Indigenous)	10.8	55.0	5.4	1.7	3.3	23.8
Sergisted shrimp meal	9.8	60.2	6.8	4.4	3.6	15.2
Prawn head meal	9.9	39.8	9.6	16.4	4.1	20.2
Squid meal	8.4	66.5	4.4	3.9	5.9	10.9
Mantis shrimp (*Squilla*)	10.7	44.2	4.4	5.7	4.3	30.7
Clam meat meal	7.7	48.1	13.6	Trace	25.8	5.0
Meat meal	8.0	50.0	4.4	6.8	25.8	5.0
Meat and bone meal	-	51.0	10.0	-	-	16.0
Blood meal	10.0	65.3	0.5	-	-	-
Silkworm pupae	9.8	62.2	7.6	1.3	1.9	17.2
Poultry feather meal	-	85.0	3.2	1.5	-	-
Poultry hatchery waste	-	40.0	-	-	15.2	18.0
Poultry Offal	8.6	60.3	10.1	2.5	6.2	12.3

Contd....

Plant and Plant by-products						
Soybean meal	10.5	51.5	1.0	8.9	19.7	8.5
Corn (maize) gluten	6.8	48.2	2.4	4.8	34.0	3.8
Groundnut cake meal	7.7	48.4	7.6	2.1	28.2	6.0
Groundnut cake meal	13.1	46.9	5.0	8.9	18.0	8.1
Mustard cake	9.2	23.6	9.6	6.3	40.9	10.4
Sunflower cake meal	7.0	26.7	2.0	30.1	26.4	7.7
Sesame cake meal	4.9	34.0	10.8	13.0	24.8	12.5
Sesame cake meal	9.8	38.7	6.0	10.7	15.8	19.0
Rape seed cake meal	11.0	35.9	0.9	13.2	32.1	6.9
Sal seed cake meal	8.6	8.2	2.9	1.7	68.4	10.2
Cotton seed cake meal	7.0	37.0	6.7	13.0	35.3	1.0
Coconut cake meal	8.9	25.9	11.2	17.9	27.2	8.9
Coconut cake meal	8.4	20.3	11.4	16.2	37.5	6.2
Corn meal	10.4	9.5	4.0	3.8	68.7	1.7
Sorghum	10.0	9.0	2.8	3.0	75.1	0.1
Wheat flour	12.5	12.5	2.0	1.8	70.0	1.3
Rice flour	11.5	9.1	0.3	Trace	78.6	0.5
Refined wheat flour	12.3	11.1	0.3	Trace	78.6	0.5
Rice bran	8.7	9.0	4.5	13.2	40.8	23.8
Wheat bran	10.6	10.8	2.5	9.7	6.4	3.0
Tapioca flour	8.5	2.0	0.5	3.5	68.5	2.4
Pistia meal	4.9	19.5	1.3	11.7	37.0	25.6
Leucaena meal	11.8	33.1	4.7	9.0	34.2	7.2
Press mud from sugarcane industry	-	15.4	7.8	23.3	0.8	-
Molasses	-	3.2	-	-	60.8	5.0
Single Cell Protein						
Spirulina	7.8	60.9	9.0	7.5	1.8	13.0
Yeast (bakers)	1.4	56.1	2.1	0.3	30.2	9.9

CHO = Digestible carbohydrate; Blank indicates data is not available
Source: Ayyappan, S. and Ahmad Ali, S. (2007)