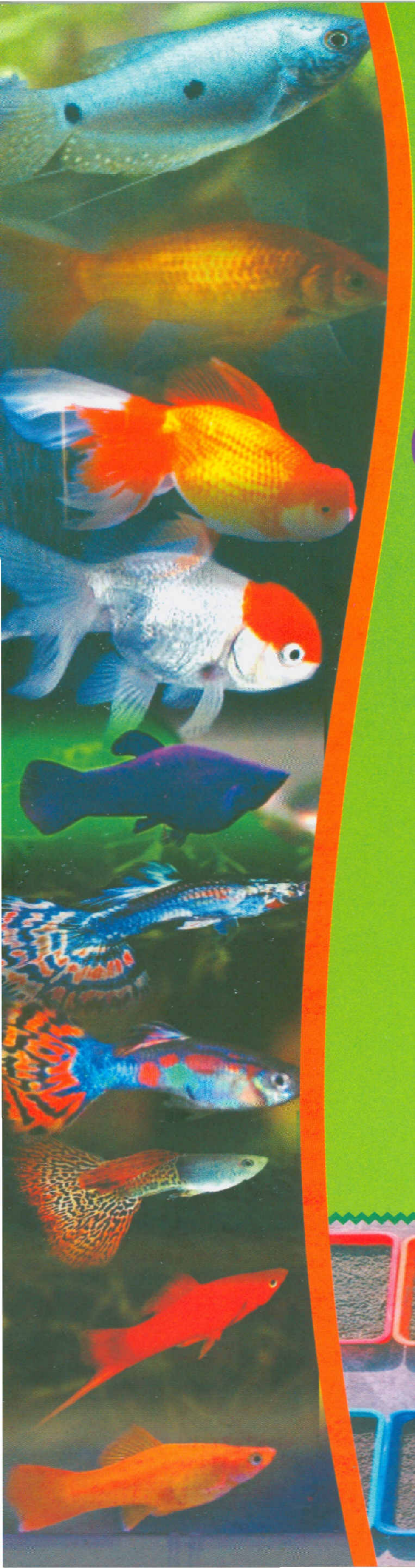

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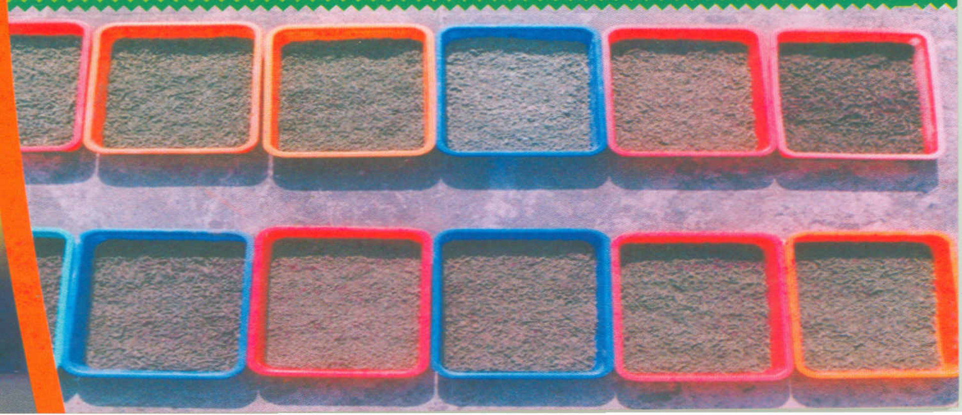

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Contents

PREFACE

At present, ornamental fish farming is the fastest growing aquaculture sector in the world with a global trade of US $ 9.0 billion per annum and a growth rate of over 8 per cent. In ornamental fish trade, freshwater ornamental fish contribute 85 per cent of the total and the rest are from marine species. More than 5,000 species of freshwater ornamental fish are traded each year, out of which 700 to 800 are most common. Approximately, 1.0 billion ornamental fish are exported annually involving more than 100 countries. The entire value of the industry inclusive of retail sales, associated materials, wages and non-exported products, was estimated to be US $ 15 billion. Though Asian countries contribute 90 per cent of the ornamental fish trade around the globe, India's share to the global trade is less than 0.01 per cent, till recently. But the ornamental fish export in India is growing at the rate of 10 per cent per annum during the last few years. At the same time, the domestic ornamental fish market in the country is also growing at 20 per cent rate per year. India is very rich in terms of ornamental fish genetic resources with more than 200 varieties of indigenous ornamental fish available in the North Eastern States and Western Ghats of the country. In addition, more than 100 species of exotic ornamental fish varieties have already been domesticated to the Indian condition and are traded to the different parts of the world. The Marine Product Export Development Authority, Kochi and the National Fishery Development Board, Hyderabad, had given a lot of emphasis during the 11th Five Year Plan and also in the ensuing 12th Year Plan for the research and development of ornamental fish farming in the country. Although ornamental fish farming has already been recognized as the significant contributor to the Indian aquaculture industry, the main problem in the growth of this industry is the non-availability of quality feed at an affordable price. Many of the ornamental fish growers until now grow the ornamental fish using the diets that are meant for other food fish species. Moreover, the ornamental fish industry in India is fully depending on the imported feeds, which are not only costly but also not sure about their nutrient quality. Therefore, there is an urgent need for development of nutritionally balanced cost-effective species specific practical diets to realize better growth and dietary performance of ornamental fish, for which the determination of nutrient requirements is the basic pre-requisite. The study on nutrient requirement and feed development for ornamental fish is more important than the food fish as the former is reared in a very limited water environment where the chances of water quality deterioration is faster due to nitrogen and organic loads derived from deteriorating unused feed and excreta. Once the nutrient requirements of the species are known, the locally available conventional and non-conventional feed ingredients can be used for formulating the practical diets. First time in India, a comprehensive study was undertaken in this Institute on the nutrient requirement of common freshwater ornamental fishes. Based on the nutrient requirements, species specific nutritionally balanced cost-effective ornamental fish feeds were prepared using locally available feed ingredients. The feeds were prepared by using a simple hand pelletizer which is very handy and available in the market in a much lower cost. In the present technical bulletin, the results on nutrient requirement and feed development are presented for the benefit of aquarium fish traders and hobbyists who can save on the cost of feed to a large extent without compromising on the growth and health of fish.

N.P.SINGH
Director

Chapter-I
Introduction

The art of rearing and keeping of ornamental fish is a very age old practice. It first appeared in China towards 800 B.C. with gold fish Carassius auratus. Today keeping of fish in aquarium has become a passion among millions of people throughout the world. It is the second biggest hobby in the world nest only to photography. It is estimated that the number of species known as ornamental is 1,600 of which 750 are from freshwater and the rest are marine species. The term ornamental fish is a misnomer and as such there is no definition of ornamental fish. Any fish having consumer preference is called ornamental fish. At present, the global ornamental fish trade is over 9.0 billion US dollar and it is growing 10% per annum. Asian countries produce 85 per cent of the ornamental fish. The main producers of the ornamental fish are Singapore, China, Indonesia, Malaysia, Korea, Japan, Srilanka and Bangladesh. India's share in ornamental fish trade is estimated to be ₹ 158.23 lakhs which is only 0.008 per cent of the global trade. The other countries which are involved in ornamental fish trade are USA, Great Britain, Germany, France, Italy, Spain, Netherlands, Australia, Israel and Czech Republic. Freshwater ornamental fish contribute 85 per cent of the global ornamental fish trade and rest 15% are from marine sector. More than 80 per cent of the global freshwater ornamental fish are being produced in the breeding farms and rest are collected from nature. In India, there are about 200 varieties of ornamental fish are being traded. In addition to these, there are about 100 indigenous varieties of ornamental fish available in the country mainly in the riverine systems of North Eastern States. Ornamental fish rearing is identified as one of the priority areas for research and development in India. India has vast potential for ornamental fish culture and trade in terms of water resources, fish genetic diversity and technical manpower. The growth of ornamental fish culture is India is 20 per cent per annum. The two main problems for the growth of ornamental fish in India are the non-availability of nutritionally balanced cost-effective balance diets and lack of standard breeding technologies.

Feed is the highest recurring cost in ornamental fish culture constituting 60 to 70 per cent of the total cost. Majority of the ornamental fish feed used in our country for rearing the freshwater ornamental fish are costly and imported from other countries.

Therefore, there is an urgent need to formulate low-cost ornamental fish feeds. But, so far the knowledge on nutrition of freshwater ornamental fish is very limited. For formulation of cost-effective nutritionally balanced diet, the determination of nutrient requirement of a particular fish is the prime and basic requisite. In the present bulletin, the nutrient requirement and diet development of fish with a special reference to few common ornamental fish is discussed in brief. The experimental results and the diet formulation given in this technical bulletin are the outcomes of the research carried out by ICAR Research Complex for Goa over the years.

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Chapter-II
Nutrients

The primary concern in fish culture is to increase fish production per unit of culture space. Supplementary feeding with artificial diets is an effective measure to increase fish production. However, to render the production economical, supplemental diets must be formulated in accordance with the basic nutritional requirements of the particular species, which include protein, lipid, carbohydrate and energy.

1. Protein

Knowledge of the optimum dietary protein level is a prerequisite to formulate a nutritionally balanced low-cost diet for feeding fish. As protein represents the most expensive component in fish feed, it is important to determine the optimal requirement level for growth and survival. A significant reduction in feed cost can be achieved if diets with low protein could be fed to fish without compromising growth and health. However, inadequate protein in the diet results in reduction or cessation of growth. On the other hand, if too much protein is supplied in the diet, only part of it will be used to make new proteins and the remainder will be converted to energy. Besides these, inclusion of dietary protein levels beyond the optimum level results in high level of ammonia production, which affects the voluntary feed intake and growth of fish. But the utilization of dietary protein by an organism depends on types of diet, digestibility of dietary protein, its amino acid profile, the ratio of energy to protein in diet and the amount of protein supplied. Other factors that affect protein utilization are animal size, sex, genotype and environmental conditions.

2. Carbohydrate

Carbohydrate serves as the least expensive source of dietary energy and helps in improving the pelleting quality of practical fish diets. Feed cost per unit of fish produced can be minimized by optimal use of low-cost energy carriers such as carbohydrate-rich ingredients, ensuring that the use of costly protein is kept as low as possible. Replacing dietary protein by carbohydrate or lipid energy may result in a higher production per unit spent of costly protein sources such as fishmeal, and the effluent nitrogen can be reduced per unit of fish produced. Carbohydrates also served as precursors for various metabolic intermediates necessary for growth, i.e., dispensable amino acids and nucleic acids. In the absence of adequate dietary carbohydrates or lipids, fish have only protein available to meet their energy needs. Insufficient energy from non-protein sources demands more protein to be catabolized to provide energy leading to lower growth rate of fish as less protein is available for its growth. When other energy sources are available, the protein is utilized for growth instead of energy. Therefore, it is important to provide an adequate carbohydrate level in the diet in order to reduce catabolism of protein for energy and for synthesis of glucose, which reduce protein retention and increases the nitrogen release to the environment. The ability of fish to utilize carbohydrate appears to be related to their digestive and metabolic systems adapted to the different aquatic environment and dietary carbohydrate level and complexity. The carbohydrate utilization of the fish depends up on the feeding habit, structure and function of the digestive system. The capacity of fish to utilize carbohydrate varied by species and in response to variables such as digestibility and starch complexity, degree of gelatinization of starch, sources of carbohydrate, interaction of carbohydrate with other nutrients and ratio of gelatinized to non-gelatinized starch in the diet.

3. Lipid

Lipid is considered as one of the important nutrient next to protein, which plays a major role for optimum utilization of dietary protein for growth. Lipids are almost completely digestible by fish and seem to be favoured over carbohydrate as an energy source. Special attention is now being given by researchers, feed manufactures and farmers to develop feeds, which maximize nutrient retention with minimum nutrient loss. Fish are known to utilize protein preferentially to lipid or carbohydrate as an energy source. Therefore, it is important from a nutritional, environmental and economical point of view to improve protein utilization for tissue synthesis rather than energy purposes. The optimization of dietary digestible protein/ energy ratio (DP/PE) has proven to have an important role on protein and energy utilization. The increase of DE content of fish diets, by lipid supplementation, has been shown to have a protein sparing effect, therefore reducing nitrogen to the environment.

The increase in dietary lipid levels must be carefully evaluated as it may affect the carcass composition due to an increase of lipid deposition. The localization and composition of lipid deposits also strongly influence the nutritional value, organoleptic properties, transformation yields and storage time of fish carcass. Excess lipid not only suppresses de novo fatty acid synthesis, but also reduces the ability of fish to digest and assimilate it, leading to reduced growth rate. Again, excess lipid in the diet may also result in the production of fatty fish ultimately having a deleterious effect on flavour, consistency and storage life of the finished product. Excessive amounts of lipid in diet also possess problem in feed manufacturing.

4. Energy

Successful fish culture depends up on the provision of diets containing adequate levels of energy and appropriate balance of nutrients to permit the most efficient growth and to maintain the health of the animal under given circumstances. Dietary energy level is also critical because protein in the feed is utilized as an energy source when feed deficient in energy is fed to fish; whereas, when feed excessive in energy is fed, feed consumption decreased and result in growth reduction due to lack of other necessary nutrients for normal growth. As protein constitutes the single most expensive item in fish diets, it is imperative to incorporate only the amount necessary for normal maintenance and growth. Any excess dietary protein is considered as biologically and economically wasteful. Incorporation of appropriate levels of non-protein energy sources in the diet determines the efficiency of protein utilization and hence the growth of fish. Carbohydrate and lipid are the major non-protein sources in fish diet. Compared to lipid, carbohydrate is much less expensive, available abundantly and a ready source of energy. Carbohydrate also improves the pelleting quality of the diet due their reasonably good binding properties. Therefore, it is suggested that the carbohydrate may be added in excess of the required amounts that can be efficiently utilized for energy by fish. Again, use of high level of lipid as dietary energy source may create problem in pelleting and keeping quality of feed in addition to adversely affecting the fish whole body composition.

Not only the assessment of dietary protein (P) and energy (E) are necessary but also understanding the relationship between these two requirements has become increasingly important. The diets with optimum P/E ratio produce best growth, feed utilization and protein retention. Improper dietary protein, energy levels and/or their ratio will lead to an increase of fish production cost and deterioration of water quality resulting from waste feed and fish excreta; thus, they are important in formulating commercial feed.

5. Protein sparing effect of carbohydrate

The amount of protein to be included in a fish diet is influenced by protein to energy ratio (P/E), protein digestibility and amount of non-protein energy in the diet. When insufficient non-protein energy is available in the feed, dietary protein is deaminated in the body to supply energy rather than being used for tissue growth and protein synthesis. Excess protein results in high level of ammonia production, which might affect voluntary feed intake and growth of fish. It is reported that adequate levels of non-protein energy sources, like lipid and carbohydrate in the diet, could minimize the use of protein as a source of energy, of which carbohydrate is the most economic. In omnivorous and warm water fishes such as carps, carbohydrate utilization is high compared to other species. It is important to provide adequate carbohydrate in the diet in order to reduce the catabolism of protein for energy and for synthesis of glucose, which reduces protein retention and increases nitrogen release to the environment. Knowledge of optimal level of protein and the protein-sparing effect of carbohydrate may be useful to reduce fish feed cost.

6. Fish feed ingredients and their digestibility

In order to meet the nutrient and energy requirement of fish through practical feeding and to replace one ingredient with the other for economic reasons, knowledge of digestibility coefficients for ingredients is essential. A feedstuff may appear from its chemical composition to be an excellent source of nutrients but will be of little actual value unless it can be digested and absorbed in the target species. Together with chemical analysis, digestibility determination may allow a more thorough estimation of nutritive value of a particular protein source in a complete diet for fish. Protein is useful only if it can be digested and the various degradation products obtained absorbed efficiently by the fish. Therefore, the determination of apparent nutrient and energy digestibility coefficients of different fish feed ingredients is very much essential before formulating the practical diets.

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Chapter-III

Identification and analysis of locally available fish feed ingredients

To formulate the cost-effective nutritionally balanced fish feed, the identification and utilization of locally available potential feed ingredients particularly the agro-industry by-products is very important. The Institute has identified 30 locally available conventional and non-conventional feed ingredients suitable for fish feed formulation after analysing their proximate composition (Table 1). The dry matter, crude protein, ether extract, crude fibre and ash contents of these ingredients varied from 13.7 to 95.4%, 9.0 to 70.1%, 0.5 to 35.0%, 0.4 to 31.0% and 1.9 to 40.6%, respectively.

Some of the conventional and non-conventional feed ingredients used for formulating the practical diets for freshwater ornamental fishes

Chicken Liver

Mussel meat

Beef liver

Low valued prawn

Fish waste

Chicken waste

Earthworm

Fish processing by-products

Snail

Table 1. Proximate composition (% dry matter) of some of the locally available feed ingredients.

Ingredients	D.M.	C.P.	E.E.	C.F.	T. Ash
1. Fish meal	93.80	42.00	6.00	3.00	31.50
2. Prawn shell waste	93.70	32.00	1.50	22.50	40.60
3. Groundnut oil cake	95.40	42.00	9.00	8.50	6.90
4. Wheat bran	89.90	13.90	4.00	10.50	6.90
5. Cotton seed cake	91.90	26.00	8.00	21.00	14.00
6. Maize	91.10	9.00	4.00	2.20	1.90
7. Spent yeast	94.10	43.00	0.50	N	7.60
8. Azolla	89.80	13.00	1.20	9.00	17.60
9. Press mud	79.70	9.00	1.50	3.00	12.00
10. Brewary grain waste	91.40	26.00	15.50	15.50	3.00
11. Tur chunni	91.30	12.50	2.20	31.00	14.00
12.Gram chunni	91.80	11.00	1.80	20.00	11.30
13. Rice bran	92.30	12.80	13.80	13.80	10.50
14. Wheat bran	91.30	12.25	1.80	10.60	6.90
15. Soybean meal	91.80	48.30	21.20	6.50	8.00
16. Rice polish	89.90	12.20	1.80	13.20	13.80
17. Chicken liver	15.20	66.10	23.50	2.00	10.40
18. Prawn meal	26.70	64.30	5.00	1.20	14.10
19. Mussel meat meal	13.71	57.20	13.40	1.00	9.40
20. Squid meal	11.57	70.10	5.00	1.10	10.00
21. Oyster meal	13.80	48.00	10.10	1.20	17.00
22. Snail	30.26	52.50	4.00	0.80	16.00
23. Freshwater fish processing waste	32.27	45.50	19.00	1.80	18.00
24. Marine fish processing waste	30.00	56.50	9.60	0.80	16.00
25. Surimi by-product	32.00	56.00	6.00	1.60	17.50
26. Chicken offal	29.70	50.75	35.00	0.60	13.50
27. Earthworm	17.25	49.00	14.00	0.40	13.20

D.M. - Dry matter, C.P.- Crude protein, C.F.- Crude Fibre, E.E.-Ether extract, T. Ash-Total Ash

Chapter-IV

Nutrient requirement and diet development of gold fish, *Carassius auratus*

Since time immemorial, gold fish has been one of the most sought after ornamental fish by aquarium fish keepers throughout the world. It is considered to be the most popular ornamental fish due to its many variations such as colour, finnages, tail, shape, size and body structure. May aquarist believe that a community aquarium tank is not a complete ones unless it is having few varieties of gold fish. Though similar to golden carp (*Carassius carassius*), gold fish lacks barbels and a dark spot at the base of each scale. It is one of the oldest known aquarium fish. It was developed in China more than 1000 years ago. There are about 100 varieties of gold fish that appeals to a wide range of aquarium fish lovers. The common gold fish varieties are shubunkin, wakin, jikin, ryukin, fantail, demekin, tosakin, comet, veil tail, moor, oranda, red cap, lion head, phoenix, pompon, telescope eye, celestial, bubble eye, meteor, golden orfe, etc.

For successful rearing of gold fish, it is reported that gold fish require about 40% protein and 4.0 kcal/g energy. Based on the nutrient requirement of this fish as reported earlier, four iso-proteinous (40.0 % crude protein) cost-effective nutritionally balanced practical diets (based on chicken liver, lean prawn meal, mussel meal or squid meal as main dietary protein sources) were formulated and compared with the two commercial diets (59.0 % crude protein) procured from local market. The ingredients and the proximate compositions of the formulated and commercial diets are given in Tables 2 and 3. The diets were fed to the gold fish fingerlings (4.61±0.43 g) for a period of 30 days at 10 per cent of their body weight. The experiment results indicated no significant differences in growth and nutrient utilization of fish fed formulated diets and the commercial diets (Table 4). However, the costs of the formulated diets were found to be much cheaper (₹.80-300/kg) than the commercial diets (₹.1100-3500/kg) used in the experiment. From the growth performance and economics of fish rearing it is concluded that the lean prawn meal based diet is the best and suggested for use for rearing the gold fish.

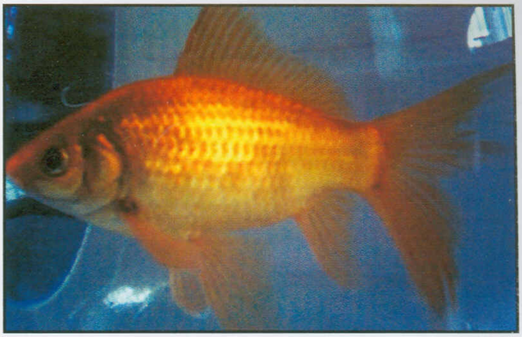
With each of the formulated feeds, more than 100% growth was achieved within one month of rearing. Hence, aquarium fish traders can rear small fish for about one month using one of the formulated feeds, obtain fish weighing twice or more the original weight and sell them at a much higher price as bigger aquarium fish always command better prices than smaller ones. Fish weighing 5 g sell at ₹ 20/- whereas fish weighing 10 g fetches ₹. 50-60/- in the local market. The equipment (hand pelletizer) used to prepare the feeds used in the present study is readily available to hobbyists and small scale aquarium fish traders.

Forms of purified diets used for nutrient requirement study of freshwater ornamental fishes

Table 2. Ingredient composition of formulated ornamental fish feeds used for growth performance study on gold fish, *Carssius auratus.*

Ingredient composition (% dry matter)				
Ingredients	**T-1 (Chicken liver based)**	**T-2 (Prawn meal based)**	**T-3 (Mussel meal based)**	**T-4 (Squid meal based)**
Chicken liver	25	--	--	--
Prawn meal	--	25	--	--
Mussel meal	--	--	35	--
Squid meal	--	--	--	20
Fish meal	25	25	25	25
GN Cake	20	20	20	25
Wheat bran	10	10	10	10
Maize	10	10	10	10
Mineral & Vit. Mix	3	3	3	3
Oil	2	2	2	2
Binder	5	5	5	5

Red cap Gold fish



Common Gold fish

Table 3. Proximate composition of the prepared and market procured ornamental fish diets used for growth performance of gold fish, *Carassius auratus*.

Feeds	Dry Matter	Total Ash	Acid Insol. Ash	Crude Protein	Crude Fat	Crude Fibre	Energy (kcal/g of feed)
Chicken Liver based diet	2.50	17.20	1.00	40.50	7.50	2.00	4.33
Prawn Meal based diet	93.10	19.80	5.20	40.00	3.50	3.20	3.96
Mussel Meal based diet	92.20	15.56	2.40	40.40	10.00	1.50	4.55
Squid Meal based diet	91.90	16.10	3.00	40.15	5.50	1.00	4.31
Tubifex Worm Diet	92.30	18.95	2.00	59.20	9.00	0.01	4.71
Brine Shrimp Flake Diet	93.50	13.80	0.20	59.00	13.80	1.50	4.89

Table 4. Comparative growth performance and costs of six gold fish, *Carassius auratus* feeds.

Parameters	OFF-I (Chicken liver based)	OFF-II (Prawn meal based)	OFF-III (Mussel meal based)	OFF-IV (squid meal based)	C-1 (Tubifex worm)	C-2 (Brine Shrimp Flake)
1.Weight increment (g)		6.30 b	5.73 b	6.72 b	9.26a	6.54 b
2. FCR		1.860 a	1.890 a	1.830 a	1.460 a	1.720 a
3. SGR		2.810 a	2.835 a	2.706 a	3.781 a	3.171 a
4. PER		1.343 ab	1.322 ab	1.364 a	1.164 bc	0.995 c
5. Cost/kg of feed (₹)		88.75	58.70	147.85	3500	1150
6.Cost of production for 1 kg biomass		177.50	110.35	269.08	5110.00	1978.00
7. C.P.(%)		40.50	40.00	40.15	59.00	59.00

Mean values with same superscripts in each row are not significant ($p>0.05$)
Values are means of three replicates in each experimental diet ± SE.

Chapter-V
Nutrient requirement and diet development of blue gourami, *Trichogaster trichopterus*.

Gourami is one of the most preferred ornamental fish for community rearing in aquarium tank. There are about 14-15 commercially important varieties of gouramies that are available in the aquarium fish market of our country. They are : giant gourami, kissing gourami, pink kissing gourami, snake skin gourami, blue gourami, pearl gourami, moonlight gourami, albino gourami, croaking gourami, dwarf gourami, paradise fish, golden honey gourami, red honey gourami etc. Among gouramies, the blue gourami (*Trichogaster trichopterus*) is one of the most praised and sought after fish by the hobbyists. It is a very peaceful fish. The fully grown male some times may chase the other fishes in the community aquarium tank but it rarely harm them. It is a nest builder and shows a high degree of parental care. The feelers or soft flagellum found in the fish served as a sensory aid to know about the food and other individuals of its surrounding. Among the egg layers, blue gourami is relatively easy to breed. For the successful rearing of blue gourami, diet plays an important role. The study regarding the nutrient requirement of blue gourami is very limited. Therefore, an attempt was made to determine the nutrient requirement of blue gourami and based on the nutrient requirement several cost-effective nutritionally balanced practical diets were formulated. In addition to nutrient requirement, several other nutritional trials were undertaken which are given in details below.

a) Protein and lipid requirement of blue gourami, *Trichogaster trichopterus*.

To know the protein and lipid requirement of blue gourami, nine semi-purified diets (casein-gelatin-dextrin-corn starch based) were prepared taking three levels of protein (30, 35 and 40 %) and three levels of lipid (6, 8 and 10 %) (Tables 5 and 6). Each experimental diet was fed in triplicate tanks (100 l capacity with 40 l water) in an indoor static water system. In each tank, 10 healthy fingerlings were stocked and the fish were fed ad libitum for a period of 90 days. The seasoned tap water was used as rearing medium. The water temperature was recorded daily at 0930 and 1430 h of the day and other water quality parameters were analysed in every 15 days interval. The fish were batch weighed in every 15 days to know the growth and general health status of the fish. The growth and nutrient utilization of fish was significantly better ($p<0.05$) in fish fed 35 per cent protein and 8 per cent lipid than the other experiment diets indicating that the optimum protein and lipid requirement of blue gourami fingerling is 35 and 8 per cent, respectively (Tables 7). The whole body carcass composition of fish is presented in Table 8.

Table 5. Ingredient composition (% dry matter) of the experimental diets used for protein and lipid requirement study of blue gourami, *Trichogaster trichopterus.*

Ingredient	T-1 (30% CP; 6% L)	T-2 (30% CP; 8% L)	T-3 (30% CP; 10% L)	T-4 (35% CP; 6% L)	T-5 (35% CP; 8% L)	T-6 (35% CP; 10% L)	T-7 (40% CP; 6% L)	T-8 (40% CP; 8% L)	T-9 (40% CP; 10% L)
Casein	27.5	27.5	27.5	32.0	32.0	32.0	36.5	36.5	36.5
Gelatin	6.9	6.9	6.9	8.0	8.0	8.0	9.1	9.1	9.1
Dextrin	12.0	10.6	9.3	10.0	8.6	7.2	7.90	6.5	5.2
Corn starch	28.0	24.9	21.6	23.3	20.0	16.8	18.5	15.3	12.0
CMC	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Vitamin & Mineral	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Oil	6.0	8.0	10.0	6.0	8.0	10.0	6.0	8.0	10.0
α-Cellulose	12.6	15.1	17.7	13.7	16.4	19.0	15.0	17.6	20.2

Blue gourami

Table 6. Chemical composition of the experimental diets used for protein and lipid requirement study of blue gourami, *Trichogaster trichopterus*.

Parameter	Experimental diets								
	T-1 (30% CP; 6% L)	T-2 (30% CP; 8% L)	T-3 (30% CP; 10% L)	T-4 (35% CP; 6% L)	T-5 (35% CP; 8% L)	T-6 (35% CP; 10% L)	T-7 (40% CP; 6% L)	T-8 (40% CP; 8% L)	T-9 (40% CP; 10% L)
Crude protein	30.10	29.75	30.45	35.27	34.92	35.18	40.14	40.01	40.38
Ether extract	5.92	8.08	9.94	6.06	7.96	10.08	5.94	8.05	9.96
Ash	4.20	3.70	3.50	4.10	3.80	3.60	3.80	3.60	3.30
Total Carbo-hydrate	59.78	58.47	56.11	59.57	58.32	56.14	60.12	58.34	56.36
Calculated DE (kcal/g)	4.13	4.26	4.36	4.14	4.25	4.36	4.14	4.25	4.37

Golden gourami

Pearl gourami

Table 7. Growth and nutrient utlisation of blue gourami, T*richogaster trichopterus* fed different levels of protein and lipid.

Parameter	Experimental diets								
	T-1 (30% CP; 6% L)	T-2 (30% CP; 8% L)	T-3 (30% CP; 10% L)	T-4 (35% CP; 6% L)	T-5 (35% CP; 8% L)	T-6 (35% CP; 10% L)	T-7 (40% CP; 6% L)	T-8 (40% CP; 8% L)	T-9 (40% CP; 10% L)
Initial weight (g)	0.57	0.60	0.62	0.62	0.61	0.61	0.60	0.63	0.64
Final weight (g)	5.88 ^{f}	6.99 ^{d}	6.27 ^{ef}	6.39 ^{e}	8.25 ^{a}	7.42 ^{c}	6.10 ^{ef}	7.83 ^{b}	7.22 ^{cd}
Weight gain (g)	5.31 ^{f}	6.39 ^{d}	5.65 ^{ef}	5.77 ^{e}	7.63 ^{a}	6.82 ^{c}	5.50 ^{ef}	7.21 ^{b}	6.59 ^{cd}
FCR	1.94 ^{a}	1.83 ^{b}	1.91 ^{a}	1.77 ^{c}	1.55 ^{f}	1.70 ^{de}	1.93 ^{a}	1.66 ^{e}	1.73 ^{cd}
SGR	2.59 ^{d}	2.72 ^{c}	2.58 ^{d}	2.60 ^{d}	2.89 ^{a}	2.78 ^{b}	2.57 ^{d}	2.80 ^{b}	2.70 ^{c}
PER	1.71 ^{f}	1.84 ^{e}	1.72 ^{f}	1.87 ^{de}	2.16 ^{a}	1.95 ^{bc}	1.72 ^{f}	2.00 ^{b}	1.91 ^{cd}
PRE	28.2 ^{f}	30.5 ^{f}	28.8 ^{d}	30.9 ^{f}	36.4 ^{a}	32.9 ^{bc}	28.6 ^{e}	33.8 ^{b}	32.3 ^{c}

Mean values with same superscripts in each row are not significant ($p>0.05$).
Values are means of three replicates in each experimental diet ± SE.

Table 8. Whole body chemical composition (% DM) of blue gourami, *Trichogaster trichopterus* fed different levels of protein and lipid at the start and end of the experiment.

Parameter	Experimental diets								
	T-1 (30% CP; 6% L)	T-2 (30% CP; 8% L)	T-3 (30% CP; 10% L)	T-4 (35% CP; 6% L)	T-5 (35% CP; 8% L)	T-6 (35% CP; 10% L)	T-7 (40% CP; 6% L)	T-8 (40% CP; 8% L)	T-9 (40% CP; 10% L)
Moisture	73.56	73.12	72.62	73.82	73.10	72.98	74.32	73.90	73.58
Crude protein	62.32	61.86	61.22	63.20	62.72	62.26	64.82	64.35	64.08
Ether extract	20.97	21.46	22.10	20.16	20.59	21.08	18.51	18.98	19.23
Ash	12.60	12.20	11.70	12.82	12.50	12.18	13.26	12.95	12.40
Total Carbo-hydrate	4.11	4.48	4.98	3.82	4.19	4.48	3.41	3.72	4.29
Calculated DE (kcal/g)	4.54	4.58	4.64	4.49	4.53	4.57	4.39	4.43	4.46

b) Effect of different levels of carbohydrate on the growth performance and nutrient utilization of blue gourami, *Trichogaster trichopterus*.

In this experiment, the protein and lipid was kept at 35 and 8 per cent, respectively as per the requirement of gourami obtained in the previous studies and the effect of different levels of carbohydrate on the growth performance of gourmai fingerling (Trichogaster trichopterus) was studied for a period of 60 days. The different carbohydrate levels maintained were 20, 25, 30, 35, 40 and 45 per cent. The percent and the proximate composition of the experimental diets are presented in Tables 9 and 10. The 500 l capacity indoor fibre-reinforced tanks with 100 l of water (static system) were used for the experiment. The other experimental methodologies were same as that of protein and lipid requirement study. The growth and nutrient utilization of fish fed 40% carbohydrate level was significantly better ($p<0.05$) than the other diets (Table 11). The whole body carcass composition of the fish is presented in Table 12.

Table 9. Ingredient composition (% DM) of the experimental diets used for carbohydrate requirement study of blue gourami, *Trichogaster trichopterus*.

Parameter	Experimental diets					
	T-1 (20% CHO)	T-2 (25% CHO)	T-3 (30% CHO)	T-4 (35% CHO)	T-5 (40% CHO)	T-6 (45% CHO)
Casein	32.0	32.0	32.0	32.0	32.0	32.0
Gelatin	8.0	8.0	8.0	8.0	8.0	8.0
Dextrin	6.0	7.5	9.0	10.5	12.0	13.5
Corn starch	14.0	17.5	21.0	24.5	28.0	31.5
CMC	2.0	2.0	2.0	2.0	2.0	2.0
Vitamin and Mineral Mix	5.0	5.0	5.0	5.0	5.0	5.0
Veg. oil	4.0	4.0	4.0	4.0	4.0	4.0
Cod liver oil	4.0	4.0	4.0	4.0	4.0	4.0
α-Cellulose	25.0	20.0	15.0	10.0	5.0	0.0

Table 10. Chemical composition (% DM) of the experimental diets used for carbohydrate requirement study of blue gourami, *Trichogaster trichopterus.*

Parameter	Experimental diets					
	T-1 (20% CHO)	T-2 (25% CHO)	T-3 (30% CHO)	T-4 (35% CHO)	T-5 (40% CHO)	T-6 (45% CHO)
Crude protein	35.87	35.21	34.70	35.17	34.56	35.28
Ether extract	8.11	8.03	7.98	8.06	7.96	8.00
Ash	5.86	5.36	5.20	5.80	5.38	5.98
Total Carbohydrate	50.16	51.40	52.12	50.97	52.10	50.74
Calculated DE (kcal/g)	4.17	4.19	4.19	4.17	4.18	4.19

Table 11. Effect of different levels of carbohydrate on the growth and nutrient utilization of blue gourami, *Trichogaster trichopterus*.

Parameter	Experimental diets					
	T-1 (20% CHO)	T-2 (25% CHO)	T-3 (30% CHO)	T-4 (35% CHO)	T-5 (40% CHO)	T-6 (45% CHO)
Initial weight (g)	1.78	1.76	1.77	1.76	1.75	1.75
Final weight (g)	4.27[f]	4.48[e]	4.76[d]	5.68[c]	7.19[a]	6.86[b]
Weight gain (g)	2.49[f]	2.72[e]	2.98[d]	3.92[c]	5.44[a]	5.11[b]
FCR	1.98[a]	1.93[b]	1.89[b]	1.82[c]	1.69[e]	1.75[d]
SGR	1.46[f]	1.55[e]	1.64[d]	1.95[c]	2.36[a]	2.28[b]
PER	1.41[e]	1.46[d]	1.52[c]	1.56[c]	1.71[a]	1.62[b]
PRE	23.22[f]	24.50[e]	25.86[d]	26.91[c]	29.67[a]	27.99[b]

Mean values with same superscripts in each row are not significant ($p>0.05$).
Values are means of three replicates in each experimental diet ± SE.

Table 12. Whole body carcass composition of the of blue gourami, *Trichogaster trichopterus* fed different levels of carbohydrate at the start and end of the experiment.

Parameter	Experimental diets						
	Initial	T-1 (20% CHO)	T-2 (25% CHO)	T-3 (30% CHO)	T-4 (35% CHO)	T-5 (40% CHO)	T-6 (45% CHO)
Moisture	75.34	74.92	74.46	73.75	73.26	72.76	72.19
Crude protein	66.50	65.62	64.75	63.87	63.45	62.78	61.25
Ether extract	16.20	17.08	17.53	18.45	18.82	19.42	21.18
Ash	13.30	12.89	12.53	12.22	11.94	11.68	11.36
Total Carbohydrate	4.00	4.41	5.19	5.46	5.79	6.12	6.21
Calculated DE (kcal/g)	4.28	4.33	4.37	4.43	4.46	4.50	4.60

c) Effect of different sources of carbohydrate on growth and nutrient utlisation of blue gourmai, *Trichogaster trichopterus*.

To know the effect of different sources of carbohydrate viz. corn starch, wheat flour, potato starch, tapioca powder and rice flour on growth performance of blue gourami, Trichogaster trichopterus fingerling, an experiment was conducted for a period of 60 days. In all experimental diets, 35 per cent protein, 8 per cent lipid and 40 per cent level of carbohydrate was maintained based on the nutrient requirement of gourami as observed in the earlier two experiments. The 1.0 ton capacity outdoor cement cisterns with 100 l of water (static system) were used for the experiment. The other experimental procedures were same as that of earlier studies. The experimental results after 30 days of rearing indicated that the growth and nutrient utilisation of blue gourami fed on potato starch as carbohydrate source was maximum than the other diets containing other sources of carbohydrate.

d) Development of practical growers diets for blue gourmai, *Trichogaster trichopterus*.

As per the nutrient requirement of blue gourami determined from our earlier studies, nine practical diets with 35 per cent crude protein and 4.0 kcal/g energy were formulated using snail meat, freshwater fish waste, surimi by-product waste, earthworm, squid, mussel, chicken liver and lean prawn meal as major protein source in addition to fish meal and groundnut oil cake. The proximate compositions of the ingredients are presented in Table 13. The ingredient and proximate composition of the diets are presented in Tables 14 and 15, respectively. The diets were fed to blue gourami fingerling in triplicate groups in a close water system. The fish were fed thrice daily close to an apparent satiation level for 45 days. The FRP tanks with 200 l water volume was used as rearing medium. The experimental results (Table 16) showed that the fish fed freshwater fish waste, surimi by-product, squid, mussel, chicken liver and low-valued prawn meal based diets had significantly higher ($p<0.05$) growth and nutrient utilization than the snail, chicken waste and earthworm based diets indicating the possibility of use of freshwater fish waste and surimi-by products as protein source in formulating the grower diets for blue gourami.

Table 13. Proximate composition (% dry matter) of ingredients used for formulating the practical diets for blue gourami, *Trichogaster trichopterus*.

Ingredient	Parameters			
	Dry matter	Crude protein	Ether extract	Ash
Snail	30.26	52.50	4.00	16.00
Fish waste	32.27	45.50	19.00	18.00
Surimi by-product	32.00	56.00	6.00	17.50
Chicken offal	29.70	50.75	35.00	13.50
Earthworm	17.25	49.00	14.00	13.20
Squid	14.67	66.50	8.00	12.00
Mussel	17.28	65.62	12.00	9.60
Chicken liver	23.66	60.37	23.66	10.50
Prawn meal	92.20	63.87	4.50	18.36
Fish meal	92.20	52.50	8.16	16.12
Groundnut oil cake	93.50	42.00	7.50	7.68
Wheat bran	91.30	12.25	1.80	7.30

Table 14. **Ingredient composition (% dry matter) the formulated practical diets used for growth performance of blue gourami, *Trichogaster trichopterus*.**

Ingredient	Experimental diets								
	T-1 (Snail meal)	T-2 (Fish waste)	T-3 (Surimi by-product)	T-4 (Chick-en offal)	T-5 (Earth-worm)	T-6 (Squid)	T-7 (Mussel)	T-8 (Chicken liver)	T-9 (Prawn meal)
Snail	40.0	-----	-----	-----	-----	------	-----	-----	-----
Fish waste	-----	45.0	-----	-----	-----	-----	-----	-----	
Surimi by-product	-----	-----	40.0	----	-----	-----	-----	-----	-----
Chicken offal	-----	-----	-----	35.0	----	-----	-----	-----	-----
Earthworm	-----	-----	-----	-----	40.0	-----	-----	-----	-----
Squid	-----	-----	-----	-----	-----	28.0	-----	-----	-----
Mussel	-----	-----	-----	-----	-----		30.0	-----	-----
Chicken liver	-----	-----	-----	-----	-----	-----	-----	33.0	-----
Prawn meal	-----	-----	-----	-----	-----	-----	------		32.0
Fish meal	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
GN Cake	16.0	18.0	16.0	22.0	20.0	20.0	20.0	20.0	18.0
Wheat bran	25.0	23.0	26.0	29.0	24.0	35.0	34.0	31.0	31.0
Vit. & Min.	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Oil	5.0	-----	4.0	-----	2.0	3.0	2.0	2.0	5.0
Binder	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0

Table 15. Proximate composition of the formulated practical diets used for growth performance of blue gourami, *Trichogaster trichopterus*.

Experimental diet	Dry matter	Crude protein	Ether extract	Crude fibre	Ash
T-1 (Snail)	92.3	35.33	8.2	1.95	12.4
T-2 (Fish waste)	92.8	35.10	9.8	2.27	13.5
T-3 (Surimi by-product)	93.2	35.25	10.0	1.94	14.2
T-4 (Chicken offal)	92.4	35.14	8.9	1.85	9.5
T-5 (Earthworm)	93.5	35.49	8.0	1.90	12.3
T-6 (Squid)	93.1	35.24	7.6	1.88	12.5
T-7 (Mussel)	93.6	35.58	10.4	1.76	12.1
T-8 (Chicken liver)	92.1	35.45	10.2	1.69	11.9
T-9 (Prawn meal)	93.8	35.35	7.9	2.38	13.5

Table 16. Growth performance of blue gourami, *Trichogaster trichopterus* fed different practical diets after 45 days of experiment duration.

Treatments	Initial weight (g)	Final weight (g)	Weight gain (g)	FCR	SGR	PER
T-1 (Snail)	3.57 a	7.40 bc	3.83 b	1.67 c	1.62 c	1.70 b
T-2 (Freshwater fish waster)	3.52 a	7.55 ab	4.03 ab	1.62 cd	1.70 b	176 ab
T-3 (Surimi by-products)	3.51 a	7.60 ab	4.08 a	1.58 d	1.71 ab	1.80 a
T-4 (Chicken offal)	3.57 a	6.83 d	3.26 d	2.04 a	1.44 e	1.39 d
T-5 (Earthworm)	3.54 a	7.08 cd	3.54 c	1.87 b	1.54 d	1.51 c
T-6 (Squid meal)	3.49 a	7.73 ab	4.24 a	1.55 d	1.76 a	1.83 a
T-7 (Mussel meal)	3.55 a	7.67 ab	4.12 a	1.57 d	1.71 ab	1.79 a
T-8 (Chicken liver meal)	3.61 a	7.80 a	4.19 a	1.55 d	1.71 ab	1.82 a
T-9 (Lean prawn meal)	3.50 a	7.55 ab	4.05 ab	1.60 cd	1.71 ab	1.78 a

Mean values with same superscripts in each row are not significant ($p>0.05$).
Values are means of three replicates in each experimental diet ± SE.

e) Replacement of fish meal protein by surimi by-product protein in the diets of blue gourami, *Trichogaster trichopterus*.

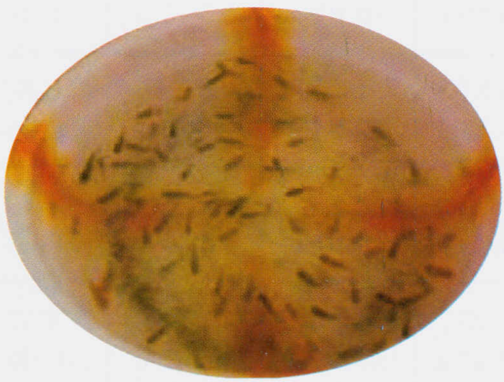
In this experiment, six diets were formulated replacing the fish meal protein by surimi by-product protein at 0 (control), 12.5, 25, 50, 75 and 100 per cent level and fed to blue gourami fingerling in triplicate groups three times a day close to apparent satiation for 45 days. The compositional details of the diets are given in Tables 17 and 18. The rearing system as mentioned above for the practical diets (grower) of gourami was followed in this experiment also. The study indicated that the fish meal protein can be replaced 50 per cent by surimi by-product protein (Tables 19 and 20) without sacrificing the growth and nutrient utilization of blue gourami fingerlings. The whole body carcass composition of the fish is presented in Table 21.

Table 17. Ingredient composition (% dry matter) of diets used for study on fish meal protein replacement by surimi by-product protein.

Ingredients	Experimental diets (g/100g diet)					
	Fish meal protein replaced by Surimi by-product protein (%)					
	0.0%	12.5%	25.0%	50.0%	75.0%	100.0%
Fish meal	42.0	36.6	31.1	20.5	9.4	----
Surimi by-product	----	5.4	10.9	21.5	32.0	43.5
Groundnut Oil Cake	20.0	22.0	22.0	22.0	24.0	20.0
Wheat bran	20.0	18.0	18.0	18.0	16.0	18.5
Dextrin	10.0	10.0	10.0	10.0	10.0	10.0
Carboxymethyl cellulose	2.0	2.0	2.0	2.0	2.0	2.0
Mineral and vitamins	2.0	2.0	2.0	2.0	2.0	2.0
Oil	4.0	4.0	4.0	4.0	4.0	4.0

Table 18. Proximate composition (% dry matter) of diets used for study on fish meal protein replacement by surimi by-product protein.

Parameters	Experimental diets					
	Fish meal protein replaced by Surimi by-product protein (%)					
	(0.0%)	(12.5%)	(25.0%)	(50.0%)	(75.0%)	(100.0%)
Crude protein	35.21	35.69	35.50	35.30	35.70	35.10
Ether extract	9.76	9.81	9.70	9.49	9.43	8.98
Ash	11.56	12.00	11.83	12.20	12.60	11.90
NFE	43.47	42.50	42.97	43.01	42.27	44.06
Energy (kcal/g)	4.02	4.00	4.01	3.98	3.97	3.97



Gourami young ones

Table 19. Growth and nutrient utilization of *Trichogaster trichopterus* fed different experimental diets.

Nutritional indices	Experimental diets: Fish meal protein replaced by surimi by-product protein (%)					
	0.0 (C)	12.5 (D-1)	25.0 (D-2)	50.0 (D-3)	75.0 (D-4)	100.0 (D-5)
Initial weight (g)	4.74 ±0.02a	4.86 ±0.01a	4.84 ±0.08 a	4.77 ±0.04 a	4.74 ±0.04 a	4.80 ±0.08 a
Final weight (g)	11.55 ±0.15 a	11.75 ±0.05 a	11.59 ±0.11 a	11.46 ±0.10a	10.05 ±0.13 b	9.63 ±0.09 c
Weight gain	6.81 ±0.13 a	6.88 ±0.04 a	6.74 ±0.03a	6.69 ±0.06 a	5.31 ±0.10 b	4.83 ±0.06 c
Feed:Gain	1.34 ±0.03 a	1.36 ±0.01 a	1.39 ±0.03 a	1.41 ±0.03 a	1.56 ±0.03 b	1.65 ±0.03 c
SGR (% day-1)	1.98 ±0.02 a	1.96 ±0.01 a	1.94 ±0.02 a	1.95 ±0.00 a	1.66 ±0.01 b	1.55 ±0.02 c
PER	2.13 ±0.04 a	2.06 ±0.02 a	2.03 ±0.04 a	2.02 ±0.04 a	1.80 ±0.04 b	1.73 ±0.04 c
HSI	1.76 ±0.03 a	1.81 ±0.02 a	1.78 ±0.03 a	1.82 ±0.02 a	1.79 ±0.04 a	1.77 ±0.05 a
VSI	7.38 ±0.07 a	7.45 ±0.06 a	7.48 ±0.03 a	7.51 ±0.04 a	7.56 ±0.07 a	7.49 ±0.06 a

Mean values with same superscripts in each row are not significant ($p>0.05$).
Values are means of three replicates in each experimental diet ± SE.
SGR (Specific growth rate) = ln final weight- ln initial weight/Experiment duration (days);
Feed Gain = Total feed intake (dry weight)/Total live weight gain;
Protein efficiency ratio (PER) = Total live weight gain/Total protein in take;
Hepatosomatic index (HSI) = Liver weight/Body weight X 100;
Viscerosomatic index (VSI) = Weight of the whole digestive tract/Body weight X 100

Table 20. Nutrient retention and apparent digestibility of *Trichogaster trichopterus* fed different experimental diets.

Parameters	Experimental diets					
	Fish meal protein replaced by surimi by-product protein (%)					
	0.0 (C)	12.5 (D-1)	25.0 (D-2)	50.0 (D-3)	75.0 (D-4)	100.0 (D-5)
Nutrient and Energy Productive Values (%)						
PPV	39.64 ±0.84 [a]	38.66 ±0.27 [a]	37.91 ±0.71 [a]	37.46 ±0.73 [a]	33.38 ±0.85 [b]	31.76 ±0.72 [b]
LPV	19.30 ±0.46 [a]	19.17 ±0.18 [a]	19.46 ±0.57 [a]	19.69 ±0.35 [a]	17.57 ±0.44 [b]	17.49 ±0.39 [b]
EPV	20.99 ±0.42 [a]	20.39 ±0.17 [a]	20.13 ±0.54 [a]	19.80 ±0.37 [a]	17.77 ±0.39 [b]	16.50 ±0.34 [c]
Apparent Digestibility Coefficients (ADCs; %)						
$ADC_{Protein}$	94.30 ±0.10 [a]	94.24 ±0.09 [a]	94.15 ±0.05 [a]	94.12 ±0.03 [a]	93.86 ±0.05 [b]	93.21 ±0.09 [c]
ADC_{Lipid}	93.51 ±0.11 [a]	93.48 ±0.11 [a]	93.45 ±0.05 [a]	93.33 ±0.02 [a]	93.07 ±0.05 [a]	92.69 ±0.10 [a]
ADC_{Energy}	92.46 ±0.08 [a]	92.33 ±0.13 [a]	92.24 ±0.06 [a]	92.19 ±0.12 [a]	91.65 ±0.06 [b]	90.28 ±0.12 [c]

Mean values with same superscripts in each row are not significant ($p>0.05$). Values are means of three replicates in each experimental diet ± SE.

Protein, lipid and energy productive values (PPV, LPV and EPV; %)= Nutrient (protein, lipid and energy) gain in body/Nutrient (protein, lipid and energy) in take X 100

ADC Nutrients= 100 X [1- (% dietary Cr_2O_3 / % faecal Cr_2O_3 X % faecal nutrient / % dietary nutrient)]

Table 21. Whole body composition (g kg-1 wet weight) of *Trichogaster trichopterus* fingerlings fed different experimental diets.

Parameters	Initial	Final					
		Fish meal protein replaced by surimi by-product protein (%)					
		0.0 (C)	12.5 (T-1)	25.0 (T-2)	50.0 (T-3)	75.0 (T-4)	100.0 (T-5)
Dry matter	257.6^{b} ±2.1	268.2^{a} ±1.1	267.4^{a} ±1.5	266.7^{a} ±0.0	266.0^{a} ±0.8	265.2^{a} ±1.6	264.0^{a} ±1.8
Crude protein	167.7^{c} ±1.1	179.5^{a} ±1.5	179.1^{ab} ±1.0	178.4^{ab} ±0.8	178.1^{ab} ±0.7	176.9^{ab} ±1.3	175.8^{b} ±1.0
Ether extract	32.4^{a} ±0.3	28.1^{c} ±0.2	28.4^{bc} ±0.2	28.6^{bc} ±0.3	28.8^{bc} ±0.2	28.9^{bc} ±0.3	29.2^{b} ±0.3
Total ash	36.6^{a} ±0.7	30.6^{e} ±0.6	31.4^{de} ±0.5	32.2^{cde} ±0.6	32.8^{bcd} ±0.5	33.6^{bc} ±0.7	34.5^{b} ±0.7
Calculated energy (MJ/kg)	4.35^{a} ±0.07	4.56^{a} ±0.12	4.50^{a} ±0.07	4.51^{a} ±0.07	4.51^{a} ±0.07	4.47^{a} ±0.10	4.40^{a} ±0.12

Mean values with same superscripts in each row are not significant (p>0.05).
Values are means of three replicates in each experimental diet ± SE.
Calculated digestible energy (DE)= [%CPx4+ %EEx9+%TCx4], where CP=crude protein, EE=ether extract and TC=total carbohydrate

f) Effect of different oil from different sources on growth, nutrient utilization and whole body composition of blue gourami, *Trichogaster trichopterus*.

To evaluate the effect of different oils on growth and dietary performance of blue gourami, Trichogaster trichopterus fingerlings, an experiment was conducted in which plant (soybean and sunflower) or animal (cod liver and surimi by-product) oils were used alone or in combination in the diet. In our earlier study, we concluded that the protein, lipid and energy requirements of blue gourami are 35 per cent, 8 per cent and 4.0 kcal/g, respectively. As per the requirement of this species, a basal diet containing 35% protein and 4.0 kcal/g energy was formulated in which the oil from different oil sources viz. sunflower oil (T-1), soybean oil (T-2), cod liver oil (T-3), surimi by-product oil (T-4), sunflower and cod liver oils (T-5) and sunflower and surimi by-product oils (T-6) was incorporated at the level of 8% (Table 22). The diets were fed ad libitum to the fish in triplicate groups for a period of 60 days in a closed water system with 100 l of water. The study results indicated that the growth and dietary performance are significantly better ($p<0.05$) in fish fed with diets containing animal oil than the plant oil. Again, the combination of plant and animal oils resulted in significantly better ($p<0.05$) growth and nutrient utilization than the plant or animal oil used alone (Table 23). The study results suggest the possibility of use of surimi by-product oil alone or in combination with plant oil without compromising the growth and nutrient utilization in blue gourami fingerlings.

Table 22. Composition of the basal diet used for the study on effect of different oil sources on growth and nutrient utilization of blue gourami, *Trichogaster trichopterus*.

Ingredients	% Composition
Casein	32
Gelatin	8
Dextrin	12
Corn starch	28
CMC	2
Mineral and Vitamin Mix	5
L-Cellulose	5
Oil	8

Table 23. Growth and nutrient utilization of blue gourami, *Trichogaster trichopterus* fed diets containing oil from different sources.

Nutritional indices	Source of oil					
	Sunflower (T-1)	Soybean (T-2)	Cod liver (T-3)	Surimi by-product (T-4)	Sunflower + Cod liver (T-5)	Sunflower + Surimi by-product (T-6)
Initial Weight (g)	14.02 ±0.43[a]	13.87 ±0.13[a]	13.81 ±0.38[a]	13.82 ±0.20[a]	14.01 ±0.19[a]	13.97 ±0.17[a]
Final Weight (g)	17.78 ±0.39[c]	17.55 ±0.37[c]	20.09 ±0.98[b]	19.76 ±0.22[b]	21.87 ±0.24[a]	22.07 ±0.25[a]
Weight Gain (g)	3.76 ±0.05[c]	3.68 ±0.25[c]	5.61 ±0.06[b]	5.95 ±0.04[b]	7.86 ±0.10[a]	8.10 ±0.10[a]
FCR	2.07 ±0.03[c]	2.02 ±0.02[c]	1.87 ±0.03[b]	1.82 ±0.02[b]	1.63 ±0.02[a]	1.58 ±0.02[a]
SGR	0.40 ±0.01[c]	0.39 ±0.02[c]	0.62 ±0.03[b]	0.60 ±0.02[b]	0.74 ±0.01[a]	0.76 ±0.00[a]
PER	1.41 ±0.02[c]	1.41 ±0.01[c]	1.53 ±0.03[b]	1.59 ±0.02[b]	1.75 ±0.03[a]	1.82 ±0.03[a]

Mean values with same superscripts in each row are not significant ($p>0.05$).
Values are means of three replicates in each experimental diet ± SE.

Chapter-VI

Nutrient requirement and diet development of guppy, *Poecilia reticulata.*

Guppy is a favourite and prized live bearing fish. It is one of the most traded ornamental fish. There are more than 50 pure and cross bred varieties of guppy are available in the market and among them the most important varieties are grass, king cobra, peacock, mosaic and tuxedo. Guppy is compatible to other fish and therefore, can be reared in community tank. It can grow 2-3 inch in size and takes 4-5 months to get matured and can breed 8-10 times in a year. The life span of guppy is one and half to two years. It eats on mosquito larvae and thereby used in controlling the malaria. It is a very hardy fish and withstands wide fluctuations of water quality parameters. As guppy contribute about 20 to 25 per cent of the ornamental fish trade, it is very much essential to formulate the cost-effective practical diets based on the nutrient requirement of fish. Therefore, the study on nutrient requirement of this fish was attempted so as to formulate the cost-effective nutritionally balanced practical diets.

a) Study on protein and lipid requirement of guppy

To determine the protein and lipid requirement of guppy, *Poecilia reticulata*, nine iso-caloric (3.5 kcal/g) purified diets (casein-gelatin-dextrin based) were prepared taking three levels of protein (30, 35 and 40 %) and three levels of lipid (6, 8 and 10 %) as indicated in Tables 24 and 25. Each experimental diet was fed in triplicate tanks (100 l capacity with 40 l water) in an indoor static water system. In each tank, 10 healthy fingerlings were stocked and the fish were fed ad libitum for a period of 60 days. The seasoned tap water was used as rearing medium. The water temperature was recorded daily at 09.30 and 14.30 h of the day and other water quality parameters were analysed in every 15 days interval. The fish were batch weighed in every 15 days to know the growth and general health status of the fish. The growth and nutrient utilization of fish was significantly better ($p<0.05$) in fish fed 30% protein and 10% lipid than the other experiment diets (Table 26) indicating that the optimum protein and lipid requirement of guppy fingerling is 30 and 10 per cent, respectively.

Table 24. Ingredient composition (% dry matter) of the experimental diets used for protein and lipid requirement study of guppy, *Poecilia reticulata.*

Ingredient	T-1 (30% CP; 6% L)	T-2 (30% CP; 8% L)	T-3 (30% CP; 10% L)	T-4 (35% CP; 6% L)	T-5 (35% CP; 8% L)	T-6 (35% CP; 10% L)	T-7 (40% CP; 6% L)	T-8 (40% CP; 8% L)	T-9 (40% CP; 10% L)
Casein	27.5	27.5	27.5	32.0	32.0	32.0	36.5	36.5	36.5
Gelatin	6.9	6.9	6.9	8.0	8.0	8.0	9.1	9.1	9.1
Dextrin	12.0	10.6	9.3	10.0	8.6	7.2	7.9	6.5	5.2
Corn starch	28.0	24.9	21.6	23.3	20.0	16.8	18.5	15.3	12.0
CMC	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Vitamin & Mineral	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Oil	6.0	8.0	10.0	6.0	8.0	10.0	6.0	8.0	10.0
α-Cellulose	12.6	15.1	17.7	13.7	16.4	19.0	15.0	17.6	20.2

Table 25. Chemical composition (% dry matter) of the experimental diets used for protein and lipid requirement study of guppy *Poecilia reticulata.*

Parameter	Experimental diets								
	T-1 (30% CP; 6% L)	**T-2 (30% CP; 8% L)**	**T-3 (30% CP; 10% L)**	**T-4 (35% CP; 6% L)**	**T-5 (35% CP; 8% L)**	**T-6 (35% CP; 10% L)**	**T-7 (40% CP; 6% L)**	**T-8 (40% CP; 8% L)**	**T-9 (40% CP; 10% L)**
Crude protein	30.66	30.45	29.98	35.66	35.51	35.40	40.52	40.12	39.96
Ether extract	5.92	8.08	9.94	6.06	7.96	10.08	5.94	8.05	9.96
Ash	4.20	3.70	3.50	4.10	3.80	3.60	3.8	3.60	3.30
Total Carbo-hydrate	59.78	58.47	56.11	59.57	58.32	56.14	60.12	58.34	56.36
Calculated DE (kcal/g)	4.13	4.26	4.36	4.14	4.25	4.36	4.14	4.25	4.37

Table 26. Growth performance of guppy, *Poecilia reticulata* in protein and lipid requirement study in 60 days of rearing.

Treatment	Initial weight (g)	Final weight (g)	Weight gain (g)	FCR	SGR	PER
T-1 (30% CP; 6% L)	1.52[a]	3.62[de]	2.10[f]	1.92[b]	1.44[de]	1.71[d]
T-2 (30% CP; 8% L)	1.53[a]	3.87[bc]	2.34[d]	1.76[d]	1.55[c]	1.87[b]
T-3 (30% CP; 10% L)	1.47[a]	4.20[a]	2.73[a]	1.46[g]	1.75[a]	2.24[a]
T-4 (35% CP; 6% L)	1.50[a]	3.54[e]	2.04[fg]	2.01[a]	1.43[ef]	1.39[g]
T-5 (35% CP; 8% L)	1.53[a]	3.77[cd]	2.24[e]	1.81[cd]	1.50[cd]	1.56[e]
T-6 (35% CP; 10% L)	1.49[a]	4.09[a]	2.60[b]	1.58[f]	1.69[ab]	1.78[c]
T-7 (40% CP; 6% L)	1.54[a]	3.52[e]	1.97[g]	2.03[a]	1.37[f]	1.21[h]
T-8 (40% CP; 8% L)	1.52[a]	3.63[de]	2.11[f]	1.83[c]	1.45[de]	1.34[g]
T-9 (40% CP; 10% L)	1.51[a]	4.01[ab]	2.50[c]	1.67[e]	1.63[b]	1.48[f]

Mean values with same superscripts in each row are not significant ($p>0.05$).
Values are means of three replicates in each experimental diet ± SE.

b) Formulation and evaluation of grower diets for guppy, *Poecilia reticulata*

As per the nutrient requirement of guppy, Poecilia reticulata, nine practical diets with 30 per cent crude protein, 10 per cent lipid and 4.0 kcal/g energy were formulated (Tables 27, 28 and 29) using snail meal, freshwater fish waste, surimi by-product waste, chicken waste, earthworm, squid, mussel, chicken liver and lean prawn meal as major protein source in addition to fish meal and groundnut oil cake and fed to the guppy fingerling in triplicate groups in a close water system. The fish were fed thrice daily close to an apparent satiation level for 60 days. The FRP tanks with 200 l water volume were used as rearing medium. The experimental results indicated that the fish fed squid meal, lean prawn meal, mussel meal and surimi by-product based diets had significantly better ($p<0.05$) growth and nutrient utilization than the snail meal, freshwater fish waste, chicken waste, earthworm and chicken liver based diets (Table 30).

Guppy with finnage patterns

Table 27. Proximate composition of the ingredients used for formulation of practical diets for guppy, *Poecilia reticulata*.

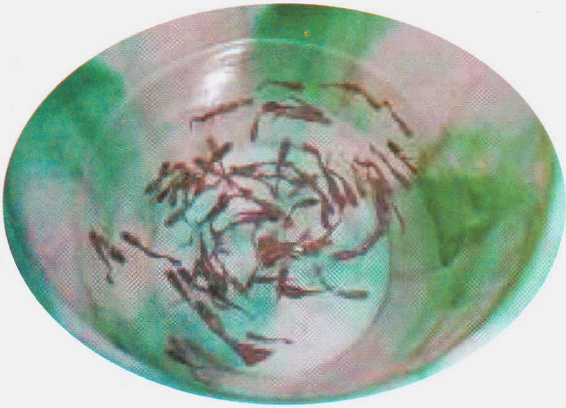
Ingredient	Parameters			
	Dry matter	Crude protein	Ether extract	Ash
Snail	30.46	51.62	4.00	15.58
Fish waste	32.28	45.48	18.00	18.30
Surimi by-product	33.42	55.12	6.50	16.86
Chicken offal	29.34	49.90	33.60	12.52
Earthworm	17.76	50.75	13.88	12.86
Squid	14.92	66.50	8.00	11.78
Mussel	17.70	65.62	11.58	9.84
Chicken liver	24.38	60.37	24.36	10.36
Prawn meal	92.44	63.87	5.00	19.10
Fish meal	92.55	52.50	8.00	15.98
Groundnut oil cake	93.28	42.00	10.00	6.98
Wheat bran	91.62	12.25	2.00	7.60

Table 28. Ingredients composition of the practical diets used for growth performance study of guppy, *Poecilia reticulata*.

Ingredient	Experimental diets								
	T-1 (Snail meal)	**T-2 (Fish waste)**	**T-3 (Surimi by-product)**	**T-4 (Chicken offal)**	**T-5 (Earth-worm)**	**T-6 (Squid)**	**T-7 (Mussel)**	**T-8 (Chicken liver)**	**T-9 (Prawn meal)**
Snail	30.0	-----	-----	-----	-----	------	-----	-----	-----
Fish waste	-----	35.0	-----	-----	-----	-----	-----	-----	
Surimi by-product	-----	-----	30.0	----	-----	-----	-----	-----	-----
Chicken offal	-----	-----	-----	30.0	----	-----	-----	-----	-----
Earthworm	-----	-----	-----	-----	32.0	-----	-----	-----	-----
Squid	-----	-----	-----	-----	-----	25.0	-----	-----	-----
Mussel	-----	-----	-----	-----	-----		26.0	-----	-----
Chicken liver	-----	-----	-----	-----	-----	-----	-----	28.0	-----
Prawn meal	-----	-----	-----	-----	-----	-----	------		28.0
Fish meal	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
GN Cake	15.0	16.0	18.0	20.0	15.0	20.0	16.0	16.0	15.0
Wheat bran	32.0	30.0	28.0	33.0	30.0	31.0	35.0	34.0	32.0
Vit. & Min.	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Oil	6.0	2.0	7.0	-----	6.0	7.0	6.0	5.0	8.0
Binder	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0

Table 29. Proximate composition of practical diets developed for guppy, *Poecilia reticulata*.

Experimental diet	Dry matter	Crude protein	Ether extract	Crude fibre	Ash
T-1 (Snail)	92.4	30.19	10.14	1.90	12.6
T-2 (Fish waste)	92.6	30.96	11.51	2.48	13.8
T-3 (Surimi by-product)	93.1	29.75	12.04	2.16	14.7
T-4 (Chicken offal)	92.6	30.30	11.97	1.75	9.2
T-5 (Earthworm)	93.2	31.06	11.42	1.86	12.0
T-6 (Squid)	93.3	30.24	11.80	1.80	12.2
T-7 (Mussel)	93.8	29.75	11.22	1.66	11.9
T-8 (Chicken liver)	92.3	30.84	11.30	1.72	11.6
T-9 (Prawn meal)	93.6	30.18	11.14	2.46	13.8



Guppy young ones

Table 30. Growth and nutrient utilization of guppy, *Poecilia reticulata* fed different practical diets.

Diet	Nutritional indices					
	Initial weight (g)	Final weight (g)	Weight gain (g)	FCR	SGR	PER
Snail meal	0.27 ±0.01[a]	2.55 ±0.07[c]	2.28 ±0.11[c]	2.25 ±0.04[a]	3.74 ±0.01[c]	1.47 ±0.03[d]
Fish processing waste	0.28 ±0.01[a]	3.10 ±0.05[b]	2.82 ±0.04[b]	1.84 ±0.03[c]	4.03 ±0.02[b]	1.76 ±0.03[b]
Surimi by-product	0.27 ±0.00[a]	3.46 ±0.06[a]	3.19 ±0.06[a]	1.68 ±0.02[d]	4.23 ±0.03[a]	2.00 ±0.03[a]
Chicken waste	0.27 ±0.00[a]	2.28 ±0.05[d]	2.01 ±0.04[d]	2.30 ±0.03[a]	3.57 ±0.02[d]	1.43 ±0.02[d]
Earthworm meal	0.27 ±0.01[a]	2.68 ±0.07[c]	2.41 ±0.06[c]	2.05 ±0.03[b]	3.82 ±0.01[c]	1.57 ±0.03[c]
Squid meal	0.27 ±0.00[a]	3.58 ±0.10[a]	3.31 ±0.10[a]	1.64 ±0.02[d]	4.31 ±0.05[a]	2.02 ±0.03[a]
Mussel meal	0.27 ±0.00[a]	3.38 ±0.07[a]	3.11 ±0.07[a]	1.70 ±0.02[d]	4.23 ±0.04[a]	1.98 ±0.03[a]
Chicken liver	0.27 ±0.01[a]	3.07 ±0.08[b]	2.80 ±0.07[b]	1.88 ±0.02[c]	4.05 ±0.01[b]	1.72 ±0.02[b]
Prawn meal	0.27 ±0.00[a]	3.53 ±0.08[a]	3.31 ±0.08[a]	1.66 ±0.02[d]	4.30 ±0.02[a]	1.99 ±0.03[a]

Mean values with same superscripts in each row are not significant ($p>0.05$).
Values are means of three replicates in each experimental diet ± SE.

Chapter –VII

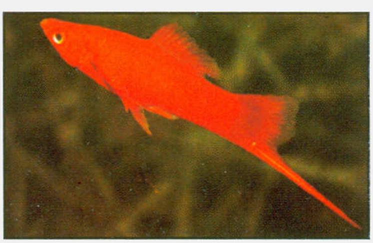
Study on nutrient requirement of sword tail, *Xiphophorus hilleri*

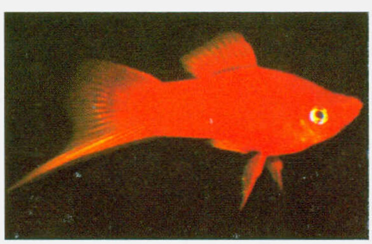
Swordtail is an important live bearing fish. Generally, the size of the female in 3 inch and the male is smaller then the female. Male have sword like extension in tail fin. Male is also more aggressive than female. It is a compatible fish and can be reared in community tanks. It is very easy to breed and the fecundity of this 150 young ones/female. The studies on nutrient requirement and diet development for successful rearing of sword tail are given below.

a) Study on protein and lipid requirement of sword tail, Xiphophorus hilleri

Nine casein-gelatin-corn starch based iso-caloric (4.0 kcal/g) semi-purified diets were formulated (Tables 31 and 32) with three levels of protein (30, 35 and 40%) and three levels of lipid (6, 8 and 10%) and fed to the sword tail fingerling in triplicate groups for a period of 60 days in a static water system with 100 l of rearing water medium. In each replicated tank, 10 fish were stocked and the fish were fed ad libitum to the apparent satiation level. The intermediary sampling was done in every 15 days by batch weighing of the fish. The water temperature was recorded every day at 0830 h and 1430 h. The other water quality parameters were measured in every 15 days. The left over feed and the excreta were removed everyday by siphoning. About 50% water exchanged was performed every day. The tanks were cleaned in every 15 days. The water qualities parameters were found to be in the ideal range of fish rearing. The growth and nutrient utilization data indicated that the sword tail fingerling require 40% protein and 6% lipid in their diet (Table 33).

Sword Tail





Male

Female

Table 31. Ingredient composition (% dry matter) of the experimental diets used for protein and lipid requirement study of sword tail, *Xiphophorus hilleri*.

Ingredient	T-1 (30% CP; 6% L)	T-2 (30% CP; 8% L)	T-3 (30% CP; 10% L)	T-4 (35% CP; 6% L)	T-5 (35% CP; 8% L)	T-6 (35% CP; 10% L)	T-7 (40% CP; 6% L)	T-8 (40% CP; 8% L)	T-9 (40% CP; 10% L)
Casein	27.5	27.5	27.5	32.0	32.0	32.0	36.5	36.5	36.5
Gelatin	6.9	6.9	6.9	8.0	8.0	8.0	9.1	9.1	9.1
Dextrin	12.0	10.6	9.3	10.0	8.6	7.2	7.9	6.5	5.2
Corn starch	28.0	24.9	21.6	23.3	20.0	16.8	18.5	15.3	12.0
CMC	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Vitamin & Mineral	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Oil	6.0	8.0	10.0	6.0	8.0	10.0	6.0	8.0	10.0
α-Cellulose	12.6	15.1	17.7	13.7	16.4	19.0	15.0	17.6	20.2

Table 32. Chemical composition (% dry matter) of the experimental diets used for protein and lipid requirement study of sword tail, *Xiphophorus hilleri*.

Parameter	Experimental diets								
	T-1 (30% CP; 6% L)	T-2 (30% CP; 8% L)	T-3 (30% CP; 10% L)	T-4 (35% CP; 6% L)	T-5 (35% CP; 8% L)	T-6 (35% CP; 10% L)	T-7 (40% CP; 6% L)	T-8 (40% CP; 8% L)	T-9 (40% CP; 10% L)
Crude protein	29.75	30.10	30.51	34.12	35.00	35.44	39.37	40.25	40.68
Ether extract	5.96	8.10	10.02	6.08	7.98	10.06	5.98	8.08	9.98
Ash	4.40	3.90	3.70	4.30	4.00	3.80	4.00	3.80	3.50
Total Carbo-hydrate	59.89	57.90	55.77	55.50	53.02	50.70	50.65	47.87	45.84
Calculated DE (kcal/g)	4.12	4.25	4.35	4.13	4.24	4.35	4.14	4.25	4.36

Table 33. Growth performance of sword tail, *Xiphophorus hilleri* fed different levels of protein and lipid.

Nutrient levels	Nutritional indices					
	Initial weight (g)	Final weight (g)	Weight gain (g)	FCR	SGR	PER
30%CP 6% L	0.45 ±0.01 [a]	1.58 ±0.06 [e]	1.13 ±0.05 [e]	1.91 ±0.04 [c]	2.09 ±0.06 [e]	1.72 ±0.09 [ef]
30%CP 8% L	0.43 ±0.01 [a]	1.32 ±0.06 [f]	0.89 ±0.05 [f]	2.01 ±0.02 [b]	1.85 ±0.04 [g]	1.66 ±0.02 [f]
30%CP 10% L	0.45 ±0.01 [a]	1.12 ±0.07 [g]	0.67 ±0.06 [g]	2.15 ±0.03 [a]	1.53 ±0.06 [g]	1.52 ±0.03 [g]
35%CP 6% L	0.44 ±0.01 [a]	2.08 ±0.07 [c]	1.64 ±0.06 [c]	1.69 ±0.03 [e]	2.59 ±0.01 [c]	1.96 ±0.03 [c]
35%CP 8% L	0.45 ±0.01 [a]	1.82 ±0.05 [d]	1.37 ±0.04 [d]	1.80 ±0.02 [d]	2.45 ±0.06 [d]	1.82 ±0.02 [de]
35%CP 10% L	0.45 ±0.01 [a]	1.62 ±0.03 [e]	1.17 ±0.02 [e]	1.90 ±0.03 [c]	2.14 ±0.04 [e]	1.73 ±0.03 [ef]
40%CP 6% L	0.44 ±0.00 [a]	2.66 ±0.08 [a]	2.22 ±0.08 [a]	1.48 ±0.03 [g]	2.98 ±0.05 [a]	2.28 ±0.05 [a]
40%CP 8% L	0.45 ±0.01 [a]	2.32 ±0.05 [b]	1.87 ±0.04 [b]	1.58 ±0.04 [f]	2.73 ±0.02 [b]	2.10 ±0.05 [b]
40%CP 10% L	0.45 ±0.01 [a]	2.10 ±0.06 [c]	1.66 ±0.05 [c]	1.68 ±0.03 [e]	2.59 ±0.02 [c]	1.95 ±0.03 [cd]

Mean values with same superscripts in each row are not significant ($p>0.05$).
Values are means of three replicates in each experimental diet ± SE.

b) Formulation and evaluation of grower diets for sword tail, *Xiphophorus hilleri*.

As per the nutrient requirement of sword tail, Xiphophorus helleri, nine practical diets with 40 per cent crude protein and 4.0 kcal/g energy were formulated using snail meal, freshwater fish waste, surimi by-product waste, chicken waste, earthworm, squid, mussel, chicken liver and lean prawn meal as major protein source in addition to fish meal and groundnut oil cake and fed to the sword tail fingerlings in triplicate groups in a close water system. The proximate composition of the ingredients used and the ingredient and the proximate composition of the experimental diets are presented in Tables 34, 35 and 36. The fish were fed thrice daily close to apparent satiation level for a period of 60 days in triplicate groups with 10 fish/tank. For rearing the fish, flow-trough FRP tanks with 100 l water were used. From the study it was found that the diet containing freshwater fish waste, snail and chicken liver as non-conventional protein sources gave statistically on par ($p>0.05$) results in terns of growth and nutrient utilization when compared to diets containing different conventional protein sources such as mussel meal, chicken liver, squid meal and prawn meal (Table 37). The study results suggests the possibility of use of freshwater fish waste, snail and chicken liver as non-conventional protein sources in developing the nutritionally balanced cost-effective practical diets of sword tail fingerlings.

Table 34. Proximate composition of the ingredients used for formulation of practical diets for sword tail, *Xiphophorus helleri*.

Ingredients	Dry matter	Crude protein	Ether extract	Total ash
Groundnut oil cake	93.10	42.87	9.60	7.60
Fish meal	92.16	54.25	8.40	15.56
Wheat bran	91.65	11.37	2.20	7.42
Snail	30.62	53.25	4.20	15.60
Marine fish waste	33.20	56.50	8.60	14.88
Fresh water fish waste	32.28	46.02	20.16	17.98
Chicken waste	29.86	48.12	29.86	13.29
Earthworms	16.82	49.87	12.00	12.90
Squids	14.80	66.37	8.20	12.00
Mussels	17.10	65.62	12.30	9.50
Chicken liver	23.45	61.25	14.86	10.42
Prawn meal	92.32	63.00	5.20	18.38

Table 35. Ingredients composition (% dry matter) of the practical diets fed to sword tail, *Xiphophorus helleri* fingerlings.

Ingredients	Experimental diets								
	T-1 (snail meal)	T-2 (Fresh water fish waste)	T-3 (Marine fish waste)	T-4 (Chicken waste)	T-5 (earth-worm)	T-6 (Squid)	T-7 (Mussel)	T-8 (Chicken liver)	T-9 (Prawn meal)
Snail	45.0	----	----	----	----	----	----	----	----
Freshwater fish waste	----	48.0	----	----	----	----	----	----	----
Marine fish waste	----	----	42.0	----	----	----	----	----	----
Chicken waste	----	----	----	46.0	----	----	----	----	----
earthworm	----	----	----	----	45.0	----	----	----	----
Squid	----	----	----	----	----	36.0	----	----	----
Mussel	----	----	----	----	----	----	38.0	----	----
Chicken liver	----	----	----	----	----	----	----	40.0	----
Prawn meal	----	----	----	----	----	----	----	----	38.0
Fish meal	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Groundnut oil cake	20.0	25.0	25.0	25.0	25.0	22.0	18.0	22.0	20.0
Wheat bran	18.0	12.0	14.0	15.0	15.0	25.0	29.0	23.0	25.0
Vit.& Min.	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Oil	2.0	----	----	----	----	2.0	----	----	2.0

Table 36. Proximate composition (% dry matter) of the experimental diets fed to sword tail, *Xiphophorus helleri* fingerlings.

Treatments / Diets	Parameters			
	Dry matter	Crude protein	Ether extract	Ash
T-1 (Snail)	92.0	39.99	6.95	12.4
T-2 (Fresh water fish waste)	92.3	39.59	12.78	13.4
T-3 (Marine fish waste)	93.4	40.97	6.12	14.9
T-4 (Chicken waste)	92.8	39.95	16.78	9.2
T-5 (Earthworm)	93.6	40.27	8.47	12.2
T-6 (Squid)	93.8	41.58	8.01	12.6
T-7 (Mussel)	93.0	41.36	7.51	11.7
T-8 (Chicken liver)	92.5	41.96	8.96	11.2
T-9 (Prawn meal)	93.7	40.77	6.99	14.1

Process of formulating the practical diets for the freshwater ornamental fishes

Mixing

Hand pelleting

Drying

Table 37. Growth and dietary performance of sword tail *Xiphophorus helleri* fed different practical diets.

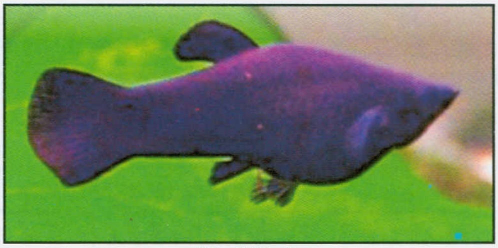
Diet	Nutritional indices					
	Initial weight (g)	Final weight (g)	Weight gain (g)	FCR	SGR	PER
Snail meal	7.33 ±0.14 [a]	12.09 ±0.15 [ab]	4.76 ±0.27 [ab]	1.57 ±0.03 [bc]	0.83 ±0.05 [ab]	1.60 ±0.03 [a]
Freshwater fish processing waste	7.39 ±0.21 [a]	12.12 ±0.40 [ab]	4.73 ±0.41 [ab]	1.58 ±0.03 [bc]	0.82 ±0.06 [ab]	1.57 ±0.03 [ab]
Marine fish processing waste	7.57 ±0.08 [a]	10.84 ±0.16 [c]	3.27 ±0.10 [c]	1.73 ±0.03 [a]	0.60 ±0.01 [c]	1.41 ±0.02 [c]
Chicken waste	7.58 ±0.10 [a]	12.77 ±0.05 [a]	5.19 ±0.14 [a]	1.50 ±0.02 [c]	0.87 ±0.03 [a]	1.65 ±0.02 [a]
Earthworm meal	7.50 ±0.02 [a]	11.56 ±0.03 [bc]	4.06 ±0.03 [bc]	1.66 ±0.03 [ab]	0.72 ±0.01 [bc]	1.49 ±0.03 [bc]
Squid meal	7.56 ±0.18 [a]	12.30 ±0.28 [ab]	4.74 ±0.44 [ab]	1.58 ±0.05 [bc]	0.81 ±0.07 [ab]	1.57 ±0.05 [ab]
Mussel meal	7.47 ±0.23 [a]	12.47 ±0.16 [a]	4.99 ±0.26 [a]	1.52 ±0.03 [c]	0.86 ±0.05 [a]	1.64 ±0.03 [a]
Chicken liver	7.56 ±0.09 [a]	12.71 ±0.46 [a]	5.12 ±0.51 [a]	1.50 ±0.03 [c]	0.86 ±0.07 [a]	1.63 ±0.03 [a]
Prawn meal	7.56 ±0.10 [a]	12.35 ±0.09 [ab]	4.79 ±0.01 [ab]	1.57 ±0.02 [bc]	0.82 ±0.01 [ab]	1.59 ±0.02 [a]

Chapter-VIII

Study on nutrient requirement of molly, *Poecilia latipinna.*

Molly, Poecilia latipinna is an important live bearing fish which can be reared in a community aquarium tanks as it is compatible to other aquarium fish. The common varieties of molly that are available in the market are: black molly, white molly, marble molly, 24 carat gold molly, gold dust molly and red sail fin molly. The life span of molly is ranged between 2 to 4 years and it grows up to 5 inch in length. It gets matured in four months and breeds 6-8 times in a year. The ideal rearing temperature for molly is 20 to 24 °C. As it is a live bearer, the young ones starts feeding just after birth. For the successful rearing of molly, an attempt was made to formulate the species specific cost-effective practical diets after elucidating the nutrient requirement of this fish.

a) Study on nutrient requirement of molly, *Poecilia latipinna.*



Black Molly

To determine the protein and lipid requirement of black molly, Poecilia latippina, nine iso-caloric (4.0 kcal/g diet) casein-gelatin-dextrin based semi-purified diets with three levels of protein (30,35 and 40%) and three levels of lipid (6, 8 and 10%) were formulated and analyzed (Tables 38 and 39). The formulated diets were fed to fish for a period of 60 days at ad libitum close to apparent sanitation level. For rearing the fish, flow-trough FRP tanks containing 100 l water was used. The study results indicated that the fish fed 40% protein and 6% lipid had significant higher (P>.05) growth and nutrient utilization in terns of weight gain, specific growth rate, food conversion ratio and protein efficiency ratio (Table 40).

Table 38. Ingredient composition (% dry matter) of the experimental diets used for protein and lipid requirement study of black molly *Poecilia latipinna*.

Ingredient	T-1 (30% CP; 6% L)	T-2 (30% CP; 8% L)	T-3 (30% CP; 10% L)	T-4 (35% CP; 6% L)	T-5 (35% CP; 8% L)	T-6 (35% CP; 10% L)	T-7 (40% CP; 6% L)	T-8 (40% CP; 8% L)	T-9 (40% P;10% L)
Casein	27.5	27.5	27.5	32.0	32.0	32.0	36.5	36.5	36.5
Gelatin	6.9	6.9	6.9	8.0	8.0	8.0	9.1	9.1	9.1
Dextrin	12.0	10.6	9.3	10.0	8.6	7.2	7.90	6.5	5.2
Corn starch	28.0	24.9	21.6	23.3	20.0	16.8	18.5	15.3	12.0
CMC	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Vitamin & Mineral	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Oil	6.0	8.0	10.0	6.0	8.0	10.0	6.0	8.0	10.0
α-Cellulose	12.6	15.1	17.7	13.7	16.4	19.0	15.0	17.6	20.2

Table 39. Chemical composition (% dry matter) of the experimental diets used for protein and lipid requirement study of black molly, *Poecilia latippina*.

Parameter	Experimental diets								
	T-1 (30% CP; 6% L)	T-2 (30% CP; 8% L)	T-3 (30% CP; 10% L)	T-4 (35% CP; 6% L)	T-5 (35% CP; 8% L)	T-6 (35% CP; 10% L)	T-7 (40% CP; 6% L)	T-8 (40% CP; 8% L)	T-9 (40% CP; 10% L)
Crude protein	29.75	30.12	30.62	35.18	35.37	35.62	39.93	40.12	40.37
Ash	4.50	4.00	3.80	4.40	4.10	3.90	4.20	4.00	3.70
Calculated DE (kcal/g)	4.14	4.28	4.37	4.15	4.26	4.37	4.17	4.28	4.38

Table 40. Effect of different protein and lipid levels on growth and nutrient utilization of black molly, *Poecilia latippina*.

Nutrient levels	Nutritional indices					
	Initial weight (g)	Final weight (g)	Weight gain (g)	FCR	SGR	PER
30%CP 6% L	1.05 ±0.01[a]	4.79 ±0.06 [g]	3.74 ±0.04 [h]	1.66 ±0.03 [cd]	2.53 ±0.00 [f]	2.03 ±0.05 [c]
30%CP 8% L	1.07 ±0.01[a]	4.48 ±0.07 [h]	3.41 ±0.06 [g]	1.79 ±0.03 [ab]	2.38 ±0.01 [g]	1.86 ±0.03 [de]
30%CP 10% L	1.08 ±0.02 [a]	4.26 ±0.05 [i]	3.18 ±0.02 [f]	1.88 ±0.03 [a]	2.28 ±0.02 [h]	1.74 0.03 [e]
35%CP 6% L	1.05 ±0.02 [a]	5.88 ±0.07 [d]	4.83 ±0.05 [c]	1.64 ±0.05 [d]	2.87 ±0.02 [c]	2.02 ±0.05 [c]
35%CP 8% L	1.05 ±0.02 [a]	5.56 ±0.06 [e]	4.51 ±0.04 [d]	1.76 ±0.03 [bc]	2.78 ±0.02 [d]	1.88 ±0.04 [d]
35%CP 10% L	1.09 ±0.00 [a]	5.20 ±0.05 [f]	4.11 ±0.04 [e]	1.87 ±0.03 [a]	2.61 ±0.01 [e]	1.75 ±0.03 [de]
40%CP 6% L	1.05 ±0.02 [a]	7.02 ±0.08 [a]	5.97 ±0.06 [a]	1.42 ±0.03 [f]	3.16 ±0.01 [a]	2.36 ±0.06 [a]
40%CP 8% L	1.05 ±0.02 [a]	6.48 ±0.08 [b]	5.43 ±0.06 [b]	1.53 ±0.03 [e]	3.08 ±0.04 [b]	2.18 ±0.05 [b]
40%CP 10% L	1.14 ±0.03 [a]	6.10 ±0.05 [c]	4.96 ±0.01 [c]	1.63 ±0.04 [de]	2.79 ±0.03 [d]	2.02 ±0.05 [c]

Chapter IX
Summary

Study on nutrient requirement is the pre-requisite for formulation of nutritionally balanced cost-effective diets of ornamental fish. The results on nutrient requirement of common freshwater ornamental fish viz. blue gourami, guppy, sword tail and molly indicated that the protein, lipid and energy levels for optimum growth and nutrient utilisation varied between 30-40%, 6-10% and 3.5-4.0 kcal/g, respectively (Table 41). To formulate cost-effective practical diets, several locally available conventional and non-conventional feed ingredients were identified. Based on the nutrient requirement of the fish, the species specific cost-effective practical diets were formulated using identified potential conventional and non-conventional feed ingredients.

Table 41. Nutrient requirement of common freshwater ornamental fish.

Fish	Protein requirement (%)	Lipid requirement (%)	Energy requirement (k cal/g)
Blue gourami	35	8	3.5
Guppy	30	10	4.0
Sword tail	40	6	4.0
Molly	40	6	4.0

Feeding trials conducted on the selected ornamental fishes using the developed practical diets indicated the following results and possibilities:

1. Practical diets developed for gold fish (*Carassius auratus*) using chicken liver, lean prawn meal, mussel meal or squid meal, with 40.0 per cent crude protein, showed as good a result to that of two commercial feeds having 59.0 per cent crude protein and were much cheaper (₹. 80 – 300 / kg), compared to that of commercial ornamental feeds costing ₹. 1,100 – 3,500/kg.

2. Grower diets developed for gourami (*Trichogaster trichopterus*), using freshwater fish waste, surimi by-product, squid, mussel, chicken liver or low valued prawn as protein source showed better growth performance and nutrient

utilization compared to other protein sources used, indicating use of easily available by-products for formulating effective practical diets.

3. Study results indicated that surimi oil alone or in combination with plant oil instead of plant and animal oil alone gave uncompromised growth and nutrient utilization.

4. Grower diets developed for guppy (*Poecilia reticulata*) using squid meal, lean prawn meal or surimi by-product as protein source were better than other ingredient based diets in growth and nutrient utilization.

5. Use of freshwater fish waste, snail or chicken liver as non conventional protein source in grower diets gave better growth results in sward tail (*Xiphophorus helleri*) fingerlings.

Many of non-conventional feed ingredients used for preparing the practical diets were procured free of cost as they are generally discarded by the food processing industries as waste by-products. Therefore, the precise evaluation of feed cost with respect to each formulated diet is bit difficult in the present context. However, considering the nominal values of these non-conventional feed ingredients, the cost of the formulated diets are found to be in the range of ₹. 200-500/kg, which is much cheaper than the cost of the commercial diets (₹. 1100-3500/kg) that are available in the local market.

Table 42. The diets developed for gold fish, *Carassius auratus*.

Ingredients	Diet-1	Diet-2	Diet D-3	Diet D-4
Chicken liver	25	--	--	--
Prawn meal	--	25	--	--
Mussel meal	--	--	35	--
Squid meal	--	--	--	20
Fish meal	25	25	25	25
GN Cake	20	20	20	25
Wheat bran	10	10	10	10
Maize	10	10	10	10
Mineral & Vit. Mix	3	3	3	3
Oil	2	2	2	2
Binder	5	5	5	5

Table 43. The diets developed for blue gourami, *Trichogaster trichopterus*.

Ingredients (% Dry matter)	Diet-1	Diet-2	Diet-3	Diet-4	Diet-5	Diet-6
Freshwaterfish processing waste	45.0	-----	-----	-----	-----	
Surimi by-product	-----	40.0	-----	-----	-----	-----
Squid	-----	-----	28.0	-----	-----	-----
Mussel	-----	-----		30.0	-----	-----
Chicken liver	-----	-----	-----	-----	33.0	-----
Prawn meal	-----	-----	-----	------		32.0
Fish meal	10.0	10.0	10.0	10.0	10.0	10.0
GN Cake	18.0	16.0	20.0	20.0	20.0	18.0
Wheat bran	23.0	26.0	35.0	34.0	31.0	31.0
Vit. & Min.	2.0	2.0	2.0	2.0	2.0	2.0
Oil	-----	4.0	3.0	2.0	2.0	5.0
Binder	2.0	2.0	2.0	2.0	2.0	2.0

Table 44. The diets developed for guppy, *Poecilia reticulate*.

Ingredients (% Dry matter)	Diet-1	Diet-2	Diet-3	Diet-4
Surimi by-product	30.0	-----	-----	-----
Squid	-----	25.0	-----	-----
Mussel	-----		26.0	-----
Prawn meal	-----	-----	------	28.0
Fish meal	10.0	10.0	10.0	10.0
GN Cake	18.0	20.0	16.0	15.0
Wheat bran	28.0	31.0	35.0	32.0
Vit. & Min.	5.0	5.0	5.0	5.0
Oil	7.0	7.0	6.0	8.0
Binder	2.0	2.0	2.0	2.0

Some of the nutritionally balanced diets which are developed in the Institute for successful rearing of common freshwater ornamental fish species are given in Tables 42 to 45.

Based on the nutritional requirement assessed through the nutritional experiments conducted at the Institute, ingredient profiles of choice of 4 to 7 nutritionally balanced diets developed by the Institute using easily available local ingredients for successful rearing of four important and common freshwater ornamental fish species viz. gold fish, gourami, guppy and sward tail are given in tables 42, 43, 44 and 55, respectively.

The experimental facilities used for the studies on nutrient requirement and development of practical diets for freshwater ornamental fishes

Table 45. The diets developed for sword tail, *Xiphophorus helleri*.

Ingredients	Diet-1	Diet-2	Diet-3	Diet-4	Diet-5	Diet-6	Diet-7
Snail	45.0	----	----	----	----	----	----
Freshwater fish waste	----	48.0	----	----	----	----	----
Chicken waste	----	----	46.0	----	----	----	----
Squid	----	----	----	36.0	----	----	----
Mussel	----	----	----	----	38.0	----	----
Chicken liver	----	----	----	----	----	40.0	----
Prawn meal	----	----	----	----	----	----	38.0
Fish meal	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Groundnut oil cake	20.0	25.0	25.0	22.0	18.0	22.0	20.0
Wheat bran	18.0	12.0	15.0	25.0	29.0	23.0	25.0
Vit.& Min.	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Oil	2.0	----	----	2.0	----	----	2.0

Conclusion

The several feeding experiments that were performed in the Institute using the formulated cost-effective nutritionally balanced diets (as per the nutrient requirement of the species) showed that all the ornamental fish varieties tested have the potential to grow 2-3 times of their initial size (length and weight) within 30-60 days culture duration. As the price of the ornamental fish is size dependant, the ornamental fish traders can grow the small fish to a bigger size by using these formulated diets developed by the Institute with minimum possible time and sell these in a much higher price. Like any other fish farming, the feed constitute the major input cost in ornamental fish rearing also. Many of the commercial feeds that are available in the local ornamental fish markets are imported ones and obtained from the countries like Singapore, Hongkong, Malaysia, Indonesia, Thailand, South Korea, China and Japan. These imported feeds are not only very costly but also unsure of their nutrient quality. Therefore, some of the enterprising ornamental traders, farmers, unemployed educated youths and self help groups can manufacture these species specific nutritionally balanced feeds and sell to the home aquarists and hobbyists with proper vacuum packing and can get a handsome income. Almost all the feed ingredients used in formulating the different ornamental fish feeds are available locally. The feed formulation process is also very simple and easy to follow. The feeds can be formulated with a simple hand pelletizer which is generally used in many households for making snacks and available in any common hardware shop.

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