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Aquat. Living Resour. 16 (2003) 533–540
Aquatic Living Resources
www.elsevier.com/locate/aquliv

Review

Nutrient requirements of ornamental fish

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Received 12 May 2003; accepted 24 June 2003

Abstract

Although fish have been kept for more than three centuries as ornamentals, and the development of manufactured feed since 50 years ago has contributed to the tremendous growth of this hobby, nutrition of ornamental fish is based on extrapolation of results derived from food fishes under intensive farming conditions. Some research on nutrient (protein, minerals) requirements of growing freshwater ornamental species (live-bearers) in a production environment has been conducted, mainly in Singapore, with emphasis on the provision of live feed during the early stages of the life cycle. Protein requirements varied from around 30% dietary protein for growing omnivorous goldfish (*Carassius auratus*) to 50% for the carnivorous discus (*Symphysodon aequifasciata*). Whereas mineral (phosphorus, iron, magnesium, zinc) requirements have received some attention in the guppy (*Poecilia reticulata*), few researches have concentrated on vitamin requirements of ornamental species. Requirements for fatty acids have been conducted mainly on marine ornamentals (damselfish, seahorses), and accentuated the need for dietary supplementation of *n*-3 highly unsaturated fatty acids. Fish kept in public and home aquaria presents the problem of diversity of species in the same enclosure, each with its own specific requirements and needs. Maintenance energy levels of ornamental fish varied from 0.068 kJ per day for small neon tetras (*Paracheirodon innesi*) to 0.51 kJ per day for moonlight gouramis (*Trichogaster microlepsis*) kept at a water temperature of 26 °C. Research on nutrient requirements of ornamental fish urges for suitable measurements other than only growth rate in order to determine optimal dietary inclusion levels.

Résumé

Les exigences alimentaires des poissons d'ornementation. Les exigences alimentaires des poissons d'ornementation. L'élevage de poissons ornementaux effectué pendant plus de trois siècles et le développement de la manufacture d'aliment depuis 50 ans ont contribué à l'essor de ce loisir, mais la nutrition des poissons ornementaux se fonde sur une extrapolation de données dérivées de poissons de consommation et en conditions de culture intensive. Quelques études ont été faites sur les besoins alimentaires (en protéines, en éléments minéraux) d'espèces ornementales d'eau douce (des poissons vivipares) dans le cadre de production, à Singapour en particulier, et sur la nécessité d'aliment vivant dans les premiers stades de leur cycle de vie. Les besoins protéiniques varient de 30 % de protéine brute pour le poisson rouge omnivore (*Carassius auratus*), jusqu'à 50 % pour le discus carnivore (*Symphysodon aequifasciata*). Les besoins en minéraux (phosphore, fer, magnésium et zinc) ont été étudiés pour le guppy (*Poecilia reticulata*), mais peu d'investigations ont été faites pour connaître les besoins vitaminiques des espèces ornementales. Les besoins en acides gras ont été étudiés chez les poissons ornementaux marins (demoiselles, hippocampes) et se limitent à la supplémentation diététique en acides gras très insaturés *n*-3. Que les poissons soient présentés en aquariums publics ou cultivés en aquariums personnels, un problème de diversité d'espèces se pose dans un même bassin ; chaque espèce ayant ses exigences spécifiques. Leur besoin énergétique d'entretien varie de 0,07 kJ/jour pour les petits néons-tétras (*Paracheirodon innesi*) jusqu'à 0,51 kJ/jour pour les gouramis serpents (*Trichogaster microlepsis*), élevés dans une eau à 26 °C. Dans la recherche sur les besoins alimentaires des poissons ornementaux, il faut utiliser des paramètres adéquats, autres que le taux de croissance pour obtenir les taux optimaux des nutriments.

Keywords: Ornamental fish; Nutrient requirements

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doi:10.1016/j.aquliv.2003.06.001

1. Introduction

Ornamental fish keeping in the Far East dates back to over a thousand years ago, in Europe since the early 17th century. Only a few hundred of the 4000–5000 fish species currently being kept as pet fish worldwide are very popular and commonly kept by a large number of fish hobbyists, whereas specialist-hobbyists and zoos are often involved with the rare species (Pannevis, 1993). The implementation of ornamental fish breeding and rearing still relies greatly upon fish sourced from the wild, as wild populations are historically where the majority of ornamental fish have been sourced from with well-established collection industries. However, due to popular demand and pressure on wild resources, farming of ornamental fish, especially the tropical live-bearers (guppies, swordtails, mollies), is now an established industry in countries such as Singapore. This review was written to give insight into nutrient requirements of ornamental fish, firstly under commercial farming conditions that concentrate on maximum growth rate, and thereafter in a public or home aquaria environment where fish are kept for display and emphasis shifts to other variables such as colouration and gonad maturation (breeding health), rather than fast growth. It concentrates on scientific sound studies specifically related to nutrition of species used in the ornamental fish trade, as the basic general principles of fish nutrition and nutrition of food fishes are well described in numerous publications (for example, NRC, 1977, 1983, 1993; Hepher, 1988; Lovell, 1989; Steffens, 1989; De Silva and Anderson, 1995; Halver and Hardy, 2002).

Some species that might be used as ornamental fish are also exploited as food fishes. For example, high growth rates of black pacu, *Colossoma macropomum*, one of the most important fishes of the Amazon Basin, which can grow to 1 m and 30 kg, under laboratory conditions (Günther and Boza, 1993; Van der Meer et al., 1995), suggests that this species might be a suitable candidate for production under intensive aquaculture conditions (Van der Meer et al., 1997a,b). Similarly, the Mayan cichlid (*Cichlasoma urophthalmus*), that sometimes appears in aquarium trade, but is limited due to its big size, is targeted as an aquaculture species in its native range (Martinez-Palacios et al., 1996).

2. Aquaculture of ornamental fish

2.1. Freshwater species

Ornamental fish have traditionally been fed live feed, which is often nutritionally deficient, and can act as the transmitter of diseases (parasitic, bacterial and viral) if it is not stored correctly (Pannevis, 1993; Earle, 1995). However, large commercial producers of aquarium fish in Singapore emphasise the importance of regular supplementation of formulated feeds with live feed, as the inclusion of live feed improves growth (Fernando et al., 1991). It was demonstrated by Kruger et al. (2001a) that a daily supplementation of *Daphnia* spp. as live feed to swordtail (*Xiphophorus helleri*) broodstock maintained on an artificial flake diet resulted in a significant increase in fecundity as a result of more rapid growth, a higher number of embryos, and an improved feed conversion ratio, while supplementation of diets with *Artemia* increased growth of juvenile angelfish (*Pterophylum scalare*) (Degani, 1993). Some species, such as the ruby barb (*Puntius nigrofasciatus*), a voracious and indiscriminate feeder, prefers live feed to artificial feeds (Weerasooriya et al., 1999).

In freshwater ornamental fish culture, *Moina* used to be the most common live feed organism for feeding young fish in the industry (Lim et al., 2001). However, as *Moina* is cultured in water enriched with organic manure, an increasing number of ornamental fish farmers have shifted from the use of potentially contaminated *Moina* to *Artemia* nauplii for feeding their fish (Lim et al., 2001). Decapsulated *Artemia* cysts were found by Lim et al. (2002b) as a more hygienic and off-the-shelf alternative to *Artemia* nauplii for growth of adult guppies (*Poecilia reticulata*) and fry from guppies, platies (*Xiphophorus maculates*), swordtails, mollies (*Poecilia sphenops*) and black neon tetras (*Hyphessobrycon herbertaxelrodi*).

Large-scale discus (*Symphysodon aequifasciata*) breeders rely mostly on live food such as Tubifex, blood worms and *Artemia* nauplii to feed the growing fry (Chong et al., 2000). The rotifer, *Brachionus calyciflorus*, compared to egg yolk, could be used to improve growth and survival of juvenile dwarf gourami (*Colisa lalia*) and brown discus. The use of rotifers resulted in that discus larvae could be reared in absence of the dependence of body slime of parents as nutrient source during the first 2 weeks of exogenous feeding (Lim and Wong, 1997).

2.1.1. Protein and amino acids

Proteins are large, complex molecules made up of various amino acids that are essential components in the structure and functioning of all living organisms (NRC, 1983). The first need regarding protein requirements of fish is to supply the indispensable amino acid requirement of the animal, and secondly to supply dispensable amino acids or sufficient amino nitrogen to enable their synthesis (Macartney, 1996). Ornamental fish in captivity need to utilise their dietary protein with the utmost efficiency, as the breakdown products of protein metabolism (mainly ammonia) will directly pollute their living environment (Pannevis, 1993; Ng et al., 1993; Earle, 1995; Pannevis and Earle, 1995; Macartney, 1996; Raj and Jesily, 1996). The protein requirements for growing some ornamental fish under captive conditions are presented in Table 1.

The protein requirements of these juvenile omnivorous (guppy, goldfish, tin foil barb), carnivorous (discus) and herbivorous (redheaded cichlid) ornamental fish species are in accordance with requirements reported for food fishes (NRC, 1993). Requirement in the above is to be understood

Table 1
Protein requirements of ornamental fish species

Common name	Species name	Initial size (g)	Energy	Protein source	Parameters	Dietary requirements (%)	Reference
Guppy	*P. reticulata*	0.10	13.10 kJ g^{-1} ME	Fish meal, casein	Weight gain, feed conversion, gonadal development	30–40	Shim and Chua (1986)
Goldfish	*C. auratus*	0.20	11.72 kJ g^{-1} DE	Fish meal, casein	Weight gain, feed conversion, protein efficiency ratio	29	Lochmann and Phillips (1994)
		0.008	20.3 kJ g^{-1} GE	Fish meal, casein	Specific growth rate, feed efficiency, nutrient retention	53	Fiogbé and Kestemont (1995)
Tin foil barb	*Barbodes altus*	0.81	20.38 kJ g^{-1} GE	Casein	Weight gain	41.7	Elangovan and Shim (1997)
Discus	*S. aequifasciata*	4.45–4.65	21.65 kJ g^{-1} GE	Fish meal, casein	Specific growth rate	44.9–50.1	Chong et al. (2000)
Redhead cichlid	*Cichlasoma synspilum*	0.28	1.55 kJ g^{-1} DE	Fish meal	Specific growth rate	40.81	Olvera-Novoa et al. (1996)

GE, gross energy; ME, metabolisable energy; DE, digestible energy.

as a dietary percentage of protein needed for optimal growth, rather than a true requirement, that is the amount of protein needed per animal per day (Guillaume, 1997). Requirements stated in Table 1 were derived through dose–response studies over periods of 8–12 weeks, and are only applicable to similar conditions under which it was evaluated. According to Shim et al. (1989) female dwarf gouramis receiving a diet with 25–45% protein had the highest fecundity. Although female guppies receiving 15% dietary protein weighed less than those receiving either 31% or 47% dietary protein, no significant difference in fecundity between 15% and 47% dietary protein levels have been found (Dahlgren, 1980).

However, the relative ontogenetic stage of the fish being fed can significantly affect the protein level required in their food. A high requirement level for protein (53%) was found for goldfish (*Carassius auratus*) larvae, in comparison to 29% for juvenile fish (Table 1). A similar high requirement for essential amino acid requirements of goldfish larvae in comparison to requirements of juvenile food fishes (tilapias) has been reported (Table 2). This could be attributed to an important growth phase for larvae in a short time (20 days), or due to a lack of a selective system of macromolecular protein absorption in larvae compared to juvenile fish (Fiogbé and Kestemont, 1995).

Table 2
Essential amino acid requirements (g per 100 g protein) of goldfish (*C. auratus*) larvae (Fiogbé and Kestemont, 1995) compared to requirements of juvenile tilapia (*Sarotherodon mosambicus*) (Jauncey, 1983)

Amino acid	Goldfish	Tilapia
Arginine	7.8	2.8
Lysine	11.8	3.8
Histidine	4.1	1.1
Isoleucine	6.0	2.0
Leucine	9.1	3.4
Valine	7.0	2.2
Phenylalanine	5.6	2.5
Threonine	6.4	2.9
Methionine	3.4	–

Fish eat to satisfy their energy requirement, and protein and energy in the diet should be balanced (Macartney, 1996). Although fish use energy efficiently as an energy source, excessive dietary intake may restrict protein consumption and subsequent growth (NRC, 1977). Kruger et al. (2001b) stated that it would appear that a diet with at least 45% protein at a 6% lipid level is needed for the best specific growth rate and feed conversion of growing (6–8 weeks of age) swordtails.

Because of the increasing cost of high quality fish meal, requirements for aquafeeds that increase, and to help reduce fishing pressure which is currently causing declining stocks of fish that are turned into meal, priority is given internationally to the search for alternatives for fish meal in animal feeds as a source of protein. Fish meal might be substituted by soybean meal up to 37% of the diet, replacing 33% of the fish meal protein, to achieve normal growth in juvenile tin foil barb (Elangovan and Shim, 2000).

2.1.2. Lipids and fatty acids

Dietary lipids are important sources of energy and fatty acids that are essential for normal growth and survival of fish. Although fish have a low energy demand, and is thus susceptible to deposition of excessive lipid (Earle, 1995), lipids do have a role as carriers for fat-soluble vitamins and sterols, are important in the structure of biological membranes at both the cellular and subcellular levels, are components of hormones and precursors for synthesis of various functional metabolites such as prostoglandins, and are also important in the flavour and textural properties of the feed consumed by fish (NRC, 1983). Fish in general require fatty acids of longer chain length and a higher degree of unsaturation than mammals.

Fatty acids with low melting points are needed at the lower body temperature to support cell membrane flexibility at low water temperatures (Earle, 1995). In general, freshwater fish require either dietary linoleic acid (18:2*n*-6), or linolenic acid (18:3*n*-3), or both, whereas marine fish require dietary

Table 3
Mineral requirements of ornamental fish species

Mineral	Common name	Species name	Initial size (g)	Parameters	Dietary requirements (%)	Reference
Phosphorus	Tiger barb	*Barbus tetrazona*	0.33	Weight gain	0.52[a]	Elangovan and Shim (1998)
Phosphorus	Guppy	*P. reticulata*	0.24	Weight gain, mineralisation	0.53–1.23	Shim and Ho (1989)
Iron	Guppy	*P. reticulata*	4 weeks	Prevention of hypochromic, microcytic anaemia[b]	0.008	Shim and Ong (1992)
Magnesium	Guppy	*P. reticulata*	0.17	Weight gain	0.054	Shim and Ng (1988)
Zinc	Guppy	*P. reticulata*	0.25	Weight gain, feed conversion	0.01	Shim and Lee (1993)

[a] Originating from potassium phosphate monobasic (KH_2PO_4).
[b] A condition characterised by a reduced blood cell count, haemoglobin content, haematocrit, and erythrocyte values.

eicosapentaenoic acid (20:5*n*-3) and/or docosahexaenoic acid (22:6*n*-3) (NRC, 1993). However, in the freshwater common carp it has been demonstrated that dietary levels of dietary docosahexaenoic acid significantly affected egg hatchability (Shimma et al., 1977), as has been demonstrated in many species of food fishes (Rainuzzo et al., 1997). Compared to requirements of fatty acids determined with freshwater and marine food fishes (NRC, 1993), research on fatty acids requirements of ornamental fish, specifically the need for broodstock to achieve optimal larvae quality, is lacking. According to Lochmann and Brown (1997) supplemental phospholipids are not essential for survival of small (0.3 g) juvenile goldfish. About 1% of linolenic acid (18:3*n*-3) is required in the diet of carp to keep lipogenesis low and to prevent overproduction of oleic acid (Farkas et al., 1978).

2.1.3. Carbohydrates

No dietary requirement for carbohydrates has been demonstrated in fish. However, carbohydrates present a cheap energy source, that would “spare” the catabolism of other components such as protein and lipids to energy. Warm water fish can use much greater amounts of dietary carbohydrate than cold water and marine species (NRC, 1993). Most herbivorous fish, such as goldfish and koi carp, use the microflora in their hind gut to digest complex carbohydrates (Pannevis, 1993; Earle, 1995). Carbohydrate digestibility can vary from 70% in goldfish to as low as 50% for moonlight gourami (*Trichogaster microlepis*) (Pannevis, 1993).

2.1.4. Minerals

Minerals are inorganic elements required by fish for tissue formation and various functions in metabolism and regulation (NRC, 1977). Ornamental fish can absorb some water-soluble minerals from the water, complicating studies in determining dietary mineral requirements (Shim and Ho, 1989). Of all the minerals required by fish, phosphorus is one of the most important because it is essential in growth, bone mineralisation and lipid and carbohydrate metabolism, and is needed in the diet due to low content in natural water. Furthermore, the pollution of water by excess phosphorus excreted appeared highly critical, as this may lead to eutrophication. In accordance to results obtained with food fishes (NRC, 1993), dietary calcium was found to be non-correlated to fish growth in guppies (Shim and Ho, 1989). Requirements of ornamental fish during the growth phase for some minerals are presented in Table 3. Similar as with food fishes, depressed appetite, scoliosis and lordosis have been reported in guppies fed phosphorus deficient diets (Shim and Ho, 1989).

2.1.5. Vitamins

Vitamins are organic compounds required in relative small quantities in the function of most forms of life, but which some organisms are unable to synthesise (NRC, 1983). Fracalossi et al. (1998) reported that the lowest level of ascorbic acid tested in their study (25 mg kg^{-1} diet) was sufficient to prevent growth reduction and ascorbic acid deficiency signs (deformed opercula and jaws, haemorrhage in the eyes and fins, lordosis) in juveniles (29.2 g) of an Amazonian ornamental fish, the Oscar (*Astronotus ocellatus*). Oscars without ascorbic acid supplementation took 25 weeks to start presenting clinical ascorbic acid deficiency signs. Blom et al. (2000) proposed a conservative dietary ascorbic acid requirement of 360 mg kg^{-1} diet necessary to maintain maximum tissue storage of this vitamin in angelfish juveniles. Stress-resistance, evaluated as resistance to osmotic shock in pre-aerated water containing 35 sodium chloride, was significantly higher in guppies fed a moist formulated diet supplemented with ascorbic acid at either 1000 or 2000 mg kg^{-1} diet compared to fish fed a control diet without any supplementation (Lim et al., 2002b). Water-soluble vitamins are most vulnerable to nutrient leaching. A large percentage of vitamin C, vitamin B_{12}, choline, and panthothenic acid are lost in water within 30 s of feeding some commercial flake diets (Pannevis and Earle, 1994a).

2.1.6. Carotenoids

Fish use oxygenated carotenoids, one of the most important groups of natural pigments, for pigmentation of skin and flesh. Carotenoids commonly occurring in freshwater include beta-carotene, lutein, taraxanthin, astaxanthin, tunaxanthin, alpha-, beta-doradexanthins, and zeaxanthin (NRC, 1983, 1993). As fish cannot synthesise these pigments, they rely on dietary supply of carotenoids to achieve their natural skin pigmentation, one of the most important quality criteria informing the market value of ornamental high value species such as Koi carp (*Cyprinus carpio*) and goldfish (Paripatananont et al., 1999; Lovell, 2000; Gouveia et al., 2003). Red colouration is imparted in goldfish and common carp by astaxanthin, a carotenoid that is readily metabolised from the yellow pigment zeaxanthin (Hata and Hata, 1972, 1973, 1976). Goldfish metabolised very little beta-carotene and no lutein to astaxanthin (Hata and Hata, 1972). Under certain well-defined culture conditions (nitrogen depletion, high salinity and light intensity) the algae *Chlorella vulgaris, Haematococcus pluvialis* and *Arthrospira maxima* (*Spirulina*) will accumulate secondary carotenoids and might be used to replace costly synthetic colourings in ornamental fish feed (Gouveia et al., 2003).

2.2. Marine ornamental species

Research on breeding and larval rearing of marine ornamental fishes is still relatively in its infancy (Ignatius et al., 2001). Clownfish (*Amphiprion percula*) is not only the most popular marine fish species in the aquarium trade, but is also considered as a reference fish for scientific studies on nutrition and egg and larval quality (Delbare et al., 1995). It was shown in the marine clownfish that fry can be weaned onto a formulated dry feed from 7 days after hatch with no significant reduction in survival as compared to controls receiving enriched *Artemia*, although the optimum time of weaning on a dry formulated feed was found to be between 15 and 20 days after hatch. From 32 days after hatch, supplementation of diets with live or natural feeds is unnecessary (Gordon et al., 1998). Higher survival and growth of larvae was observed in feeding of a combination of rotifer and copepod, which signifies the suitability of copepods to *Artemia* (Ignatius et al., 2001). Woods (2003) demonstrated that juvenile seahorses (*Hippocampus abdominalis*) of 1–2 months old could be successfully weaned onto both frozen and artificial foods, but newborn juveniles were not successfully weaned on the artificial food.

2.2.1. Fatty acids

Marine ornamental fish are unable to biosynthesise docosahexaenoic acid either de novo or from shorter chain precursors such as linolenic acid (Sargent et al., 1997, 1999). Docosahexaenoic acid must be present in the diet to maximise survival of larvae of the coral reef damselfish (*Acanthochromis polyacanthus*) (Southgate and Kavanagh, 1999), and newborn seahorses (*Hippocampus* sp.) (Chang and Southgate, 2001). The optimum level of dietary docosahexaenoic acid to support optimal growth and survival in seahorses is greater than 9.3 mg g^{-1} dry weight (Chang and Southgate, 2001). This could be achieved by enriching *Artemia* with *n*-3 highly unsaturated fatty acids (Southgate and Kavanagh, 1999; Chang and Southgate, 2001).

3. Fish kept in aquaria

The development of manufactured feed could be considered as one of the contributing factors to the tremendous growth of this hobby's widespread popularity over the past 50 years (Earle, 1995). The increased acceptability of and reliance upon manufactured feed for ornamental fish have focused the attention on the nutritional requirements of these animals. Most information on the quantitative and qualitative nutrient requirements of ornamental fish kept in public and home aquaria is derived principally from research carried out by the aquaculture industry since the 1970s. These results do have limitations in their applicability to ornamental fish, because it is based on a small number of species of fish raised for food, which are often kept under totally different conditions from those of fish kept as ornamentals in public or home aquaria (Pannevis, 1993; Earle, 1995).

One of the main problems is the diversity of species kept in home and public aquaria and how to provide them with adequate diets (Pannevis and Earle, 1995; Macartney, 1996). With the exception of a small number of tropical freshwater carnivorous fish species (Cichlidae), and goldfish and koi carp, ornamental fish are seldom kept in a single-species environment (Macartney, 1996). It is impractical to feed very specific diets to individuals in an aquarium environment (Pannevis, 1993; Pannevis and Earle, 1995). The diet must be suitable for all tank inhabitants, which may include herbivores, omnivores, and carnivores. Not only will these fishes have different nutrient requirements, but also the digestibility of various components of the diet will differ depending on the natural diet and intestinal morphology. Furthermore, the physical characteristics of the diet and the feeding regime must satisfy the different lifestyles and feeding habits, such as surface, middle, and bottom feeders, and diurnal variations in feeding among these groups. Physical characteristics of the diet also play an important role when species of various weights are fed on the same diet. Food particles need to be small enough for the smaller species to ingest, but large enough to be identified and eaten by the larger species (Macartney, 1996).

The general nutritional classification of ornamental fish is based on biotic (i.e. physiology, life stage or feeding behaviour) and abiotic (i.e. environmental temperature, salinity) factors. Temperature (temperate, tropical, arctic), environmental salinity (sea water, brackish water, fresh water) and water hardness (soft water, hard water), are the important abiotic nutritional classifications. The most important biotic nutritional classifications are those of herbivorous, omnivorous or carnivorous ornamental fish. The combination of the main classification groups results in more than 18 distinguishable nutritional groups of ornamental fish. Ornamental fish can exhibit a very consistent preference for one diet over another when the two diets are fed simultaneously (Pannevis, 1993).

As ornamental fish are poikilotherms, their maintenance energy requirements adapt to changes in water temperature.

Table 4
Maintenance feeding requirement of five popular species of ornamental fish (Pannevis and Earle, 1994b)

Common name	Species name	Initial size (g)	Maintenance feeding requirement (mg feed per day)	Maintenance energy requirement (J DE per day)
Goldfish	*C. auratus*	3.59	14.36	239
		4.78	11.47	191
		8.06	25.79	429
		11.66	18.33	306
Neon tetra	*P. innesi*	0.18	3.8	68
Leopard danio	*Brachydanio rerio*	0.30	<7.2	<128
Kribensis	*Pelvicachromis pulcher*	1.02	<10.2	<182
Moonlight gourami	*T. microlepis*	1.87	<28.5	<508

DE, digestible energy; GE, gross energy. Goldfish diet, 19.38 kJ g^{-1}; GE, 16.65 kJ g^{-1} DE. Diet for other species, 19.66 kJ g^{-1} GE; 17.83 kJ g^{-1} DE. Water temperature at 20 °C for goldfish and 26 °C for other species.

Fish mobilise very little glycogen as an energy substrate (Pannevis, 1993; Earle, 1995). Maintenance feeding levels are low, ranging from 4 mg feed per day for small neon tetras up to 29 mg feed per day for moonlight gouramis (Table 4).

4. Conclusion and recommendations

Feeding of ornamental fish is based on extrapolations of nutrient requirements and practices derived from food fish under intensive cultured conditions aimed at maximum growth in a short time period. This might be of value for farming of ornamental species, but would be unsuitable for fish kept in public and home aquaria. For example, high dietary protein levels necessary for growth of juvenile fish kept in large ponds might present problems of nitrogen breakdown products with adult fish kept in small home aquaria as well as ineffective use of excess protein in metabolism. Fish kept in home aquaria are normally already in the adult stage of their life cycle, and different species are kept together in the same environment. The latter not only complicated the satisfaction of different nutrient requirements, but also feeding regimes, and type of feed presentation. A better approach than to satisfy the needs of individual species would be to minimise deviations, thus to develop an intermediate feed that would satisfy the crude requirements of all species.

The digestibility values of nutrients in feed ingredients and diets are not yet established in ornamental species. Availability of these values would not only result in least cost diet formulation for ornamental species, but would also be a valuable tool in reducing pollution of the living environment.

Furthermore, research on influence of nutrition on ornamental fish is hampered by a lack of suitable measurement other than growth. Whereas the measurement of skin colour is possible through well-established subjective and objective techniques, this would evaluate the influence of only carotenoids as dietary component. Although loss of body weight and subjective development of certain artefacts might present an indication of a lack of nutrients, this approach would identify minimum dietary levels, and not optimum well-being of the animal. Measurement of nutrient requirements has to be correlated with animal welfare, a field that is still unexploited with aquatic species.

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