Common Carp, *Cyprinus carpio* 18

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Introduction

The common carp (*Cyprinus carpio*) belongs to the family Cyprinidae. In nature, carp live in the middle or lower reaches of a river with slow currents, or in marshes. Their habitats are usually weedy areas with a muddy bottom. Carp fry feed on zooplankton such as rotifers and copepods, but as they grow up they become benthic feeders, feeding on animals and other organic material.

The cyprinids have been farmed since ancient times and today they are undoubtedly the most important teleost family cultivated on a global scale, the current production figure reaching over 13 million tons year^{-1}. The common carp is an important culture species among the cyprinids, next only to silver carp and grass carp (Fig. 18.1), and its production has doubled over the last decade, reaching about 2.5 million tons in 1998, valued at US$2.8 billion (Fig. 18.2). A large percentage of this is from the Asian region, particularly China. While production of common carp is widely practised, only about 3% of the cyprinids are cultivated in intensive systems (Tacon, 1993).

Traditionally, carp are cultured in ponds or rice paddies, while advanced culture systems include irrigation ponds, running-water systems and net cages in lakes. The more organized culture techniques involve maintenance of breeders, fry production, yearling production and marketable fish production. The operations and feeding practices are outlined in Table 18.1. Relatively low-cost prepared diets are in vogue and little effort has been made to supply adequate amounts of nutrients from carefully selected ingredients, despite the existence of a great deal of scientific information.

Nutrient Requirements

The dietary requirements of common carp for protein, amino acids, lipids, fatty acids, carbohydrates (starch), vitamins, minerals, energy and protein/energy ratios have been investigated by many researchers and reviewed (Satoh, 1991;

 Nutrient Requirements and Feeding of Finfish for Aquaculture (eds C.D. Webster and C. Lim)

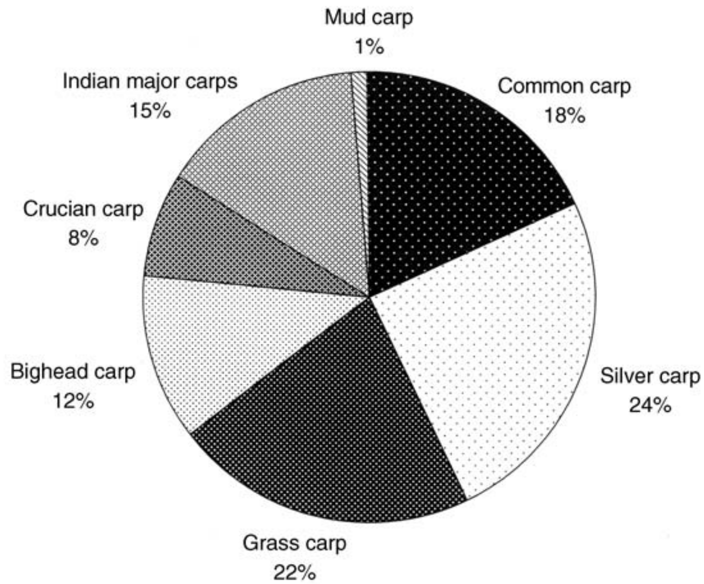

Fig. 18.1. The share of common carp among various farmed cyprinids.

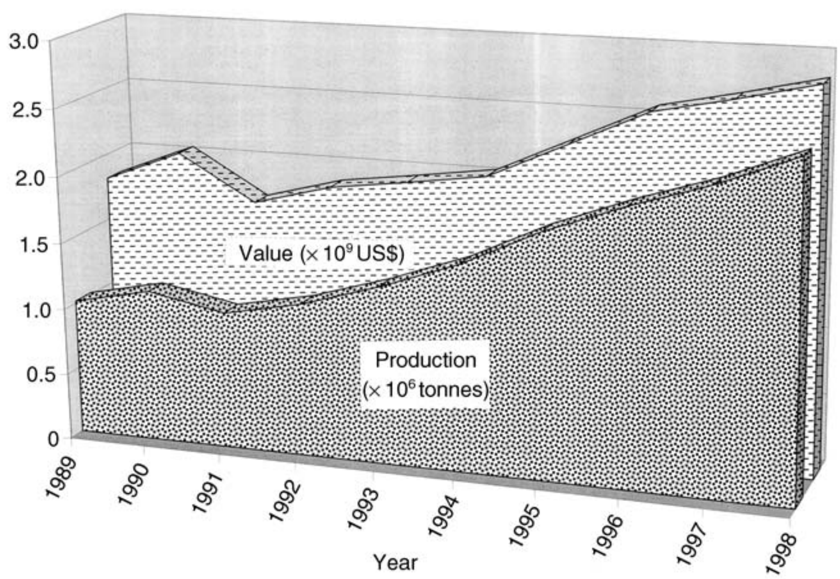

Fig. 18.2. The production and value of cultured common carp during the last decade.

Omae, 1992; Song, 1994; De Silva and Anderson, 1995; Kaushik, 1995; Takeuchi, 1999). This chapter incorporates some of the more recent information on nutrition of the carp. A snapshot of the macronutrient requirements of the common carp is provided in Table 18.2.

Table 18.1. Culture systems and feeding practices for different stages of common carp, *Cyprinus carpio* (modified from Kafuku, 1992).

Fish stage	Production system	Feeds/feeding
Parent fish	Spawning pond	Diets with 70% vegetable matter and 30% animal matter enriched with vitamins and minerals
Fry	Stagnant-water pond	Daphnia and other zooplankton
Yearlings	Stagnant-water pond	Artificial diets
	Half-running-water pond	Pellets fed over five times a day
	Farm pond	
Market-size fish	Farm pond, running-water pond	Artificial diets, silkworm pupae
	Spring-water pond	Vegetables, boiled wheat
	Circulating-water pond	
	Floating net cage	

Table 18.2. Macronutrient requirements of common carp, *Cyprinus carpio*.

Nutrient	Requirement
Protein	30–35 g 100 g^{-1}
Lipid	5–15 g 100 g^{-1} (related to energy)
Essential fatty acid	
Linoleate	1 g 100 g^{-1}
Linolenate	1 g 100 g^{-1}
Digestible energy	13–15 MJ kg^{-1} (310–360 kcal)
Carbohydrate (as starch)	30–40 g 100 g^{-1}

Protein and amino acids

Ogino and Chen (1973) and Ogino (1980b) reported that the daily requirement of common carp for protein is about 1 g kg^{-1} body weight for maintenance and 12 g kg^{-1} body weight for maximum protein retention. The efficiency of nitrogen utilization for growth, however, is highest with a protein intake of 7 to 8 g kg^{-1} body weight day^{-1}.

Investigations on the optimal requirement of common carp have demonstrated that crude protein levels ranging from 30 to 38% appear to satisfy the fish (Jauncey, 1982; Watanabe, 1988). Generally, this level has been determined by using semipurified diets containing a single high-quality protein source, such as casein, whole-egg protein or fish-meal. If sufficient digestible energy is contained in the diet, the optimal protein level can be effectively kept at 30–35% (Watanabe, 1982).

The whole-body amino acid profile of carp is not affected by variations in diet or by the age of the fish (Schwarz and Kirchgessner, 1988). The same ten essential amino acids (EAA) described for most fish are indispensable for carp growth too. The quantitative requirement for amino acids was established through different studies and is shown in Table 18.3. It should also be noted that there may be minor changes in the requirement of individual amino acids, depending on the growth stages (Baloguma, 1995). The lysine requirement at the fingerling stage is 2.25% of the diet (6% of protein) and decreases to 1.75% (5.4%) at the juvenile stage, whereas it does not change in the case of methionine. As has been recognized in other fish, cystine and tyrosine can spare or replace certain portions of dietary methionine and phenylalanine, respectively. In a recent observation on sulphur amino acid synthesis, Yokoyama *et al.* (2001) demonstrated that the hepatic cysteinesulphinate decarboxylase (CSD) (EC4.1.1.29) activity of carp is quite low compared with that of rainbow trout (*Oncorhynchus mykiss*) and tilapia (*Oreochromis niloticus*), where the values are 50 times higher. This is despite the fact that the carp muscle contains a high amount of taurine. CSD is an enzyme involved in the biosynthesis of taurine from cysteine and, if its activity is low, it would mean that carp requires dietary taurine supplements.

Ogino (1980a) reported that amino acid requirements could be estimated from data on the amino acid profile of the whole-body and daily body protein deposition. If a diet containing 35% protein with 80% of protein digestibility is fed daily at a level of 3% of the body weight, it can be assumed that the fish deposits 0.58 g of protein 100 g^{-1} of body weight daily. Data based on these assumptions are shown in Table 18.3, and the requirements determined by these two methods agree fairly well. However, the deposition rate does not account for metabolic pathways of amino acids that do not lead to protein synthesis. Further the

Table 18.3. Amino acid requirement of common carp, *Cyprinus carpio*.

	Nose (1979)			
Amino acid	% in dietary protein	% in diet	Ogino (1980a) (% in dietary protein)	Dabrowski (1983b) (mg kg^{-1} day^{-1})
Arginine	4.3	1.6	4.4	506
Histidine	2.1	0.8	1.5	145
Isoleucine	2.5	0.9	2.6	255
Leucine	3.3	1.3	4.8	429
Lysine	5.7	2.2	6.0	458
Methionine	2.1	0.8	1.8	105
Cystine	5.2	2.0	0.9	n/a
Phenylalanine	3.4	1.4	3.4	254
Tyrosine	2.6	1.0	2.3	190
Threonine	3.9	1.5	3.8	213
Valine	3.6	1.4	3.4	305
Tryptophan	0.8	0.3	0.8	n/a

n/a, Values not available.

absorption of individual amino acids differs greatly depending on protein source and time after feeding (Dabrowski, 1983a, 1986). In this context, the absorption rate describing metabolic amino acid requirements might prove useful, although it needs further study. Recently Akiyama *et al.* (1997) compared the A/E ratios (relative proportion of each EAA to the sum of the EAA) among fish species, and placed common carp adjacent to catla (*Catla catla*), both of which belong to the same family, Cyprinidae.

Energy

There is little information on the energy requirements of carp, compared with the volume of data on other aspects of nutrition. As described in other teleosts, both fasting metabolic rates and maintenance energy requirements are affected by water temperature. The resting metabolic rates at temperatures below 17°C are quite low (Kaushik, 1995). A linear relationship between nitrogen (N) intake and heat increment in feeding has also been proposed, the value being around 40 kJ g^{-1} N intake (Chakraborti *et al.*, 1992; Kaushik, 1995).

Protein and lipid requirements are related to digestible energy. The optimum range of the digestible energy/protein ratio for the maximum growth was 97–116 when based on the measured digestible energy (Takeuchi *et al.*, 1979b). A dietary energy budget was provided by Ohta and Watanabe (1996) for carp fed a practical diet comprising 25% fish-meal, 4% meat meal, 10% soybean meal and 8% maize-gluten meal as the main protein sources. The partitioning based on gross energy intake (100%) at the level required for maximum growth was: 29.9% lost as faecal energy, 1.5% as non-faecal energy, 31.9% as heat increment and 36.7% as net energy (including 12.6% for maintenance and activity and 24.1% as productive energy). The authors also reported that the digestible energy requirements for maximum growth were 285, 548 and 721 kJ kg^{-1} body weight day^{-1} (at feeding rates of 1.83, 3.60 and 5.17% of body weight day^{-1}, respectively), being influenced by both diet and fish size.

Lipids and fatty acids

Carp is an omnivorous fish and can utilize effectively both lipids and carbohydrates as dietary energy sources, and therefore the digestible energy content is more important than lipid content in the diet. It has been shown that the enrichment of the digestible energy content from 13 to 15 MJ kg^{-1} diet by addition of lipid at levels of 5–15% to diets did not result in improvement in growth performance nor net protein utilization (Takeuchi *et al.*, 1979a). Further, the negative aspect of increasing dietary lipids seems to be the increase in its body deposition, particularly as visceral fat (Zeitler *et al.*, 1983; Murai *et al.*, 1985).

As far as the essential fatty acids (EFA) are concerned, common carp and grass carp (*Ctenopharyngodon idella*) require both n-6 and n-3 fatty acids. It has been estimated that a supply of 1% of each of these fatty acids leads to best growth and feed efficiency in juvenile common carp (Takeuchi and Watanabe, 1977). However, there are other reports that the quantitative requirements may be lower (Kaushik, 1995). Though the deficiency symptoms related to EFA do not easily show up in common carp, poor growth, high mortality and skin depigmentation have been reported. On the other hand, in grass carp, a related species, the deficiency manifested as lordosis, resembling 'Sekoke disease', but is not characterized by apparent muscular dystrophy (Takeuchi *et al.*, 1992).

The role of medium-chain triglycerides (MCT) in the nutrition of carp larvae has been recently studied (Fontagné *et al.*, 1999, 2000). While tricaproin (C6:0), tricaprin (C10:0), trilaurin (C12:0) and triolein (C18:1) produced efficient growth and survival, tricaprylin (C8:0) proved to be a very poor source. The peculiarity of tricaprylin among the other MCT, which seemed to be well utilized up to 30 g 100 g^{-1} of total dietary fatty acid, was related to an unexplained disorganization of the fatty acid enzyme systems.

Phospholipids (PL) have numerous roles in larval feeding including an influence on texture, resistance to oxidation and water stability of food particles (Coutteau *et al.*, 1997). Attention should be paid to an adequate dietary PL supply when carp larvae are offered artificial diets instead of PL-rich live food (Geurden *et al.*, 1995). Dietary PL deficiency resulted in an accumulation of fat droplets in the enterocytes of the anterior intestine, an increase in the height of mucosal epithelium and a reduction in mean hepatocyte volume. However, supplementation of phosphatidylcholine (PC) from hen egg-yolk or from soybean prevented intestinal steatosis and increased the hepatocyte volume (Fontagné *et al.*, 1998). The foregoing study also suggested that PL are needed for absorption of neutral lipids although the benefits were independent of their emulsifying properties. On comparing several PL sources prepared from soybean lecithin, Geurden *et al.* (1998) found that while PC was important for obtaining high initial growth, phosphatidylinositol was responsible for normal development of carp larvae. They suggested that dietary PL supplements should preferably be a blend similar in composition to that of the larval body. In a later study Geurden *et al.* (1999) pointed out the conservative distribution of the PL classes in fish of a given size, irrespective of the diet, explaining that only limited remodelling is needed.

Carbohydrates

Several studies have been conducted on carbohydrate utilization in common carp. The amylase activity in the digestive tract and the digestibility of starch in fish are generally lower than those of terrestrial animals. Among fish, the intestinal activity of amylase is higher in omnivorous fish, including common carp, than in carnivorous fish. It has been found that the ratio of intestine length to body length in carp is 1.8–2.0, the values being four times greater than those of rainbow trout and eel (*Anguilla japonicus*), and this accounts for the better utilization of carbohydrates by carp. Murai *et al.* (1983) investigated the effects of various dietary carbohydrates and the frequency of feeding on patterns of feed utilization by carp. While the starch diet produced the highest weight gain and feed efficiency at two daily feedings, glucose and maltose were as efficiently utilized as starch when fed at least four times daily. This indicates that there is a drop in the absorption efficiency of glucose and maltose when large amounts are fed at a time.

Ogino *et al.* (1976) found that common carp used carbohydrate effectively as an energy source. Later Takeuchi *et al.* (1979a) also confirmed the dietary value of carbohydrates as energy sources. Based on the results of many studies, the optimum range of dietary carbohydrate may be considered to be 30–40% for common carp.

Vitamins and minerals

The qualitative and quantitative vitamin requirements of carp have been well investigated; a summary, including deficiency signs, has been provided in Table 18.4. Dietary requirements for folic acid and vitamins B_{12}, D and K have not

Table 18.4. Vitamin requirements of common carp and deprivation-induced symptoms (Satoh, 1991; NRC, 1993).

Vitamin	Requirement ($mg\ kg^{-1}$)	Deficiency signs
Thiamine	0.5	Poor growth, nervousness, skin depigmentation, subcutaneous haemorrhage
Riboflavin	7	Anorexia, poor growth, haemorrhages in hepatopancreas, skin and fin, emaciation, photophobia, nervousness, anterior kidney necrosis
Pyridoxine	6	Anorexia, ascites, ataxia, exophthalmia, convulsions, nervous disorders, anaemia, low hepatopancreatic transferase
Pantothenate	30	Anorexia, poor growth, irritability, haemorrhages in skin, lethargy, exophthalmia
Niacin	28	Anorexia, poor growth, poor survival, haemorrhages in skin, high mortality
Biotin	1	Poor growth, erythrocyte fragility and fragmentation, lethargy, increased number of dermal mucous cells
Choline	500	Poor growth, fatty hepatopancreas, vacuolization of hepatic cells
Inositol	440	Anorexia, poor growth, dermatitis, loss of skin mucosa
Vitamin A	4000 IU	Anorexia, poor growth, exophthalmia, skin depigmentation, twisted opercula, haemorrhagic fin and skin
Vitamin E	100	Muscular dystrophy, exophthalmia, lordosis, kidney degeneration, pancreatic degeneration
Vitamin C	required	Caudal fin erosion and deformed gill arches in larval stage, poor growth

been observed yet, but some of these vitamins can be synthesized by intestinal microflora in carp and other freshwater fish (Lovell and Limsuwan, 1982).

Vitamin requirements of common carp may be affected by various factors, such as fish size, water temperature and diet composition. For example, juvenile or adult common carp do not require vitamin C because they can synthesize ascorbic acid from D-glucose. However, fry of common carp do show vitamin C deficiency signs, such as caudal fin erosion and deformed gill arches (Dabrowski *et al.*, 1988). Studies with first-feeding larvae have indicated that the level required for maximum tissue storage (270 mg ascorbic acid equivalent kg^{-1}) is higher than that needed for survival and growth (45 mg ascorbic acid equivalent kg^{-1}) (Gouillou-Coustans *et al.*, 1998). In regard to vitamin E, the requirement may increase corresponding to the level of polyunsaturated fatty acids in the diet.

Recently, extrusion techniques have been used to make floating fish diets and certain vitamins may be destroyed during diet manufacture and storage. To provide a safety margin, supplemental levels of vitamins in fish diets are always higher by two to five times the requirement levels.

Mineral requirements and their deficiency signs are summarized in Table 18.5. (It has been reported that common carp require cobalt, copper, iron magnesium, manganese, phosphorus and zinc.) Carp lack an acid-secreting stomach essential for digesting and solubilizing various compounds containing both calcium and phosphorus; thus the availability of phosphorus depends on the water solubility of the salt and ingredients (Satoh *et al.*, 1992, 1997). Phosphorus from tricalcium phosphate or fish-meal (FM) (white and/or brown FM) is less available than that from the more soluble mono- and dicalcium phosphates.

Table 18.5. Mineral requirements of common carp and deprivation-induced symptoms (Satoh, 1991; NRC, 1993; Kim *et al.*, 1998).

Mineral	Requirement	Deficiency signs
Phosphorus	6–8 g kg^{-1}	Poor growth, skeletal abnormality, low feed efficiency, low ash in whole body and vertebrae, increased visceral fat
Magnesium	0.4–0.5 g kg^{-1}	Poor growth, anorexia, high mortality, sluggishness and convulsions, cataracts, high mortality, high calcium content in bone, reduced magnesium in bone
Iron	150 mg kg^{-1}	Low specific gravity, haemoglobin content and haematocrit values, abnormal mean corpuscular diameter
Zinc	15–30 mg kg^{-1}	Poor growth, high mortality, erosion of fins and skin, low zinc content in bone
Manganese	13 mg kg^{-1}	Poor growth, dwarfism, skeletal abnormalities, high mortality, low calcium, magnesium, phosphorus, zinc and manganese in bone
Copper	3 mg kg^{-1}	Poor growth
Cobalt	0.1 mg kg^{-1}	Poor growth

Supplementation of monobasic phosphate to FM-based diets resulted in an increase in growth response of common carp. It has also been found that an exogenous supply of copper, manganese, magnesium and zinc is necessary for carp diets. However, it should be noted that an excess amount of tricalcium phosphate may inhibit the availability of trace elements, such as zinc and manganese, though to a much lesser extent than in rainbow trout (Satoh *et al.*, 1989). In a study examining the interaction between zinc deficiency and lipid intake, malabsorption of nutrients was observed and it was linked to the lipid deposition in the intestine (Taneja and Arya, 1994).

Practical Diets

Changing with the times, traditional ways of feeding carp with crude feeds prepared on site from local ingredients have given way to feeding commercially prepared diets. But in China, where carp culture predominates, there are still farms where natural food, fresh food and simple processed dry food are being used (Song, 1994). Several plant- and animal-based diets are available for carp. The former include oilcakes, beans, grains and brans, grasses and tree leaves, while the latter include FM, meat and bone-meal, silkworm pupae meal, blood meal, feather meal and chicken-farm waste. In his review Song (1994) has dealt extensively with the ingredients mentioned here, in the context of carp farming.

Prepared diets for carp are currently FM-based. Efforts are under way to produce alternative diets, aimed not only at reducing prices but also at making the diets more suitable to the environment. The expanded pellet is rapidly becoming popular for feeding many of the cultivated species, including carp. This pellet has characteristics between those of an extruded pellet and a steam pellet, along with being cost-effective. This section summarizes some of the recent success in practical diet development for common carp.

Digestibility of ingredients

It is well known that the apparent digestibility of protein (APD) and energy in several diet ingredients appears to be species-specific and temperature-dependent. This is particularly true for plant ingredients. Table 18.6 shows the apparent digestibility of protein and energy in various feedstuffs at different water temperatures for carp (Takeuchi, 1991). The digestibility values were not influenced by fish size, which ranged from 3 to 295 g.

In formulating diets for the carp, efforts are going on to replace FM with plant protein sources, taking advantage of the fact that carp utilize the latter efficiently. Takeuchi *et al.* (1990) reported that the availability of carbohydrate ingredients – potato starch, maize starch, maize, rye, wheat flour – was improved by the extrusion treatment, which elevated the gelatinization level as well as the energy value. Jeong *et al.* (1992) investigated the effect of the dietary gelatinized carbohydrate ratio and digestible energy content on carp fingerlings fed a diet

Table 18.6. The apparent digestibilities of protein and energy from various diet ingredients in carp at different temperatures (from Takeuchi, 1991).

	Proximate composition			Apparent digestibility (%)					
				Protein			Energy		
Ingredients	Moisture (%)	Protein (%)	Gross energy (MJ kg^{-1})	15°C	20°C	25°C	15°C	20°C	25°C
White fish-meal	8.8	65.8	0.17	94	90	92	86	89	88
Local fish-meal	10.8	63.5	0.18	90	90	93	87	87	86
Meat meal	11.8	69.0	0.22	91	91	95	76	79	82
Silkworm pupa meal	7.8	52.6	0.24	87	86	88	80	79	82
Maize-gluten meal	8.8	64.3	0.22	82	88	93	73	80	85
Defatted soybean meal	10.7	45.3	0.17	94	96	95	76	79	80
Defatted wheat-germ meal	10.6	31.3	0.17	92	93	94	70	74	77
Defatted rice bran	11.3	18.8	0.16	60	85	88	48	71	76
Wheat flour	13.1	15.8	0.16	78	79	80	49	73	79

containing raw and extruded potato starch. Growth performances were best when the gelatinization level was 40% in the low-energy diet (19.7 MJ kg^{-1}) and 20% in the high-energy diet (20.9 MJ kg^{-1}).

Soybean-protein concentrate (SPC), a promising diet ingredient for common carp, had superior apparent digestibility coefficients (ADC) for protein and lipid at 18°C compared with herring meal (HM), indicating the suitability of the plant ingredient for common carp (Kim *et al.*, 1998). However, the ADC of energy was not found to be different between SPC and HM. In another study evaluating the suitability of oilcakes, such as those made from sesame, mustard, linseed, groundnut and copra, incorporated at levels ranging from 25% to 75% of total protein, it was found that the APD were broadly similar, ranging from 78% to 90% (Hasan *et al.*, 1997).

Malt-protein flour (MPF), a brewery by-product, has been tested as yet another alternative protein source. MPF could substitute 40% or 60% of white FM (WFM) in fingerling carp diets, the latter level being possible when crystalline EAA are present, without any adverse effects on weight gain, feed efficiency or protein retention (Yamamoto *et al.*, 1996). Further, it was also demonstrated that a combination of MPF and soybean meal (SBM), at a replacement level of 60%, produced a significantly higher weight gain than did the WFM diet. Therefore MPF is a good choice as an alternative ingredient.

In formulating fish diets using multiple protein sources, information on protein digestibility as well as individual amino acid availability is essential. Though extrusion processing of a diet or ingredient improves the energy availability by gelatinization of the carbohydrate, it also generates high temperatures and pressures, which can cause losses of amino acids by oxidation and ultimately decrease the availability of some of them, such as lysine, through the Maillard reaction. Therefore, the influence of extrusion processing on the amino acid availability (AAA) from protein sources requires careful examination, as illustrated by the following study on common carp by Yamamoto *et al.* (1998). They compared the APD of several protein sources: WFM, SBM, extruded SBM (ExSBM), MPF, ExMPF and corn (maize)-gluten meal (CGM), and found that it was about 1.9% lower than true protein digestibility (TPD). Extrusion processing generally increased the apparent AAA of the ingredients. The differences between true and apparent AAA were as small as those observed between TPD and APD; however, relatively large differences were noted for several amino acids, such as lysine in CGM and threonine in ExMPF. These results demonstrated that WFM, SBM, ExSBM and MPF are good protein ingredients for carp diets, the exception being CGM. In the search for further alternative sources, it should be borne in mind that, although the individual AAA of a protein source approximates the protein digestibility value, the differences between true and apparent AAA are large for several amino acids. Thus, it is deemed essential to determine individual true AAA, which will allow a more precise assessment of the nutritional quality of diet ingredients and the formulation of practical and economic carp diets.

Tuna oil was evaluated as a lipid source in carp diets (Appleford and Anderson, 1997). There was a significant reduction in the ADC with the increase in inclusion level (from 83% to 59% for oil levels of 10% and 15%, respectively); however, an improvement in digestibility was recorded upon prolonged adaptation at the higher level. Comparing beef tallow and various hydrogenated fish-oils with differing melting-points, Takeuchi *et al.* (1979c) pointed out that the digestibility of fish-oil with a high melting-point (53°C) was very low, especially in carp weighing less than 10 g. When the melting-point of the hydrogenated fish oil was lower (38°C) it was effectively utilized, the digestibility being more than 70%, regardless of fish size and water temperature. Therefore, lipid ingredients of inferior quality might serve as a dietary energy source without any adverse effects, but only if additional lipids provide the necessary level of EFA for the fish.

Alternatives to fish-meal

Among all the tested alternatives, SBM has been the most widely used. A long-term study combining both laboratory- and field-based situations proved the efficacy of a hypoproteic soybean-based diet (Noble *et al.*, 1998).

A complete replacement of brown FM (BFM) with a combination of SBM, CGM and meat meal (MM) enriched with synthetic amino acids, such as lysine, methionine and threonine, to match the BFM diet could not produce comparable growth and diet utilization, although palatability was as good as the FM diet (Pongmaneerat *et al.*, 1993). Pongmaneerat *et al.* (1993) recommended a 56% replacement of BFM in the diet for carp by a combination of 25% SBM and 10% CGM at a 38% dietary protein level. This contrasts with a replacement level of about 90% at 44% dietary protein level achieved for rainbow trout (Fig. 18.3; Pongmaneerat, 1993). Although it is generally accepted that carp can utilize plant proteins more efficiently than can rainbow trout, the inferior levels attained in carp could be ascribed to the comparatively lower utilization of supplemental crystalline amino acids. It also remains to be tested if taurine was a limiting amino acid, as suggested earlier.

Experiments on replacing dietary FM also proved that environmental phosphorus loading could be lowered proportional to the FM levels. Based on total phosphorus and nitrogen loading, Jahan *et al.* (2000) suggested that a suitable level of FM in carp diet was 20–25% in combination with blood meal and defatted SBM. In another study, Kim *et al.* (1997) reported that dietary inclusion of fish-protein concentrate was also effective in decreasing phosphorus excretion.

Studies with carp fry indicated that 25% inclusion of linseed or groundnut oilcakes produced growth comparable to diets prepared with FM as the sole

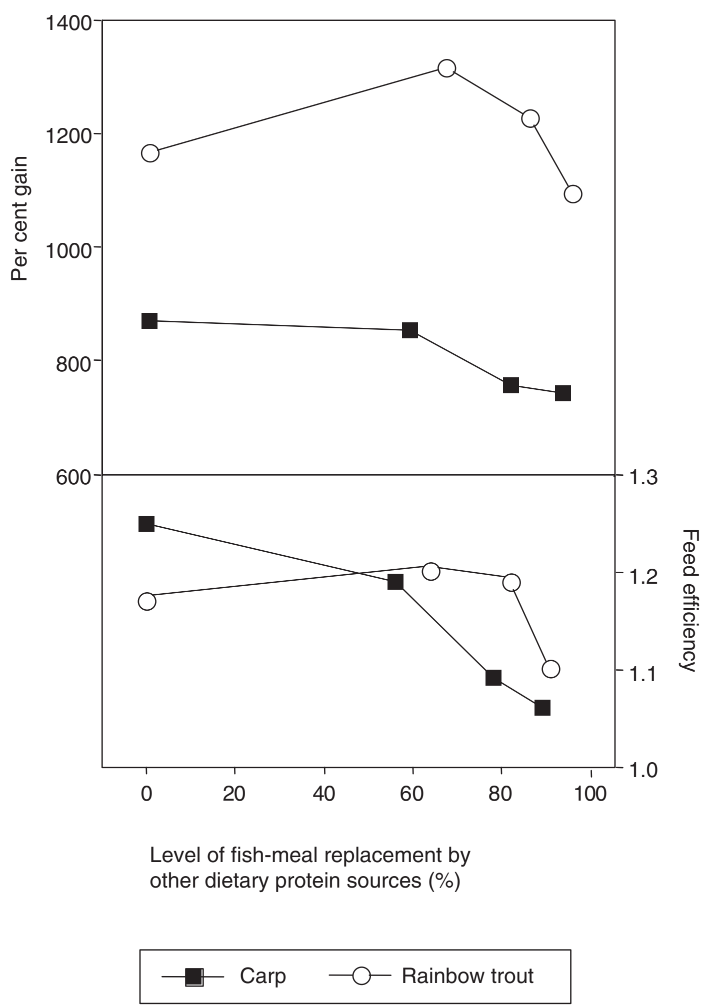

Fig. 18.3. Comparison of fish-meal replacement in dietary protein sources in relation to per cent gain and feed efficiency between carp and rainbow trout.

protein source, indicating the suitability of the two plant ingredients (Hasan *et al.*, 1997). Incorporation of SPC up to 40% did not adversely affect survival and growth of larvae; however, dietary levels of 60 or 70% resulted in growth retardation, which was not overcome by supplementation of sulphur amino acids (Escaffre *et al.*, 1997).

Feeding Practices

Intensification of carp culture should consider the impact of the use of proper feeding rates, not only in achieving optimum growth, but also in controlling aquatic wastes. Under semi-intensive culture, determination of variations in nutrient input and turnover from natural productivity using standard procedures is required. For intensive operations, appropriate formulations and feeding practices should be adopted, considering the potential digestive- and metabolic-waste discharge. In an elaborate study in Kasumigaura Lake, Japan, feeding rates have been established for commercial and regulated diets (Tables 18.7 and 18.8). The Kasumigaura diet is a low-protein, high-energy diet and as a result the feeding rates were higher for the smaller size ranges. Further, the rates were strongly dependent on the water temperature and fish size, highlighting the importance of determining the ration size for each and every culture operation. The preferred optimal temperatures for growth lie between 30 and 32°C, but retardation of growth occurs with a drop in temperature until around 10°C, when aphagia ensues. However, growth hormone treatment was found to stimulate appetite and growth during winter temperatures, making it possible to

Table 18.7. The temperature- and fish-size-based changes in daily feeding rate of carp fed on official standard-based commercial diets (from Miyatake, 1997).

Water temperature (°C)	Body weight (g)											
	2–5	5–10	10–20	20–30	30–40	40–50	50–100	100–200	200–400	400–600	600–800	800–1000
15	4.5	3.7	3.2	2.8	2.5	2.3	2.0	1.7	1.5	1.3	1.1	0.9
16	4.8	4.0	3.4	3.0	2.7	2.4	2.1	1.8	1.6	1.4	1.1	0.9
17	5.2	4.3	3.7	3.2	2.9	2.6	2.2	1.9	1.7	1.5	1.2	1.0
18	5.6	4.7	4.0	3.4	3.1	2.8	2.3	2.0	1.8	1.6	1.3	1.0
19	6.0	5.1	4.3	3.7	3.4	3.0	2.5	2.2	1.9	1.7	1.3	1.1
20	6.5	5.5	4.6	4.0	3.7	3.2	2.7	2.4	2.2	1.8	1.4	1.2
21	7.0	6.0	4.9	4.3	4.0	3.4	2.9	2.6	2.1	1.9	1.5	1.3
22	7.6	6.5	5.3	4.6	4.3	3.7	3.1	2.8	2.3	2.0	1.6	1.4
23	8.2	7.0	5.7	4.9	4.6	4.0	3.4	3.0	2.5	2.1	1.7	1.5
24	8.8	7.5	6.1	5.3	4.9	4.3	3.7	3.2	2.7	2.3	1.8	1.6
25	9.5	8.0	6.5	5.7	5.2	4.6	4.0	3.4	2.9	2.5	2.0	1.7
26	10.2	8.5	6.9	6.1	5.5	4.9	4.3	3.7	3.1	2.7	2.2	1.8
27	10.9	9.0	7.4	6.5	5.8	5.2	4.6	4.0	3.3	2.9	2.4	1.9
28	11.6	9.5	7.9	6.9	6.2	5.6	4.9	4.3	3.6	3.1	2.6	2.0
29	12.3	10.1	8.4	7.4	6.6	6.0	5.2	4.6	3.9	3.3	2.8	2.1
30	13.1	10.7	8.9	7.9	7.0	6.4	5.7	4.9	4.2	3.5	3.0	2.2

Table 18.8. The temperature and fish size based changes in daily feeding rate of carp fed on a low protein, high energy Kasumigaura regulated carp diet (from Miyatake, 1997).

Water temperature (°C)	Body weight (g)								
	1–5	5–10	10–50	50–100	100–200	200–400	400–600	600–800	800–1000
15	4.65	3.42	2.16	1.59	1.26	0.95	0.84	0.76	0.69
16	5.15	3.80	2.39	1.76	1.40	1.05	0.94	0.84	0.77
17	5.17	4.21	2.65	1.95	1.55	1.17	1.04	0.93	0.85
18	6.33	4.66	2.94	2.17	1.72	1.30	1.15	1.03	0.95
19	7.02	5.17	3.26	2.40	1.90	1.44	1.28	1.14	1.05
20	7.78	5.73	3.61	2.66	2.11	1.59	1.41	1.26	1.16
21	8.62	6.35	4.00	2.95	2.34	1.76	1.57	1.40	1.29
22	9.65	7.04	4.44	3.27	2.59	1.96	1.74	1.55	1.43
23	10.60	7.81	4.92	3.62	2.88	2.17	1.93	1.72	1.58
24	11.75	8.65	5.45	4.02	3.19	2.40	2.13	1.91	1.75
25 and over	13.02	9.60	6.04	4.45	3.53	2.66	2.37	2.11	1.94

culture the fish even under unfavourable climatic conditions (Teskeredžic *et al.*, 1995).

As carp culture continues to expand, more and more of the culture operations will become intensive, necessitating the development of advanced diet formulations, which could also address related issues of environmental concern.

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