The nutrition of stomachless phytoplanktivorous fish in comparison with Tilapia

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Abstract

The contents of alimentary tracts of stomachless phytoplanktivorous fish, including silvercarp (*Hypophthalmichthys molitrix*), *Esomus danrica thermoicos*, and *Amblypharyngodon meletinus* were investigated microscopically and compared with those of Tilapia (*Oreochromis mossambicus*, a fish with stomach).

The predominance of detritus in the food and the low efficiency with which phytoplankton is utilized prove, that stomachless fish are not primarily herbivorous. The possibility of omnivorous feeding as an alternative is discussed. These results may contribute to our understanding of the role of filterfeeders in aquaculture and ecosystems.

Introduction

Herbivorous fish like silvercarp and Tilapia are used in intensive fish culture. They also play an important role in the controversy over phytoplankton control as related to eutrophication of surface waters (Opuszynski, 1979; Herodek *et al.*, unpubl.). It has been assumed that algae are the major food of these fish. However, stomachless fish may not be able to lyse or break the cellwall of phytoplankton sufficiently (Moriarty *et al.*, 1973).

Thus the true significance of algae in the nutrition of these fish is questionable (for reviews see: Opuszynski, 1979; Barthelmes & Jähnichen, 1978). Therefore three stomachless fish, silvercarp (*Hypophthalmichthys molitrix*), *Esomus danrica thermoicos* and *Amblypharyngodon meletinus* were investigated and compared with Tilapia (*Oreochromis mossambicus*, with stomach) to illuminate the problem of energy supply of these so-called herbivorous fish.

Material and methods

Silvercarp were collected in September from an intensive fish culture in Szarvas, Hungary. Tilapia, *Esomus* and *Amblypharyngodon* were caught during the summer months in Parakrama Samudra by R. Hofer (Schiemer, 1983). Only *Amblypharyngodon* is common in the offshore area. Tilapia and *Esomus* are supposed to feed near the bottom (Schiemer & Hofer, 1983).

Subsamples from the fore-gut and hind-gut from three fish were pooled and stored in 4% formalin, diluted with water and pipetted into a sedimentation chamber for identification by light microscopy and counting. The general pattern was confirmed by a semiquantitative examination of eight additional specimens. Only cells with intact cellwall and protoplast were counted. *Scenedesmus* appeared microscopically identical in the fore-gut and hind-gut of all four species. This result was expected due to the cellulose cellwall of *Scenedesmus* (Bisalputra & Weier, 1983; Becker *et al.*, 1976) and results of experiments showing that *Scenedesmus* is not digested by silvercarp (Prowse, 1964, 1965; Barthelmes,

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1977; Spataru, 1977; Spittler, 1979). *Scenedesmus* therefore, was used as a stable marker in the food.

In addition, the motility of mobile plankton species in the gut of silvercarp was examined under the microscope immediately after dissection. Digestibility of the different algae species was calculated after Windell's equation (1978).

$$\text{Digestibility} = 100 - \frac{\% \text{ Marker (Scenedesmus) in the food}}{\% \text{ Marker (Scenedesmus) in the faeces}} \times$$
$$\frac{\% \text{ Nutrient (Algae) in the faeces}}{\% \text{ Nutrient (Algae) in the food}} \times 100$$

$$(1)$$

The relative importance of phytoplankton species in food consumption was estimated by multiplying the relative numerical abundance of each species in the fore-gut with the volume of the algae, estimated after Rott (1981, 1983). The relative consumption of a group of algae was then expressed as a percentage of the total mass of ingested algae. Species occurring in very low numbers were not taken into account.

The relative consumption yields, in combination with the digestibility of the algae species, the relative energetic benefit obtained from a particular type of food:

$$\text{Benefit (\%)} = \frac{\text{Consumption (\%)} \times \text{Digestibility (\%)}}{100} \quad (2)$$

Results

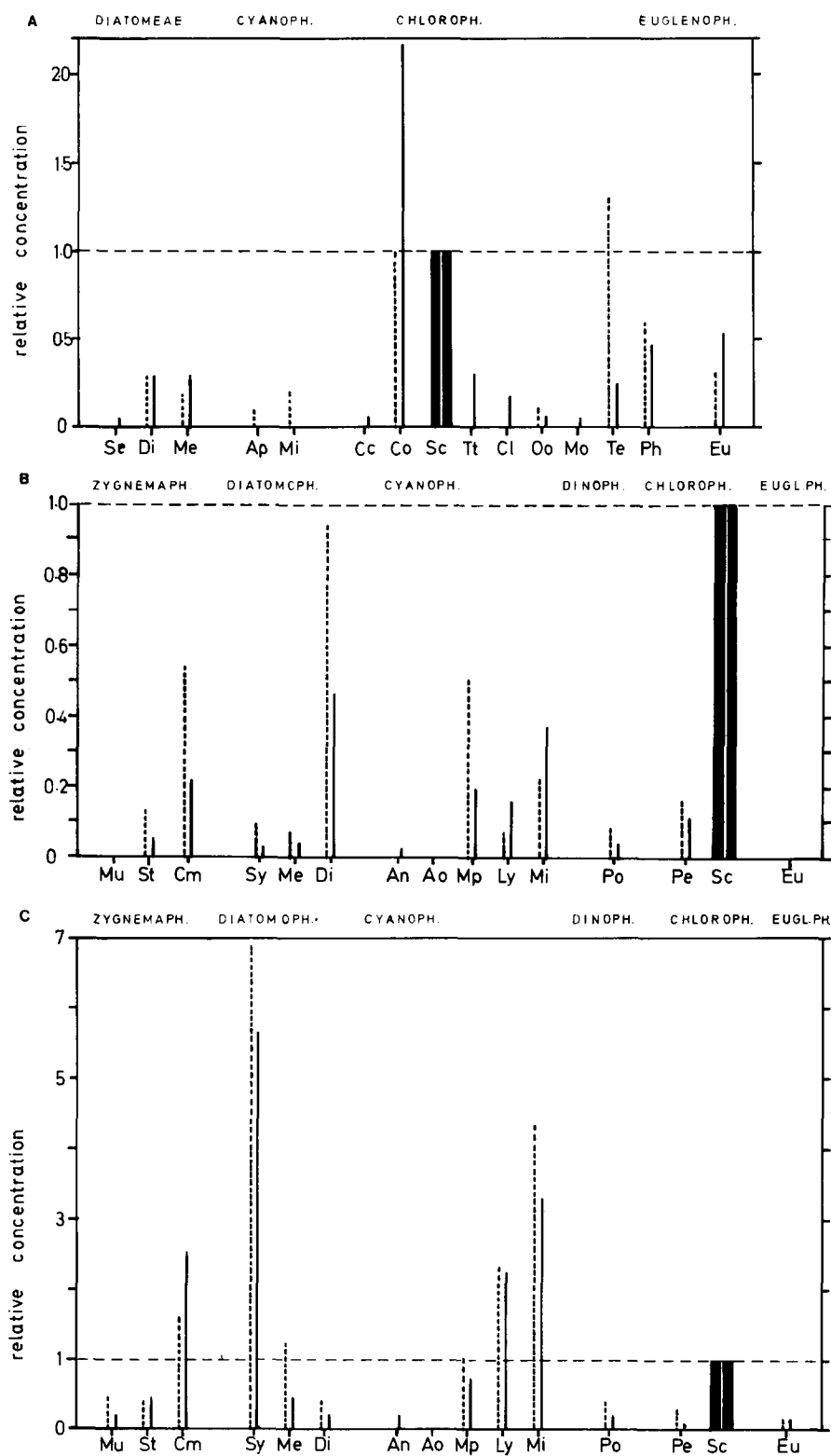Detritus comprised the predominant component in the gut contents of silvercarp and was also ingested in large amounts by the fish from Parakrama Samudra. 15 species of algae were identified, of which only a few were abundant in the alimentary tracts. Most of the algae could not be utilized by stomachless fish (Fig. 1), whereas fish with stomach (Tilapia) efficiently digested phytoplankton (Fig. 2). *Synedra, Microcystis, Cosmarium* and *Lyngbya* predominated in the gut of *Amblypharyngodon* but were little digested. *Esomus* ingested primarily algae in a detrital state. *Diatomophyceae* and *Cosmarium* were utilized to some extent (Fig. 1B; 1C).

However, a general comparison of stomachless fish (*Esomus* and *Amblypharyngodon*) and Tilapia shows a clear distinction between the two physiological groups (Fig. 3). *Diatomophyceae* are the most predominant group of algae in the fore-gut of the three fish species but, due to a less efficient digestibility by stomachless fish, the nutritional benefit from these algae is much higher for Tilapia. Although *Cyanophyceae* are well digested by Tilapia, the benefit from these algae is low, due to a relatively low consumption (Fig. 3).

The low abundance of algae in the gut of silvercarp and the heterogenous distribution of phytoplankton in the shallow silvercarp ponds (unpubl.) render the interpretation of species specific digestibility in this fish difficult (Fig. 1A). However, most of the algae that were found in the fore-gut appeared intact in the hind-gut.

This indication of a very low digestibility of algae is corroborated by observations on fresh gut contents of silvercarp. For example, *Euglena* was even more mobile in the hind-gut than in the fore-gut.

Fig. 1. Number of algae relative to *Scenedesmus* in the Fore-gut (dotted lines = Algae in Fore-gut/*Scenedesmus* in Fore-gut) and Hind-gut (full lines = Algae in Hind-gut/*Scenedesmus* in Hind-gut) of stomachless fish. Aggregates were counted as single numbers. A. Sivercarp (*Hypophthalmichthys molitrix*). Total count of *Scenedesmus* colonies was 10 in fore-gut and 17 in hind-gut. Se = *Stephanodiscus*, Di = *Diatomophyceae* (without *Stephanodiscus* and *Melosira*), Me = *Melosira*, Ap = *Aphanizomenon*, Mi = *Microcystis*, Co= *Chlorococcale*, co = *Coccales* (single cells), Sc = *Scenedesmus*, Tt = *Tetrastrum*, Cl = *Coelastrum*, Oo = *Oocystis*, Mo = *Monoraphidium*, Te= *Tetraedron*, Ph = *Phacotus*, Eu = Euglenophyceae.
B. *Esomus danrica thermoicos*. Total count of *Scenedesmus* colonies was 78 in fore-gut and 85 in hind-gut. Mu = *Mougetia*, St=*Staurastrum*, Cm = *Cosmarium*, Sy = *Synedra*, Me = *Melosira*, Di = *Diatomophyceae* (without *Synedra* and *Melosira*), An=*Anabaena*, Ao= *Anabaenopsis*, Mp= *Merismopedia*, Ly= *Lyngbya*, Mi= *Microcystis*, Po= *Peridinopsis*, Pe= *Pediastrum*, Sc= *Scenedesmus*, Eu = Euglenophyceae.
C. *Amblypharyngodon meletinus*. Total count of *Scenedesmus* colonies was 18 in fore-gut and 19 in hind-gut. For abbreviations of algae see legend to Fig. 1B.
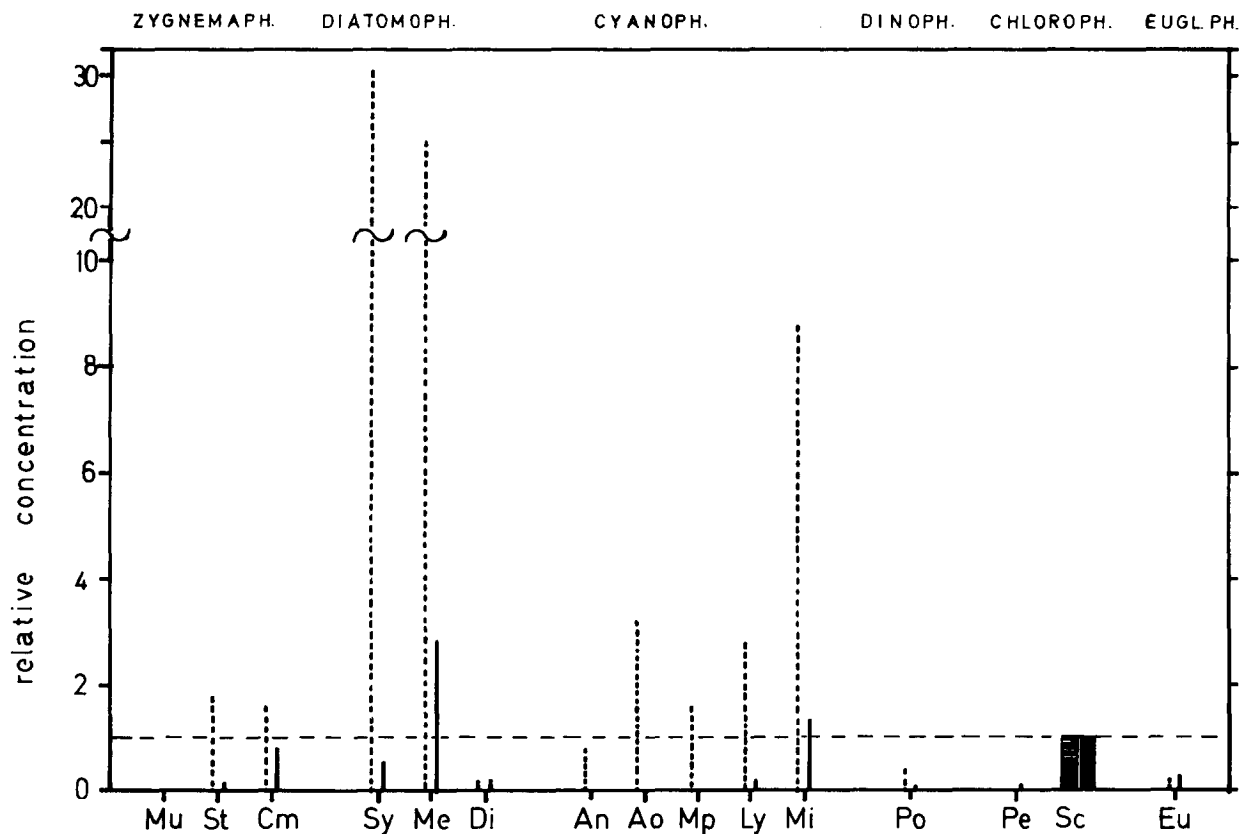
ZYGNEMAPH.   DIATOMOPH.   CYANOPH.   DINOPH.   CHLOROPH.   EUGL.PH.

Mu   St   Cm   Sy   Me   Di   An   Ao   Mp   Ly   Mi   Po   Pe   Sc   Eu

Fig. 2. Number of algae relative to *Scenedesmus* in the fore-gut (dotted lines = Algae in fore-gut/*Scenedesmus* in fore-gut) and hind-gut (full lines = Algae in hind-gut/*Scenedesmus* in hind-gut) of fish with stomach, Tilapia (*Oreochromis mossambicus*). Total count of *Scenedesmus* colonies was 5 in fore-gut and 28 in hind-gut. For abbreviations of algae see Legend to Fig. 1B.

Discussion

The primary interest in this investigation was an examination of the digestibility of algae, supposed to be the major food of the so-called phytoplankti-vorous fish.

Fish with stomach. Tilapia is an important herbivorous and detritivorous species in tropical and subtropical impoundments (Lowe-McConnel, 1975). It is able to assimilate algae because it has a stomach with gastric glands. Tilapia assimilates up to 70–80% of ingested carbon from *Microcystis, Anabaena* and *Nitzschia* and 50% from *Chlorella* (Moriarty & Moriarty, 1973). Microscopic investigation of the alimentary tracts fully confirmed this contention (Fig. 2). Contradictory results (Dokulil, 1983) might be explicable by periods of low assimi-

lation efficiency due to varying exposure of the ingested algae to low pH in the stomach (Moriarty *et al.*, 1973).

Fish without stomach. My results proved that stomachless fish cannot utilize the major part of ingested algae which therefore cannot meet the energy requirements of these fish. Many studies deal with the nutrition of silvercarp (for reviews see: Barthelmes & Jähnichen, 1978; Opuszynski, 1979).

Microscopic investigation of my material showed that, in contrast to Nie & Chiang (1954), Panov *et al.* (1969) and Kajak *et al.* (1977), Diatomophyceae were apparently not destroyed during gut passage. Panov *et al.* (1969) claim that *Anabaena* and *Apha-nizomenon* are more efficiently digested than the green algae *Scenedesmus, Ankistrodesmus* and *Chlorella*. This may be due to the more resistant
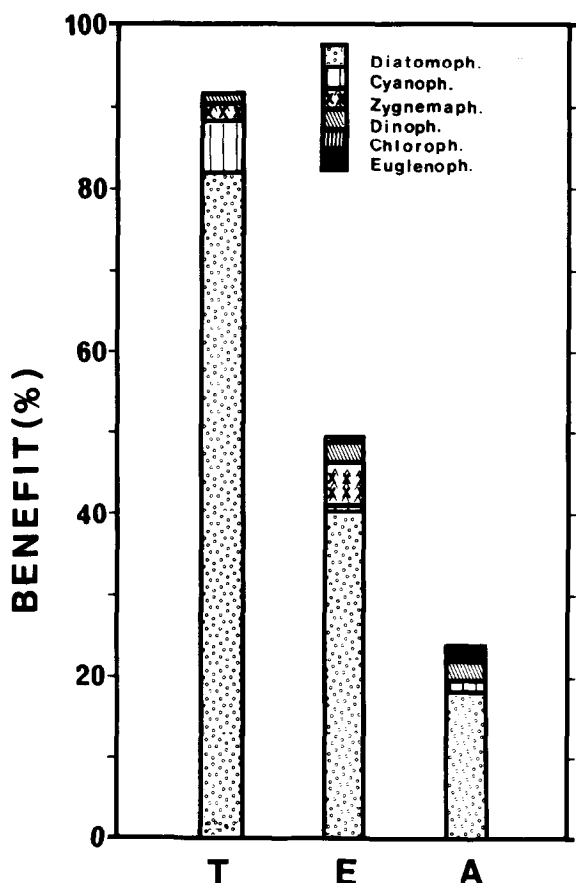
Fig. 3. Nutritional benefit (%) from ingested phytoplankton. Tilapia a fish with stomach is compared with *Esomus* and *Amblypharyngodon*, two fish without stomach.

$$\text{Benefit } (\%) = \frac{\text{Consumption } (\%) \times \text{Digestibility } (\%)}{100}$$

Negative values were counted as zero. T = Tilapia, E = *Esomus*, A = *Amblypharyngodon*.

structure of the cellwall of green algae.

On the other hand, Savina (1968), Sirenko *et al.* (1973), Kajak *et al.* (1977) and Prowse (1964, 1965) found low or even no digestion of blue-greens. Minz *et al.* (1976) postulate that silvercarp grow well on *Protococcales* (= *Chlorococcales*). In accord with my results, however, Prowse (1964, 1965), Barthelmes (1977), Spataru (1977) and Spittler (1979) state that green algae and *Euglena* are hardly utilized by herbivorous fish.

Contradictory data in the literature and in the present investigation (Fig. 1A) may be due to a changing algae pattern in the pond (unpubl.) during the passage time, which is above 10 hours in silvercarp (unpubl.), and to a low abundance of algae in the intestine of these fish (Fig. 1A, 1B). Other results (Fig. 1B) can probably by explained by the different physiological conditions of the filtered algae. Sedimented algae in the benthos are exposed to higher mechanical stress and hence their cellwall might be broken more easily by the fish. Other authors reach the same conclusion that dead algae in a 'detrital-state' are better assimilated than living algae, and allow good growth of the fish (Barthelmes & Jähnichen, 1978; Opuszynski, 1979). The detritus component in the gut of silvercarp was highly predominant in the present study which was also indicated by the biochemical composition of the gut contents (Gnaiger & Bitterlich, 1984), but values between 0% (Lupaceva, 1969) and 99.9% (Kopylova after Borucky, 1973) have been reported. Therefore, a controversy over the digestibility of different algae species is of minor practical importance in most situations.

Aquatic detritus consists of a mixture of plant debris and amorphous organic matter associated with heterotrophic and autotrophic microorganisms (Mann, 1972). Although many species ingest large amounts of detritus, its nutritional value for stomachless fish has been questioned (Bowen, 1976). While Lin *et al.* (1981) deny any caloric gain from detritus by silvercarp, Spittler (1979) considers detritus at least as a supplementary nutrient. In contrast, Mann (1972) remarks, that 'detritus comprises the largest source of energy for the dense population of cyprinid fishes in the Thames River'. Opuszynski (1979) adds, that the nutritional value depends on the quality of detritus. Recent results by Bowen (1984, in press) confirm this conclusion. In agreement with Mann (1972), he distinguishes two types of organic detritus: morphous particles that show remnants of previous cellular structures, and smaller, amorphous particles. According to Bowen 'amorphous detritus contains considerably less refractory organic matter, is more digestible when treated with simple digestive enzymes, and supports much better growth of a test detritivore'.

To what extent zooplankton is important in the food of stomachless herbivorous fish remains unclear. Selectivity may depend on zooplankton density (Opuszynski, 1979) and on the capability of zooplankton to avoid predation (Woltereck, 1908). Actually, selection and digestion of zooplankton by

silvercarp is indicated by Opuszynski (1979) and Barthelmes & Jähnichen (1978). Freshly examined samples of fore-gut and hind-gut of silvercarp, as well as formalin fixed subsamples of alimentary tracts of the fish from Parakrama Samudra, did not contain intact zooplankton. However, incubation of gut contents of silvercarp with fresh plankton from the pond showed that zooplankton is digested immediately and hence cannot be found in the alimentary tracts (Bitterlich & Gnaiger, 1984). Therefore, *Amblypharyngodon* may well contribute to the exceptionally high elimination of rotifers observed in Parakrama Samudra (Duncan, 1983).

Acknowledgements

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