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Food utilization in the fish *Tilapia mossambica* fed on plant and animal foods

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KURZFASSUNG: **Die Nahrungsausnutzung des Fisches *Tilapia mossambica* bei pflanzlicher und tierischer Kost.** Die Nahrungsausnutzung des herbivoren Fisches *Tilapia mossambica* wurde bei unterschiedlichem Futterangebot untersucht. Als Nahrung dienten die Grünalge *Spirogyra maxima*, Ziegenleber und lebende Kaulquappen. Mit Algennahrung allein konnten Jungfische ihren Energiebedarf nicht decken. Wurde darüber hinaus Ziegenleber verfüttert, so erhöhte sich sowohl die aufgenommene Nahrungsmenge als auch die Nahrungsausnutzung. Maximale Konversionsraten wurden bei ausschließlich tierischer Kost erzielt.

INTRODUCTION

Only a few publications are available concerning food utilization in herbivorous fishes (see PANDIAN, 1975). MENZEL (1959) found that angelfish *Holacanthus bermudensis*, fed on epizoan-free filamentous algae, failed to deposit protein; he concluded that, though the utilized algae were sufficient to meet the metabolic energy requirements, the animal matter ingested intentionally or accidentally by the angelfish was essential to insure "true growth" (GERKING, 1952). However, the bluegill sunfish *Lepomis macrochirus*, fed on different combinations of the alga *Chara* sp. and animals, failed to yield evidence for more efficient utilization of *Chara*, and the bluegill fed ad libitum on *Chara* provided further evidence that the fish neither will nor can consume enough algae to meet its metabolic energy demands (KITCHELL & WINDELL, 1970). The grasscarp *Ctenopharyngodon idella* showed absorption efficiencies of 20 or 40 %, when fed exclusively on the plant *Lactuca sativa* or *Tubifex* spp. (FISCHER, 1972); these values are far lower than those usually reported for herbivorous (e. g. *H. bermudensis:* 72 %; MENZEL, 1959) or carnivorous fishes (e. g. *Ophiocephalus striatus:* 83 %; PANDIAN & VIVEKANANDAN, 1975). When offered different combinations of these food organisms, *C. idella* fed a diminishing quantity of tubificids in the absence of *L. sativa*, and in the combinations providing less than 24 % *L. sativa* (FISCHER, 1973). Thus, even the limited available information on food utilization in the herbivorous fishes is contradictory, and calls for more comprehensive work.

MATERIAL AND METHODS

Fingerlings of the herbivorous fish *Tilapia mossambica* (1.5 ± 0.25 g) belonging to the same parents were acclimated in individual glass aquaria (1 l capacity) to the respective food combinations for 10 days at 28° ± 1° C. *Spirogyra maxima*, a natural food of *T. mossambica* (CHACKO & KRISHNAMURTHI, 1954), was chosen as plant food; the goat-liver and frog's tadpole (mobile prey; size: 25 mg) served as animal foods. The algal filaments were washed carefully to remove associated animal matter. The individuals, which received different combinations of plant and animal foods (Table 1) were fed for 8 h/day, for a period of 15 to 20 days. Care was taken to collect unfed animal food remains with a pipette. Unfed plant remains were collected by filtering the entire aquarium with a fine sieve (160 μm) every day after 8 h algal supply. Suitable corrections were made for the fluids lost from the liver pieces and the amount of plant material photosynthesised during the 8 h feeding period. The test individuals were observed frequently to remove the faecal segments intact with a pipette causing least disturbance. "Sacrifice method" (MAYNARD & LOOSLI, 1962) was used for determining the water content of the test individuals. Absorption efficiency was estimated for each fish relating the quantity of total food absorbed (food consumed-faeces) to the quantity of total food consumed. Conversion efficiency (K_2) was estimated relating the growth of the fish to the quantity of total food absorbed (PANDIAN, 1967a).

RESULTS AND DISCUSSION

In the first series of experiments, different rations of *Spirogyra maxima* ranging from 4 to 40 mg dry food/g, live fish/day were offered to *Tilapia mossambica;* the maximum amount of *Spirogyra* that the fish could consume in the given situation was 29.3 mg-g-day (Table 1). Absorption efficiency increased with increasing rations of *S. maxima* from about 50 % to 78 %; this may indicate that increasing the volume of ingested *S. maxima* stimulated increase in the rates of enzyme secretion and/or activity (see PANDIAN, 1975). as well as enhancing peristalsis (PANDIAN, 1967a), which augmented digestion rate. All groups fed on *S. maxima* lost different amounts of body substance ranging from 0.7 to 3.0 mg dry body substance/g live fish/day; the group fed ad libitum (40 mg/g/day) lost the minimum of 0.7 mg/g/day. The present observation supports the conclusions of MENZEL (1959) and KITCHELL & WINDELL (1970) that to insure "true growth" in herbivorous fishes, animal matter is essential, and that a herbivorous fish neither will nor can consume and utilize sufficient amounts of algae to meet its metabolic energy demands. Different combinations of *S. maxima* with goat-liver in proportions ranging from 42 to 86 % resulted in increased consumption (up to 38 mg/g/day), absorption efficiency (94 %), and these, in turn, insured "true growth" rate of up to 9 mg/g/day. This supports the previous observation of KITCHELL & WINDELL (1970) that supplementing algae with animal matter increases feeding rate. The response of *Ctenopharyngodon idella* consuming a diminished quantity of tubificids in the absence of plant food (FISCHER, 1973) differs from the responses of *Tilapia mossambica* and *Lepomis macrochirus,* which increased feeding rate with the increasing proportion of supplemented animal matter.

Supplementation of animal matter to *Spirogyra maxima* appears to produce a better "digestive climate", which resulted in decreasing the nondigestible, non-absorbable fraction of *S. maxima* in *Tilapia mossambica.* For instance, in the combination, which was supplemented by 42 % liver, the amounts of *S. maxima* and liver consumed were 10.0 ± 1.16 and 15.2 ± 1.25 mg/g/day, respectively, and the amount of total faeces defecated was 2.2 mg/g/day; among the series feeding exclusively on *S. maxima,* the group receiving 14 mg/g/day absorbed the food with 62 % efficiency, i. e. as much as 5.4 mg of *S. maxima* was not digestible and absorbable, and hence defecated as faeces. Assuming all the 2.2 mg of faeces defecated by the group receiving 58 % *S. maxima* + 42 % liver was contributed by the non-digestible, non-absorbable fraction of *S. maxima* alone, this is less than half of what (5.4 mg) was defecated as faeces by the group feeding 14 mg *S. maxima* g/day. Furthermore, the argument that the high absorption efficiency exhibited by the series receiving liver supplemented diet was partly or solely due to the fact that they consumed a larger volume of food, which augmented digestion rate, may not be applicable here. For the group which received only *S. maxima* and fed 29 mg/g/day, and the group feeding 28 mg food supplemented with 68 % liver-g-day displayed a statistically highly significant difference in its efficiency to absorb food ($t = 10.870$; $P < 0.001$); the former's efficiency was only 78.5 % against the latter's 92 %. The fact that *Lepomis macrochirus* fed on *Chara* supplemented with animal matter failed to yield evidence for more efficient utilization of *Chara* sp. differs from that of *Tilapia mossambica* in which supplementation of *S. maxima* with animal matter resulted in better absorption efficiency.

The observation that the supplementation of animal matter increased the digestible fraction of *Spirogyra maxima* and hence absorption efficiency of *Tilapia mossambica* is interesting and unexpected. In this connection, the local action of secretagogues, i. e. partially digested animal matter, in modifying the "digestive climate" is important. It is not clear how such partially digested liver products could have modified the "digestive climate" favourably towards the reduction of the non-digestible, non-absorbable fraction of *S. maxima* in *T. mossambica.* This is currently being investigated.

The third series, which fed exclusively on an animal diet consisting of liver pieces or live tadpoles of frog exhibited the highest feeding rates (over 41 mg/g/day), as well as the highest rate (over 10 mg/g/day) and efficiency (over 26 %) of food conversion. Both the groups showed about 94 % absorption efficiency, which is comparable to that observed in the tarpon *Megalops cyprinoides* (PANDIAN, 1967b). Energy cost of predation on mobile prey organisms such as frog's tadpole appears to have decreased feeding rate from 47 to 41 mg/g/day and conversion efficiency from 30 to 26 % in *Tilapia mossambica* receiving animal diet.

Table 1

Tilapia mossambica. Rates and efficiencies of feeding, absorption and conversion. Food: different rations and combinations of *Spirogyra maxima* and animal matter for a period of 15 to 20 days. Each value represents the average performance of minimum 3 individuals. Water content: *T. mossambica:* 79.4 %; *S. maxima:* 86.2 %; liver: 74.9 %; Tadpole: 87.8 %

Experiment	Food	Feeding rate *(mg/g/day)	Conversion rate *(mg/g/day)	Absorption efficiency (%)	Conversion efficiency (K_2) (%)
Series I To test effect of rations	Starved	0.0 ± 0.00	— 3.0 ± 0.13	—	—
	S. maxima	3.9 ± 0.20	— 2.6 ± 0.10	49.9 ± 4.81	—
	„	7.5 ± 0.15	— 3.0 ± 1.21	54.8 ± 3.60	—
	„	14.1 ± 0.46	— 1.3 ± 0.10	61.6 ± 0.75	—
	„	22.0 ± 0.20	— 0.9 ± 0.25	69.9 ± 1.72	—
	„ (ad libitum)	29.3 ± 4.04	— 0.7 ± 0.20	78.5 ± 2.49	—
Series II To test effect of supplementing animal food	58 % *S. maxima* + 42 % liver	25.2 ± 2.32	+ 3.6 ± 0.30	91.5 ± 0.48	15.8 ± 0.62
	32 % *S. maxima* + 68 % liver	27.8 ± 2.54	+ 5.1 ± 0.91	92.1 ± 0.10	20.1 ± 1.46
	14 % *S. maxima* + 86 % liver	37.6 ± 3.57	+ 9.1 ± 0.51	93.9 ± 0.39	26.0 ± 1.98
Series III To test effect of animal food	100 % liver	47.0 ± 1.60	+ 13.3 ± 0.71	94.5 ± 0.41	30.0 ± 0.95
	Frog's tadpole	40.6 ± 1.83	+ 9.8 ± 1.84	93.4 ± 0.40	25.9 ± 5.01

* The rates are expressed in mg dry food/g live fish/day

SUMMARY

1. When fed rations ranging from 4 to 29 mg (dry) *Spirogyra maxima*/g live fish/day, absorption efficiency of *Tilapia mossambica* increased from 50 to 78 %; the young *T. mossambica* could not consume and utilize sufficient algae to meet its metabolic energy requirement.
2. On supplementing the algal food with goat liver, the fish consumed not only more food (38 mg/g/day) but also enhanced the absorption efficiency to 94 %.
3. Given only the liver pieces, the fish consumed 47 mg-g-day; it displayed 95 and 30 % of absorption and conversion efficiencies. However, the fish preyed upon and could consume only 41 mg tadpoles/g/day and convert with 26 % (K_2) efficiency.

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