Feeding frequency, daily ration and feed utilisation of an optimal dry diet by early juvenile *Oreochromis mossambicus*

PS Thorpe and T Hecht*
Department of Ichthyology and Fisheries Science, Rhodes University, PO Box 94, Grahamstown 6140, South Africa

Abstract

An optimal dry feed, based principally on the amino acid composition of the yolk sac, was developed over a two-year period for the primary nursing of early juvenile *Oreochromis mossambicus*. The feed consisted of Torula yeast (47%), a high protein concentrate (44,39%), *Spirulina* (5%), a vitamin supplement (0,45%), additional vitamin C supplement (0,16%), and a methionine supplement (3%). Ration size was determined and varied according to age: 30,4% body mass/d for the first 5 d after the start of exogenous feeding, 30,6% body mass/d up to day 10 and 25,1% body mass/d up to day 15. Optimum feeding frequency was found to be every 1 h and 15 min 8 times/10 h day. A feed conversion ratio of 1,24 and a protein efficiency ratio of 0,682 were obtained. The digestibility of the feed was 81,3% with a digestible energy value of 16,1 kJ/g. The established dry feed is suitable for use in commercial hatcheries.

Introduction

Since the late 1940s, tilapias have become increasingly important in fish culture, especially in warm climates throughout the world (FAO 1980, Hepher and Pruginin, 1982). Although they are endemic to Africa, their distribution has been widened by artificial introductions (mainly since the 1950s) to include much of the tropics and subtropics (Pullin and Lowe-McConnel, 1982). The rapid development of tilapia farming in the world has brought about a great demand for fry of good quality and quantity (Guererro and Guererro, 1985). Thus it is crucial to investigate methods to meet this demand.

Much work has been done on the feeding biology and nutritional requirements of *Oreochromis mossambicus* (Balarin, 1979; Bowen, 1981; Jauncey and Ross, 1982; Macintosh and De Silva 1984; Santiago et al., 1985). Despite these efforts, however, no attempt has been made to formulate a specific diet for early juvenile *O. mossambicus* (Appelbaum, 1984). Since the transition to exogenous feeding is the most critical period in the life history of a fish (Balon, 1975; Rana, 1986), and because the physiological development of the early juveniles depends largely on the quality of the initial available food, it is essential to develop feeds which adequately satisfy their nutritional requirements (Bowen, 1981; Appelbaum, 1984). Tilapine species will readily feed on particulate matter because of their detritivorous habits (Rana, 1985). Theoretically, therefore, under hatchery conditions, early juveniles can be directly weaned onto dry diets.

Intensive early juvenile rearing of non-salmonids presently still relies to a large extent on the culture of live food organisms (Horvarth, 1979; Bryant and Matty, 1980; Dabrowski and Poczyczynski, 1988; Tucker, 1988). The difficulty involved in the formulation of artificial diets for early juveniles containing all the required nutrients, lies in the fact that their enzyme systems are generally underdeveloped (Horvarth, 1979; Uys and Hecht, 1987). Nevertheless there is a need for balanced artificial feeds as they very often have definite advantages over live food organisms (Girin, 1979; Nose, 1979; Uys and Hecht, 1985).

Based on the available information on the natural feeding ecology of *O. mossambicus*, and an amino acid analysis of yolk sac fry, and multiplicative feed-testing trials, Thorpe and Hecht (in press) formulated an optimal artificial feed for the early juveniles of this species. The aims of the trials described in this paper were to establish the optimal feeding frequency, the daily ration and the utilisation of the formulated feed by early juvenile *O. mossambicus*.

Material and methods

The experimental facility consisted of a recirculating system with biological filtration. The system incorporated 6 serial biological filters (total filter volume = 8,64 x 10^3 *ℓ*). The filters were constantly aerated. The system also included primary and secondary clarifiers to prevent solid waste from entering the biological filters of the system. Water quality was monitored and maintained well below critical thresholds. Temperature was constant at 25°C. For all the trials the feed was freeze-dried. The composition of the feed is shown in Tables 1 and 2.

Digestibility and daily ration trials

Three duplicate trials using early juveniles 5, 10 and 15 days after the start of exogenous feeding were undertaken. The following procedure was used: Twelve hours prior to the trials 30 fish were removed from the holding tanks and placed in two 7 *ℓ* funnels. The volume of the funnels was maintained at 5 *ℓ* with an exchange every 30 min. Prior to the introduction of food the flow was switched off and a solid perspex disk was placed in the base of the funnel to prevent the feed moving down the tube of the funnel and to give the fry full access to the feed. At 08:00 one gram of feed was introduced to the funnel and the fry were allowed a 3-min feeding period during which they fed to satiation. The perspex disc was then removed and care was taken to wash all excess feed adhering to it, back into the funnel. The contents of the funnel was then emptied into a large beaker and flushed out with water to remove any remaining food. The fish were caught in a net placed under the funnel. Any food adhering to the net was rinsed into the beaker. The funnel was then refilled

*To whom all correspondence should be addressed.
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TABLE 1
FORMULATION AND COMPOSITION OF AN OPTIMAL DRY FEED FOR *OREOCHROMIS MOSSAMBICUS* FRY (THORPE AND HECHT, IN PRESS)

Formulation	
Dried Torula yeast *(Candida utilis)*	47,00%
High protein mix (Weider Super Protein)	44,39%
Multivitamin	0,45%
Additional vitamin C	0,16%
Spirulina	5,00%
Additional free methionine	3,00%
Total	**100,00%**
Nutrient composition	
Proximate analysis (% dry weight)	
Protein (Nx6,25)	56,80%
Lipid	4,50%
Carbohydrate	13,50%
Minerals	17,00%
Vitamins	0,61%
Other (talc, fibre etc.)	7,59%
Total	**100,00%**
Vitamin composition	
A	4 189 IU/kg
D	841 IU/kg
E	89 IU/kg
K	?
Thiamine	50 mg/kg
B2	59 mg/kg
B6	18 mg/kg
B12	136 µg/kg
Pantothenic acid	94 mg/kg
Biotin	70 mg/kg
Choline	48 mg/kg
Niacin	278 mg/kg
Ascorbic acid	1 642 mg/kg
Folic acid	214 µg/kg
Inositol	24 mg/kg
Amino acids (expressed as g/kg)	
EAA	
Arginine	24,9
Histidine	12,1
Isoleucine	29,3
Leucine	38,5
Lycine	39,2
Methionine	10,3
Phenylalanine	21,5
Threonine	21,6
Tryptophan	4,6
Valine	27,6
NEAA	
Alpha alanine	17,9
Aspartic	34,8
Cystine	3,1
Glutamic	89,2
Glycine	18,0
Proline	26,3
Serine	22,7
Tyrosine	15,7

TABLE 2
MINERAL CONTENT OF THE OPTIMUM FEED. GIVEN AS A % OF TOTAL MASS UNLESS OTHERWISE INDICATED

Calcium	0,82
Phosphorus	2,30
Sulphur	?
Sodium	0,02
Chloride	0,20
Potassium	2,71
Magnesium	10,4
*Iron	49,1 mg/kg
*Copper	13,7 mg/kg
*Manganese	16,5 mg/kg
*Zinc	123 mg/kg

*Trace minerals

and the fish replaced immediately. They remained in the funnel for a further 8 h to evacuate their guts, whereupon the faeces were collected using filter paper.

The water/feed mixture in the beaker was then filtered through a freeze-dried filter paper disk of known weight to collect the remaining feed. The remaining feed and the filter paper was once again freeze-dried and weighed. The weight of the uneaten food could then be calculated by subtraction. By subtracting this mass from the original amount fed, the amount of feed consumed by the fish could be determined. The daily ration could then be determined from the above results, by multiplying the amount of feed consumed on each test day by 5 (number of feeds per day) and determining its percentage of the body mass. The food conversion ratio (FCR) and the protein efficiency ratio (PER) (Castell and Tiews, 1980; Jauncey and Ross, 1982; Teshima et al., 1986) were calculated for day 5, 10 and 15.

The metabolisable energy was determined by collecting the faeces from the filter paper after freeze-drying, weighing it accurately to 0,1 mg, and firing it in an adiabatic bomb calorimeter, followed by firing the known amount of feed eaten by the fry and calculating the difference in energy.

Feeding frequency trials

For the feeding frequency trials 10 glass aquarium tanks measuring 35 x 35 x 35 cm maintained at a capacity of 30 ℓ were used. Water from the main system was introduced via a closed loop system, so as to maintain equal flow to all the tanks. The constant level exit siphons from the rearing tanks were covered with gauze so as not to lose fry. Flow rate was maintained at 60 ℓ/h·tank giving a turnover for each tank of approximately 30 min. Each rearing tank was stocked with 200 three-day-old juveniles (just prior to the initiation of exogenous feeding). The calculated stocking density was 6,66 fish/ℓ. The daily ration calculated from the previous trial was used in the feeding frequency trials.

Five duplicate groups were then fed at the same daily ration but at different intervals (Table 3). Larval growth in mass (mg) and length (mm) was measured on day 5, 10 and 15. These data were used to calculate the mass increment per unit length. For this purpose, a sample of 30 juveniles were collected from each tank, measured to the nearest 0,5 mm total length and weighed accurately to 0,1 mg. The ration was adjusted proportionally on days 5 and 10. Results were analysed using the ANOVA facility on the statistical program "Statgraphics".

TABLE 3 EXPERIMENTAL FEEDING FREQUENCIES OF THE 5 GROUPS	
Group	**Interval**
1 (control)	5/d every 120 min
2	4/d every 150 min
3	6/d every 100 min
4	8/d every 75 min
5	10/d every 60 min

TABLE 4 WATER QUALITY IN THE REARING SYSTEM		
	Mean	**Threshold**
Ammonia	0,09 mg/ℓ	0,4 mg/ℓ
Nitrate	4,30 mg/ℓ	35,0 mg/ℓ
Nitrite	0,02 mg/ℓ	0,4 mg/ℓ
Oxygen	7,15 mg/ℓ	

TABLE 5 TOTAL FEED EATEN (TFE), MASS GAINED (MG) AND FEED CONVERSION RATIO (FCR). N = 30			
Day	**TFE**	**MG**	**FCR**
5	340 mg	250,15 mg	1,36:1
10	765 mg	658,50 mg	1,16:1
15	1 020 mg	826,50 mg	1,23:1

TABLE 6 RANGE TEST TO SHOW DIFFERENCE INGROWTH OF *O. MOSSAMBICUS* FED AT 5 DIFFERENT FEEDING FREQUENCIES			
Feed groups	**Count**	**Average**	**Homogenous**
1	120	3,677	*
2	120	3,686	**
3	120	3,727	**
4	120	3,807	*
5	120	3,811	*

Results

Table 4 shows the mean water quality data for the duration of the experiments.

Digestibility and daily ration trials

The gross energy content of the feed was 19,8 kJ/g, of which the fish were able to digest 16,1 kJ/g. Therefore the feed has a digestibility of 81,3%. The daily ration was calculated at 30,4% body mass/d at day 5; 30,6% body weight/d at day 10; and 25,1% bodyweight/d at day 15.

The results of the feed conversion trials are tabulated in Table 5. An average feed conversion ratio of 1,24 (1,24 g of feed fed to 1 g gain in wet mass) was found. The mean PER for the 15-d period was 0,682 (0,68 g protein fed per 1 g wet mass gain). The crude protein content of the feed was 56%.

Feeding frequency trials

The results of the feeding frequency trials are shown in Figs. 1 and 2, and the results of the range test (to show differences in growth) are represented in Table 6. There was a significant difference in growth ($p<0,001$) between the feeding frequency of 6 and 8 times per day, but there was no significant difference in growth between the 8 and 10 times per day feeding frequencies. This indicated an optimal feeding frequency of 8 times per day at 1-h and 15-min intervals (during daylight hours.). Feeding at night was not attempted as *O. mossambicus* shows little or no feeding activity at night (Jauncey and Ross, 1982). No significant difference was found between replicates.

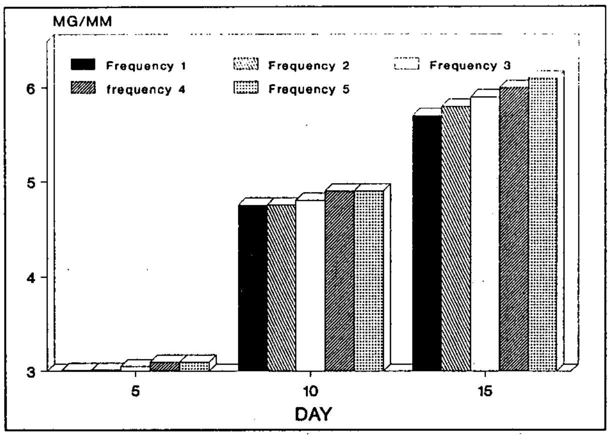

Figure 1
Mass increment/unit length (mg/mm) of O. mossambicus early juveniles fed at five different feeding frequencies. Day 1 juveniles had a mean of 1,45 mg/mm

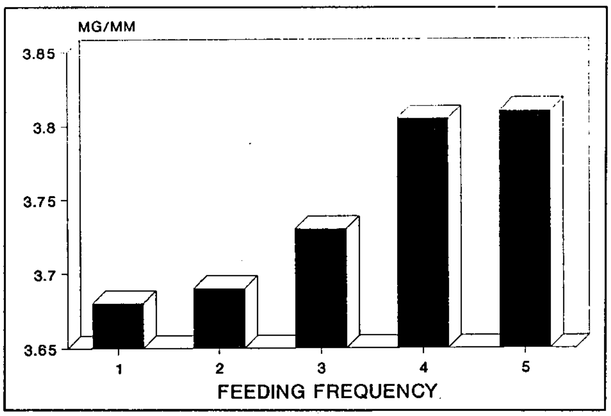

Figure 2
Mean mass increment/unit length (mg/mm) of samples taken over the duration of the five feeding frequency trials

Discussion

There is an inverse relationship between fish size and food intake on a percentage body mass basis (Jauncey and Ross, 1982). Macintosh and De Silva (1984) advocated a feeding rate of 36% body mass/d for first feeding fry, decreasing gradually so that by the 20th day the feeding rate was down to 20% body mass/d. These results compare favourably with those obtained in our experiments.

The feed conversion ratio of the formulated feed developed in our laboratory was found to be 1,24. This is a significant improvement on the results presented by Macintosh and De Silva (1984), who obtained a FCR of 1,96 (dry feed fed/wet mass gain) at a similar stocking density of 6 fry/ℓ.

The feeding ecology of *O. mossambicus* indicates that under natural conditions a high proportion of daylight hours are spent browsing, whereas at night there is little or no feeding activity (Whitfield and Blaber, 1982; Bowen, 1981; Jauncey and Ross 1982). This suggests that their digestive system is more suited to deal with regular supplies of small quantities of food than occasional large feeds. Macintosh and De Silva (1984) recommended that *O. mossambicus* and *O. niloticus* should be fed a minimum of 4 times a day in static tanks and 8 times a day in recirculating and flow-through systems. Jauncey and Ross (1982) stress that the feeding behaviour and physiology of tilapia is best suited to frequent small meals. Andrews and Page (1975), however, suggest that there is an optimum feeding frequency above which additional feedings have no advantage. This frequency is related to stomach size and gastric evacuation time, which in turn is dependent on temperature (Kono and Nose, 1971; Nose, 1979; Jauncey and Ross, 1982; Hofer and Newrkla, 1983), the size of a single meal and the physical and chemical properties of the feed (Elliot, 1972). Our findings that early juvenile *O. mossambicus* should be fed the formulated feed 8 times per day during daylight hours mirror the recommendations of Macintosh and De Silva (1984).

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