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Effect of Feeding Frequency on Growth Performance, Feed Efficiency and Bioenergetics of Golden Mahseer Early Fry

YASMEEN BASADE* **and MADAN MOHAN**
Directorate of Coldwater Fisheries Research
Bhimtal, District Nainital, Uttarakhand
India. Pin: 263 136

Abstract

In the upland regions of India, the indigenous golden mahseer *Tor putitora* (Hamilton), is well recognized as one of the important game as well as food fish and for that reason in commercial fisheries too, it should occupy an important position. In the past, there has been a great decline in the fishery of golden mahseer and is now feared to be endangered. Thus, development of fisheries of this fish in impoundment waters will play a significant role in economy of the country because high mortality is associated with first feeding of golden mahseer in controlled conditions of hatchery. To enhance the growth of golden mahseer under culture systems, it becomes necessary to know about its feeding regime. Feed accounts major portion of the cost of fish culture system. A trial was conducted, to establish optimum feeding frequency, for rearing early fry of golden mahseer. The influence of feeding frequency on survival, growth performance, feed efficiency, protein efficiency ratio (PER), meal size and bioenergetic parameters was studied in the early fry of golden mahseer. Fish were stocked in tanks with flow through water system keeping three replicates for each treatment. Feeding was carried out four times a day, three times a day, two times a day and once a day for a period of 45 days. Frequency of feeding was found to significantly influence the growth parameters, feed efficiency, meal size and the bioenergetic parameters. Net weight gain, percent weight gain and specific growth rate (SGR) were significantly higher ($p < 0.05$) in fish fed three times a day than those fed one, two and four times a day. Feed conversion ratio (FCR), feed conversion efficiency (FCE) and PER were significantly better ($p < 0.05$) in fish fed three and four times a day compared with those fed one and two times a day. Meal size of 70% was significantly higher ($p < 0.05$) for fish fed three times a day compared to those fed one, two and four times a day. Fish fed three times a day had higher feeding rate 148.93 $Jg^{-1}.day^{-1}$, absorption rate 142.12 $Jg^{-1}.day^{-1}$ and absorption efficiency 95.43 $Jg^{-1}.day^{-1}$ compared with those fed with all other feeding frequencies. However, the percentage survival was independent of the treatments. This suggests that the best feeding frequency for golden mahseer early fry is three times a day.

*Corresponding Author. Tel: +91 5942 247 280
Email : yasmeenbasade@yahoo.co.in

Introduction

Considered as one of the popular game fish with respected characteristics as a food fish, the golden mahseer *Tor putitora* (Hamilton) forms fisheries in the cold waters of Central Himalayan region of India. The coldwater regions of India previously could not be brought under the purview of aquaculture developments owing to various inherent problems related to degradation of aquatic habitat by anthropogenic activities, lack of scientific investigations pertaining to fish species, etc. Fortunately, in recent years, in support of golden mahseer, the biological investigations had already commenced and commendable success on production of stocking material through artificial fecundation have been achieved, and attempts are being made to assess their culture feasibilities (Tripathi 1977; Kohli et al. 2005; Joshi et al. 2007). Golden mahseer, an indigenous coldwater fish with desirable characteristics such as amenability to culture in captivity, capacity to accept supplementary feed and ability to tolerate wide range of environmental parameters, forms an interesting candidate for aquaculture in coldwater regions of India (Cordington 1939; Jhingran & Sehgal 1978; Chauhan et al. 2007). Thus the development of fisheries of this species will play a significant role in country's economy.

One of the major developmental constraints for golden mahseer aquaculture is lack of proper knowledge of larval growth and survivorship to the juvenile stage. The main constraints to intensify golden mahseer culture are the unpredictable and usually poor survival and growth rates of start feeding fry. Among the factors, which influence survival and growth, feeding could be considered as most relevant. To produce golden mahseer most efficiently, it is important to use appropriate diet as well as feeding strategies that will maximize growth rate and feeding efficiency. Nutritional research on golden mahseer has mainly focused on the development of diet (Mohan & Basade 2005; Keshavnath et al. 2007); less attention has been given to the practical issues of feed management. Feed management in aquaculture includes feed size, feeding rate, timing of feeding and feeding frequency (i.e. number of feedings per day). Among these issues, feeding frequency has been described for several species as a major factor influencing growth characteristics (Boujard & Leatherland 1992; Lee et al. 2000; Bolliet et al. 2001; Sanchez-Muros et al. 2003). The optimal number of feedings per day of a fixed daily ration may depend on species, age or size, environmental factors or food quality (Goddard 1996). Some researcher's findings demonstrate that the lowest food conversion and maximum growth rates can be achieved at the optimal feeding frequency (Andrews & Page 1975; Siraj et al. 1988). Feeding frequency, however, may affect food conversion, variability in fish size and loss of water-soluble nutrients from feed (Piper 1982). Suitable feeding frequency also affects the growth, survival and condition factor

of fish (Pfeiffer & Lovell 1990; Kayano et al. 1993; Vega et al. 1994; Sager & Winkelman 2006).

The aim of this study was to evaluate the effects of feeding frequency on the growth performance, survival, feed efficiency and bioenergetic parameters of golden mahseer early fry reared in flow through hatchery system.

Materials and Methods

Study site and experimental design

Golden mahseer fry produced at the Mahseer Seed Production Unit, Directorate of Coldwater Fisheries Research, Bhimtal, were procured for the study, and the trials were conducted at the same site. The test fish were treated with potassium permanganate and acclimatized to the feed and the rearing conditions before start of the experiment. The fry were randomly stocked in 12 experimental tanks (1.0 x 1.0 x 0.45 m; water depth 0.3 m) having flow through water system.

Feed and feeding

Fish were fed with the formulated feed (40% protein and 15% lipid) at a rate of 10% of biomass per feeding. Feed was delivered 1 (at 08:00 hours), 2 (0800 and 17:00 hours), 3 (08:00, 13:00 and 17:00 hours) and 4 (08:00, 1100, 14:00, 17:00 hours) times a day. Feed was given in circular feeding trays, one tray per unit. Daily at each feeding time, the uneaten feed was collected for weighing, and then the trays were rinsed and cleaned before placing the next feed. Faeces were collected by siphoning once in a day before adding fresh water. Feed rations were adjusted weekly, according to fish biomass and survival.

Chemical analysis

The biochemical composition of the experimental diets, test fish and faeces was analyzed using AOAC (Association of Analytical Chemists) (1995) methods in terms of dry matter, crude protein, crude fat, crude fibre, ash and nitrogen free extract. Gross energy content was calculated by applying standard conversion factors for fat (39.54 k.Jg^{-1}), protein (20.08 k.Jg^{-1}) and carbohydrates (17.15 k.Jg^{-1}) as recommended by Brett & Groves (1979).

Growth performance, feed efficiency and bioenergetic parameters

The average total length and body weight of fish were recorded initially and then subsequently at regular weekly intervals. On conclusion of the trial, the final total length

and body weight attained by the fish were recorded separately for all the replicates of each treatment. Growth performance, feed efficiency, survival and bioenergetic parameters (Charles et al. 1984) were determined in terms of net weight gain, percent weight gain, SGR, FCR, FCE, PER, meal size, feeding rate, absorption rate, absorption efficiency, conversion rate, conversion efficiency, metabolic rate and survivability.(SGR: specific growth rate = (Final weight – Initial weight)/days x 100. FCR: feed conversion ratio = Feed intake/Weight gain. FCE: feed conversion efficiency = (Weight gain/Feed intake) x 100. PER: protein efficiency ratio = Weight gain/Protein intake. Meal size (percentage of food consumed per feeding) = (Amount of food offered – Amount uneaten)/Amount of food offered x 100. Feeding rate = Energy consumed ($J.day^{-1}$)/ Initial live weight of fish (g). Absorption rate = Energy consumed – Energy of faeces ($J.day^{-1}$)/Initial live weight of fish (g). Absorption efficiency = Energy consumed – Energy of faeces (J)/Energy consumed (J) x 100. Conversion rate = Initial energy content of fish – Final energy content of fish ($J.day^{-1}$)/Initial live weight of fish (g). Conversion efficiency = Initial energy content of fish – Final energy content of fish (J)/Energy consumed (J) x 100. Metabolic rate = Absorption rate – Conversion rate.

Water quality management

Water quality parameters were monitored at regular weekly intervals as per standard methods (APHA 1998), and temperature being a crucial factor was monitored twice daily, in morning and evening throughout the experimental period. Water temperature ranged from 10-12°C, pH 7.0-7.2, dissolved oxygen 8.2-8.6 $mg.L^{-1}$, free carbon dioxide 0-1.2 $mg.L^{-1}$, total alkalinity 90-96 $mg.L^{-1}$ and water flow rate was maintained at 0.5-1.0 $L.min^{-1}$.

Statistical analysis

One-way analysis of variance technique was used to test the difference between treatment means for the different feeding frequencies studied, and when significant difference ($p < 0.05$) was observed between treatments, further analysis was carried out using multiple range test at 5% level of significance (Snedecore & Cochran 1994).

Results

The growth performance, feed efficiency, bioenergetic parameters and survivability of golden mahseer fry increased with increase in feeding frequency from one meal per day to three meals per day and with further increase in feeding frequency to four meals per day the above parameters decreased (Table 1).

Table 1. Effect of feeding frequency on growth performance, feed efficiency and bioenergetic parameters of golden mahseer early fry

Parameters	No. of meals day^{-1}			
	1	2	3	4
Initial weight (mg)	191.00 ± 0.58	194.33 ± 0.33	191.00 ± 1.00	193.67 ± 0.33
Final weight (mg)	307.00 ± 3.15^{a}	330.5 ± 1.22^{b}	376.33 ± 0.88^{c}	370.67 ± 0.67^{c}
Net weight gain (mg)	116.00 ± 3.61^{a}	136.00 ± 1.00^{b}	185.33 ± 1.76^{c}	177.00 ± 0.58^{d}
Percent weight gain (%)	60.75 ± 1.94^{a}	69.98 ± 0.58^{b}	97.05 ± 1.40^{c}	91.39 ± 0.34^{d}
SGR (% day^{-1})	1.58 ± 0.04^{a}	1.77 ± 0.01^{b}	2.26 ± 0.03^{c}	2.16 ± 0.01^{d}
FCR	3.87 ± 0.10^{a}	3.76 ± 0.02^{a}	3.25 ± 0.03^{b}	3.22 ± 0.01^{b}
FCE (%)	25.89 ± 0.64^{a}	26.58 ± 0.15^{a}	30.78 ± 0.29^{b}	31.02 ± 0.09^{b}
PER	0.64 ± 0.01^{a}	0.65 ± 0.003^{a}	0.77 ± 0.01^{b}	0.76 ± 0.00^{b}
Meal size (%)	60.03 ± 0.04^{a}	65.01 ± 0.003^{b}	70.00 ± 0.003^{c}	67.49 ± 0.003^{d}
Feeding rate (Jg^{-1}·day^{-1})	112.06 ± 0.84^{a}	125.71 ± 0.28^{b}	148.93 ± 0.70^{c}	140.88 ± 0.16^{d}
Absorption rate (Jg^{-1}·day^{-1})	103.33 ± 1.27^{a}	117.99 ± 0.53^{b}	142.12 ± 0.67^{c}	133.65 ± 0.32^{d}
Absorption efficiency (%)	92.21 ± 0.45^{a}	93.86 ± 0.25^{b}	95.43 ± 0.20^{c}	94.87 ± 0.20^{c}
Conversion rate (Jg^{-1}·day^{-1})	2.31 ± 0.07^{a}	2.86 ± 0.02^{b}	4.26 ± 0.06^{c}	3.64 ± 0.01^{d}
Conversion efficiency (%)	4.90 ± 0.15^{a}	5.45 ± 0.04^{b}	6.82 ± 0.06^{c}	6.32 ± 0.02^{c}
Metabolic rate (Jg^{-1}·day^{-1})	101.14 ± 1.09^{a}	115.12 ± 0.51^{b}	137.86 ± 0.61^{c}	130.01 ± 0.31^{d}
Survival (%)	99.11 ± 0.44^{a}	98.67 ± 0.77^{a}	99.56 ± 0.44^{a}	98.67 ± 0.00^{a}

Data represent the mean ± SEM of three replicates. Values on the same line with different superscripts are significantly different ($p < 0.05$).

Net weight gain, percent weight gain and SGR were significantly higher ($p < 0.05$) in fish fed three times a day compared with those fed one, two and four times a day. FCR, FCE and PER showed no significant differences ($p > 0.05$) in fish fed three times and four times a day; however, these values were significantly better ($p < 0.05$) than fish fed one and two times a day. Meal size (% feed consumed per feeding) was also significantly higher ($p < 0.05$) in fish given feed three times a day compared with those fed one, two and four times a day. In fish fed three times a day, feeding rate (148.93 ± 0.70 $Jg^{-1}.day^{-1}$), absorption rate (142.12 ± 0.67 $Jg^{-1}.day^{-1}$) and conversion rate (4.26 ± 0.06 $Jg^{-1}.day^{-1}$) were significantly more ($p < 0.05$) than that for fish fed at all other feeding frequencies. Consequently, metabolic rate (137.86 ± 0.61 $Jg^{-1}.day^{-1}$) was also significantly greater ($p < 0.05$) in fish fed three times a day compared with those fed one, two and four times a day. Although the absorption efficiency and conversion efficiency showed no significant difference ($p > 0.05$) in fish fed three and four times a day, but they were significantly higher ($p < 0.05$) than those fish fed one and two times a day. Percentage survival was found to be independent of the treatment effects.

Discussion

In aquaculture, mostly the fishes are fed more than one meal per day (Thomassen & Fjaera 1996), and research on feeding frequency, although limited, has shown that increased feeding frequency results in increased growth rates (Charles et al. 1984; Tsevis et al. 1992; Hung & Storebakken 1994; Wang et al. 1998; Charles et al. 2006). Also in this study, significant increase in net weight gain, percent weight gain, SGR was observed with increase in feeding frequency from one meal per day to three meals per day. But with further increase in feeding frequency up to four meals per day, the growth parameters assessed were observed to decrease significantly compared with fish fed three meals per day. Investigations on other fish species have similarly revealed that growth generally increases with feeding frequency up to a given limit (Andrews & Page 1975; Grayton & Beamish 1977; Siraj et al. 1988; Tsevis et al. 1992; Wang et al. 1998; Charles et al. 2006). This suggests that three meals per day is the optimum feeding frequency for golden mahseer early fry. Optimum feeding frequency for different fish species varies. Growth rates were higher for common carp, *Cyprinus carpio* (Charles et al. 1984), rainbow trout, *Oncorhynchus mykiss* (Ruohonen et al. 1998) and tambaqui, *Colossoma macropomum* (Silva et al. 2007) when fed three meals per day. The most favourable feeding frequencies reported for various fish are one meal per day for *Channa striatus* (Sampath 1984), two meals per day for channel catfish, *Ictalurus punctatus* (Andrews & Page 1975), and juvenile sunshine bass, *Morone chrysops* x *M. saxatilis* (Webster et al. 2001), four meals per day for striped bass, *Morone saxatilis* (Powell 1973), six meals per day for ayu larvae, *Plecoglossus altivelis* (Cho et al. 2003), continuous feeding for African catfish, *Clarias lazera* (Hogendoorn 1981) and once every 48 hours for young grouper, *Epinephelus tauvina* (Chua & Teng 1978).

Dividing total daily feed, of 10% of body weight, into three meals probably increased the nutrient absorption capacity of fish from feed, as fish had access to nutrients more often during the day (Silva et al. 2007). Further it was observed that feeding frequency was strongly influenced by the time of gastric evacuation (Riche et al. 2004). Nile tilapia, *Oreochromis niloticus*, had an appetite 4 hours after food was offered; therefore a feeding management that offers meals every 4 hours is the best strategy for that species growth. In affirmation to this study, Silva et al. (2007) also observed that in tambaqui feeding frequency of three meals per day, provided at a median interval of 4 hours between meals during day light, offered better growth when food supplied on each meal was close enough to fish satiety, for example, 10% of body weight per day. In this study too when feed was given at 10% of body weight per day by 4 hour intervals with a feeding frequency of three meals per day during the day time, golden mahseer early fry grew better.

Feeding frequency had a significant effect on food consumption of golden mahseer early fry. The FCR, FCE and PER values were significantly better for golden mahseer that were fed at higher feeding frequencies of three to four meals per day than those fed at one to two meals per day. Meal size too increased with increase in feeding frequency being significantly more in fish fed three meals per day and reduced significantly with further increase in feeding frequency to four meals per day. Likewise Kayano et al. (1993) described lower FCR values for red-spotted grouper when fed at higher feeding frequencies, and Charles et al. (1984) accounted lower FCR in common carp fed at increased feeding frequencies. In other fish species too, food consumption was found to increase with feeding frequency but up to a given limit (Andrews & Page 1975; Grayton & Beamish 1977; Siraj et al. 1988; Tsevis et al. 1992; Wang et al. 1998; Charles et al. 2006).

Food intake is governed by hunger level or satiation level, which in turn depends on the amount of food remaining in the stomach (Brett 1971; Pandian 1975). *C. carpio* consumed maximum amount of feed when fed after deprivation of 8 hours; however, when fed after deprivation of 12, 24, 48 and 72 hours, the feed consumption decreased (Charles et al. 1984). Such a partial compensation for the infrequent meal was also observed in the catfish, *Heteropneustes fossilis* (Marian et al. 1982). In the sunfish, *Lepomis macrochirus*, Windell (1967) found that because of degenerative changes in the pyloric caecae, prolonged starvation decreased the food intake. When feeding frequency increased above three meals per day, the total intake of food per feeding dropped considerably due to the limited capacity of the stomach as most of the food in the stomach remained undigested (Charles et al. 1984). Moreover, frequent feeding forces food through the alimentary canal more quickly and causes incomplete digestion (Dawes 1930).

In this study, all the bioenergetic parameters, namely feeding rate, absorption rate, absorption efficiency, conversion rate, conversion efficiency and metabolic rate, were significantly affected by feeding frequency and were found to increase significantly with increase in feeding frequency up to three meals per day. However, at a higher feeding frequency of four meals per day compared with the optimum feeding frequency of three meals a day, feeding rate, absorption rate, conversion rate and metabolic rate decreased significantly, whereas absorption efficiency and conversion efficiency although declined but not significantly. Some researchers observed that in *C. carpio* (Charles et al. 1984), *C. striatus* (Sampath 1984) and *H. fossilis* (Marian et al. 1982), feeding frequency significantly influenced all the bioenergetic parameters except for absorption efficiency. Frequent feeding no doubt increased food intake and conversion; however, there was always a limit for intensive feeding (Charles et al. 1984). Because food consumption, growth and all the bioenergetic parameters were not significantly enhanced by increasing the number of meals from three to four times per day, as a result a feeding frequency of three meals per day at the ration size of 10% of body weight seems to be sufficient for maximal growth of the early fry of golden mahseer.

This study comprehends that manipulating feeding frequency can be an effective strategy of feed management for rearing of golden mahseer early fry, in view of the fact that feeding frequency significantly influenced their growth performance, feed efficiency and bioenergetics. The growth parameters – net weight gain, percent weight gain and SGR; the feed efficiency FCR, FCE, PER and meal size; and the bioenergetic parameters – feeding rate, absorption rate, absorption efficiency, conversion rate, conversion efficiency and metabolic rate were observed to be superior in case fish fed daily feed scheduled 10% of body weight (to satiation) divided into three meals. This demonstrates that golden mahseer early fry most efficiently used the feed when fed three times a day to satiation. Suggesting that for golden mahseer early fry feeding frequency of three meals per day is the most advantageous to achieve better growth performance with optimum feed efficiency under flow through rearing conditions.

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