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Performance of different types of diets on experimental larval rearing of endangered *Chitala chitala* (Hamilton) in recirculatory system

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Abstract

This is the first report on the successful larval rearing of captive bred population of *Chitala chitala* (Hamilton). *C. chitala* is one of the endangered fresh water fish species in India for which the development of controlled larval rearing procedures are needed for stock enhancement. Fifteen days old post-hatchlings were stocked for 28 d in a 30 L recirculatory tanks using eight different diets i.e. live feed (tubifex worms, chironomous larvae, zooplanktons,), dry feed (dry tubifex, spirulina, daphnia) and other non-conventional feed (fish eggs and boiled egg-yolk). Fishes accepted all types of diets. The study revealed that specific growth rate (SGR) was higher in post-hatchlings fed on live tubifex worms (2.40 ± 0.72) followed by fish eggs (2.15 ± 0.71), dry tubifex (2.12 ± 0.40), chironomous larvae (1.91 ± 0.44), spirulina (1.79 ± 0.38), daphnia (1.42 ± 0.79) and planktons (1.37 ± 0.77) whereas minimum SGR was recorded with boiled egg-yolk (0.63 ± 0.5). A highly significant difference ($p < 0.01$) in SGR was observed in fish fed on live feed (tubifex worms, chironomous larvae, planktons, spirulina), dry tubifex and fish eggs whereas for daphnia and boiled egg-yolk it was only significant ($p < 0.05$). The final mean weight and weight gain showed highly significant difference ($p < 0.01$) in live tubifex, zooplanktons, spirulina, chironomous larvae, dry tubifex and fish eggs, whereas daphnia and boiled egg-yolk fed larvae showed significant difference ($p < 0.05$). Highest mean survival rate on day 28 was observed in live tubifex worms (94%) and chironomous larvae (92%). The post-hatchlings reared with spirulina and daphnia showed same survival rate of 88% whereas the lowest mean survival of 66% was recorded in boiled egg-yolk. The experiments showed that captive bred post-hatchlings of *C.chitala* could be reared in experimental recirculatory system for attaining higher growth and survival during early life stages. However, methods to improve the larval rearing have to be improved further for commercial farming of the species.

Keywords: *Chitala chitala*; Larval rearing; Recirculatory system; Live and dry feed; SGR; Growth and survival

1. Introduction

Selection of a new potential freshwater species for aquaculture has tremendous importance for the sustainable development of the aquaculture sector as well as in conservation programme. Feather back *Chitala chitala,* commonly known as “moi”, is widely distributed in all African and Asian countries including

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India, Pakistan, Bangladesh, Sri Lanka, Nepal, Thailand and Indonesia. It is a bony fish, belonging to the order Osteoglossiformes under family Notopteridae. It constitutes an important component of riverine fisheries and is considered as one of the most commercially important and highly priced food fish of India. The fish is known specifically for its delicious meat quality and nutritive value besides its ornamental significance in abroad. The species commands high market demand and has been prioritized as a new candidate for freshwater aquaculture system (Ponniah and Sarkar, 2000; Ayyappan et al., 2001). They are generally carnivorous and insectivorous in nature but sometimes they also feed on crustaceans and planktons and occasionally they are cannibalistic in nature. They change their feeding habits completely at early stage and start feeding voraciously on carp fry and aquatic insects (Alikunhi, 1957). Recently there has been a steady decline in wild stocks in India and according to Conservation Assessment and Management Plan (CAMP, 1998), this species has been categorized as endangered (EN). Regarding aquaculture a few attempts have been made by the farmers to develop *chitala* culture based on wild-caught juveniles and a maximum growth up to 1–2 kg/year has been obtained under polyculture system (unpublished farmers data).

Recently, the first successful induced spawning of *C. chitala* has been achieved by Sarkar et al. (2006). But larval rearing is still considered as most critical and, therefore, the development of rearing technology is essential for conservation of endangered fish species. Success of larval rearing depends mainly on the availability of suitable diets that are readily consumed, efficiently digested and that provide the required nutrients to support higher growth and health. However, no information is available on the feeding behavior, dietary preference etc. of this species. This is the first report from India on the successful rearing of larvae under captivity of the induced bred population.

The present study aims to evaluate growth performances and survival rates of *C. chitala* post-hatchlings fed on eight different diets comprising live and commercially prepared dry diet for captive bred population of *C. chitala* under experimental recirculatory system.

2. Material and methods

C.chitala post larvae were obtained from captive adults by induced spawning developed by the authors under farm condition (Sarkar et al., 2006). The post-hatchlings were fed on egg-yolk, live mixed zooplanktons, predominantly consisting of copepods, rotifers and cladocerans in rectangular nylon hapa fitted in the nursery pond (0.06 ha) for the first 10–15 d before commencement of the experiments.

2.1. Experimental set up

A larval rearing experiment was conducted in a recirculatory system with 8 different feeds namely live tubifex, chironomous larvae, planktons spirulina, daphnia, dry tubifex, fish eggs and boiled egg-yolk for a period of 28 d. All recirculatory systems had the same efficiency and experiments were carried out under similar environmental conditions in the wet laboratory. The diagrammatic sketch of the experimental recirculatory system is shown in Fig. 1. Each recirculatory system consisted of series of three circular tanks (25 L) measuring 19 × 15.5 in. (height × diameter) arranged in a 2-tier system having partitions with separate water inlets and drains for each. There was a provision for uplifting water from large tanks (37 × 25 × 19.5 in.) fitted at the bottom for storage to upper tank with same measurements. Both tanks were installed at the height of 56 in. An upliftment of water took place through a monobloc tullu pump set (230–250 V, 2800 rpm and 0.6 A) fitted with repeated cyclic meter. Separate tanks were used for each of the food and three replicates were used for each treatment. The adjustment in the feeding ration was made as per intensity of feed intake recorded from time to time during the experiment. In each recirculatory system, the post larvae were fed at 10% body weight per day during the first week, 8% per day during the second week and 5% per day during the third and fourth weeks respectively. Rations were given twice daily i.e. of the morning (10.00 h) and evening (16.00 h). Satiations were determined based on visual observation of acceptance and refusal of feed. The total length (TL) of larvae stocked initially ranged from 41.11 ± 4.9 mm to 48.8 ± 7.04 mm with an average size of 45.26 ± 2.43 mm. The body weight ranged from 0.5 ± 0.06 g to 0.97 ± 0.29 g with an average weight of 0.66 ± 0.13 g.

Fishes were initially stocked in a fiberglass reinforcement tank (FRP) and kept for 5–7 d for acclimatization. The larvae were then stocked in separate recirculatory tanks for different feeds. Each of the tanks measured 5 in. × 4 in. in size and stocked with larvae. Live tubifex and chironomous were collected from unpolluted areas of nearby river

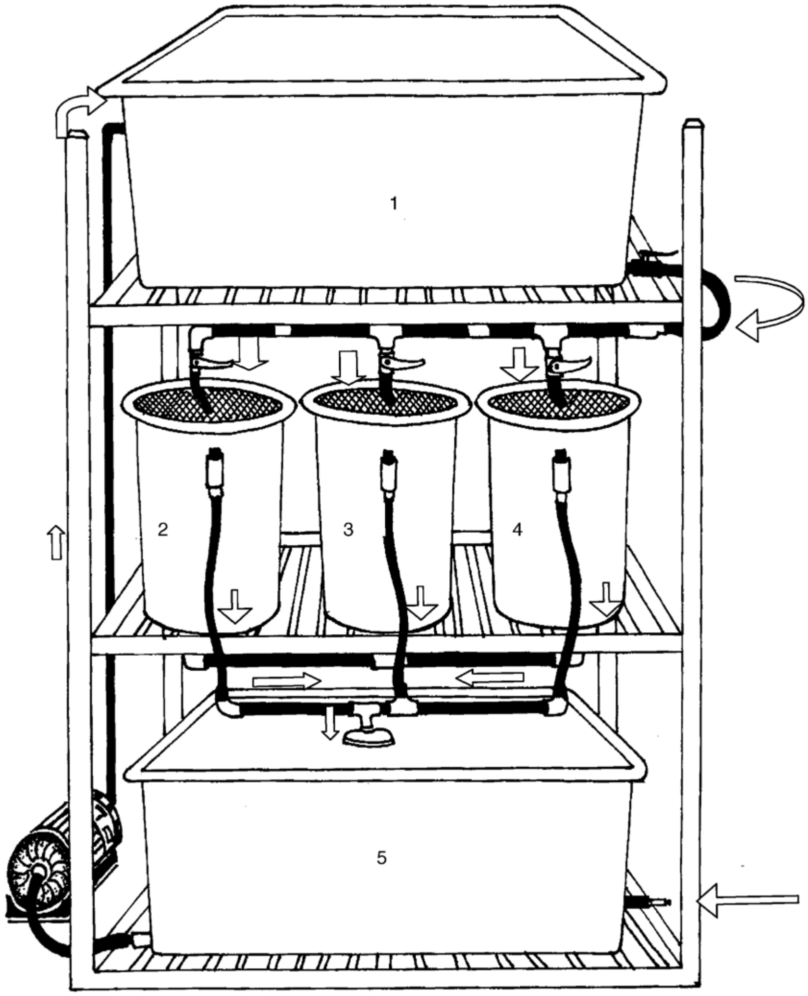

Fig. 1. Diagramatic sketch of the experimental recirculatory system.

Gomti close to the Lucknow City. Live tubifex worms (*Tubifex tubifex*) and zooplanktons (copepods) were cultured in laboratory. Dry tubifex were bought from the market (Red sea freeze dried tubifex, Insha, Mumbai), which contained 52% proteins, 12% fat, 2% fiber and 5% moisture. The spirulina was procured from the local market, which were floating type, and consisted 32% crude protein, 4% crude fat, 5% crude fiber, 10% crude ash 9% moisture and 31% nitrogen free extract. Freeze dried daphnia (Taiwan make) were collected from the local market which consisted 52% crude fat, 12% crude protein, 2% crude fiber, 2% moisture and 12% ash. Fish eggs were collected by dissecting a fresh gravid catfish *Mystus vittatus* (order Siluriformes, family Bagridae) daily which were cultured in the uncontaminated pond. Eggs were washed in tap water to remove blood vessels before providing in the recirculatory tank. Each tank was stocked with ten healthy and almost the same size of *C. chitala*. Before releasing the fish, they were dipped with 1 ppm of $KMnO_4$ solution for few seconds. About 50% of the water volume was exchanged each time by means of siphoning and refilled, so that the fish were sampled for length and weight increments. Water exchange was done in the morning at 10.00 h prior to feeding. On every 7th day, 10 post-hatchlings were sampled. They were placed in paper towel in order to absorb water and weighed in electronic balance to the nearest 0.01 mg. The length was measured by digimatic calipers (Mitutoyo make) to the nearest 0.01 mm. Survival rates were calculated by taking into account the remaining and discarded post-hatchlings.

The specific growth rate (SGR) was calculated to determine the growth performance during the experimental period according to the following relation:

$$\mathrm{SGR} = 100(Ln\ W_2 - Ln\ W_1)/\Delta t$$

$$\text{Weight gain percent} = W_2 * 100/W_1$$

where, $W_2, W1 =$ Final and initial weight.

$$\text{Weight gain percent per day} = \text{weight gain percent}/\text{no. of days.}$$

The behavior of the fish was also observed during the course of the experiment, especially during feeding. The other parameters like weight gain (%,) survival (%) were also recorded. Each time after taking length and weight measurements, the fishes were dipped with 1 ppm KMnO4 solution for few seconds.

2.2. Water chemistry

The physico-chemical condition of water including water temperature, pH, dissolved oxygen (DO), total dissolved solids (TDS), conductivity were measured early in the morning prior to feeding at a depth of 20 cm by using a multiparameter water analysis instrument (model No.Multi 340i, WTW, Germany). Total alkalinity and total hardness were determined by the sulphuric acid titration method as per APHA (1989). Parameters like nitrate (NO_3) and phosphate (PO_4) were determined on weekly basis by using spectrophotometer (Spectroquant NOVA 60,). Ammonia and nitrite concentrations were determined at the same time using spectrophotometer kits. Dead larvae were removed and counted twice a day, simultaneously to water changes, to estimate the percentage of survival rate per 24 h. On the last day of the experiment, all the remaining larvae were individually counted for the calculation of actual survival rate.

2.3. Statistical analysis

Analysis of variance (ANOVA) was used to test the effects of the treatments on various growth and feed

Table 1
Mean weight, length, specific growth rate, weight gain % of *C.chitala* post-hatchlings fed on different types

Parameters	Feeds						
	Live tubifex worms	Chironomous larvae	Planktons	Spirulina	Daphnia	Dry tubifex	Fish eggs	Boiled egg-yolk
Initial mean length (mm±SD)	44.21±7.0	45.98±5.0	48.8±7.04	46.97±5.58	46.81±6.0	41.11±4.9	45.19±7.20	43.07±10.0
Initial mean weight (g±SD)	0.60±0.10	0.66±0.08	0.72±0.16	0.6±0.06	0.65±0.12	0.5±0.06	0.65±0.14	0.97±0.29
Final mean length (mm±SD)	69.04±10.65	67.81±5.4	68.11±6.2	54.97±2.62	56.43±5.6	52.01±4.9	69.38±8.30	64.59±15.5
Final mean weight (g±SD)	2.01*±0.27a	1.73*±0.35b	1.28*±0.2b	1.48*±0.18b	1.002**±0.4c	0.89*±0.1c	1.99*±0.26b	1.74**±0.9b
Weight gain (%) per day (g±SD)	348.17**±112.8a	258.96*±59.0b	182.67*±46.96b	225.96*±41.4b	158.93**±71.8c	176.6*±33.2c	314.05*±66.5b	178.66**±75.8b
SGR (g±SD)	2.40**±0.72a	1.91*±0.44b	1.37*±0.77c	1.79*±0.38b	1.42**±0.7c	2.128*±0.4a	2.15*±0.70a	0.63**±0.5c

*Significant ($p<0.05$) **Highly significant ($p<0.01$). Mean±S.D. ^{a,b,c} Figures in the same row having the same superscript are not significantly different ($p>0.05$).

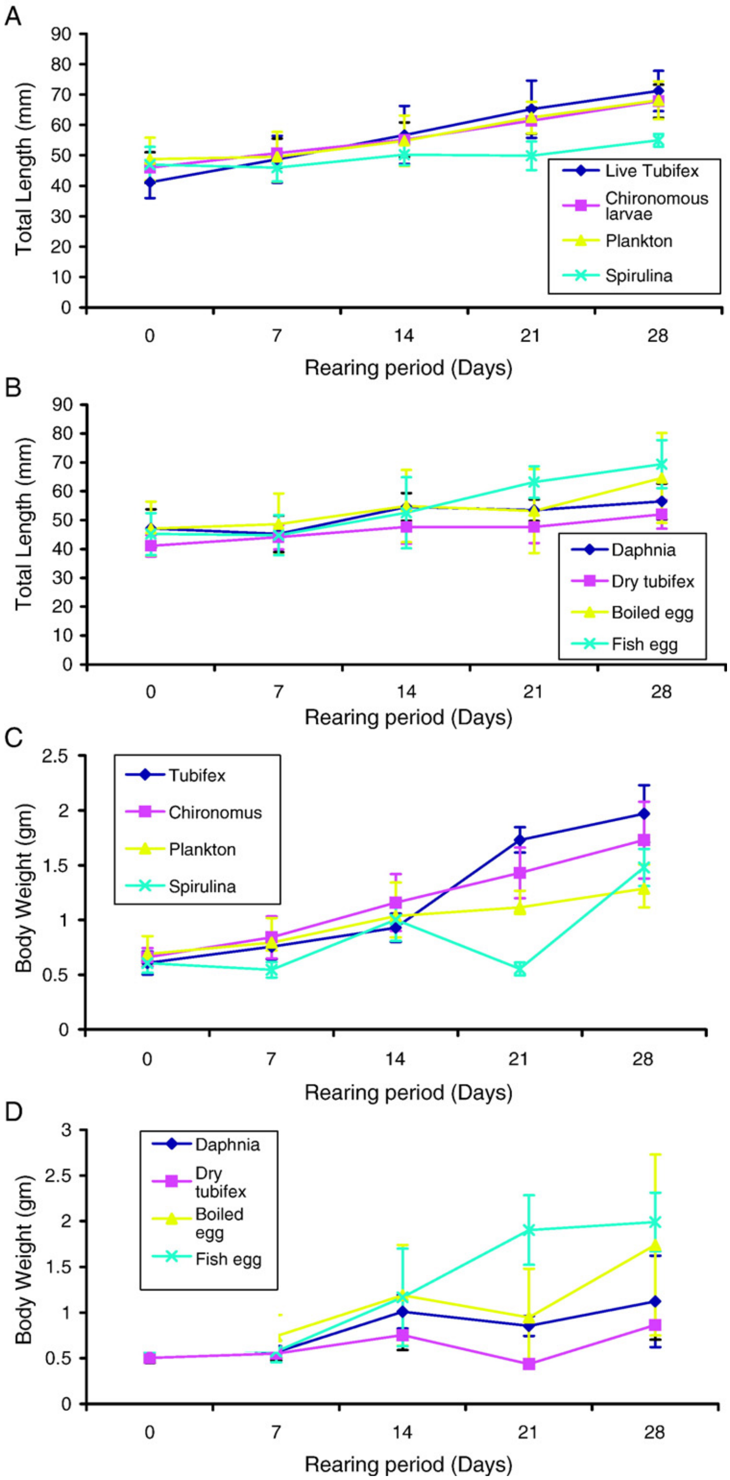

Fig. 2. (A–D) Total mean length (mean ± S.D.) and body weight (mean ± S.D) of *C. chitala* post-hatchlings reared in different tanks with eight different diets.

utilization parameters. Tukey's Multiple Range test was applied to determine the significance level of the treatments. Differences were considered significant at $p<0.05$. All data were analyzed using SPSS (11.0) version for windows software program for statistical analysis. Data are presented as treatment means ± SE.

3. Results

Water recirculatory system used in the larval rearing of *C. chitala* was found to be useful with respect to levels of water quality, growth and survival. The parameters of growth of the post-hatchlings of *C. chitala* reared in different tanks with eight different feeds are shown in Table 1 and Fig. 2 (A–D). Post-hatchlings appeared to adapt easily to captive conditions and immediately accepted the diets. In recirculatory tanks, they continuously moved in circle in the middle of the water column and coming to the surface to feed. During experimental rearing period in the recirculatory system *C. chitala* showed typical preying habit of swallowing feed with moving upward and downward directions. They also showed good swimming behavior. No attacking behavior was noticed during the experiment. The fish became sluggish after feed intake and took shelter in the artificial caves as a hiding cover. It was observed that the rate of feed intake was higher in live tubifex, fish eggs, chironomous larvae and planktons as compared to other feeds tested. The observations also showed that daphnia feed would evenly spread out on the top layer of the water, slowly sinking after 15–30 min while for boiled egg-yolk rapid break down of feed in the recirculatory tank led to increase fouling rates.

During the experimental rearing, the larvae were negatively phototactic and aggregated in the dark hiding areas of the larval rearing tanks provided at the bottom. The larvae fed on live tubifex worms and fish eggs showed a rapid growth rate and attained the highest final length and weight as compared to those that were fed with chironomous larvae, fish eggs, boiled egg-yolk, planktons, dry tubifex, daphnia and spirulina. Analysis of variance (ANOVA) revealed a significant effect of diet on growth. The final mean length and mean weight showed highly significant difference ($p<0.001$) in live tubifex, chironomous larvae, spirulina, planktons, dry tubifex and fish eggs, while the feed like daphnia and boiled egg-yolk showed significant difference ($p<0.05$) only. Thus the final mean length and mean weight showed an increase in body length and weight in all treatment groups. The standard deviation of final mean length and mean weight at the end of the experiment varied greatly.

3.1. Specific growth rate and weight gain (%)

The Specific Growth Rate (SGR) was calculated to determine the growth performance during the experimental period and the results are shown in Fig. 3. In the experiment, higher value of SGR was observed for larvae fed on live tubifex worms showing an average of 2.40±0.72 g/day, followed by fish eggs (2.15 ±0.71), dry tubifex (2.12±0.40), chironomous larvae (1.91±0.44), spirulina (1.79±0.38), daphnia (1.42 ±0.79) and planktons (1.37±0.77). However, SGR was lower in larvae fed on boiled egg-yolk (0.63±0.5) (Fig. 3). Highly significant ($p<0.01$) variation in SGR was observed in chronomous larvae, planktons, spirulina, dry tubifex and fish eggs, while it was significant ($p<0.05$) for live tubifex, daphnia and boiled egg-yolk.

Among other growth parameters, weight gain percentage was higher in live tubifex (348.17±112.8) followed by fish eggs (314.05±66.56), chironomous larvae (258.96±59.01), spirulina (225.96±41.49), planktons (182.67±46.96), boiled egg-yolk (178.66±75.88), dry tubifex (176.6±33.20) and daphnia (158.93±71.88). ANOVA done for weight gain percent of different diet indicated highly significant difference ($p<0.01$) in chironomous larvae, plankton, spirulina, dry tubifex and fish egg while it was significant ($p<0.05$) in live tubifex, daphnia and boiled egg-yolk.

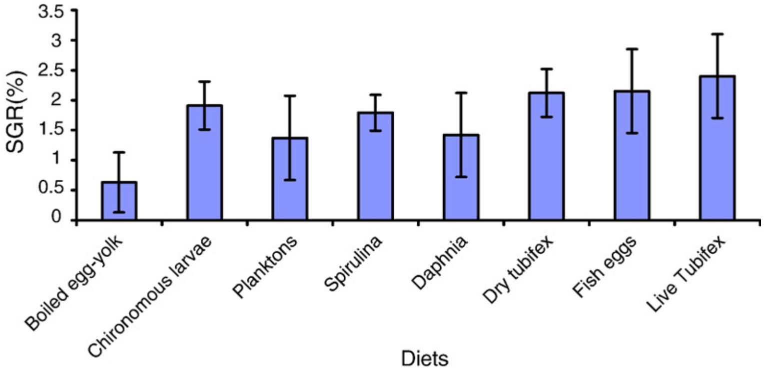

Fig 3. Specific growth rate (mean±S.D.) of *C. chitala* fed with eight different diets.

3.2. Survival rates

The mean survival rate of *C. chitala* post-hatchlings fed on eight different diets during the experimental period varied from 94.0 to 66.0% on day 28. The results indicated maximum mean survivability for live tubifex worms (94%) followed by chironomous larvae (92%). The larvae reared with diet spirulina and daphnia were the same (88%) whereas 82% survivality was recorded for larvae fed on planktons. Seventy-four percent survival was recorded in both dry tubifex and fish eggs whereas low rate of survival was observed in larvae fed on boiled egg-yolk (66%).

3.3. Water chemistry

Mean values of water quality were calculated to provide an overview of changes in the recirculatory tank during the experimental period. Water recirculatory system used in the experiment larval rearing of *C. chitala* was found to be useful with respect to levels of dissolved oxygen, free carbon dioxide and maintaining water flow. The system also reduced negative environmental impact and maintained stable water quality conditions in the systems. No marked variation in water quality parameter was observed in experimental system treated with different diets except boiled egg-yolk treatments where rapid breakdown of feed caused fouling in the system. All the parameters were under the tolerance limit of fish and they did not exhibit any distress during the experiment. Dissolved oxygen (DO) is the key factor in rearing of larvae because larvae need optimum level of oxygen for maintaining their physiological condition. In the present study, mean dissolved oxygen level in the recirculatory fish tank was 9.12±0.14 mg/L at 10.00 h. The water pH was 8.46±0.04 during rearing period, a higher level whereas mean free Co_2 was 0.36±0.07 ppm. In the daytime, fish consumed more oxygen while their carbon dioxide excretion reduced the pH range.

Temperature plays an important role in larval rearing. An average air and water temperatures ranged from 28.18±0.13 and 26.07±0.37 °C respectively. The results of the mean values of other water quality parameters in the recirculatory systems were as follows; alkalinity 60.08±0.71 ppm, hardness 247.06 ±4.60 ppm, total dissolved solids 362.36±1.64 ppm, and conductivity 372.26±1.28 µmhos/cm. Ammonia and nitrite concentration were on the lower side and ranged between 0.002–0.027 mg/L, and 0.01–0.016 mg/L respectively.

4. Discussion

This is the first report on the rearing of larvae under captive conditions of the farm bred population of *C chitala* in a recirculatory system. The study showed differences in the growth, SGR and survival of *C. chitala* fed on the same level of different diets in the recirculatory system having similar environmental conditions. However, many factors are related to the feeding such as stocking density, production system, type and size of rearing tanks, size of fish and quality and quantity of food (Mgaya and Mercer, 1995). In the present study, the food ration for both live and artificial diet was reduced (10% of body weight per day during the first week, 8% per day during second week and 5% per day during the third and fourth weeks) in the progressive weeks based on the intensity of feeding.

The feed intake was higher for live tubifex, fish eggs, chironomous larvae and planktons as compared to other feeds tested. We noticed the leaching of water-soluble dry diets (dry daphnia, boiled egg-yolk) in the system. Rapid break down and dispersing tendency of these feeds in the recirculatory tank led to increased fouling rates. Feed intake of fish depends on size of the prey and predator, quality, density, physical attractiveness and mode of presentation of food (James et al., 1993). They also reported that the wriggling movements of large and nutritionally rich prey organisms such as chironomous larvae and *Culex pipiens* larvae minimize the temporal and energy cost of feeding and maximize growth in *Cyprinus carpio*. Chaitanawisuti et al. (2001) reported differences in the growth and FCR of juvenile spotted Babylon influenced by feeding levels in a flowthrough seawater system. Harpaz et al. (2005) observed higher growth rates of fry of *Poecilia reticulata* when the diet was presented in the form of a finely ground powder compared to a flake form.

The present study indicated that the post-hatchlings of *C. chitala* successfully weaned on to live, artificial and other non-conventional diet on an experimental scale. However, they do show marked preference for some type over others. Live tubifex, dry tubifex and fish eggs, artificial and non-conventional diets, proved to be an excellent feed for post-hatchling rearing of *C. chitala* in terms of growth (Table 1). It was interesting to note that fish eggs of *M. vittatus* served as excellent diet for rearing post-hatchlings of *C. chitala*. The post-hatchlings fed on fish eggs acquired an average weight of 1.99 g at the end of the experiment and a SGR of 2.15, close to that was observed for the post-hatchlings fed on the live tubifex (SGR=2.4). Post-hatchlings fed on planktons; daphnia and boiled egg-yolk had lower growth than those fed on tubifex worms, fish eggs, chironomous larvae and dry tubifex. The fish eggs were tested for the first time as diet of *C. chitala* which interestingly proved to be highly useful in the experimental rearing of the post-hatchlings. The study also confirmed the feasibility of using dry tubifex to rear *C. chitala* post-hatchlings. This ability to use non-live diets by *C. chitala* has an important implication for the commercial culture of this species, as the use of these non-live feed can drastically reduce material and labour costs, which in turn would increase the economic viability of a commercial operation. During the rearing period, *C. chitala* were sluggish, and showed schooling and hiding behavior in the caves, pipes and pebbles provided at the bottom of the recirculatory tank.

Many authors have studied the effects of different nutritional diets on the growth of other larval stages of many species (Mathavan, 1976; Degani and Horowitz Levanon, 1985; Wah Lam and Shephared, 1988; Khan and Jafri, 1994; Kim et al., 1996). However, information was lacking on the rearing of featherback *C. chitala*. The tubifex worms have been used as a live feed for nursing European catfish (*Silurus glanis*) on a large scale in Hungary owing to its economic value (Horvath et al., 1981) and in Mekong catfish (*Pangasius bicourti*) as reported by Hung et al. (1999). They obtained a specific growth rate (SGR) of 36.7±1.3% per day in a 9-day experiment. Live tubifex might have stimulated the feeding behavior of *C .chitala* post-hatchlings and increased the acceptance, which supports the earlier observations (Miner and Stein, 1993; Hart et al., 1996). Degani (1991) found that juvenile *Trichogaster trichopterus* fed with live feed grew faster than those fed on formulated feed because of the palatability, high consumption rate and chemical composition of the former.

Comparatively lower growth rates of fish receiving these diets could be due in part by the physical property of the feed. Several hypotheses have been proposed to explain the low effectiveness of the dry diet as the sole food supply for fish larvae. According to Fluchter (1982), the different larval stages have specific nutritional requirements while Bergot (1986) reported that artificial feeds change the relation, which exists between the animal and its environment. A lowest survival percentage in dry tubifex could be due to the impaired feeding of larvae because of reduced feed contrast. Similar observations have been reported by Hinshaw (1985) in yellow perch larvae. Several hypotheses (Hung et al., 1999, 2002). have been proposed to explain the low effectiveness of the dry diet as the sole food supply for fish larvae. The poor growth rate and survival of *C. chitala* larvae fed with diet daphnia and boiled egg-yolk could be due to low digestibility at first feeding. Hebb et al. (2003) reported significant difference among the three pelleted diets in the percentage of dry matter lost in flat fish juvenile *Pleuronectes americanus* and indicated concerns of increased fouling rates due to rapid break down of dry feed in the tank. The deterioration of water quality and tank cleanliness due to the use of formulated feeds also probably affected the growth and survival rate of larvae in their early stage as reported by Abi-Ayad and Kestemont (1994).

Several workers have reported successful rearing of fish larvae using live zooplankton for several species (Watanabe and Fujita, 1983). Among the various species of zooplankton, the genus *Moina* (cladocereans) is known to be suitable as an initial feed for *Chanos chanos* (Villegas, 1990) and *Clarias macrocephalus* (Fermin and Boliver, 1991). Larval rearing of European cat fish (*S. glanis*) fed with Red bloodworms and tubifex, have been successfully carried out by Ronyai and Ruttkay (1990). It has also been reported that some freshwater fish species were exclusively reared on artificial diets from the beginning of exogenous feeding (Appelbaum and Van Damme, 1988; Charlon et al., 1986; Legendre et al., 1995).

In the present study, a higher mean survival (>80%) was observed for both live feed (tubifex, chironomous larvae, zooplanktons) and artificial diet (dry tubifex, spirulina, daphnia) while post-hatchlings fed with unconventional feed (fish eggs and boiled egg-yolk) had comparatively lower survival (66–74%). This could be due to the improved food intake by the post-hatchling from live and artificial diets. The low survival rate (66%) in boiled egg-yolk might be due to impaired feeding of post-hatchlings. Giri et al. (2003) observed highest survival of *Wallago attu* in larvae fed on live zooplanktons and dry feed conditions as compared to live zooplanktons alone. Hung et al. (2002) recorded a survival up to 92.7% in *Pangassius bocourti* larvae fed on live tubifex.

The results of the present study indicate that while *C. chitala* larvae actively feed on several types of organisms (tubifex, chironomous larvae, planktons), artificial diets (spirulina, daphnia and dry tubifex) and other non-conventional feed (fish egg and boiled egg-yolk), they do show marked preference for a specific type over others. The study also reveals that non-conventional feed like fish eggs of *M. vittatus* may serve as a potential diet for rearing post-hatchlings of *C. chitala*. The mean SGR was 2.12±0.40 as compared to 2.40±0.72 in live tubifex, which might be due to fish eggs having high protein contents. Patra (1992) reported that the growth rate of *Anabas testudineus* varied with isonitrogenous diets having different protein sources and it was highest with the feed containing carcass waste.

In conclusion, the results obtained by us indicate the reliability of the protocols for larval rearing in recirculatory system at experimental level by using several types of diets. The use of fish eggs, dry tubifex may be a potential diet for the early life stage of featherbacks. This research has paid attention to the fact that larval preference of live feed to dried feed is due to the movement of prey. The species deserves further study on its suitability for commercial culture because of its fine adaptation to confinement and good tolerance to captive conditions. The potential areas for further investigation to facilitate progress towards conservation and aquaculture of this species are the optimization of stocking density, improving diet presentation, feeding level and scaling up of the rearing protocols and the development of feeding strategies.

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