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Effect of water flow on growth of *Catla catla* (Hamilton, 1822) reared in recirculatory aquaculture system

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ABSTRACT

Production performance of *Catla catla* (Hamilton, 1822) was examined at different water flow rates in recirculatory aquaculture system (RAS), in Tarai region of Uttarakhand. The experiment was conducted in 12 FRP tanks of RAS with sand filter and UV filters, with four treatments and three replicates for each treatment viz., control, T₀ (83 l h⁻¹ or one time in two days); T₁ (667 l h⁻¹ or 4 times in a day); T₂ (333 l h⁻¹ or 2 times in a day) and T₃ (167 l h⁻¹ one time in a day) from November 2015 to April 2016. The fingerlings of catla having uniform body weight (10.00±0.6 g) were stocked randomly in all treatment groups at the rate of 25 no.m⁻³. Physical properties of water such as water temperature, electrical conductivity and total dissolved solids were analysed weekly throughout the experimental period and ranged from 15.8 to 27.8°C, 271 to 384.3 µS cm⁻¹ and 216.3 to 274 mg l⁻¹, respectively. Water parameters such as pH, dissolved oxygen, free carbon dioxide, alkalinity, hardness, ammonia, nitrate and phosphate were also analysed which varied from 7.2 to 8.4, 5.4 to 7.9 mg l⁻¹, 1.8 to 3 mg l⁻¹, 118 to 167.3 mg l⁻¹, 133.3 to 241.6 mg l⁻¹, 0.02 to 0.08 mg l⁻¹, 0.11 to 0.42 mg l⁻¹ and 0.02 to 0.08 mg l⁻¹ respectively. The best food conversion ratio (FCR) was recorded in T₀ (1.61) followed by T₃ (1.65), T₁ (1.70) and T₂ (1.81). Highest specific growth rate (SGR) was recorded in T₂ (0.88%), followed by T₁ (0.86%), T₃ (0.85%) and T₀ (0.84%). The best protein efficiency ratio (PER) was recorded in T₂ (2.31) followed by T₃ (2.54), T₁ (2.56) and T₀ (2.62). Among different treatment groups, the survival rate of catla varied from 78 in T₀ to 83% in T₁. Significantly higher (p<0.05) growth performance of catla was recorded in T₂ as compared to other tanks.

Keywords: *Catla catla*, Feed conversion ratio, Monoculture, Protein efficiency ratio, RAS, Specific growth rate, Water flow

In general, semi-intensive fish culture is popular in India with supplementary feeding, while extensive aquaculture is carried out in moderately large water bodies with stocking of fish seed for utilising natural productivity. Sometimes these aquaculture practices cause an impact on water resources, equally on their physical and chemical characteristics. Semi-intensive aquaculture may lead to excessive use of ground water and may cause depletion in ground water as well as other problems that include conversion of agriculture land into aquaculture, thus creating a negative impact on production of other agricultural crops. Hence, there is a need to adopt better management practices for fish production and new culture systems are to be introduced with low water requirement.

Recirculation aquaculture system (RAS) is a new water quality improvement technology; much of it developed for the waste water treatment industry, which has revolutionised our ability to grow fish in tank culture. The intensive re-circulating system provides optimum eco-physiological conditions as per the requirements of the species cultured (Losordo *et al.*, 1998). Water quality

plays an important role in the propagation of desirable aquatic organisms to achieve high survival, growth and reproduction. The association between water quality and aquatic productivity is very important for the optimum growth and survival of desirable species. The physical and chemical parameters of water are important in production of fish and other aquatic animals (Toma, 2011). All of these factors cheer the use of recirculation aquaculture system, where a large amount and high quality fish can be grown in a small volume of water. Recirculating systems can control the aquatic environment to achieve better hygiene and disease management (Summerfelt *et al.*, 2009; Tal *et al.*, 2009; Martins *et al.*, 2010b). RAS can be used for grow-out systems to produce food fish, in hatcheries to produce spawn, fry and fingerling for stocking as well as for rearing ornamental fish for home aquaria (Helfrich and Libey, 1991). Depending on the location and situation; the systems can be designed to cater for different capacities and proficiencies. In contrast to the traditional aquaculture practices, RAS offers more impartiality from the external environment (*i.e.*, increased

levels of control) which affords a basis for enhanced risk management (Rawlinson, 2002).

Catla catla (Hamilton, 1822) (*Bhakur*), a fast growing Indian major carp, is very popular in culture systems throughout India. This is a promising species for aquaculture with its fast growth, high market demands. Its advanced growth rate, compatibility with other major carps, specific surface feeding habit, and buyer preference have increased its popularity in carp polyculture systems among the fish farmers in India, Bangladesh, Myanmar, Laos, Pakistan and Thailand (FAO, 2012). The recirculating fish culture system, a new technique of producing fish in desired conditions, is growing fast in many countries. Benefits associated with these systems have led to explore their potential not only for high-valued fish species but also for lower-valued ones such as tilapia and carps. The aim of this study was to evaluate the overall growth performance and production of catla grown in recirculating aquaculture system.

The experiment was conducted for six months from November 2015 to April 2016 in 12 FRP tanks (having 250 cm dia, 85 cm height and water holding capacity of approximately 4000 l) of an indoor water recirculatory system (200 m³ water holding capacity) equipped with sufficient quantity of sand filters, biofilter, UV filter, air blower and pumping unit. The tanks were covered with net to avoid escape of experimental fish. The water flow rate in each experimental tank was maintained through separate control valves. A 3 HP air blower was used to oxygenate the water of all the 12 experimental tanks. There were 4 treatment groups having different water exchange rates with 3 replicates *viz.*, control, T₀ (83 l h⁻¹ or one time in two days) T₁ (667 l h⁻¹ or 4 times in a day), T₂ (333 l h⁻¹ or 2 times in a day) and T₃ (167 l h⁻¹ one time in a day). Each tank was stocked with healthy and disease free fingerlings of *C. catla* of almost uniform weight (10.00±0.6 g) and same age group, at the rate of 25 nos. m⁻³ (approximately 100 nos. per tank). The stocked fingerlings were fed twice a day with commercial pelleted floating feed having 28% protein (Table 1), at the rate 2-3% body weight.

The physical and chemical water quality parameters *viz.*, water temperature, electrical conductivity, total dissolved solids (TDS), dissolved oxygen (DO), free carbon dioxide (CO₂), pH, hardness, total alkalinity, ammonia (NH₃-N), nitrate (NO₃-N) and phosphate were assessed weekly throughout the study period, following standard methods (APHA, 2012).

Growth measurements such as weight and length of the fingerlings were recorded individually every 15th day and the amount of feed was adjusted according to weight of fish. At the end of 180 days of feeding, specific

Table 1. Proximate composition of formulated feed

Nutrients	Percentage
Protein	28
Fat	4
Fiber	6.5
Moisture	11

growth rate (SGR), feed conversion ratio (FCR) and protein efficiency ratio (PER) were calculated. The data was subjected to statistical analysis employing one way analysis of variance (ANOVA) using Microsoft Office 2013 and Origin Pro 9.0.

The water quality parameters recorded during the experimental period are given in Table 2. During the investigation period, the water temperature varied from 15.8 to 27.8°C and the highest temperature was recorded during April in T₀ and lowest during February in T₁. This range is within the tolerance limit for catla (Ayyappan and Jena, 2003). The highest temperature was found in T₀ during April as there is minimum water exchange (one time in 48 h) and the lowest temperature was recorded in T₁ during February (water exchange 4 times in a day) due to the addition of large quantity of low temperature water from the source. Bregnballe (2015) suggested that inlet water influences the water temperature in recirculating aquaculture system. The mean value of conductivity ranged from 271 to 384.3 µS cm⁻¹. The lowest conductivity was recorded in the month of November in T₂ and the highest during April in T₀. The higher values of conductivity recorded in T₀ and T₃ treatments could be due to increase in the concentration of dissolved inorganic compounds that contributes ions and salts (Lahora, 2003). The findings of Sinha *et al.* (2013) revealed that higher electric conductivity values indicate presence of higher concentration of dissolved salts in water. The concentration of total dissolved solids ranged from 216.3 to 274 mg l⁻¹. The highest value of TDS was recorded in the month of February in T₂ while lowest value was observed in the month of November in T₁. Fluctuations in the TDS are mainly due to the variation in the ionic composition of water (Gupta and Paul, 2013).

During the study period, the mean DO ranged from 5.4 to 7.9 mg l⁻¹ with the highest value observed during the month of April in T₁ and T₂ while the lowest value recorded in the month of January in control. DO levels affect the solubility and availability of many nutrients in aquatic ecosystems. DO values higher than 5 mg l⁻¹ have often been recommended for intensive culture practices (Santhosh and Singh, 2007). Ridha and Cruz (2001) reported that a DO range of 5.9 to 6.9 mg l⁻¹ in RAS is suitable for proper growth of fishes. Jagadeesh *et al.* (2013) recorded 6.93 to 7.80 mg l⁻¹ dissolved oxygen

Table 2. Water quality parameters recorded during experimental period

Parameter	Mean±SD	Mean±SD	Mean±SD	Mean±SD	F value	F _{crit}
Temperature (°C)	22.3 ± 0.29	21.5 ± 0.26	21.7 ± 0.18	21.9 ± 0.24	0.3981	2.703
Electrical conductivity (µS cm ⁻¹)	344.8 ± 10.0	338.5 ± 13.5	345.6 ± 12.8	345.6 ± 6.8	0.7977	
Total dissolved solids (mg l ⁻¹)	238.6 ± 9.8	240.5 ± 11.7	249.3 ± 9.7	248.1 ± 8.4	5.7532	
Dissolved oxygen (mg l ⁻¹)	6.4 ± 0.39	7.2 ± 0.57	7.2 ± 0.45	7.1 ± 0.17	23.428	
Carbon dioxide (mg l ⁻¹)	2.4 ± 0.27	2.4 ± 0.29	2.1 ± 0.17	2.2 ± 0.07	9.4155	
pH	7.6 ± 0.22	7.6 ± 0.31	7.9 ± 0.17	7.6 ± 0.08	10.832	
Alkalinity (mg l ⁻¹)	147 ± 8.3	151.8 ± 14.0	153.4 ± 10.1	138.6 ± 9.8	8.8242	
Hardness (mg l ⁻¹)	163.8 ± 16.14	159.6 ± 18.9	175.6 ± 22.9	175.6 ± 15.9	1.2984	
Ammonia-nitrogen (mg l ⁻¹)	0.06 ± 0.011	0.02 ± 0.008	0.03 ± 0.007	0.04 ± 0.014	53.839	
Nitrate (mg l ⁻¹)	0.40 ± 0.01	0.25 ± 0.15	0.21 ± 0.19	0.33 ± 0.06	31.941	
Phosphate (mg l ⁻¹)	0.07 ± 0.009	0.02 ± 0.007	0.05 ± 0.007	0.06 ± 0.006	173.96	

content during their study and suggested that this range is adequate and suitable for the optimum growth of *Labeo rohita* in RAS. The values of free CO₂ ranged between 1.8 to 3.0 mg l⁻¹. The highest value of free CO₂ was observed in the month of January and March in T₀, while the lowest value was found in the month of December in T₂. The CO₂ concentration was slightly higher in T₀ which could be due to lower oxygen concentration, minimum water exchange and deposition of organic matter. The difference in CO₂ concentration in different experimental tanks may be attributed to the different metabolic rates of the fish in the RAS which is also observed by Molleda (2007). The outcome of our study is almost similar to the earlier findings of Martins *et al.* (2009a). They recorded free CO₂ in the range of 0.20 to 2.60 mg l⁻¹ and found to be safe for culture of fish in RAS. Jagadeesh *et al.* (2007) recorded a free CO₂ range from 0.99 to 2.84 mg l⁻¹ in their study and consider it as acceptable for optimum growth of *L. rohita* in RAS.

During the present study, pH ranged from 7.2 to 8.4 in different trials. The highest value of pH recorded was in the month of April in T₃ and lowest in the month of November in T₁ and T₃. pH values recorded during the study period were found to be significantly different (p<0.05) between treatments. It was higher in T₀ as compared to other treatment groups, due to the fluctuation in CO₂ levels. Bocioc *et al.* (2002) suggested that the optimum pH for fish growth in RAS is 7 to 8. Optimum pH level for carp culture is 7.5 to 8.5 (Ayyappan, 2011). Martins *et al.* (2009a) recorded pH range 6.9-7.8 as safe level for fish culture in RAS. However, results of the present investigation was found different from earlier findings of Shnel *et al.* (2002) that pH value ranged between 6.1 and 7.6 in RAS. The total alkalinity ranged from 118 to 167.3 mg l⁻¹ during the trial period. The maximum alkalinity was recorded in the month of January in T₂ and minimum in the month of November in T₃ treatment. However, the difference in total alkalinity values recorded during the

experimental period were found to be not statistically significant between treatments (p>0.05). Jagadeesh *et al.* (2007) in their study recorded total alkalinity values in the range 80.33 to 130.33 mg l⁻¹ and it was suggested as acceptable range for culture of *L. rohita* in RAS. The results of present investigation is similar to the earlier findings of Martins *et al.* (2009a) who found it in the range of 128.84 to 142.38 mg l⁻¹ which is safe for culture of fish in RAS. The values of hardness ranged from 133.3 to 241.6 mg l⁻¹ during the experimental period. The highest value was observed in the month of February in T₃ while lowest value was obtained in the month of March and April in T₁. The value of hardness recorded during the experimental period is similar to the finding of Santhosh and Singh (2007). The recommended minimum value of hardness for fish culture is 20 mg l⁻¹ (Swann, 1997) and a range of 30 -180 mg l⁻¹ is most favourable (Santhosh and Singh, 2007). The amount of ammonia-nitrogen ranged from 0.02 to 0.08 mg l⁻¹ during the experimental period. The highest value of ammonia was observed in the month of March in T₀ while lowest value in the month of November, December, February, March and April in T₁. Ammonia concentration was found slightly higher in T₀ as compared to the other treatments due to less water exchange which results in accumulation of excretory products. In other treatments, water flow rate was higher with proper aeration and so less concentration of ammonia was recorded. The permissible limit of ammonia concentration for aquatic organisms is 0.1 mg l⁻¹ (Meade, 1985; Santhosh and Singh, 2007). Bhatnagar and Devi (2013) recommended a level of <0.2 mg l⁻¹ of ammonia as suitable for culture of fishes in freshwater ponds. The values of ammonia concentration recorded in the present investigation is below the tolerance limit of carps (Das *et al.*, 1995; Jena *et al.*, 2007) and is not in agreement with the earlier findings of Jagadeesh *et al.* (2007) who recorded NH₃-N concentration in the range from 0.032 to 0.280 mg l⁻¹. The highest value (0.42 mg l⁻¹) of nitrate was observed in the month of April in T₀ treatment while lowest value (0.11 mg l⁻¹) in the month of December in T₁ treatment. According to Timmons *et al.* (2002) NO₃-N is

considered as the minimum toxic nitrogen product. The value of nitrate was found higher in T_0 treatment compared to other treatments due to minimum water exchange. Santhosh and Singh (2007) suggested that 0.1 to 4.0 mg l⁻¹ concentration is the favourable range of nitrate for fish culture. Results of our study are in accordance with the earlier findings of Atse *et al.* (2009) who found that the nitrate range of 0.12 to 0.20 mg l⁻¹ is safe for fish production in RAS. During the experimental period, phosphate was found in the range of 0.02 - 0.08 mg l⁻¹. The highest value of phosphate was observed in the month of November-March in T_0 while the lowest value was observed in the month of November, December, January, February and April in T_1 . The lower values of phosphate were observed in T_1 treatment where water flow rate was high (four times in a day) and higher level of phosphate was found in T_0 due to minimum water exchange. Phosphate level of 0.06 mg l⁻¹ is desirable for fish culture (Stone and Thomforde, 2004). Bhatnagar and Devi (2013) suggested that phosphate concentration of 0.05-0.07 mg l⁻¹ is optimum for fish production. The results of our study contradicts the earlier findings of Martin *et al.* (2009a) who found that phosphate range of 0.47 to 1.21 mg l⁻¹ is safe for fish production in RAS.

Values of water temperature, electrical conductivity and hardness in different treatment tanks recorded during the study period were not significantly different ($p>0.05$). Whereas, total dissolved solids, dissolved oxygen, free CO₂, pH, alkalinity, ammonia-nitrogen, nitrate and phosphate in different treatment groups showed significant difference ($p<0.05$) between treatments.

The growth performance of experimental fish tested under different water flow treatments is presented in Table 3. On termination of the experiment, the final weight was found in the range of 339.3 to 425.3 g. The net weight gain during the experimental period ranged from 329.7-416.2 g in different experimental tanks which was found to be

significantly different ($p<0.05$) in different treatments. The highest growth of fish was found in the T_2 while lowest growth was recorded in T_0 treatment (control). It may be due to higher accumulation of organic materials, low DO, high CO₂ and water temperature fluctuation owing to less water exchange, which had negative impact on fish growth. Lower growth in the fishes of T_1 (water exchange 4 times a day) compared to T_2 (water exchange 2 times a day) may be due to stress from high water flow. Water quality improvement in RAS may increase feed intake rates and increase in growth of the fish. RAS provides optimal environmental conditions all year round with low ammonia and free CO₂ concentrations compared to other culture systems, contributing to fish welfare and improved FCR leading to better feed conversion efficiency (Losordo, 1998; Roque d'Orbcastel, 2008).

The highest FCR was found in the fishes of T_2 treatment which was significantly different from T_0 , T_1 and T_3 ($p<0.05$). The result revealed that the best FCR was recorded in T_0 (1.61) fishes followed by T_3 (1.65), T_1 (1.70) and T_2 (1.81) (Table 3). Ideal levels of nitrate and phosphate in T_0 tanks may be due to negligible water exchange and optimum quantity of other required parameters (free CO₂, pH and light) which facilitated growth of additional natural food leading to better FCR in control trial as compared to others. Lin *et al.* (2003) have reported a lower FCR in a RAS (1.65) than in culture pond (2.25). The results of our study are in accordance with the earlier findings of Zhang *et al.* (2009) who found FCR range of 1.54 to 1.84 in different treatment groups during fish production in RAS.

The value of specific growth rate (SGR) is used to compare growth on a daily basis. The significantly higher growth rate and SGR indicate the effective role of feed in the growth performance. The highest SGR (0.88%) was recorded in treatment T_2 (with water exchange two times in a day) after 180 days of the experiment but

Table 3. Growth performance of catla during the experimental period

Treatment	Initial weight (g)	Final weight (g)	Net weight gain (g)	Mean weight gain±SD (g)	Survival (%)	FCR	SGR (% per day)	PER
T_0 A	11.2	342.5	331.3					
T_0 B	9.2	347.2	338.0	333±4.40	78.93±0.48	1.61±0.01	0.84±0.02	2.62±0.02
T_0 C	9.6	339.3	329.7					
T_1 A	9.6	383.8	374.2					
T_1 B	9.3	385.6	376.3	375.6±1.27	82.33±0.48	1.70±0.00	0.86±0.02	2.56±0.01
T_1 C	11.1	387.6	376.5					
T_2 A	9.4	405.8	396.4					
T_2 B	9.1	425.3	416.2	404.3±9.96	81.67±0.48	1.81±0.08	0.88±0.03	2.31±0.04
T_2 C	11.5	415.8	404.3					
T_3 A	9.4	363.6	354.2					
T_3 B	10.5	359.6	349.1	351.6±2.55	80.67±0.48	1.65±0.02	0.85±0.01	2.54±0.01
T_3 C	10.1	361.7	351.6					

this was not significantly different ($p > 0.05$) from other treatments (Table 3). The results revealed that the best SGR was recorded in T₂ (0.88%) followed by T₁ (0.86%), T₃ (0.85%) and T₀ (0.84%). Enache *et al.* (2011) reported SGR range of 1.28% to 1.49% in different treatment groups during carp production in RAS. The SGR observed in the present investigation are less than the findings of Enache *et al.* (2011). The lesser value of SGR in the production of *C. atla* may be due to lower water temperature as it affects the growth directly.

Protein is the vital and expensive nutrient of formulated fish feeds (De Silva *et al.*, 1989). The results of the present study revealed that the best protein efficiency ratio (PER) was recorded in T₂ (2.31) followed by T₃ (2.54), T₁ (2.56) and T₀ (2.62) after 180 days of the experiment (Table 3) but the difference were not statistically significant ($p > 0.05$). Singh *et al.* (2011) reported PER range of 1.11 to 2.24 in different treatment groups during carp production. Higher value of PER recorded in the present study, than the findings of Singh *et al.* (2011) could be attributed to less protein content (28%) in the feed.

A significant effect of water flow rates was observed on growth parameters of the experimental fish during the present study. The water flow in recirculation aquaculture system was found to result in better water quality with minimum variation in the values of different water quality parameters *viz.*, temperature, pH, total dissolve solids, DO and conductivity. compared to the control. The physico-chemical parameters of water in RAS were within the permissible limit suitable for the growth of catla. Results of the present study indicates that feed utilisation and growth performance are better in flowing environment of RAS. Water flow rate of 333 l h⁻¹ (*i.e.*, two times in a day) was found most favourable for the growth of the experimental fish. As compared to the control, the survival was more in the treatment tanks (Table 3) where sufficient water flow was available. The study concludes that the water exchange aquaculture system where the water is reused after suitable treatment is more suitable for intensive farming of *C. catla*.

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