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Original Research Article

Effects of silver carp (*Hypophthalmichthys molitrix*) inclusion on reduction of off-flavour producing cyanobacteria from walking catfish (*Clarias batrachus*) grown in ponds

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ABSTRACT

This study was conducted to reduce the off-flavour producing cyanobacteria by introducing silver carp species, to monitor water quality, fish growth, yield and finally to analyze the benefit from *Clarias batrachus* culture. Three different treatments of silver carp inclusion were tested in walking catfish farming (stocking density of 123500 fishes/ha) under three treatments (T_1: control, with no inclusion; T_2: inclusion @ 1482 fishes/ha; and T_3: inclusion @ 988 fishes/ha), each with three replications. Catfish seeds were introduced from hatchery and were grown for a period of six months from July-December 2023 with commercial feed containing 35% protein. Significant variation ($p<0.05$) in water quality parameters were observed such as dissolve oxygen (5.28 $\pm$ .02 to 6.08 $\pm$ 0.02 mg/l), ammonia nitrogen (0.06 $\pm$ .00 to 0.02 $\pm$ 0.00 mg/l), pH (7.45 $\pm$ 0.02 to7.65 $\pm$ 0.02), transparency (28.67 $\pm$ 0.33 to 34.67 $\pm$ 0.33 cm), alkalinity (108.00 $\pm$ 1.15 to 117.33 $\pm$ 2.02 mg/l) and total dissolve solids (629.67 $\pm$ 0.67 to 653.33 $\pm$ 1.45 mg/l). While temperature was within the suitable range of fish culture. Mean highest amount of cyanobacteria was found in T_1(107672.23 $\pm$ 17783.63 cells/l) that was 11% higher and lowest inT_2 (49583.33 $\pm$ 12269.82 cells/l). Growth performance was higher in T_2 (final wt: 105.05 $\pm$ 0.05 g; SGR:2.29%) and lowest in T_1 (final wt:104.41 $\pm$ 0.04g; SGR: 2.28%). The survival rate varied from 79% to 84% during the study period. The highest benefit found in T_2(1270633.7 $\pm$ 13480.05 BDT/ha) and lowest in T_1(1083516.7 $\pm$ 19197.6 BDT/ha). This finding suggest that highest cyanobacterial growth reduces the water quality and increases the chances of off-flavour but inclusion 1482 fishes/ha can reduce the cyanobacterial growth and chances of off-flavour.

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INTRODUCTION

Aquaculture is the rapidly developing food generating sector across the globe and is continuously evolving throughout the world (Langer *et al*., 2026). With the increase in global population, the demand for the aquaculture resources is also rising. Global aquaculture reached a record 130.9 million tons, up 8.1 million tons from the 122.8 million tons documented in 2020 (FAO, 2024). Bangladesh, currently ranked third globally in aquaculture, has been witnessing an impressive annual growth rate of about 45% in fish production (Moller *et al*., 2023), while concurrently encountering similar challenges in the industry. Aquaculture is projected to play a key role in doubling fish production to meet future demand and in achieving the goals of a Smart Bangladesh by 2041 (DoF, 2024). Aquaculture includes the culture of numerous species such as shellfishes, finfishes, molluscs, and other organisms. Among them (*Clarias batrachus*) commonly known as walking catfish is a promising aquaculture species due to its high growth rate, hardiness, good taste and nutritional value, high market demand and has tremendous popularity among consumers (Hossain *et al.*, 2006). *Clarias batrachus* is threatened species and is becoming critically endangered. Devastation of natural habitats and uncontrolled introduction of alien species are responsible for reducing *Clarias batrachus* (Ahmad *et al.*, 2012). As a food fish, this species can easily digestible, it also contains a high grade protein, high concentration of iron and beneficial lipid content that may be instrumental towards its high acceptance as medicinal fish. The fish is a valuable and protein-dense food source that plays a crucial part in fulfilling the nutritional requirements of the Bangladeshi population (Ali *et al.*, 2013). Seasonal ponds under the drought prone area can potentially be used for farming of such nutrient rich high values species. Now a day under intensive and semi intensive systems off-flavor compounds are identified that create muddy or musty flavour in fishes. A musty/muddy flavor can develop in walking catfish due to the type of feed used and environmental factors such as water temperature and oxygen levels. Unfortunately, high feed cost and off-flavor problems in feed based intensive system are considered major constraints for its further promotion for farming. Off-flavour reduces the demand of consumer and market price of fish (Rahman *et al.*, 2021). To solve the problem inclusion of silver carp is a proven technique to improve the quality of pond water through controlling bloom of algae and to improve the organoleptic quality of fish (Hossain *et al.*, 2023). In Bangladesh, there are several efforts to explore the aquaculture of walking catfish with focus on stocking density (Samad & Imteazzaman, 2019), dietary vitamin (Islam *et al.*, 2019; Caesar *et al.*, 2021) and feeding frequency (Reza *et al.*, 2021) but no comprehensive studies are found on off-flavor mitigation measures. Based on these arguments and evidences, present effort is taken to study the inclusion effects of silver carp on reduction of off-flavour of walking catfish raised in ponds under drought prone area. The specific objectives were to monitor the water quality, phytoplankton density, to evaluate the fish production and economics and finally, to recommend suitable strategy for off-flavour mitigation in walking catfish raised in pond.

MATERIALS AND METHODS

Study location and duration

The study was carried out in nine farmer managed ponds for a period of six months from July to December 2023(mean area of 0.03 ± 0.00ha and depth of 1.48 ± 0.03m) located at Harian of Paba Upazila under Rajshahi district of Bangladesh and spreads from 24°23N to 28.3"N and 88°28"E to 88°43"E.

Experimental design

The current experiment was conducted with three different treatments of silver carp inclusion (T_1: no inclusion, T_2: inclusion 1482 fishes/ha, T_3: inclusion 988 fishes/ha) each with three replications. Stocking densities for walking catfish (123500 fishes/ha) were same for all treatments. Experiment layout is shown in Table 1.

Table 1. Mean water area and depth of experimental ponds under different treatments.

Pond profile	Treatments			F value	P value
	T_1	T_2	T_3		
Area (ha)	$0.03 \pm .002^a$	$0.03 \pm .003^a$	$0.03 \pm .001^a$	0.27	0.77
Depth (m)	$1.48 \pm .03^a$	$1.48 \pm .02^a$	$1.49 \pm .03^a$	0.11	0.90

Figure in a row bearing common letter (s) do not differ significantly (p>0.05)

Pond management

Aquatic weeds were removed manually from all the experimental ponds. Predatory and unwanted fishes were also removed through repeated netting. Liming was done at the rate of 250 kg/ha. After three days of liming, basal fertilization was done by using inorganic fertilizer like urea and triple super phosphate, TSP (each @ 40 kg/ha) in the experimental ponds to increase the natural food. All the ponds were stocked with hatchery produced healthy fish seeds in morning between 6:00 and 7:00 am after five days of basal fertilization. Periodic fertilization was not done except regular liming (50kg/ha/fortnight) for all ponds. Commercial feed containing (35% protein content) was given initially at 15% of body weight for first two months and then gradually reduces to 10% of body weight and finally 8% at the month of November and December. Feed was given in two times, in morning and in afternoon.

Fish pond water quality monitoring

Water quality was monitored fortnightly between 9am and 10 am. Water temperature was recorded with a Celsius thermometer at 20-30 cm below the water surface. Black and white coded Secchi disk was used to measure the water transparency (cm). HACH kit (FF2, USA) was used to determine the Alkalinity(mg/l) and ammonia-nitrogen. Dissolve oxygen (mg/l), TDS (mg/l) and pH were analyzed by using a Multimeter (HQ 40 D, HACH, USA). Phytoplankton was determined using the key after (Ward and Whipple, 1959), Prescott (1962) and Bellinger (1992) and their concentration (cells/L) in water was determined with the help of a microscope after Stirling (1985) as follows-

$$N = \frac{A \times 1000 \times C}{V \times F \times L} \quad (1)$$

Where, N = No. of plankton cells or units per liter of original water; A = Total No. of plankton counted; C= Volume of final concentrate of the samples in ml; V = Volume of a field in cubic mm; F = No. of fields counted; L = Volume of original water in liters.

Monitoring of fish growth

Fishes were sampled monthly intervals to monitor the growth performance and to adjust the feeding ration. In each sampling date, a cast net was used to collect 10% of the stocked fishes from each pond. The fishes were then placed in a digital weight machine for taking weight with an accuracy of 0.01 g and released immediately into ponds without causing any apparent harm to the fish. Growth and yield of fishes were calculated as follows-

Initial weight (g)= Weight of fish at stock

Final weight (g) =Weight of fish at harvest

Weight gain (g) = Mean final weight (g) – Mean initial weight (g)

$$\text{Specific growth rate (SGR\%, bw/d)} = \frac{\ln(\text{final weight}) - \ln(\text{initial weight})}{\text{Culture period}} \times 100 \quad (2)$$

$$\text{Survival rate} = \frac{\text{No. of fish harvested}}{\text{No. of fish stocked}} \times 100 \quad (3)$$

Yield (kg/ha) =Fish biomass at harvest – Fish biomass at stock

Economics of fish farming

Simple cost-benefit analysis was done to explore the economics of walking catfish culture with various treatments. Data on both fixed and variable costs were noted to identity the total cost (BDT/ha/180 days). Total return estimated from the market value of fish was expressed as BDT/ha/180 days. Net benefit calculated by deducting the total return from total cost was expressed as BDT/ha/180 days. CBR (Cost Benefit Ratio) was calculated as follows:

CBR = Net benefit/ Total cost

Statistical analysis

All the collected data during experiment were analyzed statistically by one-way analysis of variance (ANOVA) using SPSS statistical program (version-21). Significant difference between mean values was analyzed by Duncan's Multiple Ranges Test (DMRT) at significance level of 0.05.

RESULTS AND DISCUSSION

Fish pond water quality

The average measurement of environmental parameters under different treatments presented in (Table 2). Statistical analysis showed no significant differences in temperature under different treatments. Temperature varied from 32.04 ± 0.02 to 25.70 ± .02 °C (T_2). Rahman *et al.* (2021) studied on off flavour in pangasius ponds and recorded highest temperature in Trishal upazila (27.7 ± 0.6°C) and lowest in Sadar upazila (24.7 ± 1.0°C). At the starting of experiment, the transparency in control pond was higher but gradually the transparency reduces due to higher phytoplankton concentration in control ponds. The mean water transparency varied from 24.00 ± 1.15 to 28.66 ± 1.15 cm (T_1) and 29.66 ± 0.58 to 35.67 ± 0.33 cm (T_2). Dissolve oxygen concentration was also higher in control ponds at initial stage but dissolve oxygen gradually reduces due to phytoplankton bloom in control ponds. DO concentration vary from 5.34 ± .01 to 5.61 ± .02 mg/l (T_1) and 5.28 ± .01 to 6.11 ± .02 mg/l (T_2). During culture period Rahman *et al.* (2021) found DO level 2.5 to 5.8mg/l in different culture ponds. Islam *et al.* (2021) who recorded DO range from 5.65 ± 1.07 to 7.36 ± 0.32 mg/L that was similar with present findings. Sharmeen & Hussain (2008), recorded dissolved oxygen concentration higher during winter and lower in summer due to fluctuation in water temperature. The pH values ranged from 7.46 ± .02 to 7.64 ± 0.04 (T_1) and 7.45 ± .02 to 7.57 ± .01 (T_2) that was aligning with Hossain *et al.* (2020) who recorded fluctuation in pH between a near neutral to alkaline range in fish culture pond. Caeser *et al.* (2021) recorded pH in Tuban Regency ranged from 6.99 to 7.59. Alkalinity is an important factor for controlling pH and buffering that varied from 110.67 ± 1.15 to 117.33 ± 2.02 mg/l (T_1) and 111.33 ± 1.15 to 114.00 ± 2.0 mg/l (T_2). Ammonium-nitrogen (NH_3) concentration was higher in control ponds due to plankton decomposition (Figure 2) and varied from 0.01 ± .00 to 0.06 ± .00 mg/l (T_1) and 0.01 ± .00 to 0.03 ± .0.01mg/l (T2). Abedin *et al.* (2017) recorded the ammonia 0 to 5 mg/l and pH 6.8 to 7.4 for pangus culture. Total dissolve solid (TDS) varied from 642.67 ± 1.52 to 653.33 ± 1.15 mg/l (T_1) and 639.67 ± 1.00 to 640.67 ± 15.01mg/l (T_2) respectively. Rana & Jain (2017) found that fish do not appear to be affected by standard concentrations of TDS of 2000 mg/l. Hossain *et al.* (2023) studied that silver carp can improve the water quality by controlling algal bloom and improve organoleptic quality of fish. Talukder *et al.* (2018) and Hossain (2011), recorded the water quality parameters that was more or less similar with the present findings, who also conducted their research on Barind area of Bangladesh. Present findings suggest that the water quality like ammonia, transparency, dissolve oxygen, total dissolve solid was in better condition compared to control pond as silver carp controls the phytoplankton and maintains water quality. As a result, it also reduces the risk of off-flavour compared to control pond.

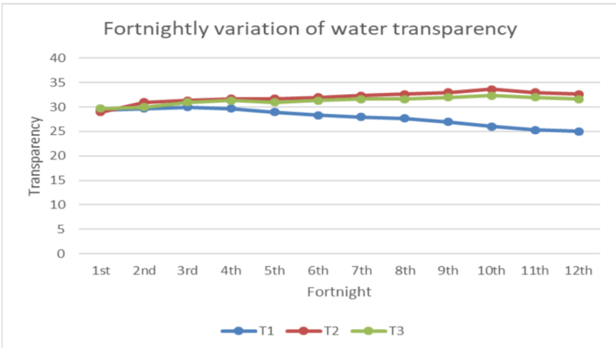

Figure 1. *Variation of water transparency under different treatments of silver carp inclusion and reduction of off-flavour.*

Table 2. Mean variation in physico-chemical parameters under different treatments.

Parameters	Treatments			F value	*p* value
	T_1	T_2	T_3		
Temperature(°C)	31.23 ± .02^a	31.17 ± .02^b	31.19 ± .01^b	2.76	0.14
Transparency (cm)	28.35 ± 1.03^c	32.30 ± 1.72^a	30.34 ± 1.22^b	4.07	0.07
DO (mg/l)	5.49 ± .03^a	5.55 ± .02^c	5.52 ± .03^b	4.06	0.07
pH	7.57 ± .00^b	7.58 ± .00^a	7.57 ± .00^a	2.60	0.15
Alkalinity (mg/l)	109.95 ± .20^b	115.58 ± 2.94^a	112.56 ± 1.83^b	1.98	0.21
NH 3 -N (mg/l)	.04 ± .00^c	.02 ± .00^a	.03 ± .00^b	4.33	0.06
TDS (mg/l)	650.58 ± 3.14^b	645.31 ± 2.02^a	647.31 ± 1.66^b	3.97	0.08

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Qualitative and quantitative status of phytoplankton

During study period total of 7 phytoplankton groups in which 4 species of Cyanophyceae,7 species of Chlorophyceae, 3 species of Bacillariophyceae and 3 species of Euglenophyceae were identified. Monthly cyanobacterial variation presented (Figure 3) and mean phytoplankton variation presented (Table 3). During study period cyanobacterial abundance was found higher compared to the other groups of phytoplankton. Cyanobacteria are most dominant group that create toxic algal blooms in freshwater ecosystems. Certain species of cyanobacteria can produce toxic substances (cyanotoxins) and several secondary metabolites (e.g., geosmin, 2-methylisoborneol, and β-ionone) (Devi *et al.*, 2021). During culture period the cyanophyceae was found more dominant at August which causes bloom in control pond (T_1). The major factors for phytoplankton blooms was rapid multiplication of cells due to high amount of nutrients, high temperature, bright sunlight, high ammonia and pH that supports bloom. *Microcystis* sp. and *Anabaena* sp. were the dominant genera among the blue-green algae cyanobacterial species of *Anabaena* (Tucker, 2000) which causes off-flavour in fish. (Podduturi *et al.*, 2020) also stated that off-flavor in outdoor aquatic systems is mainly attributed to Cyanobacteria. Auffret *et al.* (2011) also described that MIB and Geosmin are produced by certain species of cyanobacteria (e.g., Anabaena, *Raphidiopsis raciborskii*, *Aphanizomenon tropicalis*, and *Microcystis* sp.). The highest abundances of cyanophyceae was found in control pond 172677.67 $\pm$ 15376.75 cells/l in (T_1) in August 2023 shown. It shows that it has a great chance of off-flavour production as Anabaena, microcystes and aphanizomenon were the most dominant species. Similar observations were found by (Affan *et al.*, 2005). Mean cyanobacterial abundance was low 56583.33 $\pm$ 12269.82 cells/ml in (T_2) and moderate 62472.22 $\pm$ 10673.64 cells/l in (T_3), respectively. Inclusion of silver carp is a proven technique to improve the water quality through controlling algal bloom and to improve the organoleptic quality of fish (Hossain *et al.*, 2023). Present findings suggest that the off-flavour producing cyanobacteria was higher in control ponds that increases the chances of off-flavour production in control pond compared to silver carp inclusion ponds.

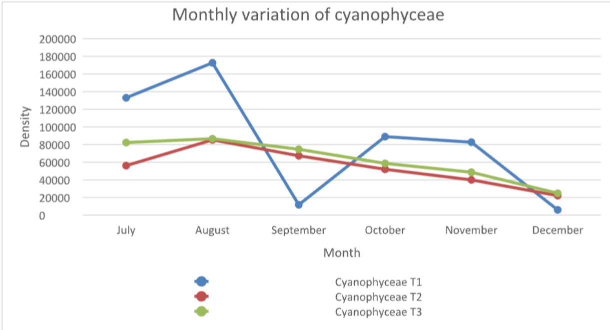

Figure 2. *Monthly variation of cyanophyceae under different treatments of silver carp inclusion and off- flavor reduction.*

Table 3. Mean concentration of phytoplankton under different treatments.

Groups of phytoplankton	Treatments			F value	*p* value
	T_1	T_2	T_3		
Cyanophyceae	107672.23 $\pm$ 17783.63^b (34.08%)	49583.33 $\pm$ 12269.82^a (31.29%)	58472.22 $\pm$ 10673.64^{ab} (32.10%)	4.04	0.08
Chlorophyceae	99666.66 $\pm$ 509.17^b (31.54%)	51888.89 $\pm$ 19803.74^a (32.75%)	56777.78 $\pm$ 16075.44^{ab} (31.17%)	3.07	0.12
Bacillariophyceae	62555.56 $\pm$ 11308.11^b (19.79%)	27222.22 $\pm$ 8557.18^a (17.18%)	33333.34 $\pm$ 8022.54^{ab} (18.30%)	4.22	0.07
Euglenophyceae	47750.00 $\pm$ 6285.45^b (15.11%)	28000.00 $\pm$ 8681.07^a (17.68%)	30166.67 $\pm$ 7088.72^{ab} (16.56%)	3.66	0.09
Total phytoplankton	315922.20 $\pm$ 46232.59^b	158361.13 $\pm$ 42979.93^a	182138.90 $\pm$ 38404.27003^{ab}	3.96	0.08

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Fish growth and yield

The mean variation of fish growth and yield among different treatments of silver carp inclusion and off-flavour reduction presented (Tables 4 and 5) while monthly variation presented (Figure 3). Mean higher values of final weight found from105.05 $\pm$ 0.05 g (T_2) and 104.65 $\pm$ 0.05 g (T_3), respectively. Whereas the lower values (p<0.05) of final weight recorded 104.41 $\pm$ 0.04 g in (T_1). Jousy *et al.* (2018) studied on magur culture reared both in monoculture and polyculture and found monoculture weight at harvest was 146.27 $\pm$ 1.36 g and polyculture 137.33 $\pm$ 2.28 g (p<0.05) that was comparatively higher from present findings. Mean weight gain varied from102.70 $\pm$ 0.04 g (T_1), 103.33 $\pm$ 0.07 g (T_2) and 102.94 $\pm$ 0.06 g (T_3) under different treatments. The survival rate also varied under different treatments and ranged from 79% to 84% both in control and silver carp treated ponds. Mian *et al.* (2019), who have reported the survival of pangas ranged between 87 and 93% in their study period that supports to present studies. Chakraborty & Nur (2012) obtained survival rate of *Heteropneustes fossilis* between 67.74 and 90.76% in semi intensive polyculture with *Anabas testudineus* similar with present studies. The specific growth rate (SGR %per day) of fish in different treatments varied during the study period. At initial stage the SGR was higher 3.98 $\pm$ 0.05 (T_2) during summer month and 95 $\pm$ 0.006 (T_2) during winter month that supports to Nabi *et al.* (2020) who found highest value SGR in T_1 (3.36) and T_2(2.76) in early stage of stinging catfish farming in ponds under drought prone area. Higher temperature in summer month enhanced the metabolic activity of fish that ultimately increased the fish growth. The highest average yield obtained as10507.33 $\pm$ 48.08 g in (T_2) and lowest 10146.66 $\pm$ 76.79 g (T_1) (i.e. control pond with high plankton density). Chandra *et al.* (2023) found that Magur (*Clarias batrachus*) in polyculture shows a greater production between 709 Kg to 772 Kg with a mean production of 750 Kg/acre. Present findings suggest that the fish production was higher in T_2 (i.e. silver carp inclusion 1482/ha) compared to others.

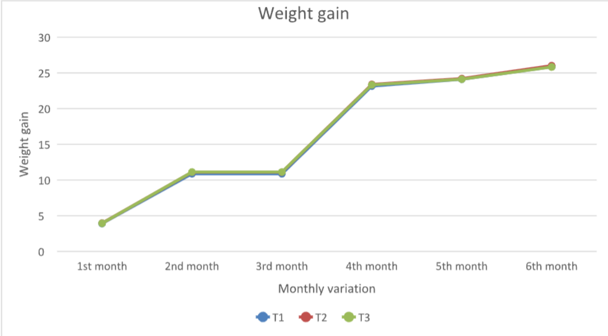

Figure 3. *Weight gain of fish under different treatments of silver carp inclusion and off-flavour reduction.*

Economics of fish farming

Total cost, net benefit and CBR of walking catfish farming under different treatments of silver carp inclusion presented (Table 6). In the present study, total cost varied significantly ($p< 0.05$) among the treatments. The mean total cost varied from 1449816.67 ± 20275.87 (T_1) to1505020.00 ± 1732.05 (T_2). Seed cost and feed cost which are variable cost in fish production and varied significantly among treatments. The cost of fish production was lower in T_1 (i.e. no silver carp seed used) and higher in T_2 (i.e. silver carp seed price was added). The highest net benefit1270633.7 ± 13480.051BDT/Ha and CBR 1.84 ± 0.02 was obtained from T_2 (i.e. return from silver carp was added) and lowest 1083516.7 ± 19197.62 BDT/Ha and CBR1.75 ± 0.01 in T_1 (i.e. return only from magur). Haque & Mazid (2005) obtained net profit for *Clarias batrachus* ranged from 1,15,047 TK/ha to 2,71,178 TK/ha that was lower from present findings. Chandra *et al.* (2023) recorded total money earned in the composite farming involving IMCs and Clarias was between INR 311510 and INR 351620 with a mean value of INR 330223.33. Hossain *et al.* (2023) analyzed cost-benefit of stinging catfish (*Heteropneustes fossilis*) in a polyculture system and significantly (p<0.05) highest net benefit was recorded in treatment T_2 which was 17.34% and 21.87% higher than the treatments T_1 and T_3, respectively. Present findings suggest that the highest total return, net benefit and CBR obtained from T_2 (i.e. silver carp inclusion1482/ha), and lowest in T_1 (i.e. control pond).

Table 4. Growth of walking catfish under different treatments.

Parameter	Treatments			F- value	*p*-value
	T_1	T_2	T_3		
Initial weight	1.71 ± 0.008^a	1.71 ± 0.018^a	1.72 ± 0.014^a	.130	0.88
Final weight	104.41 ± 0.04^a	105.05 ± 0.05^c	104.65 ± 0.05^b	2.17	0.19
Weight gain	102.70 ± 0.04^a	103.33 ± 0.07^c	102.94 ± 0.06^b	2.16	0.20
SGR	2.28 ± .003^a	2.29 ± 0.005^a	2.28 ± 0.003^a	0.80	0.49
Survival rate	80.00 ± 0.58^a	82.33 ± 0.33^b	81.33 ± 0.33^{ab}	7.40	0.02

Figure in a row bearing common letter (s) do not differ significantly (p>0.05)

Table 5. Fish yield (kg/ha) under different treatments.

Species	Treatments			F value	*p* value
	T_1	T_2	T_3		
Walking catfish	10146.66 ± 76.79^a	10507.33 ± 48.08^b	10339.33 ± 44.71^{ab}	9.57	0.01
Silver carp	0.00	992.13 ± 9.74^b	743.36 ± 23.44^c	1240.68	0.00
All species	10146.67 ± 116.61^a	11499.47 ± 327.38^b	11082.69 ± 193.93^{ab}	9.09	0.01

Figure in a row bearing common letter (s) do not differ significantly (p>0.05)

Table 6. Economics of fish farming under different treatments.

Parameters	Treatments			F value	*p* value
	T_1	T_2	T_3		
Total cost(BDT/ha/6month)	1449816.67 ± 20275.87^a	1505020.00 ± 1732.05^b	1487730.00 ± 6082.76^{ab}	5.30	0.04
Return from magur (BDT/ha/6 month)	2536666.66 ± 19197.62^a	2626833.33 ± 12021.10^b	2584833.33 ± 11176.92^{ab}	9.57	0.01
Return from silver carp (BDT/ha/ 6 month)	0.00	148820.00 ± 1173.94^a	111503.50 ± 12768.83^b	1240.68	0.00
Total return (BDT/ha/6 month)	2536666.7 ± 19197.62^a	2775653.7 ± 13480.05^c	2696337 ± 8836.18^b	70.74	0.00
Net benefit (BDT/ha/6 month)	1083516.7 ± 19197.62^a	270633.7 ± 13480.051^c	1208607 ± 8836.18^b	43.37	0.00
CBR	1.75 ± 0.01^a	1.84 ± 0.02^b	1.81 ± 0.00^b	13.77	0.006

Figure in a row bearing common letter (s) do not differ significantly (p>0.05)

Conclusion

The present study investigated water quality, fish growth and economic analysis, phytoplankton abundance and silver carp inclusion in reduction of off-flavour from *Clarias batrachus*. The higher stocking density 1482 fishes/ha of silver carp in (T_2) showed better result both in maintaining water quality, controlling plankton density, growth, yield and economics than that of control pond (T_1). The present findings show that the cyanobacterial abundance was higher in control ponds throughout the study period that indicated it has a great chance of off-flavour in control pond fishes. The cyanobacterial abundance was 36% initially in silver carp treated ponds which reduces to 20% at the end of experiment in (T_2). From present findings it can be concluded that silver carp inclusion 1482 fishes/Ha can control the cyanobacterial growth and maintains the water quality and thus reduces the chances of off-flavour.

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DECLARATIONS

Authors contribution statement: Conceptualization: M. A. H.; Methodology: S. K.S.; Software and validation: T. P., S. K.S.; and M. M. A. S; Formal analysis and investigation: M. M. A. S.; Resources: M. M. A. S.; Data curation: T.P.; Writing original draft preparation: T.P.; Writing review and editing: M. M.K.; Visualization: T.P.; Supervision: M. A. H.; Project administration: M. A. H.; Funding acquisition: M. A. H. and T.P. All authors have read and agreed to the published version of the manuscript.

Conflicts of interest: The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

Ethics approval: This study was conducted in view of the institutional ethical guidelines and does not harm the human participants.

Consent for publication: All co-authors gave their consent to publish this paper in AAES.

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Supplementary data: No supplementary data is available for the paper.

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Additional information: No additional information is available for this paper.

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