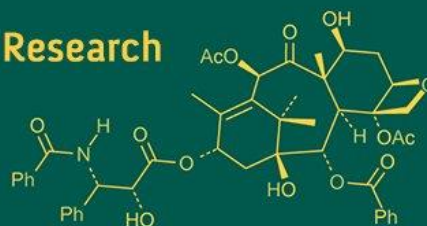
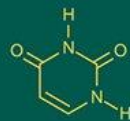
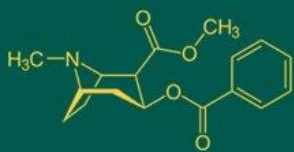


International Journal of Advanced Biochemistry Research



ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2026): 5.29
IJABR 2026; 10(7): 578-587
www.biochemjournal.com
Received: 13-05-2026
Accepted: 15-06-2026

Ediga Arun Goud
College of Fisheries, Shirgaon,
Ratnagiri, Maharashtra, India

Balasaheb Ramdas Chavan
Regional Centre, ICAR-Central
Inland Fisheries Research
Institute, Prayagraj, Uttar
Pradesh, India

Suresh D Naik
College of Fisheries, Shirgaon,
Ratnagiri, Maharashtra, India

SJ Meshram
College of Fisheries, Shirgaon,
Ratnagiri, Maharashtra, India

Harish B Dhamagaye
College of Fisheries, Shirgaon,
Ratnagiri, Maharashtra, India

Bhagchand Chhaba
LSPN College of Fisheries, Dau
Shri Vasudev Chandrakar
Kamdhenu Vishwavidyalaya,
Kawardha, Chhattisgarh,
India

Vaijnath Aitwar
College of Fishery Science,
Narasapuram, Andhra
Pradesh, India

Gora Shiva Prasad
Faculty of Fishery Sciences,
West Bengal University of
Animal and Fishery Sciences
(WBUAFS), Kolkata, West
Bengal, India

Corresponding Author:
Balasaheb Ramdas Chavan
Regional Centre, ICAR-Central
Inland Fisheries Research
Institute, Prayagraj, Uttar
Pradesh, India

Effect of different carbohydrate sources on water quality and growth performance of GIFT tilapia, *Oreochromis niloticus* (Linnaeus, 1758) fry in biofloc system

Ediga Arun Goud, Balasaheb Ramdas Chavan, Suresh D Naik, SJ Meshram, Harish B Dhamagaye, Bhagchand Chhaba, Vaijnath Aitwar and Gora Shiva Prasad

DOI: <https://www.doi.org/10.33545/26174693.2026.v10.i7h.9088>

Abstract

A 90-day experimental study was undertaken to evaluate the effects of different carbohydrate sources within a biofloc technology system on the water quality, growth performance, and survival rate of GIFT fry. Experimental treatments consisted of molasses (T₁), sugar (T₂), and jaggery (T₃), alongside a control group (T₀) without exogenous carbon addition. GIFT tilapia fry with an initial mean length of 4.40±0.03cm were stocked in 100 L circular HDPE tanks at a density of 250 fish m⁻³ following a completely randomized design. The fish were fed a commercial floating diet containing 35% crude protein, according to total body weight. The results indicated that while the overall growth and survival of the fry were not negatively affected by the type of carbohydrate source, significantly ($p<0.05$) superior growth parameters and survival rates were observed in the T₁ (molasses) treatment compared to all other experimental groups. The T₁ (molasses) group achieved a final length of 10.60±0.09cm (144.41±3.47 length gain%), a final weight of 15.80±0.10 g (1360.19±94.08 weight gain%), a specific growth rate of 2.97±0.07%day⁻¹, and a survival% of 91.20±1.49. Regarding water quality, biofloc systems exhibited significantly lower dissolved oxygen (5.44±0.24 mg L⁻¹) and pH (7.48 0.29) than the control. Conversely, the control showed higher ammonia-N (0.28±0.01 mgL⁻¹), whereas the biofloc systems exhibited higher levels of nitrite-N (0.23±0.01 mg L⁻¹) and nitrate-N (5.48±0.05 mgL⁻¹). Consequently, molasses serves as a highly effective carbon source for optimizing GIFT tilapia fry rearing and maintaining stable water quality profiles in indoor biofloc systems.

Keywords: Carbohydrates, biofloc, water quality, tilapia, growth performance

Introduction

Aquaculture additionally called aquafarming, is the farming of fish, crustaceans, molluscs, aquatic plants, algae and other organisms. It's a food manufacturing sector that offers ample opportunities to alleviate hunger, poorness and nutrient deficiency diseases. It additionally generates economic process and ensures higher use of natural resources (FAO, 2026) ^[1]. There is necessity to increase aquaculture production to satisfy the increasing demand per capita and increasing global population. In this world, more than 800 million people still suffer from chronic malnutrition. By 2050, the global population is predicted to grow by another 2 billion to 9.6 billion people. A huge challenge is to safeguard these natural resources for future generations. The development of sustainable aquaculture industry is challenged by the availability of limited natural resources as well as the impact of the industry on the environment. With these limitations in mind, the development of sustainable aquaculture industry should focus on the conceptualization of systems that utilize fewer resources including water, space, energy, capital, and at the same time has lower impact on the environment. One of the strategies to improve aquaculture production and sustainability is to focus on enhancing feed nutrient utilization. This may be developed by two different approaches, i.e. (i) by increasing the feed quality and feeding strategy so that the nutrients can be efficiently delivered and finally utilized and (ii) by re-utilizing the nutrient waste through modifications within the culture system. In an aquatic system, nutrient waste can be removed by various numerous natural biogeochemical processes involving mostly microorganisms with various functions in nutrient cycles.

The nutrient waste in an aquaculture system is mostly the undigested feed and faeces. This nutrient waste can be re-utilized directly by the lower trophic level organisms, which can utilize feed particles as their food source, or indirectly by the conversion of the nutrients into microbial biomass that may eventually be consumed by the cultured animal itself or other animals as their food source.

Biofloc is an environmentally friendly aquaculture technique which is mainly based on the principle of recycling waste nutrients particularly nitrogen into microbial biomass that can be used by the cultured animals or be harvested and processed into feed ingredients (Avnimelech, 2007; Kuhn *et al.*, 2009)^[6, 21]. BFT is considered as a new "blue revolution" because nutrients can be continuously recovered and reused in the medium, which benefits from minimal or zero water exchange. Biofloc plays an important role in nutrient recycling and maintaining water quality. Shrimp or fish consuming biofloculants has shown many benefits, such as increased growth rate, reduced FCR and related feed costs. Microorganisms play a key role in BFT systems mainly heterotrophic bacteria. The main characteristics of this system are high stocking density, heavy mixing, intense aeration, low or no water exchange and high organic matter input (Schveitzer *et al.*, 2013). Mainly these systems are developed to improve the environmental conditions, feed efficiency and immunity (Crab *et al.*, 2012) and to conserve water. The microbiota present in the system can easily take up these nitrogenous by-products, which can serve as a substrate for operating biofloc systems and production of microbial protein cells (Mishra *et al.*, 2008). Heterotrophic microbiota is stimulated to grow by maintaining the C/N ratio in the water by the modification of the carbohydrate content in the feed or by the addition of an external carbon source in the water (Avnimelech, 1999), so that the bacteria can assimilate the waste ammonium for new biomass production. High C:N ratio helps to convert ammonium and organic nitrogenous wastes to bacterial protein biomass (Avnimelech *et al.*, 1994; Avnimelech, 1999; Schneider *et al.*, 2005). Therefore, in biofloc technology, an addition of carbon sources directly to the pond water is done to promote multiplication of heterotrophic bacteria (Crab *et al.*, 2007; Uddin *et al.*, 2007). Hence, ammonium or ammonia can be maintained at a low and non-toxic concentration, and no water exchange is required. On addition of carbon, microorganisms in biofloc use nitrogen for maintenance and multiplication. Carbon source is an important input in the biofloc system that directly affect the growth of total heterotrophic bacteria. Several studies have been conducted to determine the impact of carbon sources such as glucose, acetate and glycerol (De Schryver *et al.*, 2008), wheat flour (Azim & Little, 2008), tapioca starch and maize flour (Asaduzzaman *et al.*, 2010), sucrose (Gao *et al.*, 2012), maize flour (Liu *et al.*, 2014) on development of biofloc and growth of the culture species. The results of these studies showed a similar impact of various carbon sources on biofloc development and growth of culture species^[11, 25, 5, 7, 5, 30, 10, 34, 13, 8, 20, 19, 23, 3].

Tilapia is very suitable for biofloc systems. This filter feeding herbivore adapt to the biofloculants suspended in water and therefore this robust, stable fish can grow and flourish in dense systems. The basic characteristics of biofloc tilapia production system, particularly as compared with the shrimp system, is very high biomass. According to the author's experience, the biomass of tilapia can reach 200-300 metric

tons/ha, whereas shrimp biomass is about 20 metric tons/ha in well-managed pool (Avnimelech, 2011). Tilapia showed a good growth in biofloc systems. Tilapia in the BFT regime showed the highest body weight (BW), the longest body length (BL), the best weight gain (WG) and specific growth rate (SGR) and consumed the highest amount of feed and showed the best feed conversion quantitative relation (FCR) and protein efficiency ratio (PER) compared to the opposite over-wintering regimes and control (Soltan *et al.*, 2015). The role of locally available different carbohydrate sources, on growth, survival and water quality improvement while rearing of GIFT tilapia fry is not known. Hence, the present study was undertaken to evaluate the effect of locally available different carbon sources on rearing of GIFT tilapia fry along with its effect on growth performance, survival and for improvement of water quality^[3, 32].

Materials and methods

Experimental fish and design

Fry of GIFT tilapia were procured from RGCA, Vijayawada, Andhra Pradesh. Experiment was carried out in 100 L circular HDPE containers, covered with net (mesh size 0.5 mm) at the wet laboratory of College of Fisheries, Shirgaon, Ratnagiri, Maharashtra, India. Experimental design was Completely Randomized Design (CRD) with a total of four treatments among them three treatments were of different carbon sources i.e., molasses (T₁), sugar (T₂) and jaggery (T₃) along with a control (T₀), each having five replicates. The fry weighing about 1.19 ± 0.2 g were stocked at 25 number in each tank. The fish were fed with commercial floating feed having 35% dietary protein. Feeding rates were fixed at 10%, 8%, and 4% of the total biomass and adjusted at 30 days intervals after sampling. Daily feed ration was split into three times (40%, 20% and 40%) and fed at 09:30, 13:30 and 17:30 h.

Biofloc Development and C/N ratio

Biofloc was developed in three 500 L capacity tanks as per the method given by Avnimelech (1999) and was maintained at a higher TSS level throughout the experiment which served as source of inoculum for the experimental tanks. At the start of the experiment, 60 L of biofloc and 40 L of freshwater were added to all the experimental tanks. A C/N ratio of approximately 15:1 (Mirzakhani *et al.*, 2019) was maintained according to method described by De Schryver *et al.* (2008)^[5, 24, 13].

Physico-chemical water parameters

Water quality parameters such as temperature (°C), pH, dissolved oxygen (mg L⁻¹), free carbon-dioxide (mg L⁻¹), total alkalinity (mg L⁻¹), total hardness (mg L⁻¹), ammonia-nitrogen (NH₃-N) (mg L⁻¹), nitrite-nitrogen (NO₂-N) (mg L⁻¹), nitrate-nitrogen (NO₃-N) (mg L⁻¹), and total suspended solids (mg L⁻¹) were recorded fortnightly as per the standard methods given by Boyd (1981) and APHA (2005). Floc volume (ml L⁻¹) was measured using Imhoff cone^[9, 1].

Growth parameters

To evaluate the growth and performance of the experimental animals, some parameters were considered. Length and weight of all the fishes were recorded prior to stocking. Growth and survival of all the survived fishes was recorded after every 15 days to the end of the experiment. Length of fry was measured in centimetre using a measuring scale with 0.1 mm accuracy. Gross weight of fry was taken by using

electronic balance (Contech, CT-1501). The total number of survived fishes was counted during each sampling to determine the survival. Length gain (%), weight gain (%), survival (%) and specific growth rate were calculated as follows

Lengthgain (%) = $\frac{\text{Final length} - \text{Initial length}}{\text{Initial length}} \times 100$ (Rahman & Marimuthu, 2010)^[27]

Weightgain (%) = $\frac{\text{Final weight} - \text{Initial weight}}{\text{Initial weight}} \times 100$ (Tolussi *et al.*, 2010)

Survival (%) = $\frac{\text{Total number of survived fishes}}{\text{Initial number of fish}} \times 100$ (Tolussi *et al.*, 2010)^[7]

Specific growth rate = $\frac{\ln W_2 - \ln W_1}{T} \times 100$ (Tolussi *et al.*, 2010)

Where,

- W_2 = Natural log of final weight
- W_1 = Natural log of initial weight
- T = Duration in days

Statistical analysis

All data on length, length gain, weight, weight gain, specific growth rate and survival were analysed by One-way ANOVA. Differences were considered significant at ($p < 0.05$). If difference was found significant, the means were compared by Duncan. The statistical analysis was performed using SPSS 16.0.

Results

Physico-chemical water parameters

The temperature, pH, dissolved oxygen, free carbon dioxide, total alkalinity, and hardness values were within the optimal range throughout the experiment. The water parameters are presented in Table 1. and Figure 1. No significant difference was found among the mean values of all the treatments for temperature, alkalinity and pH. Dissolved oxygen was found lower in T_1 (5.44 mg L^{-1}) and T_2 (5.48 mg L^{-1}) and no significant difference was found between these two treatments and a significant difference was found between T_3 and T_0 , with the highest dissolved oxygen in T_0 (6.04 mg L^{-1}). The highest free CO_2 ($p < 0.05$) was found in T_1 (4.69 mg L^{-1}) when compared to all other treatments. The lowest mean value for hardness was found in T_0 ($p < 0.05$) when compared to other treatments. The mean value of ammonia nitrogen was highest in control (0.28 mg L^{-1}) and no significant difference was found between all the treatments. Lowest mean value of nitrite nitrogen was observed in T_0 (0.18 mg L^{-1}) while highest mean value was found in T_3 (0.23 mg L^{-1}) and no significant difference was found among all the treatments. The mean value of nitrate nitrogen was found significantly lower ($p < 0.05$) in T_0 . Significantly higher ($p < 0.05$) mean value of floc volume and TSS was observed in T_1 (18.23 ml L^{-1} and 267.54 mg L^{-1}) respectively.

Growth parameters

The effect of different carbon sources on the growth performance of GIFT tilapia fry is presented in Table 2. and Figure 2. The final length ($10.60 \pm 0.09 \text{ cm}$), weight ($15.80 \pm 0.10 \text{ g}$), length gain (%) (144.42 ± 3.47), weight gain (%) (1360.20 ± 94.09), specific growth rate (2.97 ± 0.07) and survival (%) (91.20 ± 1.50) are found to be significantly

higher in T_1 followed by T_3 , T_2 and T_0 treatments. No significant difference between T_2 and T_3 were found for final length and lowest ($p > 0.05$) mean value for final length was observed in T_0 . All the treatments showed significant difference ($p < 0.05$) for final weight, while the lowest mean value for final weight were found in T_0 . And for length and weight gain (%) no significant differences were found between T_2 and T_3 and between T_2 and T_0 . For specific growth rate no significant ($p > 0.05$) differences were observed between T_1 and T_3 and between T_2 and T_0 . Significantly less survival was found in T_0 and no significant difference was found between T_3 and T_2 and between T_3 and T_1 .

Discussion

Water Quality Parameters

The results of this study revealed that use of different carbon sources for rearing GIFT tilapia fry in biofloc system affects water quality, growth and survival. Water quality directly affects the well-being of fishes. Water quality parameters crucial for the growth of tilapia remained consistently within optimal physiological thresholds across all biofloc treatments, irrespective of the specific organic carbon input used. The temperature recorded throughout the experimental period was in optimal range for tilapia fry. At the start of the experiment, pH was slightly less than 7.0, it was elevated and maintained above 7.0 by adding alkaline water during water exchange and when required. The pH values were lower as compared to control in biofloc treatments (Rajkumar *et al.*, 2016). The drop in pH was attributed to addition of acid by the activity of nitrifying bacteria in biofloc system (Hargreaves, 2013). In the present study we also observed lower pH in all the experimental tanks except in the control. This may probably be due to the addition of carbon sources into the water, which reduced the pH and increased microbial metabolism for decomposition of organic matter in biofloc treatments. Dissolved oxygen levels in all experimental tanks were maintained near optimal range i.e., above 4.0 mg L^{-1} . The DO level was appropriate because there was a 24h continuous aeration. Highest free CO_2 was found in T_1 which may be because of the respiration of fish and microbes of the biofloc. The total alkalinity in the experimental tanks fluctuated throughout the experimental period. This fluctuation could be due to the acid added by the activity of the nitrifying bacteria in biofloc system (Hargreaves, 2013). In addition, heterotrophic process also consumes alkalinity in biofloc system (Ebeling *et al.*, 2006). The decrease in alkalinity may be the cause for the decrease in pH levels (Hargreaves, 2013). The total alkalinity and total hardness levels as observed in this system were in the optimal range for tilapia fry (de Holanda Cavalcante *et al.*, 2012). The level of ammonia-nitrogen in all experimental tanks increased and reached peak levels on day 45 in T_1 and T_2 and on day 30 in T_3 and T_0 and then decreased till the end of the experiment. The increase in ammonia-nitrogen at the beginning of the culture may be due to less microbial load and their inability to convert the existing ammonia nitrogen into microbial biomass. Increment in the ammonia-nitrogen may be also due to growing biomass, high feeding rate, feed input and excretion of ammonia from fishes. In subsequent periods, ammonia-nitrogen may be used by heterotrophic bacteria, which can reduce ammonia-nitrogen. But the ammonia-nitrogen was within the optimum range (Liu *et al.*, 2018). Fluctuations in $\text{NO}_2\text{-N}$ and $\text{NO}_3\text{-N}$ content were observed

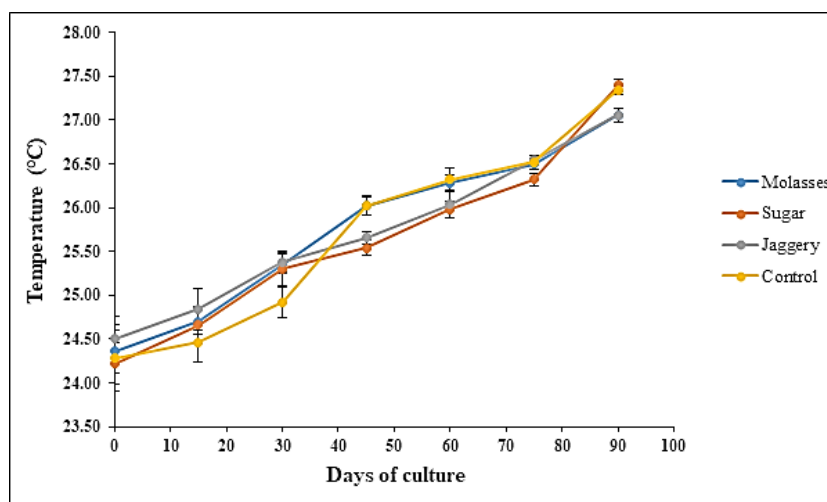
throughout the experimental period. These fluctuations are due to nitrification by nitrifying bacteria and their assimilation by heterotrophic bacteria or occurrence of denitrification in the flocs settled at the bottom of tanks (Kamiliya *et al.*, 2017). The range of nitrite-N and nitrate-N observed in the present study was suitable for culture of tilapia (less than 1 mg L⁻¹ for nitrite and 0.5-20 mg L⁻¹ for nitrate) (Emerciano *et al.*, 2017). The floc volume was observed to be in the favourable range (5 to 25 ml L⁻¹) (Liu *et al.*, 2018). The floc volume increased from the start of the experiment to the end of the experiment. Total suspended solids (TSS) were kept in the range of 129- 352 mg L⁻¹ in the present study. Initially TSS was low which increased with progress in culture period and then it was kept less than 400 mg L⁻¹ (Long *et al.*, 2015). A TSS of 200 - 500 mg L⁻¹ is sufficient for good system functionally and control ammonia without excessive water respiration (Hargreaves, 2013). So, adding carbohydrates helps grow a diverse and balanced bacterial community in the zero-water exchange system. This active bacterial population keeps the water clean and within safe limits for tilapia farming [20, 14, 12, 17].

Growth Parameters: The maximum length was observed in molasses (T₁) at the end of the experiment, while the lowest was observed in control (T₀). Similar results were also obtained in tilapia growth by Rono *et al.* (2018). Molasses was found to be better among the carbohydrates used by Ekasari *et al.* (2014) for shrimp growth. Molasses contains simple soluble sugars (sucrose, glucose, and fructose) paired with more complex organic by-products. This specific chemical matrix ensures a steady, sustainable release of carbon, minimizing the risk of a secondary carbon spike or bacterial starvation between doses and oxygen depletion (Li

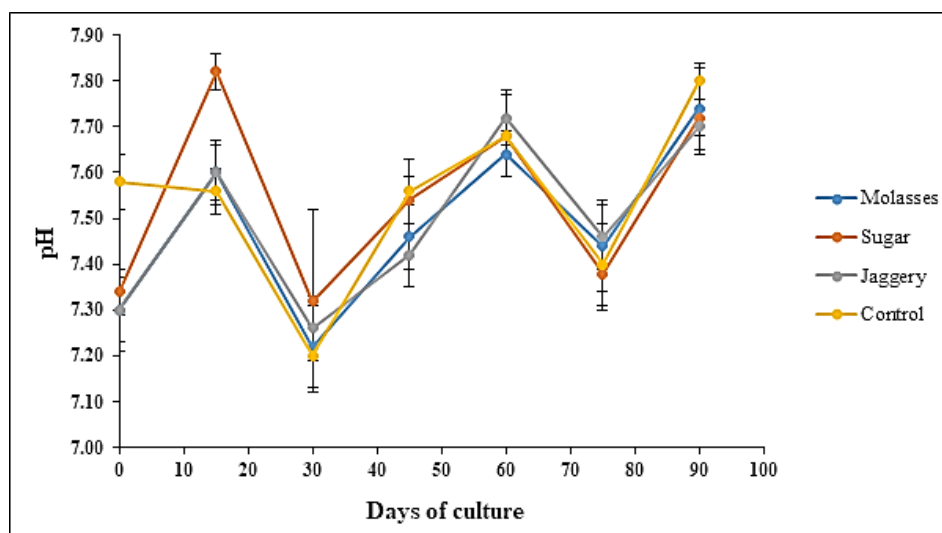
et al., 2023) [29, 15, 22]. Growth performances results showed that biofloc enhances the growth performances of the tilapia juveniles in indoor condition. Azim and Little (2008) also reported the similar findings with different cultured organisms. The higher growth performance in biofloc treatments may be due to high feed intake i.e., both feed and biofloc as compared to control. The maximum length gain (%) was observed in molasses (T₁), while the lowest was observed in control (T₀). Similar results were also obtained in tilapia growth by Rono *et al.* (2018). The bacteria contribute to the maintenance of growth and survival of Nile tilapia by acting as a probiotic (Perez Fuentes *et al.*, 2018). The maximum average weight and weight gain (%) was observed in T₁ while T₀ showed the lowest average weight. In the treatment of the molasses supplement system, the highest growth performance was recorded, this may be due to the high load of microorganisms and traces of molasses in the system can bind some of suspended particles and make them useful and available as source of food for cultured species (Rono *et al.*, 2018). The maximum SGR was observed in T₁ while T₀ showed the minimum SGR. So better SGR was observed in biofloc system when compared to the control. This finding confirmed the results of different researchers who reported that the BFT system improved tilapia growth (Azim & Little, 2008; Avnimelech & Kochba, 2008). The increase in growth performance in the BFT treatment may be partly due to the maintenance of the optimum water quality and the continuous supply of nutritious floc, the richest source of many essential fatty acids (Ekasari *et al.*, 2015; Toledo *et al.*, 2016). Many biologically active compounds are evaluated in biofloc such as carotenoids, chlorophyll and phytosteroids which are expected to contribute better growth of cultured organisms in biofloc system [8, 29, 26, 29, 8, 4, 16].

Table 1: Water quality parameters (mean ± SE) of biofloc system using different experimental carbohydrate sources.

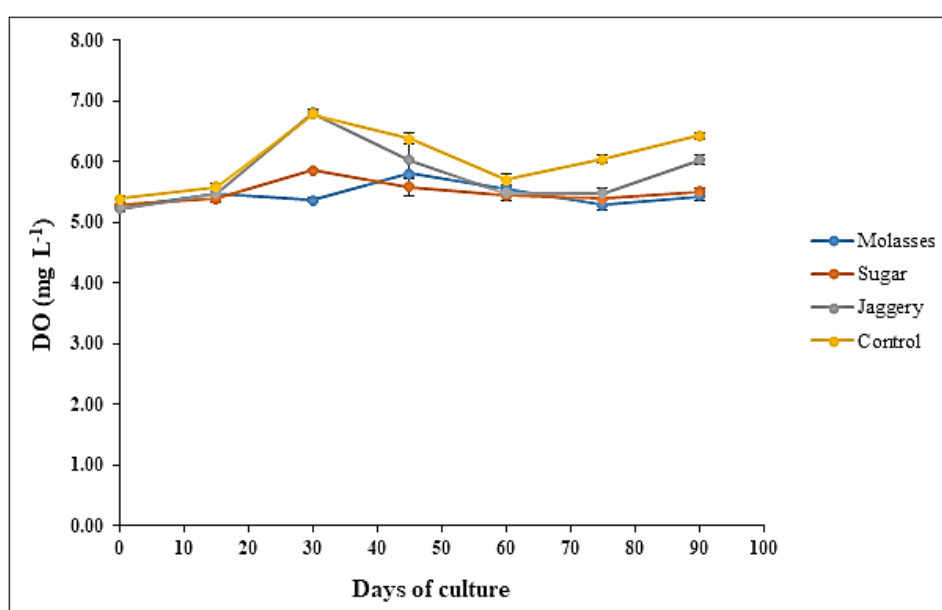
Water parameter	T ₁	T ₂	T ₃	T ₀ (Control)
Temperature (°C)	25.75 ± 0.63 ^a (23.6 - 27.3)	25.63 ± 0.52 ^a (23.5 - 27.6)	25.72 ± 0.77 ^a (23.9 - 27.3)	25.69 ± 0.68 ^a (23.2 - 27.5)
pH	7.48 ± 0.29 ^a (7.1 - 7.9)	7.54 ± 0.30 ^a (6.9 - 7.9)	7.49 ± 0.30 ^a (6.9 - 7.9)	7.54 ± 0.28 ^a (7.0 - 7.9)
Dissolved oxygen (mg L ⁻¹)	5.44 ± 0.24 ^a (5.1 - 6.7)	5.48 ± 0.20 ^a (5.1 - 6.0)	5.78 ± 0.51 ^b (5.1 - 6.9)	6.04 ± 0.14 ^c (5.3 - 6.9)
Free CO ₂ (mg L ⁻¹)	4.69 ± 0.19 ^b (4.1 - 5.3)	4.35 ± 0.16 ^a (3.9 - 4.9)	4.38 ± 0.53 ^a (3.9 - 5.3)	4.39 ± 0.30 ^a (4.0 - 5.1)
Alkalinity (mg L ⁻¹)	46.79 ± 0.58 ^a (30.5 - 60)	47.23 ± 0.65 ^a (32.4 - 60)	48.40 ± 0.77 ^a (29 - 63)	46.97 ± 0.34 ^a (32.5 - 61)
Hardness (mg L ⁻¹)	91.50 ± 0.62 ^b (76.4 - 99)	90.01 ± 0.18 ^b (80 - 98)	91.90 ± 0.84 ^b (82 - 99)	84.05 ± 0.80 ^a (69.4 - 95)
Ammonia nitrogen (mg L ⁻¹)	0.24 ± 0.02 ^a (0.08 - 0.4)	0.27 ± 0.00 ^a (0.09 - 0.4)	0.25 ± 0.01 ^a (0.09 - 0.4)	0.28 ± 0.01 ^a (0.07 - 0.5)
Nitrite nitrogen (mg L ⁻¹)	0.22 ± 0.01 ^a (0.1 - 0.4)	0.20 ± 0.01 ^a (0.1 - 0.4)	0.23 ± 0.01 ^a (0.1 - 0.4)	0.18 ± 0.01 ^a (0.1 - 0.3)
Nitrate nitrogen (mg L ⁻¹)	5.48 ± 0.05 ^b (4.5 - 6.5)	5.35 ± 0.06 ^b (4.3 - 6.0)	5.34 ± 0.04 ^b (4.3 - 5.9)	3.94 ± 0.06 ^a (3.0 - 5.5)
Floc volume (ml L ⁻¹)	18.23 ± 0.24 ^b (12 - 23.4)	17.36 ± 0.32 ^a (11 - 23.4)	16.81 ± 0.19 ^a (10.2 - 23.5)	-
TSS (mg L ⁻¹)	267.54 ± 2.00 ^c (175.5 - 380)	227.25 ± 5.01 ^b (147 - 326)	202.85 ± 3.76 ^a (124.6 - 310)	-



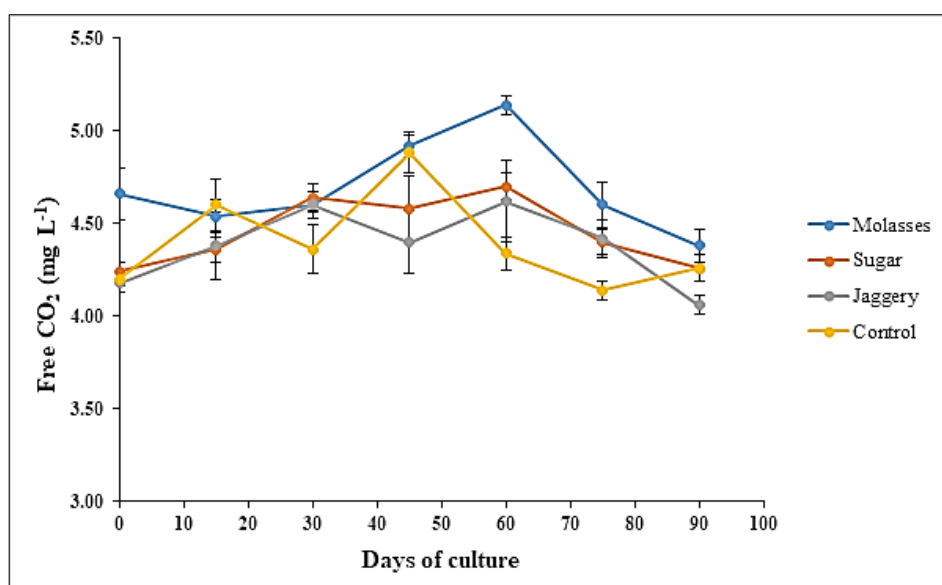
(a)



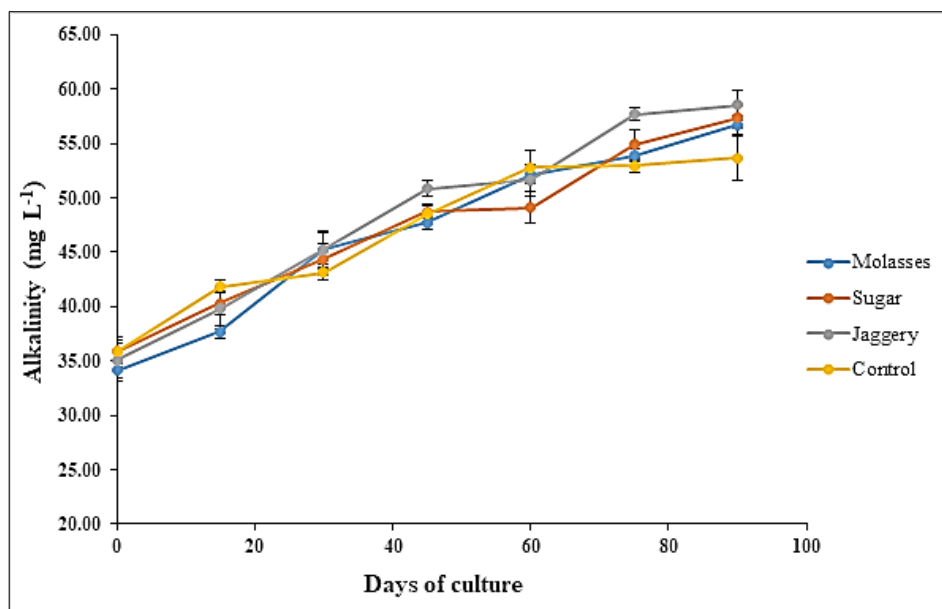
(b)



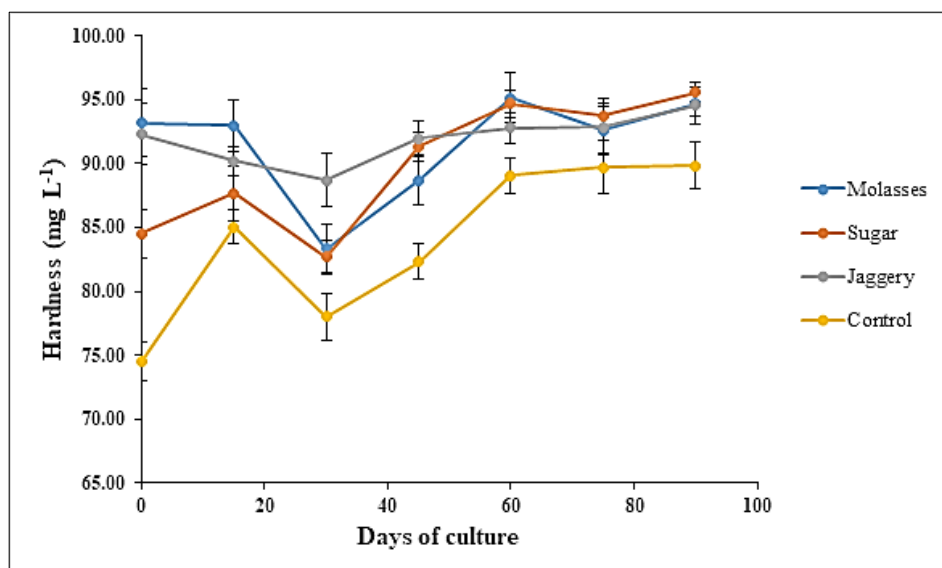
(c)



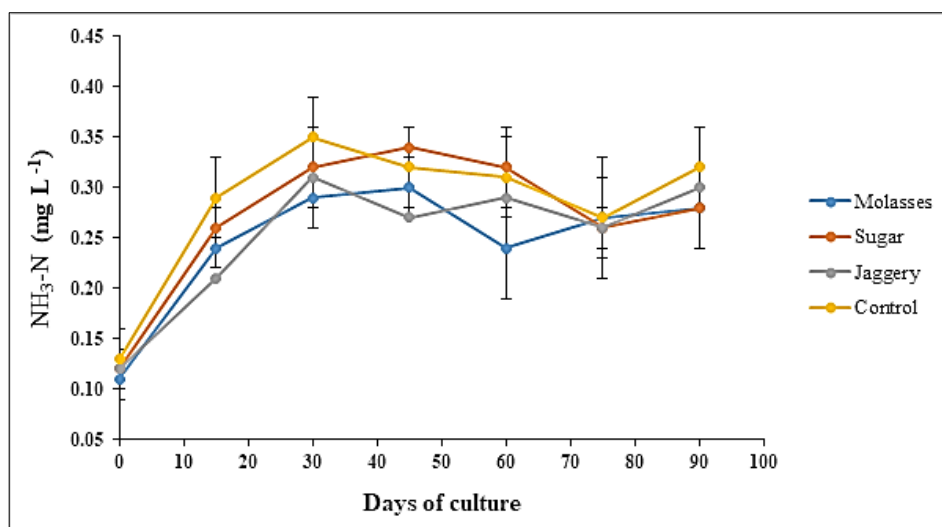
(d)



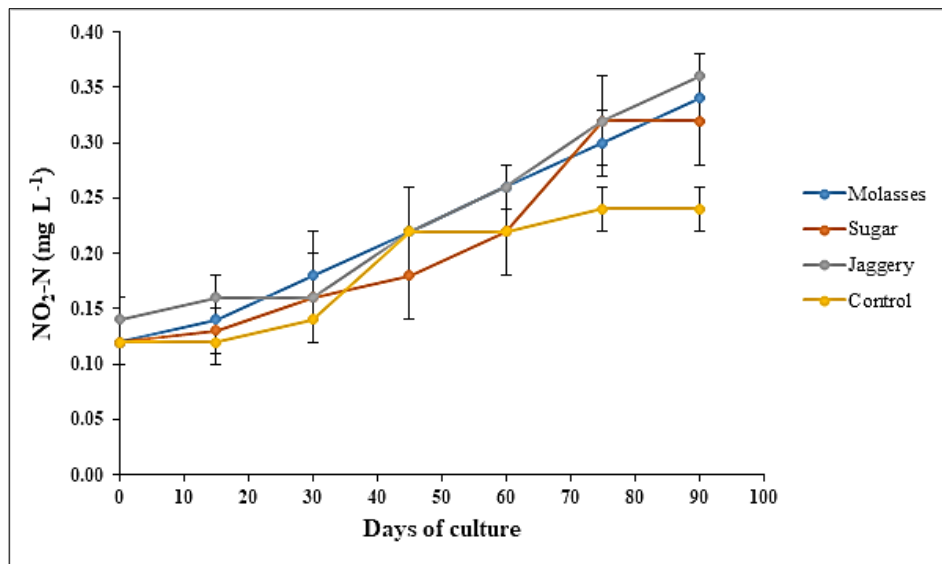
(e)



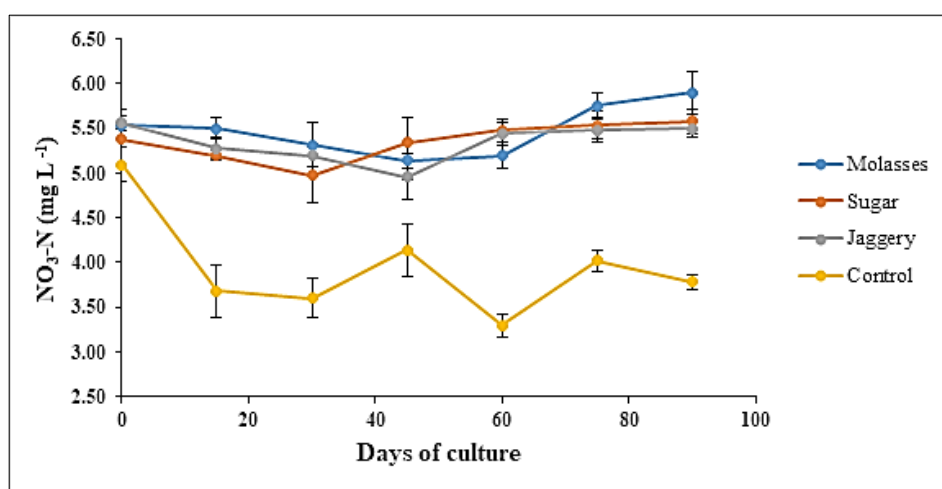
(f)



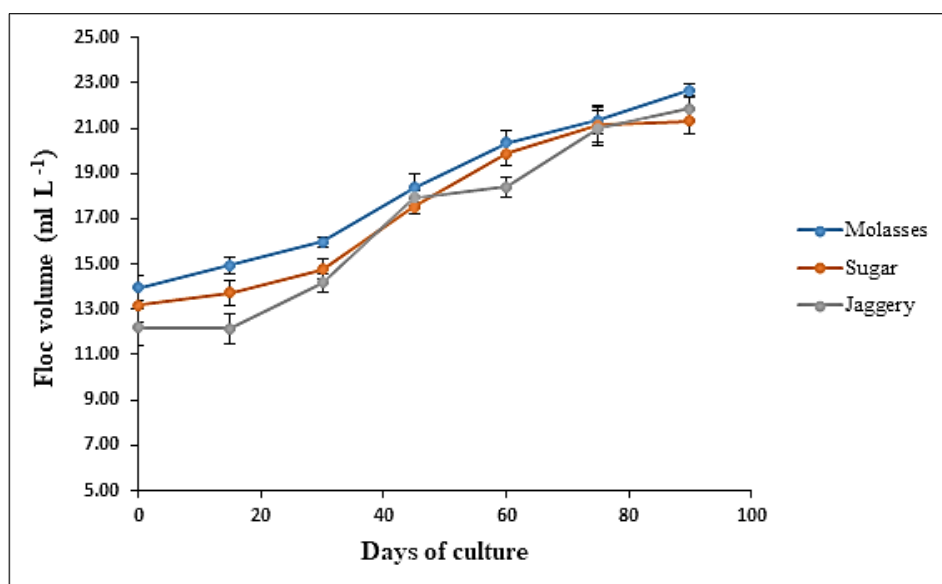
(g)



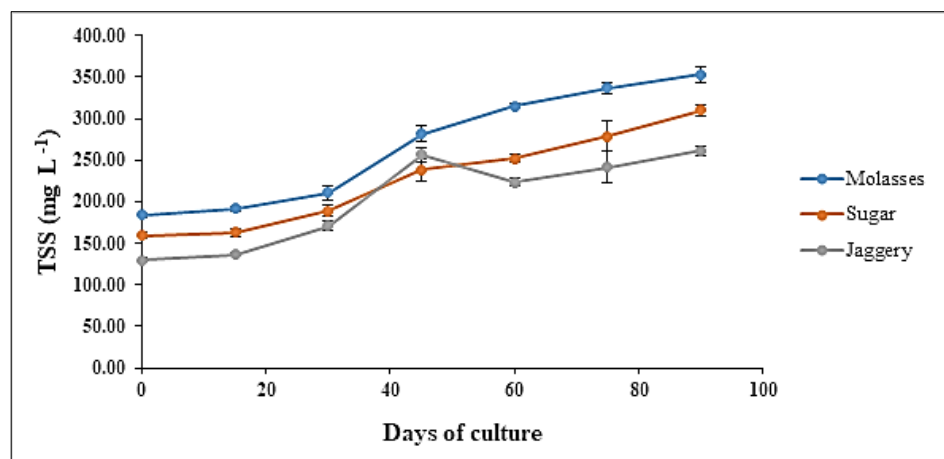
(h)



(i)



(j)



(k)

Fig 1: Water quality parameters of biofloc system using different experimental carbohydrate sources. (a) Temperature, (b) pH, (c) DO, (d) Free CO₂, (e) Alkalinity, (f) Hardness, (g) Ammonia-N, (h) Nitrite-N, (i) Nitrate-N, (j) Floc volume, (k) TSS.

Table 2: Growth parameters (mean $\pm$ SE) of GIFT tilapia fry using different experimental carbohydrate sources in biofloc system.

Growth Parameters	T ₁	T ₂	T ₃	T ₀
Initial Length (cm)	4.34 $\pm$ 0.06 ^a	4.46 $\pm$ 0.05 ^a	4.42 $\pm$ 0.08 ^a	4.40 $\pm$ 0.07 ^a
Final Length (cm)	10.60 $\pm$ 0.09 ^c	9.88 $\pm$ 0.05 ^b	10.10 $\pm$ 0.10 ^b	9.22 $\pm$ 0.09 ^a
Initial Weight (g)	1.10 $\pm$ 0.07 ^a	1.36 $\pm$ 0.05 ^a	1.18 $\pm$ 0.04 ^{ab}	1.14 $\pm$ 0.06 ^a
Final Weight (g)	15.80 $\pm$ 0.10 ^d	14.96 $\pm$ 0.11 ^b	15.28 $\pm$ 0.06 ^c	11.40 $\pm$ 0.07 ^a
Survival (%)	91.20 $\pm$ 1.49 ^c	86.40 $\pm$ 0.97 ^b	89.60 $\pm$ 0.97 ^{bc}	82.40 $\pm$ 0.97 ^a
Length Gain (%)	14441 $\pm$ 3.47 ^c	121.64 $\pm$ 2.96 ^{ab}	128.87 $\pm$ 5.28 ^b	109.86 $\pm$ 5.27 ^a
Weight Gain (%)	1360.19 $\pm$ 94.08 ^c	1007.69 $\pm$ 51.33 ^{ab}	1202.93 $\pm$ 48.45 ^{bc}	915.99 $\pm$ 67.23 ^a
Specific growth rate (SGR)	2.97 $\pm$ 0.07 ^b	2.67 $\pm$ 0.05 ^a	2.85 $\pm$ 0.04 ^b	2.57 $\pm$ 0.07 ^a

Conclusion

This study demonstrates that implementing biofloc technology (BFT) using different carbon sources significantly enhances water quality, growth performance, and survival rates of GIFT tilapia fry compared to traditional control systems. Throughout the experimental period, vital water quality parameters including temperature, dissolved oxygen, total hardness, and total alkalinity consistently remained within the optimal physiological thresholds required for healthy tilapia cultivation. Although biofloc treatments experienced expected drops in pH and fluctuations in alkalinity due to acid production from nitrifying bacteria and microbial respiration, the parameters were successfully managed. Total suspended solids and floc volumes stayed within favorable limits. Furthermore, initial increases in ammonia-nitrogen, nitrite-N, and nitrate-N eventually stabilized as thriving heterotrophic and nitrifying bacterial communities efficiently assimilated and reduced toxic nitrogenous compounds. Among the evaluated carbon inputs, molasses (T₁) emerged as the most effective carbon source. Its unique chemical matrix provides simple soluble sugars alongside complex organic by-products, ensuring a stable carbon release that prevents bacterial starvation and oxygen crashes. Consequently, the molasses-supplemented system achieved the highest average weight, maximum length gain, and superior Specific Growth Rate (SGR). This enhanced performance is attributed to optimum water quality maintenance and the continuous availability of nutritious, probiotic-rich biofloc aggregates as a supplemental food source. In conclusion, utilizing carbon sources like molasses in zero-water exchange systems promotes a balanced microbial ecosystem that keeps culture water clean while maximizing tilapia growth metrics.

References

- American Public Health Association. Standard methods for the examination of water and wastewater. 21st ed. Washington (DC): American Public Health Association; 2005.
- Asaduzzaman M, Wahab MA, Verdegem MCJ, Adhikary RK, Rahman SMS, Azim ME, *et al.* Effects of carbohydrate source for maintaining a high C:N ratio and fish-driven resuspension on pond ecology and production in periphyton-based freshwater prawn culture systems. *Aquaculture*. 2010;301(1-4):37-46. DOI:10.1016/j.aquaculture.2010.01.025.
- Avnimelech Y. Tilapia production using biofloc technology: Saving water, waste recycling improves economics. *Aquaculture Asia Magazine*. 2011;16(2):3-6.
- Avnimelech Y, Kochba M. Evaluation of nitrogen uptake and excretion by tilapia in biofloc tanks using 15N tracing. *Aquaculture*. 2009;287(1-2):163-168. DOI:10.1016/j.aquaculture.2008.10.009.
- Avnimelech Y. Carbon/nitrogen ratio as a control element in aquaculture systems. *Aquaculture*. 1999;176(3-4):227-235. DOI:10.1016/S0044-8486(99)00085-X.
- Avnimelech Y. Feeding with microbial flocs by tilapia in minimal-discharge bioflocs technology ponds. *Aquaculture*. 2007;264(1-4):140-147. DOI:10.1016/j.aquaculture.2006.11.025.
- Avnimelech Y, Kochva M, Diab S. Development of controlled intensive aquaculture systems with limited water exchange and adjusted carbon to nitrogen ratio. *Israeli Journal of Aquaculture*. 1994;46(3):119-131.
- Azim ME, Little DC. The biofloc technology (BFT) in indoor tanks: Water quality, biofloc composition, and

- growth and welfare of Nile tilapia (*Oreochromis niloticus*). Aquaculture. 2008;283(1-4):29-35. DOI:10.1016/j.aquaculture.2008.06.036.
9. Boyd CE. Water quality in warmwater fish ponds. Auburn (AL): Auburn University, Agricultural Experiment Station; 1981.
 10. Crab R, Avnimelech Y, Defoirdt T, Bossier P, Verstraete W. Nitrogen removal techniques in aquaculture for sustainable production. Aquaculture. 2007;270(1-4):1-14. DOI:10.1016/j.aquaculture.2007.05.006.
 11. Crab R, Defoirdt T, Bossier P, Verstraete W. Biofloc technology in aquaculture: Beneficial effects and future challenges. Aquaculture. 2012;356-357:351-356. DOI:10.1016/j.aquaculture.2012.04.046.
 12. de Holanda Cavalcante D, da Silva SR, Pinheiro PD, Akao MMF, do Carmo MV. Single or paired increase of total alkalinity and hardness of water for cultivation of Nile tilapia juveniles, *Oreochromis niloticus*. Acta Scientiarum. Technology. 2012;34(2):177-183. DOI:10.4025/actascitechnol.v34i2.12003.
 13. De Schryver P, Crab R, Defoirdt T, Boon N, Verstraete W. The basics of bioflocs technology: The added value for aquaculture. Aquaculture. 2008;277(3-4):125-137. DOI:10.1016/j.aquaculture.2008.02.019.
 14. Ebeling JM, Timmons MB, Bisogni JJ. Engineering analysis of the stoichiometry of photoautotrophic, autotrophic, and heterotrophic removal of ammonia-nitrogen in aquaculture systems. Aquaculture. 2006;257(1-4):346-358. DOI:10.1016/j.aquaculture.2006.03.019.
 15. Ekasari J, Azhar MH, Surawidjaja EH, Nuryati S, De Schryver P, Bossier P. Immune response and disease resistance of shrimp fed biofloc grown on different carbon sources. Fish and Shellfish Immunology. 2014;41(2):332-339. DOI:10.1016/j.fsi.2014.09.004.
 16. Ekasari J, Rivandi DR, Firdausi AP, Surawidjaja EH, Zairin M Jr, Bossier P, et al. Biofloc technology positively affects Nile tilapia (*Oreochromis niloticus*) larvae performance. Aquaculture. 2015;441:72-77. DOI:10.1016/j.aquaculture.2015.02.019.
 17. Emerenciano MGC, Martínez-Córdova LR, Martínez-Porchas M, Miranda-Baeza A. Biofloc technology (BFT): A tool for water quality management in aquaculture. In: Tutu H, editor. Water Quality. Rijeka: InTech; 2017. p. 91-109. DOI:10.5772/66416.
 18. Food and Agriculture Organization of the United Nations. The State of World Fisheries and Aquaculture 2026: Blue transformation turning vision into impact. Rome: FAO; 2026. DOI:10.4060/cd8357en.
 19. Gao L, Shan HW, Zhang TW, Bao YW, Ma S. Effect of carbohydrate addition on *Litopenaeus vannamei* intensive culture in zero-water exchange system. Aquaculture. 2012;342-343:89-96. DOI:10.1016/j.aquaculture.2012.02.022.
 20. Hargreaves JA. Biofloc production systems for aquaculture. Stoneville (MS): Southern Regional Aquaculture Center; 2013. SRAC Publication No. 4503. p. 1-11.
 21. Kuhn DD, Boardman GD, Lawrence AL, Marsh L, Flick GJ Jr. Microbial floc meal as a replacement ingredient for fish meal and soybean protein in shrimp feed. Aquaculture. 2009;296(1-2):51-57. DOI:10.1016/j.aquaculture.2009.07.025.
 22. Li C, Zhang X, Chen Y, Zhang S, Dai L, Zhu W, et al. Optimized utilization of organic carbon in aquaculture biofloc systems: A review. Fishes. 2023;8(9):465. DOI:10.3390/fishes8090465.
 23. Liu L, Hu Z, Dai X, Avnimelech Y. Effects of addition of maize starch on the yield, water quality and formation of bioflocs in an integrated shrimp culture system. Aquaculture. 2014;418-419:79-86. DOI:10.1016/j.aquaculture.2013.10.005.
 24. Mirzakhani N, Ebrahimi E, Jalali SAH, Ekasari J. Growth performance, intestinal morphology and nonspecific immunity response of Nile tilapia (*Oreochromis niloticus*) fry cultured in biofloc systems with different carbon sources and input C:N ratios. Aquaculture. 2019;512:734235. DOI:10.1016/j.aquaculture.2019.734235.
 25. Mishra JK, Samocha TM, Patnaik S, Speed M, Gandy RL, Ali AM. Performance of an intensive nursery system for the Pacific white shrimp, *Litopenaeus vannamei*, under limited discharge conditions. Aquacultural Engineering. 2008;38(1):2-15. DOI:10.1016/j.aquaeng.2007.10.003.
 26. Perez-Fuentes JA, Perez-Rostro CI, Hernandez-Vergara MP, Monroy-Dosta MDC. Variation of the bacterial composition of biofloc and the intestine of Nile tilapia *Oreochromis niloticus*, cultivated using biofloc technology and supplied different feed rations. Aquaculture Research. 2018;49(11):3658-3668. DOI:10.1111/are.13834.
 27. Rahman MA, Marimuthu K. Effect of different stocking density on growth, survival and production of endangered native fish climbing perch (*Anabas testudineus* Bloch) fingerlings in nursery ponds. Advances in Environmental Biology. 2010;4(1):178-187.
 28. Rajkumar M, Pandey PK, Aravind R, Vennila A, Bharti V, Purushothaman CS. Effect of different biofloc systems on water quality, biofloc composition and growth performance in *Litopenaeus vannamei* (Boone, 1931). Aquaculture Research. 2016;47(11):3432-3444. DOI:10.1111/are.12792.
 29. Rono K, Tarus A, Manyala JO, Obado E, Ngugi C, Egna H, et al. Effects of biofloc technology on growth performance of Nile tilapia (*Oreochromis niloticus*) fingerlings and microbial colonization in the system. International Journal of Agriculture, Environment and Bioresearch. 2018;3(5):274-288.
 30. Schneider O, Sereti V, Eding EH, Verreth JAJ. Analysis of nutrient flows in integrated intensive aquaculture systems. Aquaculture Engineering. 2005;32(3-4):379-401. DOI:10.1016/j.aquaeng.2004.09.001.
 31. Schweitzer R, Arantes R, Costodio PFS, do Espírito Santo CM, Arana LV, Seiffert WQ, et al. Effect of different biofloc levels on microbial activity, water quality and performance of *Litopenaeus vannamei* in a tank system operated with no water exchange. Aquacultural Engineering. 2013;56:59-70. DOI:10.1016/j.aquaeng.2013.04.006.
 32. Soltan MA, Abdella MM, El-Sayaad GA, Abu-El Wafa MH. Effect of some over-wintering regimes on survival and growth performance of Nile tilapia *Oreochromis niloticus*. Biological and Chemical Research. 2015;2:362-374.

33. Tolussi CE, Hilsdorf AWS, Caneppele D, Moreira RG. The effects of stocking density on physiological parameters and growth in the endangered teleost species piabanha, *Brycon insignis* (Steindachner, 1877). *Aquaculture*. 2010;310(1-2):221-228. DOI:10.1016/j.aquaculture.2010.10.007.
34. Uddin MS, Farzana A, Lipidema MK, Azim ME, Wahab MA, Verdegem MCJ. Technical evaluation of tilapia (*Oreochromis niloticus*) monoculture and tilapia-prawn (*Macrobrachium rosenbergii*) polyculture in earthen ponds with or without substrates for periphyton development. *Aquaculture*. 2007;269(1-4):232-240. DOI:10.1016/j.aquaculture.2007.05.038.