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Influence of three tier horizontal perforated sheet aerator model on fish growth in aquaculture system

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Abstract
Aquaculture is the fastest growing food industry in the world. Dissolved Oxygen concentration is the most important and critical water quality parameter in fish culture because of its direct effect on the feed consumption and metabolism of aquatic animals as well as indirect influence on the water quality. Maintaining optimum dissolved oxygen levels is critical for fish growth and survival in aquaculture systems. This study investigates the influence of a fabricated three tier horizontal perforated tray aerator model on the growth of common carp (*Cyprinus carpio*) in comparison to non-aerated tanks. Various growth parameters and water quality parameters were measured fortnightly. The dissolved oxygen content in the aerated tanks water was higher during the study period compared to non-aerated tanks water. There is not much variation in the water quality parameters both in the aerated tanks and non-aerated tanks, the same were within the permissible limit required for aquaculture. In the aerated tanks, the weight gain of the common carp was 4.03±0.233 g with the survival rate of 93.33±1.33% while in control tanks it was 3.2±0.152 g with the survival rate of 86.66±1.33%. The aerator effectively increased dissolved oxygen levels and maintained favourable water quality conditions. Results indicate that fish in aerated tanks exhibited significantly better growth performance and higher survival rates compared to non-aerated tanks. These findings underscore the importance of proper aeration in aquaculture systems for enhancing fish growth and productivity while ensuring optimum water quality ultimately increase the profit of the farmers.

Keywords: Perforated tray aerator, dissolved oxygen, growth

1. Introduction

Fish, like all other species, breathe in oxygen and exhale carbon dioxide. A crucial factor in evaluating the quality of water is dissolved oxygen, which indicates the physical and biological activity taking place in the water (Devi *et al.*, 2017) [10]. It is important to consider that healthy growth, tissue repair, and reproduction depend on the minimum amounts of dissolved oxygen (6 mg/L for cold water fish, 5 mg/L for tropical freshwater fish, and 5 mg/L for tropical marine fish) (Svobodova *et al.*, 1993) [31]. Anaerobic systems are those in which there is no dissolved oxygen (0% saturation). DO concentrations in production ponds can drop by 5–10 mg/L at night, and in ponds without aeration, they can drop to less than 2 mg/L at dawn (Boyd, 1990) [5]. Fish, plants, and other pond creatures respire at night, which lowers DO concentrations. Therefore, at night, DO concentrations in ponds are frequently below saturation during warm months (Boyd, 1998) [6]. Systems with low DO concentrations, typically between 1 and 30%, are referred as reducing or anoxic. Fish cannot survive at DO saturation levels below 30%. When the DO is less than 80% saturation, it is rarely indicative of a "healthy" aquatic habitat (Mallya, 2007) [20]. To achieve high production in any culture system, the level of dissolved oxygen must be kept at a saturation level that won't interfere with its physiological or metabolic processes (Wedemeyer, 1996) [33]. Reduced oxygen availability is thought to play a significant role in regulating food consumption. Fish farms often experience low dissolved oxygen stress due to high fish numbers and contaminated freshwater or marine environments. The amount of food needed to grow a specific amount of weight is known as the food conversion ratio, or FCR. It is the proportion of the fish's overall feed intake for the same duration of time divided by the weights they have gained during that time.

Higher growth rates result in an improvement (a decrease) in the food conversion ratio (Morkore and Rorvik 2001, Crampton *et al.*, 2003, Norgarden *et al.*, 2003) [23, 9, 25]. Fish life is at risk when DO is less than 2 ppm since there is a high chance of fish death at this concentration (Appelbaum *et al.*, 2001) [2]. Different aeration systems are used by fish farmers to enhance fish habitat and boost productivity. Some of these devices consist of basic paddle wheels that aerate water by slinging and splashing it into the air, or diffusers of different kinds that are fed by air at specific depths or at the water's bottom. (Eltawil and Eisbaay, 2016) [12]. Aerators usually run on electricity, and their energy usage affects the operational cost. It is essential to take operational and maintenance expenses into account. Some aerators may have extra features like sensors, automated controls, or monitoring system integration. The total cost of ownership of some aerators may increase due to increased maintenance requirements, the need for replacement parts, or increased operational costs. Aeration cost is the third largest cost in intensive aquaculture system after post larvae and feed cost representing about 15% of total production cost (Avinash *et al.*, 2013) [3]. The cost of the mechanical aerators is higher, and it requires more operational and maintenance costs (Mohan *et al.*, 2020) [21]. The objective of the present study was to assess the way in which the three tier horizontal perforated sheet aerator model affects the fish growth.

2. Materials and Methods

The study involved the development and evaluation of a three tier horizontal perforated sheet aerator model with regard to fish growth. The aerator model was built out of 85 × 85 x 5 cm perforated sheets of galvanized iron (GI) at the Research and Instructional Fish Farm of the College of Fisheries in Mangaluru (Fig. 1). Three replicas of the aerator design were made and fitted in three identical cement tanks (T_1, T_2 and T_3) measuring 5 x 5 x 1 meters and similarly three tanks were non-aerated kept as control (C_1, C_2 and C_3) (Fig. 2). For three hours every day, an aerator model was used to aerate the pond water.

Using a 1 H.P motor, the water from the pond was pumped and made to descend through each perforated tray. The water breaks up into tiny particles as it moves through the pores in these trays, observing the amount of oxygen in the surrounding air before it reaches the pond water.

Fig 1: Three-tier horizontal perforated sheet Aerator model used in the study

The standard methodology was followed for preparing the ponds. Common carp (*Cyprinus carpio*) fingerlings were stocked at the rate of 10000/hectare. Every fortnightly, water samples were taken in the early hours in order to examine the physical and chemical characteristics of the pond water. Surface water was collected using polythene containers and evaluated for a variety of water quality criteria (Temperature, pH, Ammonia, Dissolved oxygen, Nitrite-Nitrate, Alkalinity, Turbidity, Hardness).

Fig 2: Experimental design with Aerator model

Furthermore, utilizing oxygen fixing bottles (BOD bottles), samples for dissolved oxygen content were collected, fixed in the field, and then examined in a laboratory. Water temperature was measured by a standard mercury glass thermometer and pH by a digital pH meter (WTW pH 320). Dissolved oxygen was analyzed by Winkler's method, Alkalinity was analyzed by the titrimetric method (APHA, 1998) [1] and turbidity was measured using the digital Nephelo turbidity meter (Systronics µc 135). Ammonia was measured using the phenol-hypochlorite method (Strickland and Parsons, 1972) [29]. Nitrite, nitrate of water samples were analyzed by the standard method (Strickland and Parsons, 1972) [29].

Every two weeks, fish were sampled in relation to growth metrics. Using an electronic balance and centimeter scale, the total weight and length of each species were measured to the closest value, ensuring that at least 50% of the stock was gathered to calculate the weight gain (WG; g fish^{-1}), percentage weight gain (%WG), average daily gain (ADG; g day^{-1}), specific growth rate (SGR), survival rate (%) and feed conversion ratio (FCR) using the following formulae:

Weight gain (g) = Final weight – Initial weight.

Percentage weight gain (%) = [(Mean final weight - Mean initial weight)/Mean initial weight] x 100.

Average daily gain (g day^{-1}) = [Final weight (g) – Initial weight (g)]/Culture period (days).

Specific growth rate (SGR%) = [ln final weight – ln initial weight]/Number of days x 100.

Survival rate (%) = Number of fish survived / Initial number of fish stocked x 100.

Feed Conversion ratio = Total feed given/Animal weight gain.
With caution, the gathered species were returned to their appropriate tanks. The significant difference ($p<0.05$) between the average growth and the water quality measures from aerated and non-aerated tanks was determined by 't' test using IBM - SPSS version 26.

3. Results and Discussion

The present study is aimed at enhancing the growth of the common carp using the fabricated aerator model, considering that aeration plays a significant role in the growth and development of an organism in the aquatic system. The results obtained from the current study revealed that growth performance was better in the tanks fitted with the aerator model than in the tanks without an aerator. According to the study, aeration may be a viable technique that could enhance common carp growth and survivability.

3.1 Growth performance and Survival

Common carp growth performance was found to be significantly ($p<0.05$) higher in the tanks that were fitted with a fabricated three tier horizontal perforated sheet aerator model (treatment) than in the control (non-aerated) tanks in terms of weight gain, percentage weight gain, specific growth rate, and feed conversion ratio, all of which can lead to higher production. Several metrics related to fish growth were calculated in the current study, including feed conversion ratio (FCR), specific growth rate (SGR), average daily gain (ADG), percentage weight gain (%WG), weight gain (WG), and survival rate (%). Fish in tanks fitted with a fabricated three tier horizontal perforated sheet aerator models were found to do well, with growth characteristics expressed as mean±standard error (Table 1).

Table 1: Growth performance of Common carp in tanks (without and with fabricated aerator) during the study. Values are mean ± S.E.

Treatment	Weight gain (g/fish)	% weight gain	SGR	FCR	ADG	SR (%)
Without aerator	3.2±0.152	96.05±4.435	0.89±0.296	1.9±0.057	0.042±0.001	86.66±1.33
With aerator	4.03±0.233	127.12±12.37	1.09±0.070	1.6±0.115	0.054±0.003	93.33±1.33
p-value	0.040	0.077	0.064	0.081	0.038	0.024

The overall weight gain in the aerator-equipped tanks was determined to be 4.03±0.233 g/fish, while the weight gain in the non-aerator tanks was 3.2±0.152 g/fish (Fig. 3). Comparably, for aerated tanks and non-aerated tanks, the percentage weight gain is 127.12±12.37% and 96.05±4.435%, respectively (Fig. 4).

The fish in the tanks with and without an aerator had average daily gains of 0.054±0.003 and 0.042±0.001, respectively (Fig. 5). The specific growth rate (SGR) was 0.89±0.296 and 1.09±0.07 for tanks without aerators and with aerators, respectively (Fig. 6).

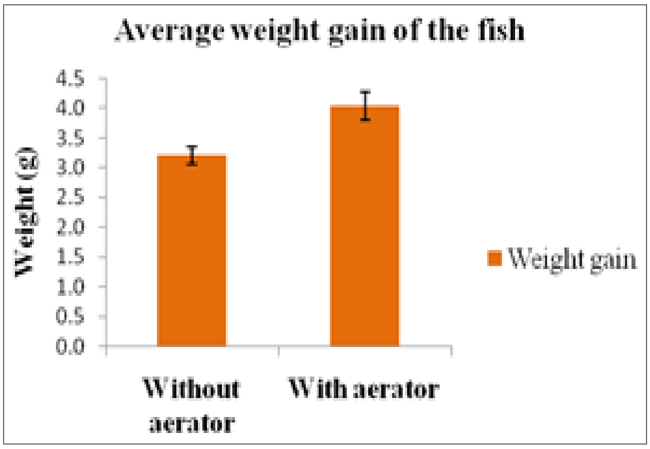

Fig 3: Comparison between the Average weight gain of fishes in the tanks with and without *the aerator*.

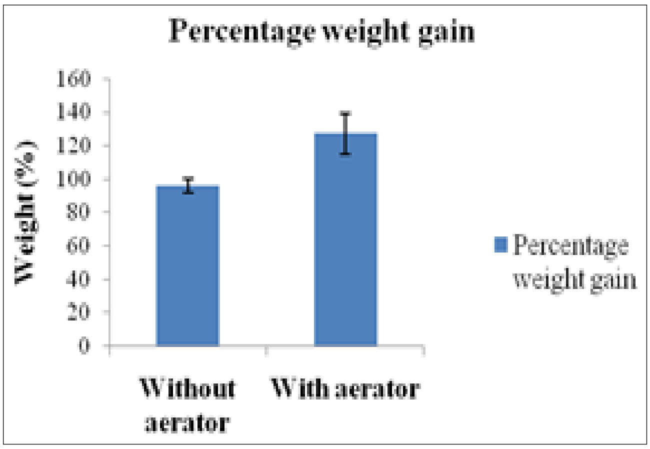

Fig. 4: Comparison between the percentage weight gain of fishes in the tanks with and without the aerator.

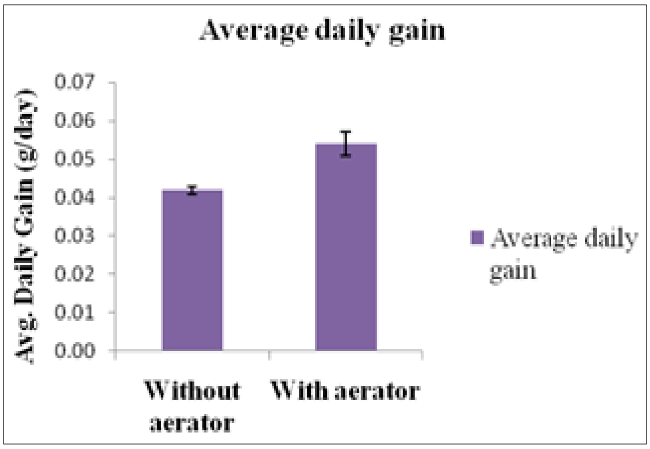

Fig 5: Comparison between the average daily gain of fishes in the tanks with and without the aerator.

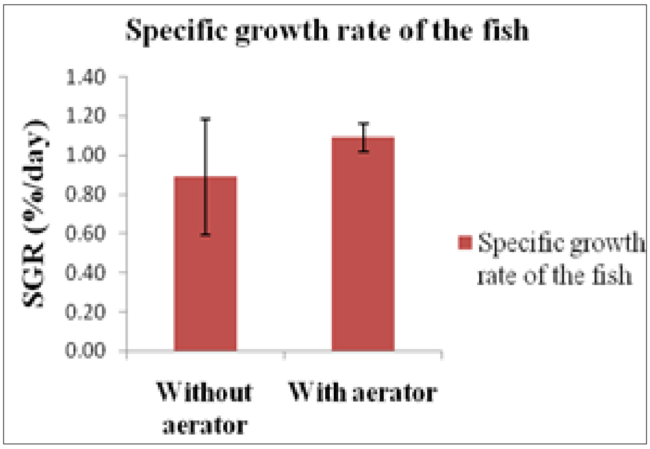

Fig 6: Comparison between the specific growth rate of fishes in the tanks with and without the aerator

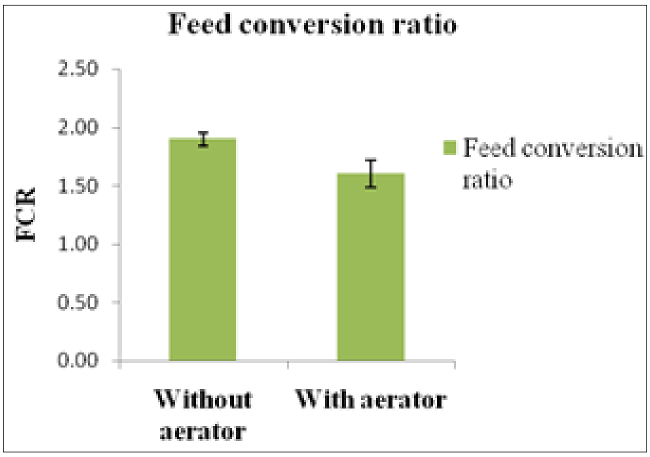

Fig 7: Comparison between the feed conversion ratio of fishes in the tanks with and without the aerator.

Magnoni *et al.* (2018) [19], in their research, observed that a decrease in DO concentrations had significantly affected the feed intake of rainbow trout. The feed conversion ratio (FCR) is observed to be higher for the fish in tanks without an aerator (1.9±0.057) than that of the fish in tanks with an aerator (1.6±0.115) (Fig. 7). Fish consistently demonstrated good feed efficiency and low FCR when fed at the required DO in water (Duan *et al.*, 2011, Sultana *et al.*, 2017, and Sarmam *et al.*, 2018) [11, 30, 28]. In addition, the survival rates were observed to be higher in the tanks with aerators, *i.e.*, 93.33±1.33%, than in the control tanks, *i.e.*, 86.66±1.33% (Fig. 8). The average survival rates in aerated and non-aerated tanks were 64% and 21% for rohu, mrigal, silver carp, and grass carp (Qayyum *et al.*, 2005) [26], and 92% and 40% for channel catfish (Hollerman and Boyd, 1980) [15], respectively.

3.2 Water quality

The aeration system not only affects the growth of the fish but also influences the physico-chemical parameters of the water, like dissolved oxygen, pH, temperature, hardness, and turbidity. Similar observations were made by Moses (1992) [24], where numerous physical, chemical, and biological elements influence the quality of water, which in turn affects how soluble it is for fish and other aquatic animal production and distribution. The water quality was determined using various parameters that are responsible for the well-being of the fish and are expressed as the mean±standard error (Table 2).

Table 2: Water quality parameters measured in tanks (without and with fabricated aerator) during the study. Values are mean ± S.E.

Treatment	Temp (°C)	pH	DO (mg/L)	Ammonia (mg/l)	Nitrite (mg/l)	Nitrate (mg/l)	Alkalinity (mg/l)	Turbidity (NTU)	Hardness (mg/l)
Without aerator	34.63±0.190	7.50±0.03	5.62±0.10	0.02±0.003	0.53±0.076	1.49±0.095	13.38±0.229	16.30±0.628	36.42±0.370
With aerator	33.69±0.116	7.10±0.072	6.37±0.037	0.013±0.003	0.25±0.030	1.14±0.058	12.42±0.325	10.75±0.290	26.85±0.684
p - value	0.61	0.008	0.003	0.101	0.027	0.036	0.074	0.001	0.000

The temperature was found to be 34.63±0.190 °C and 33.69±0.116 °C for tanks without and with an aerator, respectively. Aerators minimize stratification in the water body by increasing the interfacial area between air and water, which improves the diffusion of oxygen and also facilitates water circulation (Boyd and Martinson, 1984) [7]. The dissolved oxygen concentration in the tanks without an aerator was determined to be 5.62±0.10 mg/L, and for tanks with an aerator, it was 6.37±0.037 mg/L. The three tier horizontal perforated sheet aerator model showed better performance in increasing the dissolved oxygen of the ponds compared to the control ponds (Mohan *et al.*, 2022) [22]. In the present study, the pH values were 7.50±0.03 and 7.10±0.072, respectively, for tanks without and with an aerator. Dissolved oxygen and temperature are always negatively correlated, meaning that as temperature rises, DO decreases and vice versa. When the temperature and pH drop and the DO value rise, this could be the result of aeration-induced degasification (USEPA, 1998) [32]. For the non-aerated and aerated tanks, the ammonia was 0.02±0.003 mg/L and 0.013±0.003 mg/L, respectively. In tanks without and with aerators, the nitrite values are 0.53±0.076 mg/L and 0.25±0.030 mg/L; and nitrate values are 1.14±0.058 mg/L and 1.49±0.095 mg/L in the ponds water with aerators and without aerators respectively. In the present study, the total available nitrogen compounds (ammonia, nitrate, and nitrite) were within the acceptable limit, and the aeration system was found to reduce these compounds effectively. Incomplete decomposition of remnants such as unused feeds, manure, and metabolic waste results in a large amount of hazardous products and requires a significant amount of dissolved oxygen to be used by the process. Furthermore, the excess of hazardous compounds like hydrogen sulphide, nitrogen, ammonia, and nitrite would be detrimental to the animals that are raised (Chen *et al.*, 2013) [8]. Tanks with an aerator had an alkalinity of 12.42±0.325 mg/L, whereas tanks without an aerator had an alkalinity of 13.38±0.229 mg/L. In the current investigation, the alkalinity and hardness values fell within the ideal range. For freshwater systems, an alkalinity level of 5 to 500 mg/L is advised (Boyd, 1982 and Lawson, 1995) [4, 17]. The alkalinity should be more than 20 mg/L in fertilised ponds (Boyd, 1982) [4] and similarly for tilapia cultivation (Lucas and Southgate, 2012) [18], since total alkalinity raises fish productivity. The measured turbidity for tanks with an aerator was 10.75±0.290 NTU, while for tanks without aerator; it was 16.3±0.628 NTU. The hardness values for tanks without and with aerators were 36.42±0.370 mg/l and 26.85±0.684 mg/L, respectively. According to the EPA (1973) [13] and Jhingran (1988) [16], warm water fish require a hardness value of greater than 15 mg/L to be at their best.

In the current study, the three tier horizontal perforated sheet aerator model was efficient in increasing the dissolved oxygen concentration of the water, which is the fundamental water quality parameter that influences the growth of the cultured organisms and also has a direct or indirect effect on other physico-chemical parameters. Dissolved oxygen is an essential component in pond aquaculture environments, where it determines a range of water quality measures. Through influencing the microorganisms, it affects not only the grown organisms directly but also other chemical indices and biological population changes. The oxygenation system in the aquaculture pond can maintain the water's quality to the point where it supports the healthy growth of the organisms being cultivated (Fouda *et al.*, 2023) [14].

4. Conclusion
The current study was intended to assess the effectiveness of a designed three tier horizontal perforated sheet aerator model on the growth of common carp (*Cyprinus carpio*) in comparison to non-aerated tanks, given that aerators are an essential and vital component of the aquaculture system and their influence on growth and production. According to the study's findings, the aerator model significantly affects fish development and survival in addition to improving the water's physico-chemical characteristics. The rate of enhancing dissolved oxygen using various aerator designs might be compared in future studies. Furthermore, study must be done on an economic evaluation taking into account the design, fabrication, operation, and upkeep of the aerator model.

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