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Performance of three simple aeration columns in freshwater aquaculture system

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Abstract
The use of simple aeration columns is mainly aimed at solving the problem of low dissolved oxygen in freshwater culture systems at a very little cost. This study investigated the performance of three simple aerating devices in aquaculture systems. The three aeration columns tested in the experiment were upturned shower rose (USR), downturned shower rose (DSR) and perforated pipe (PEP). Each of them was fitted to the base of a 36.5 cm by 26.5 cm transparent plastic water tank. Water samples were collected and run through the aeration devices between the hours of (7:30 – 8:00 a.m.), (1:30 – 2:30 p.m.) and (7:30 – 8:00 p.m.), all the experiments were carried out in triplicates. The performance of the columns was estimated using Oxygen transfer efficiency (OTE) and Oxygen transfer rate (OTR). The highest mean daily average OTE (105.32±46.10%), was recorded in DSR followed by PEP (91.03±49.35%), while the least (72.18±40.41%) was recorded in USR. The highest mean daily average OTR (27140.26±4427.57 Kg/hr) was recorded in DSR, followed by (23277.45±4176.06 Kg/hr) in USR while the least daily average (20370.28±4425.56 Kg/hr) was recorded in PEP. All the experimented aeration columns are good for fish culture systems as they are all more than fifty percent efficient, however DSR performed best among the experimented simple aeration devices.

Keywords: Oxygen transfer rate, Oxygen transfer efficiency, Aeration devices, Aquaculture, Dissolved oxygen.

1. Introduction

The success of a commercial aquaculture enterprise depends on providing the optimum environment for rapid growth at the minimum cost of resources and capital. Water quality affects the general condition of the cultured organism as it determines the health and growth conditions of cultured organism. Quality of water is, therefore, an essential factor to be considered when planning for high aquaculture production. Therefore, it is necessary that the quality of water for aquaculture should be checked at regular intervals so as to avoid a high mortality of cultured fish species [1].

There are many water quality parameters in an aquatic environment, but only a few plays an important role [2]. Dissolved oxygen is the most critical water quality variable in aquaculture [3], there is a need to thoroughly understand the influence of dissolved oxygen concentrations in fresh water aquaculture. Low levels of dissolved oxygen are often linked to fish kill incidents, On the other hand, optimum levels can result to good growth, thus result to high production yield. In general, a saturation level of at least 5 mg/L is required [3]. Values lower than this can put undue stress on the fish, and levels reaching less than 2 mg/L may result to death (but 3 mg/L to some species).

Water aeration is the process of increasing the oxygen saturation of the water. Aeration is a unit process in which air and water are brought into intimate contact, and when correctly administered [4]. Aeration columns are devices used for introducing air into water, thereby improving the oxygen saturation of the water. The efficiency of the aeration process depends almost entirely on the amount of surface contact between the air and water [5]. There are two main categories of artificial in-stream aeration methods for dissolved oxygen improvement in large water bodies: systems that serve to aerate (and mix) the entire water column; and systems that selectively aerate (without mixing) thermally stratified layers. Simple aeration devices that aerate the entire water column generally are used to induce mixing as well as aeration. Mixing of thermally stratified water helps to homogenize dissolved oxygen conditions throughout the water by mixing higher dissolved oxygen concentration surface water with lower dissolved oxygen concentration bottom water [4].

There are different types of aerators used for fish culture, these include, gravity aerators, mechanical aerators, spray aerators etc. Many of these aeration systems are quite costly, with high operational costs consequently do not minimize the cost of fish production, therefore leading to a reduction in profit margin for the aquaculturist [6]. The use of simple aeration columns would readily solve the problem of low dissolved oxygen in freshwater culture systems at a very little cost. This will help maintain water at optimal DO levels and reduce the cost of production, thereby increasing the profit margin of the fish culturists. Some of the simple aerating columns in use in fish culture are perforated pipe, shower rose etc. This study, therefore compares the performance of three simple aerating devices in aquaculture.

2. Materials and Methods

2.1 Study area

The experiment was carried out in the Aquaculture laboratory of the University of Ibadan, Nigeria, Department of Aquaculture and Fisheries management.

2.2 Aeration columns

The three aeration columns tested in the experiment were upturned shower rose (USR), downturned shower rose (DSR) and perforated pipe (PEP). Each of them was fitted to the base of a 36.5 cm by 26.5 cm transparent plastic water tank. The upturned shower rose (USR) was attached to a pipe 5 cm from the base of the tank with a butterfly valve for the control of water flow from the tank through the aeration device to the receiving tank (Plate 1). Downturned shower rose (DSR) was attached to a pipe of 5 cm at the base of the plastic tank, fitted with a butterfly valve for the control of water flow from the tank, an elbow joint and a 2 cm extension from which the shower rose was attached facing down (Plate 2). Perforated pipe (PEP) was a 5 cm plastic pipe attached to the base of the plastic tank, also fitted with a butterfly valve, a t-joint and 2 cm pipes attached at each side of the t-joint, there are four holes running horizontally under the pipe with a diameter of 2.5 cm each (Plate 3). These aeration tanks were all place on a flat table placed in a way that the aeration columns were at the distance of 119 cm from the receiving tank below, the DSR was placed on an additional stand of 4.5 cm and the PEP was placed on an additional wooden stand of 2 cm while USR remained on the table without an additional stand, this was done so that the aeration columns can discharge water at the same level and maintain equal potential during the experimental process.

Plate 1: Upturned shower rose aeration column

Plate 2: Downturned shower rose aeration column

Plate 3: Perforated Pipe aeration column

2.3 Water sampling and experimental procedure

A water sample was collected from the deep well used as a primary source of water for indoor fish culture and laboratory activities in the department. The experiment was carried out three times weekly in the month of February and March 2014, between the hours of (7:30 – 8:00 a.m.), (1:30 – 2:00 p.m.) and (7:30 – 8:00 p.m.). The water sample collected from the well was carried to the laboratory for the experiment and DO was measured using NTLABS dissolved oxygen test kit before and after running through the aeration columns for four minutes. The water sample for the analysis was taken 2 cm below the water surface in the receiving tanks and all the experiment was carried out in triplicates.

2.4 Performance of the aerator columns

The performance of the columns was estimated using Oxygen transfer efficiency (OTE) and Oxygen transfer rate (OTR). OTE and OTR were estimated according to the procedure of Stenstrom and Rosso 2010 [9].

$$OTE = \frac{O_2 \text{ in} - O_2 \text{ out} \times 100}{O_2 \text{ in}}$$

Oxygen transfer rate = K_L A. (DO_S - DO) V

Where: K_L = the liquid film coefficient (h^{-1})

A = the interfacial area for the transfer (m^2)

DO_S = saturation of oxygen (kgO_2m^{-3})

DO = concentration of oxygen in the body of the liquid (kgO_2m^{-3})

V = water volume (m^3)

2.5 Data Analysis

Descriptive statistics were used to determine the mean and standard deviation of the, initial dissolved oxygen, final dissolved oxygen, Oxygen transfer efficiency (OTE) and Oxygen transfer rate (OTR) and ANOVA was used to test for significance in the differences in OTE and OTR among the three aeration devices.

3. Results and Discussion

The highest mean DO (5.67±0.29 mg/l) was recorded in DSR in the morning, while the least (4.67±0.76 mg/l) was recorded in USR also in the morning. The highest mean daily average (5.56±0.37 mg/l), was recorded in DSR followed by PEP (5.17±0.13 mg/l), while USR had the least mean daily average (Table 1). The DSR had the highest mean values at all the period.

Table 1: Mean values of DO (mg/l) in the experimented aeration devices

Period	Initial	USR final	DSR final	PEP final
Morning	2.83±0.58	4.67±0.76	5.67±0.29	5.17±0.76
Afternoon	2.17±0.29	4.83±0.76	5.50±0.50	5.17±0.76
Evening	3.50±0.00	4.83±0.29	5.50±0.50	5.17±0.29
Daily average	2.83±0.62	4.78±0.53	5.56±0.37	5.17±0.13

The highest mean OTE (155.00±18.03%), was recorded in DSR in the afternoon while the least (38.10±8.25%), was recorded in USR in the evening. The highest mean daily average OTE (105.32±46.10%), was recorded in DSR followed by PEP (91.03±49.35%), while the least (72.18±40.41%) was recorded in USR (Table 2). ANOVA did not show a significant difference (*P*>0.05) at all the period among the aeration devices. All the aeration devices had their highest OTE in the afternoon and their least in the evening. The DSR performed better at all the period followed by PEP while least performance was recorded in USR. The least performance of USR in terms of Oxygen transfer efficiency can be associated with turning up of the shower rose because it will have an effect on the partial pressure. This is in line with the position of Fujie K *et al* [7] and Al-Ahmady KK [8] who listed partial pressure among the major factors affecting oxygen transfer efficiency.

The highest mean OTR (28711.54±5195.66 Kg/hr) was recorded in DSR in the evening, while the least (20098.68±6329.01 Kg/hr) was recorded in PEP in the afternoon. The highest mean daily average (27140.26±4427.57 Kg/hr) was recorded in DSR, followed by (23277.45±4176.06 Kg/hr) in USR while the least daily average (20370.28±4425.56 Kg/hr) was recorded in PEP (Table 2). ANOVA only shows a significant difference between the aeration devices in the evening (P= 0.07), with the significant difference existing between DSR and USR as well as DSR and PEP but not between PEP and USR. Though the PEP had a better oxygen transfer efficiency (OTE) than USR but the higher surface area in DSR and USR favored their better performance in terms of OTR. This is in line with the observation of Stenstrom MK [9] who noted that oxygen transfer occurs at the surface and therefore the device with higher surface area may have higher OTR. The overall best performance of DSR can be associated with the device relatively better in terms of two major factors (area of gas-liquid interface and concentration of partial pressure) listed by Al-Ahmady KK [8].

Table 2: Performance of the experimented aeration devices

Period	USR	DSR	PEP
		OTE (%)	
Morning	65.71±12.45	103.81±28.04	83.81±14.66
Afternoon	123.33±25.17	155.00±18.03	141.67±52.04
Evening	38.10±8.25	57.14±14.29	47.62±8.25
Daily average	72.18±40.41	105.32±46.10	91.03±49.35
		OTR (Kg/hr)	
Morning	23904.15±5716.53	25283.30±2968.95	20098.68±5780.76
Afternoon	22561.22±5810.41	27425.95±5797.05	20098.68±6329.01
Evening	23366.98±1395.62^b	28711.54±5195.66^a	20913.49±2060.57^b
Daily average	23277.45±4176.06	27140.26±4427.57	20370.28±4425.56

*different superscript along the row indicates a significant difference at *P*<0.05

4. Conclusion

The need for aeration devices in fish culture systems cannot be underestimated due to vital roles of dissolved oxygen. The findings of the research show that all the aeration devices experimented are good for fish culture system as they are all more than fifty percent efficient, despite their non-requirement of extra energy source which may lead to increase in cost of fish production. However Downturned shower rose (DSR) proved to be the best both in terms of oxygen transfer efficiency and oxygen transfer rate irrespective of the time of usage.

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