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THE EFFECT OF AERATION METHOD ON NILE TILAPIA GROWTH, WATER QUALITY INDICATORS AND ENVIRONMENTAL IMPACT

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Abstract

This study discussed the effect of application optimum operational conditions for fine bubbles aeration of 0.554 $m^3.h^{-1}$ air flow rate, tube depths from water surface of 0.7 m, tube inner diameter of 11 mm, circular design shape at aquaculture greenhouse for rearing Nile Tilapia and compared with traditional water change system in three replicates for every treatment. Water change ratios were 10 and 30% for fine bubbles and traditional water change method, respectively. The experiment period were 8 weeks until reach commercial size. The water quality indicators were: Dissolved oxygen (DO), Total ammonia nitrogen (TAN), Temperature, Total dissolved solids (TDS), pH. Also, the Fish growth indicators were: Weight gain, Feed conversion ratio (FCR) and survival rate, Specific growth rate (SGR). The best FCR value was 1.181 and obtained at the seventh week for fine bubbles aeration. The maximum SGR value was 1.96 which obtained at the seventh week for fine bubbles aeration, while the minimum value was 0.86 obtained at the fifth week for water change method. The maximum mean value for dissolved oxygen was 91% of saturation obtained at fine bubbles aeration method. Also, the minimum mean value for total ammonia nitrogen was 0.32 mg/l obtained at fine bubbles aeration method. The minimum and maximum mean values for total dissolved solids (TDS) in fine bubbles treatment were 1.610 and 1.7 mg/l, respectively.

Key words: *aquaculture, water quality indicators, fine bubbles aeration, fish growth indicators*

INTRODUCTION

The brackish water produced 855,789 t of tilapia in 2017, accounting for 70% of all tilapia produced in Africa. Egypt dominates the production of farmed tilapia in Africa. In 2017, the total amount of farmed tilapia produced in Africa was 967,301 t, with Egypt producing the majority of that amount. Africa's contribution to the world's tilapia output will drop from 21% in 2017 to only 4.3% if Egypt's share is discounted [7].

The quantity of fish produced increased by 5.4% to 2.0 million tons in 2019 from 1.90 million tons in 2018. Lakes came in second with a production percentage of 7.97%, followed by marine waters with 4.9%, fresh water with 3.8% and rice fields with 0.8% of the total amount of fish produced. The revenue of fish production increased by 26.6% in 2019 to 61.1 billion LE from 48.3 billion LE in 2018. Also, the area of aquaculture farms decreased by 3.9% from 307.2 thousand feddan in 2018 to 295.2 thousand feddan in 2019 [6].

The poor water quality decreased fish productivity, higher production costs for fish farmers and hatcheries and a higher risk of disease outbreaks. Additionally, poor water quality could harm the environment and people's health, including that of consumers and workers [11].

The quantity of free, non-compound oxygen contained in water or other liquids is referred to as dissolved oxygen. Due to its impact on the aquatic life present in a body of water, it is a crucial factor in determining the quality of the water. Dissolved oxygen is the second most important component in limnology, after water itself. Too much or too little dissolved oxygen in the water can harm aquatic life and change its quality [9].

The minimum dissolved oxygen ranges for *Oreochromis niloticus* were 0.1-0.5 mg/l while the optimum was between 6 and 6.5 mg/l [1].

The most crucial period to introduce more aeration is shortly before dawn, when DO concentrations are often lowest because this is when they frequently drop below tolerable levels. Early morning DO for warmwater fish should stay above 3-4 mg/L and above 5-6 mg/L for cold-water fish. Warmwater and cold-water fish can survive with concentrations as low as 1.0-1.5 mg/L and 2.5-3.5 mg/L, respectively. However, these concentrations can raise stress, reduce appetite or aggression to eat and if low enough for a long length of time they can be deadly [5].

Due to the local fish's higher metabolic rates while they are feeding, DO drops during feeding. Fish spend more energy to eat in a competitive manner which causes an increase in metabolic rate. A DO requirement is also produced by uneaten feed and feces. This excrement provides plant nutrients that encourage the growth of phytoplankton. When phytoplankton is more abundant, the amount of DO that they need to breathe at night can increase. To raise the need for DO, phytoplankton are also continuously perishing and decomposing. The use of fertilizer can encourage the growth of algae, which can improve oxygen production and remove potentially hazardous ammonia [14].

The performance of tilapia may be significantly impacted by the interplay between diet mix and DO concentration. These researchers fed Nile tilapia (35 g) two different diets at two different oxygen saturation levels: normoxia (100%, 6.9 $mg.L^{-1}$) and hypoxia (50%, 3.5 $mg.L^{-1}$). The control diet was based on fishmeal (FM), while the other diet was based on soybean meal (SBM). Under normoxia, the FM "control" diet resulted in the highest growth rates [13].

An experiment in three nations of Nepal, Cambodia, and Kenya low-cost tilapia production with fertilization and supplemental feeding. Nile tilapia fingerlings (6.2 g) were raised in each of the three countries by feeding only with 25-30% crude protein (cp) diets at a daily feeding rate of 3% of fish body weight [10].

The daily rate of partial water exchange in clay ponds is relatively low. In fact, early in the season, when the number of fish is minimal and well below the pond's carrying capacity, it might not even be necessary. However, as fish get bigger and bigger, there is a greater need for freshwater. Based on the stocking density, fish size and species, it may reach 20% or more every day by the end of the season [12].

The total water use in aquaculture according to culture intensity and species. Water requirements for intensive aquaculture were 40-80, 10-15 and 12 m^3/kg for shrimp (20% daily water change), intensive tilapia and carp polyculture, respectively. While for semi-intensive it was 5 and 3-6 m^3/kg for carp polyculture, warmwater fish (nighttime aeration), respectively [7].

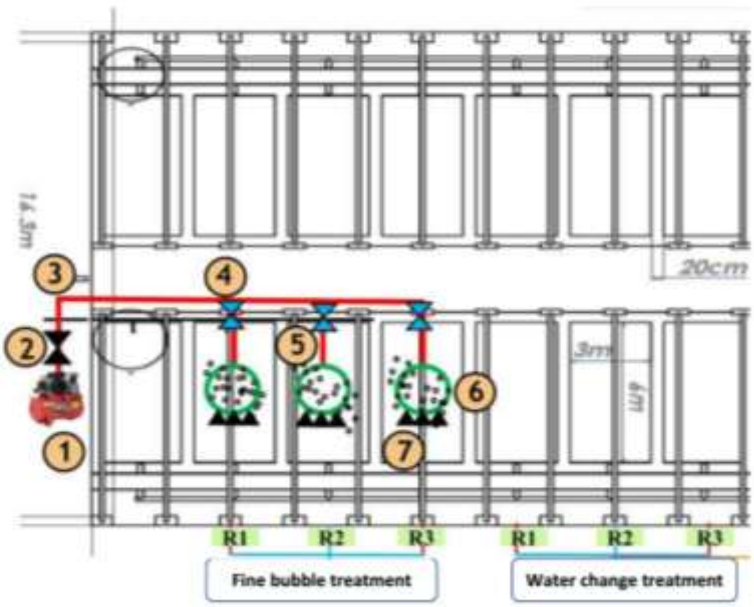
The main aims of the research were to:

- Reduce water, energy consumption and aquaculture gases emissions.
- Determine the effect of fine bubbles aeration method on water quality and fish indicators compared with water change method.

MATERIALS AND METHODS

Experiments were carried out over winter season 2021-2022 (25th Nov 2021 – 19th Jan 2022) at a private earthen aquaculture pond and greenhouse, Damro city, Kafr El-Sheikh governorate, with co-ordinates of 31°22'41.3"N and 30°47'32.4"E. The experiment was under taken to applicate the optimum operational conditions for oxygen production at aquaculture greenhouse for a rearing season in comparison with traditional water change system with three replicates for each system.

The Nile tilapia *(Oreochromis niloticus)* as aquatic fish was obtained from a private farm located in Damro city, Kafr El-Sheikh governorate, Egypt. The experimental fish start weight was 140 grams with a density of 5 fishes/m^3 for every replicate. Aquaculture water used is a mixture from lake Burullus water and agricultural drainage water. The secchi disk mean values before conducting experiments were 44 and 41 cm for water source and pond, respectively. As shown in Figures 1 and 2 the greenhouse has a design of quonset double span and covered with polyethylene (PE) plastic sheet.



Aeration system components

No.	Item
1	Air compressor
2	Main valve
3	Main air line
4	Secondary valve
5	Secondary air line
6	Aeration tube
7	Tube holder

Fig. 1. Schematic diagram for aeration system components at aquaculture greenhouse
Source: Drawn by the researchers.

It consists of 18 concrete ponds. Every pond has dimensions of 3 m width, 6 m length and 1.5 m depth. Also, every pond filled up with 18 m^3 of water. Also, three meters of diffusion tube for every greenhouse pond with 6 aeration periods/day and 30 minutes of working for period. The aeration system components consist of: an electric single-phase compressor and diffusion tube of D25-7 which made from recycled porous rubber for airmmax company, China. Fish feed were from extruded floating 25% CP, 3 mm die holes diameter. Table III.4 shows fish feed chemical composition which presented twice times daily [4].

Methods

The optimum operational conditions for oxygen productivity were applicated at aquaculture greenhouse and compared with traditional water change system in three replicates for every treatment. Water change ratios were 10 and 30% for fine bubbles and traditional water change method, respectively. The experiment period were 8 weeks until reach commercial size.

The **water quality indicators** were aquaculture water dissolved oxygen (DO), aquaculture water total ammonia nitrogen (TAN), aquaculture water temperature, aquaculture water total dissolved solids (TDS) and aquaculture water pH.

Also, the **Fish growth indicators** were fish weight gain, feed conversion ratio (FCR and survival rate) and specific growth rate (SGR). Weight gain was determined by measuring body weight at specific time. Also, for each sampling, feed conversion ratio (FCR) [3] and Specific Growth Rate (SGR (%)) [2] were calculated by the following equations:

$$FCR = \frac{dry\ feed\ consumption}{live\ weight\ gain}$$

$$SGR\ (\%) = \frac{[\ln(final\ weight) - \ln\ (initial\ weight)]}{Number\ of\ feeding\ days}$$

Operational conditions were: air flow rates of 0.554 m^3.h^{-1}, tube depth of 0.7 m from water surface for aeration tube and holder, tube wall inner diameter of 11 mm and circular design shape according to [8].

RESULTS AND DISSCUSIONS

The main experiment results include **water quality indicators** (Water dissolved oxygen, water total ammonia nitrogen (TAN), water total dissolved solids (TDS), water pH and water and air temperature) and **fish growth indictors** (Fish weight gain, Specific growth rate (SGR), Feed conversion ratio (FCR) and survival rate).

Water quality indicators

Water indicators could be conducted as follow:

Effect of fine bubbles aeration and water change treatments on dissolved oxygen values

The results showed that fine bubbles aeration method give highest values for dissolved oxygen compared to traditional method at all experimental replicates as shown in Figure 2.

The maximum mean value for dissolved oxygen was 91% of saturation obtained at fine bubbles method. Also, the minimum mean value for dissolved oxygen was 15% of saturation obtained at traditional method.

All day long, the dissolved oxygen mean value increases from 3 a.m. to reach the maximum mean value at 3 p.m., then decreases to reach minimum value at 3 a.m. this happens in all replicates and the two aeration systems. This may be due to plant photosynthesis as plants take oxygen at night and produce it at the day. Also, DO consumption at biological processes.

Over the experiment period with determining a time on the day, the highest dissolved oxygen concentration values were at fine bubbles aeration method. For example, at 3 am along all the experiment days dissolved oxygen mean values ranged between 40-52, 15-25 and 23-30% of saturation for fine bubbles method, traditional water change method and water source, respectively.

Effect of fine bubbles aeration and water change treatments on total ammonia nitrogen (TAN) values

The results declared that fine bubbles aeration method gives low values for total ammonia nitrogen compared with traditional aeration method at all experimental replicates as shown in Figures 3 and 4. The maximum mean value for total ammonia nitrogen was 4.89 mg/l obtained at traditional aeration method. Also, the minimum mean value for total ammonia nitrogen was 0.32 mg/l obtained at fine bubbles aeration method.

All day long, the total ammonia nitrogen mean value decreases from 3 am to reach the minimum mean value at 11 am, then increases to reach maximum value at 3 am this happens in all replicates and the two aeration systems.

This may be related to plant photosynthesis, feeding time and feed wastes. The results showed that at 3 am along all the experiment days, the total ammonia nitrogen mean values ranged between 2.2-3.02, 4.3-4.89 and 4.21-5.74 mg/l for fine bubbles method, traditional water change method and water source, respectively.

Unionized ammonia (NH_3) minimum mean value was 0.0018 mg/l for fine bubbles method and maximum mean value was 0.0557 mg/l for traditional water change method and all values were at permissible limits.

Effect of fine bubbles aeration and water change treatments on air and water temperature values

The obtained results showed that air temperature values in greenhouse were higher than those out the greenhouse at all days and times on the day of the experiment.

The air temperature reached the maximum value at 3 p.m. and minimum value at 3 a.m. for in and out green house, respectively at all days. The maximum and minimum mean values for air temperature in greenhouse were 39.9 and 7.3 °C, respectively.

The maximum and minimum mean values for air temperature out greenhouse were 33.8 and 6.2 °C, respectively.

The obtained results showed that water temperature values in fine bubbles treatment were higher than those at traditional water change treatment at all days and times on the day of the experiment as shown in Figures IV.20 and IV.21. The water temperature reached maximum value at 3 p.m. and minimum value at 3 a.m.

The maximum and minimum mean values for water temperature in fine bubbles treatment replicates were 31.4 and 5 °C, respectively. The maximum and minimum mean values for water temperature in traditional water change treatment replicates were 30.9 and 5°C, respectively.

This result may be due to high water change ratio in traditional water change treatment compared with fine bubbles treatment ratio, as the water in the source is colder than in greenhouse.

Effect of fine bubbles and water change values treatments on total dissolved solids (TDS)

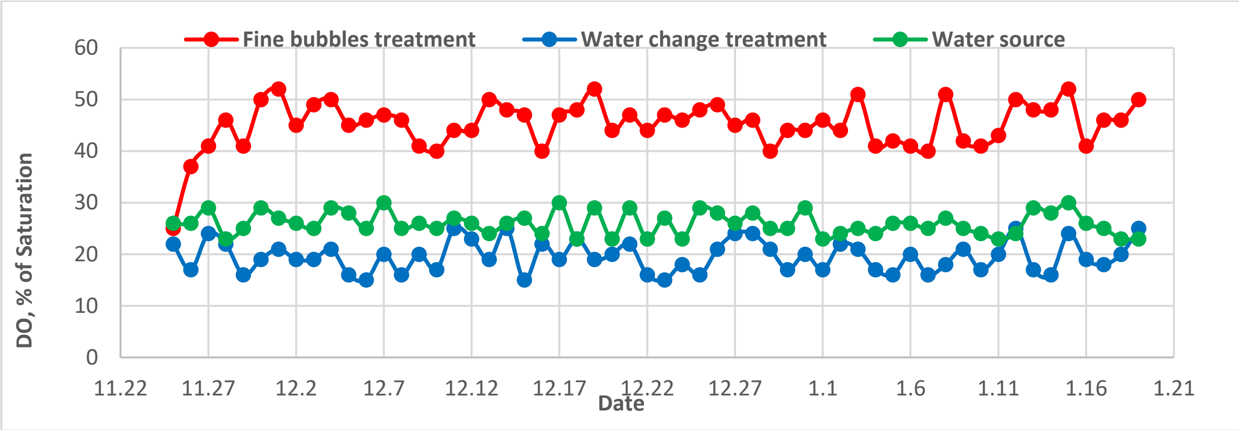


Fig. 2. Dissolved oxygen mean values for aeration by fine bubbles, water change treatments and water source at 3 a.m.
Source: Own results.

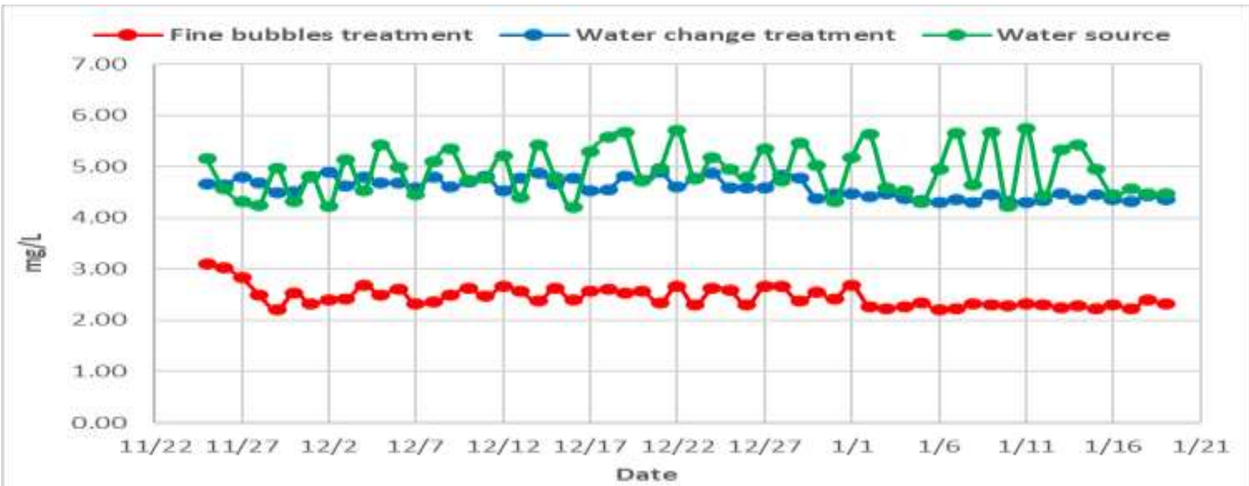


Fig. 3. Dissolved oxygen mean values for aeration by fine bubbles, water change treatments and water source at 3 a.m.
Source: Own results.

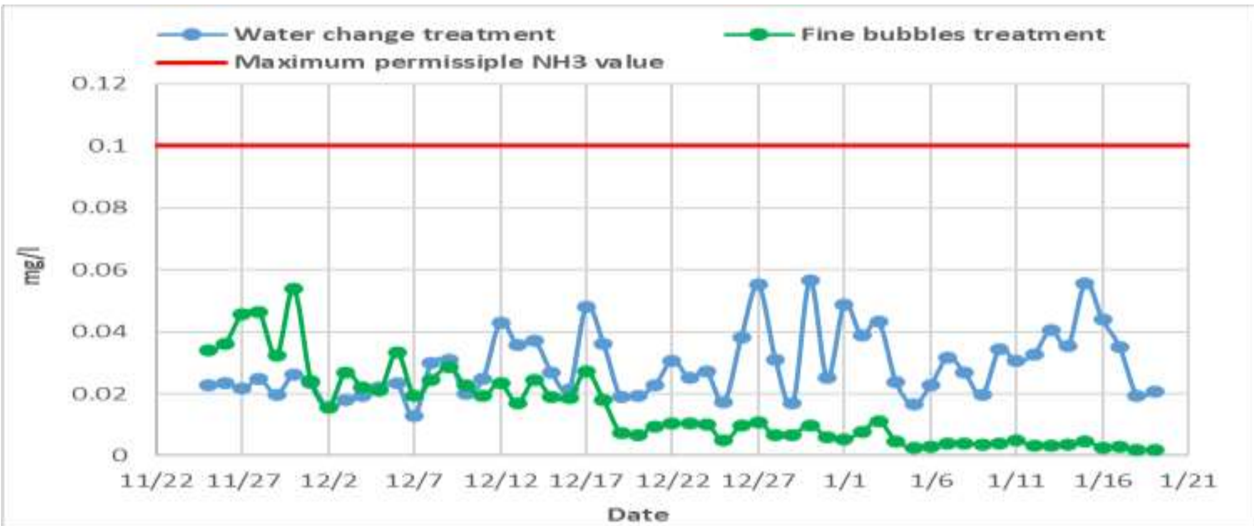


Fig. 4. Ammonia mean values for aeration by fine bubbles and water change treatments at 3 a.m.
Source: Own results.

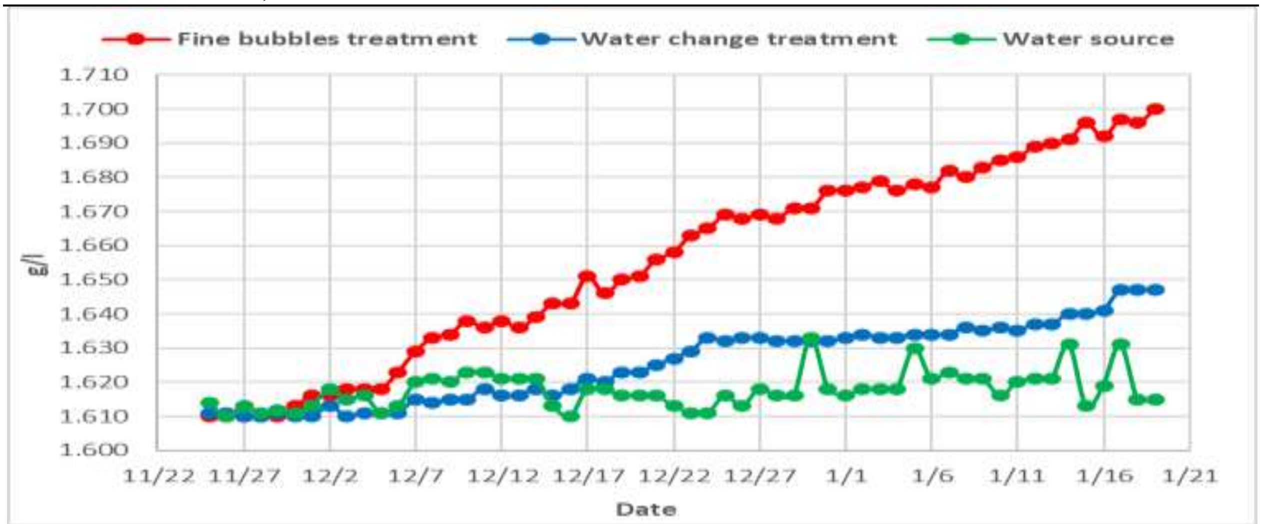


Fig. 5. TDS values for fine bubbles treatment, water change treatment and water source at 3 a.m.
Source: Own results.

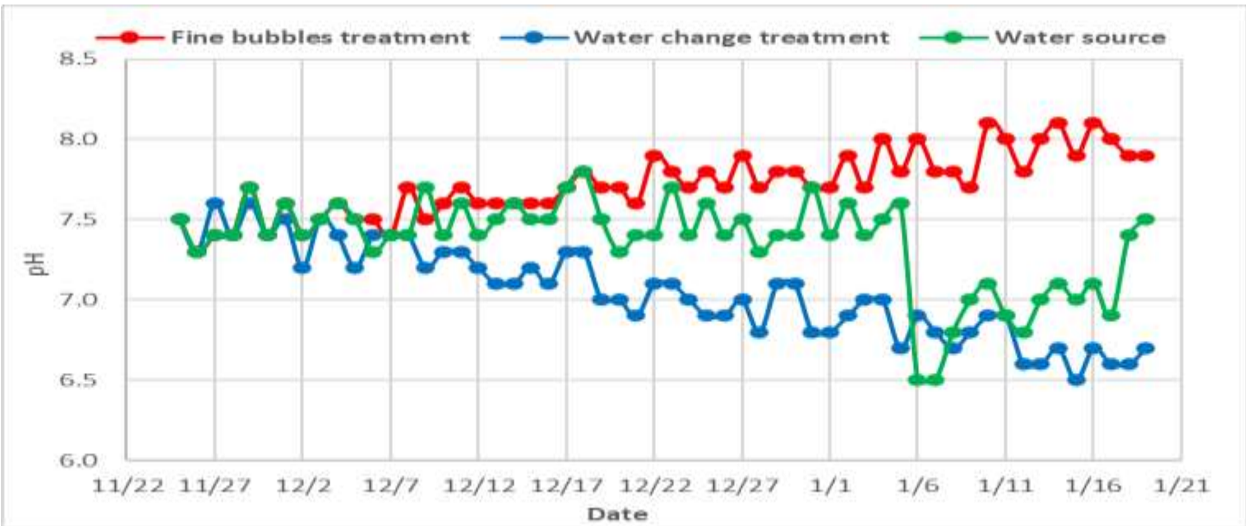


Fig. 6. pH values for fine bubbles, water change treatments and water source at 3 a.m
Source: Own results.

The obtained results showed that TDS mean values in fine bubbles treatment were higher than those at traditional water change treatment at all days and times on the day of the experiment as shown in Figures 5.

Also, the measurement time hasn't a significant effect on TDS values. The minimum and maximum mean values for TDS in fine bubbles treatment were 1.610 and 1.7 g/l, respectively.

The minimum and maximum mean values for TDS in traditional water change treatment were 1.610 and 1.647 g/l, respectively.

This result may be due to high water change ratio in traditional water change treatment compared with fine bubbles treatment ratio which removes them continuously.

Effect of fine bubbles and water change treatments on water pH values

The results showed that pH mean values in fine bubbles treatment were higher than those at traditional water change treatment at all days and times on the day of the experiment as shown in Figures 6.

The measurement time has a little significant effect on pH values, so it has low increase at 3 p.m. The minimum and maximum mean values for pH in fine bubbles treatment were 7.3 and 8.1, respectively. The minimum and maximum mean values for pH in traditional water change treatment were 6.5 and 7.6, respectively.

Fish growth indicators

Fish growth indicators classified into three partitions as follow:

Fish Weight gain

Average body weight of Nile Tilapia is affected by aeration method during the experimental periods as shown in Figure 7. Also, it declared that there an increase in weight gain for the two treatments along the experiment. However, its ratio in F.B.T more than W.C.T. along the experiment. It's conducted that the maximum weight gain for F.B.T. was 346.4 gram, while it was 308.1 g for W.C.T.

Fish feed conversion ratio (FCR) and survival rate

Results indicated that FCR values decreases with F.B.T. compared with W.C.T. at all experiment period as shown in Figure 8.

The best FCR value was 1.181 and obtained at the seventh week for F.B.T, while the maximum value for W.C.T was 1.58 and obtained at the fifth week. Also, the survival rate values were 98.89 and 91.11 % for F.B.T. and W.C.T., respectively. Whereas, the mean values of the feed conversion ratios were 1.251 and 1.46 for the treatments of fine bubble aeration and aeration by traditional method of changing water, respectively.

Specific growth rate (SGR)

Results showed that SGR values were high at F.B.T. compared with W.C.T. as shown in Figure 9. The maximum SGR value was 1.96 which obtained at the seventh week for F.B.T, while the minimum value was 0.86 obtained at the fifth week for W.C.T. SGR value influence with other conditions as temperature.

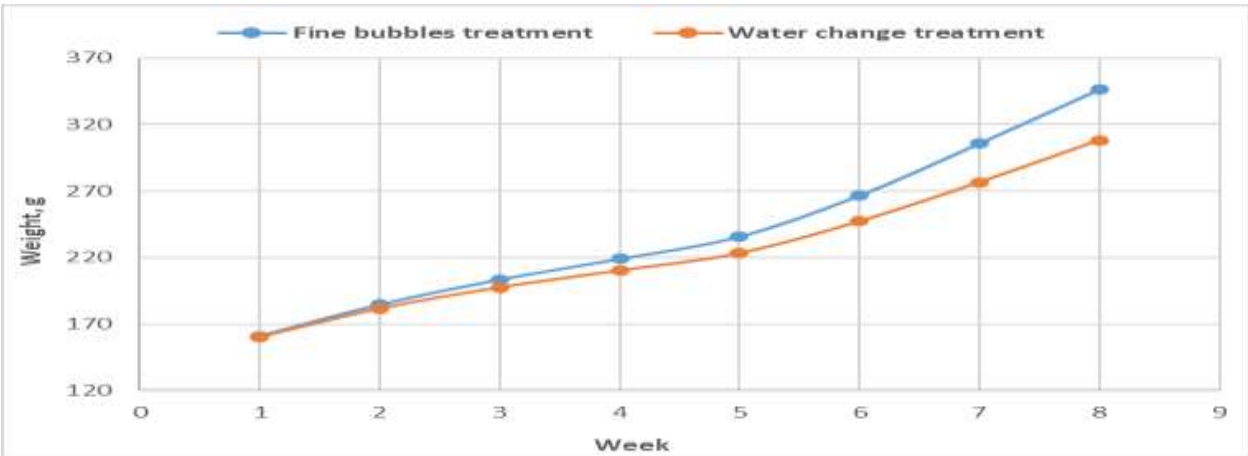


Fig. 7. Fish weight gain for aeration by fine bubbles treatment and water change treatment over the experimental period

Source: Own results.

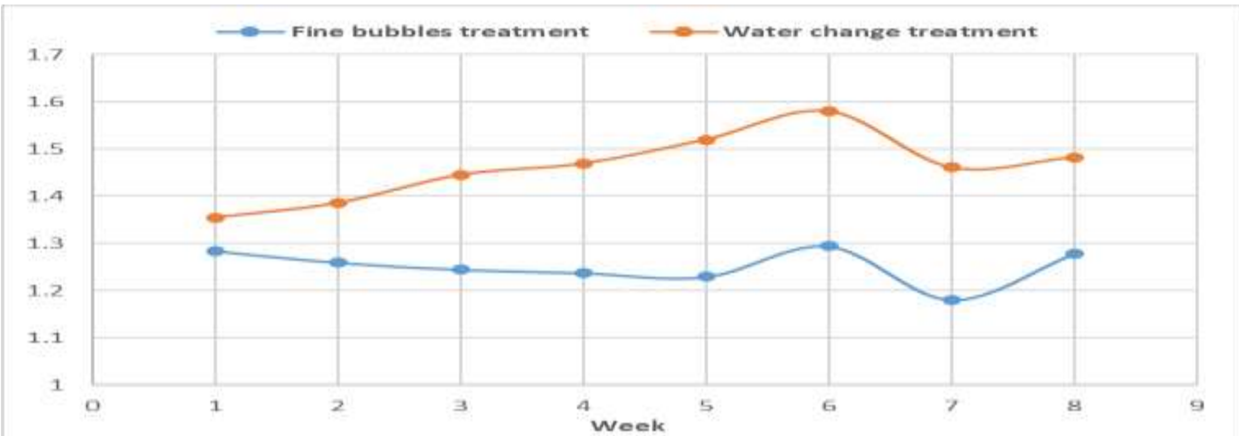


Fig. 8. FCR mean values for aeration by fine bubbles treatment and water change treatment a long experimental period.

Source: Own results.

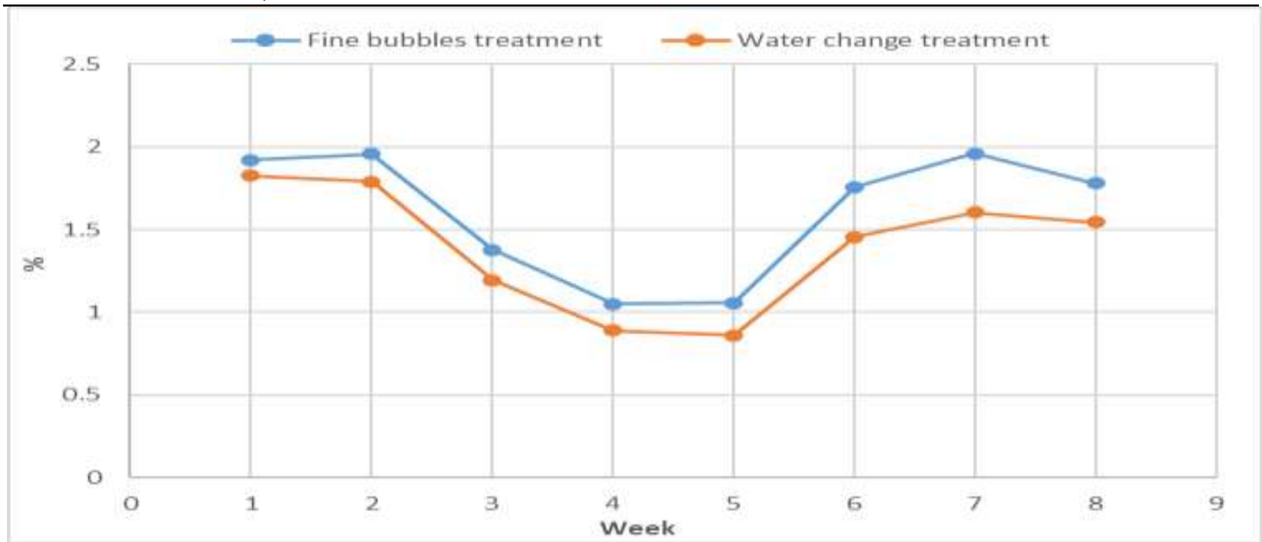


Fig. 9. SGR mean values for aeration by fine bubbles treatment and water change treatment over the experimental period.
Source: Own results.

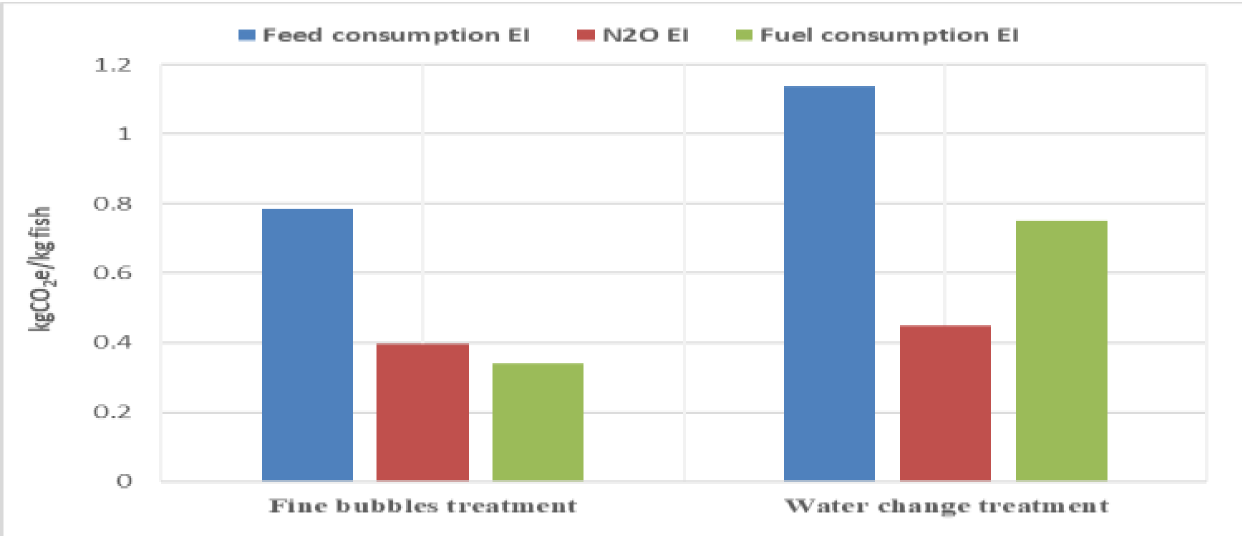


Fig. 10. Emission intensities for fine bubbles treatment and water change treatment
Source: Own results.

Effect of developed aeration system on aquaculture greenhouse emissions

The results showed that there is a reduction in GHGs emissions by using fine bubbles tube aeration method with 0.8058 kg.CO_2e/kg. fish due to reduction in feed consumed, N_2O emissions and fuel consumption. This reduction details values were 0.3529, 0.0529 and 0.4 kg.CO_2e/kg. fish for feed, N_2O emissions and fuel consumption, respectively as shown in Figure 10.

Water footprint estimation

The results showed that 1m^3 of water can produce 153.97 g of fish at F.B.T., while 42.765 g at W.C.T at experimental period (equivalent 6.498 m^3/kg. fish for F.B.T and 23.386 m^3/kg. fish for W.C.T.). These results due to the aeration efficiency of F.B.T rather than W.C.T. Also, survival rate is higher in F.B.T. than W.C.T.

CONCLUSIONS

The maximum mean value for dissolved oxygen was 91% of saturation obtained at fine bubbles aeration method.

Also, the minimum mean value for total ammonia nitrogen was 0.32 mg/l obtained at fine bubbles aeration method. The best FCR value was 1.181 and obtained at the seventh week for F.B.T, while the best value for W.C.T was 1.58 and obtained at the fifth week. Also, the survival rate values were 98.89 and 91.11 % for F.B.T. and W.C.T., respectively.

The permissible variables limits were (0.1, 0.18 and 0.23 $m^3.h^{-1}$) for air flow rate, (4, 6 and 7 mm) for tube wall thickness, (0.3, 0.50 and 0.70 mm) for tube depth from water surface and both of (circular and Longitudinal) design shapes.

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