DJAS
Damietta Journal of Agricultural Sciences
مجلة دمياط للعلوم الزراعية

Damietta Journal of Agricultural Sciences

Volume 1, Issue II, 2022

DJAS

Damietta Journal of Agricultural Sciences
http://publication.du.edu.eg/journal/ojs302design/index.php/agr/index
ISSN: 2812-5347(Print)- 2812-5355 (Online)

Evaluation of Using Micro Sprinkler for Indoor Fish ponds Aeration

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Key words:
Fish ponds
Micro Sprinkler
Aeration System
Indoor Aquaculture

Accepted 19/9/2022

ABSTRACT

Indoor fish ponds are an economic activity that helps to apply the needs of fish meat which also have the advantage of being conducted on many scales. The main objective of this study is to make evaluation of using micro-sprinkler as an alternate for traditional nozzle sprayer aerators to obtain advantages of ease of implementation and save energy for indoor fish ponds. The study has been carried out on homosexual Tilapia fish (Oreochromis niloticus) in a glass tank which was open from the top side and put in a closed room. The evaluation of water environment parameters showed that Ammonia concentration (NH_3), Potential hydrogen (pH), Electric conductivity (EC), and Turbidity (T_{ur}) were in acceptable limits to keep fish life. There was reverse proportional relationship between dissolved oxygen content (DO) and all of NH_3, EC, and T_{ur}. The proposed aeration system succeeds to apply oxygen demands when required with low energy consumption and standard aeration efficiency (SAE) value of 5.0 kg O_2/kW. h which was near to the (SAE) of nozzle sprayer. Feed conversion ratio (FCR) by the end of growing season was 1.88 with an average of fish weight 180g. The study revealed the possibility of using micro-sprinklers for indoor fish ponds aeration and recommended to investigate other possible management strategies to improve the SAE of the system and obtain higher fish productivity.

INTRODUCTION

Fish resources are critical to food security as almost the half of world's population obtain 17% of their animal protein intake from fisheries (Including aquaculture) globally in 2019 **FAO, (2022).** Fish farming process depends on Water properties, which include: Total temperature, Dissolved Oxygen (DO), Suspended Solids (SS), Total Dissolved Solids (TDS), potential of hydrogen **(**pH**),** Total Rigidity (TR), Biochemical Oxygen Demand (BOD), Nitrate - Nitrogen (NO_3-N) and turbidity **Khan et al., (2017).** Oxygen is the basic requirements for aquatic life. Heterotrophs dissolved oxygen is the only source of oxygen, which acts a vital factor not only in sustaining life but also in the regulation of their metabolic activities and food dynamics **Chang et al., (2008); Kumar et al., (2013); and Banerjee et al. (2019).** The lack of dissolved oxygen is a major factor threatening intensive aquaculture because it affects fish growth, food conversion levels, feeding efficiency, in addition to keep the suitable water quality of water environment **Dwyer et al. (1993); Clark (2003); Mallya (2007); Roy et al., (2015); and Sultana et al., (2017).** Dissolved Oxygen (DO) is usually expressed by the volume of oxygen in the water, and this is very important in the health and well-being of living organisms. Most types of fish and Thrive in the (DO) range of 5-12 mg/l to grow well. If the (DO) level drops to less than 4 mg/l, it will get tense and death begins, **Boyd et al. (2018).** Fish farmers especially in dense and semi-dense culturing need an artificial utility to control (DO) level specially in cases of high temperature times and absence of wind to avoid the risk of losing their production, **Sriyasak et al. (2013).** Artificial aeration becomes a basic factor in fish production not only due to life-saving role and health of the fish, but also has a role in production economies as they act an additive element for total production and energy cost, **El-Sayed (2007); Seginer et al., (2008); Abou Zied (2013); and Abdelrahman (2016).**

Indoor fishing where you can do farming on any scale in a closed rooms needs higher control for (DO) as it effects the quality of water to reduce water recycling. The importance of indoor fishing comes from the nature of the business which reduces the stress on caught fish from large scale aquatic fish ponds. Indoor fish ponds are essentially relying on artificial aeration where there is absence for normal aeration. In many cases small scale indoor fish ponds need low cost and low energy consumption aeration systems to maximize the profits of this activity. Nozzle aerators are pushing water bubbles to contact air and back downward carrying oxygen to the ponds. These systems are considered energy saving systems **Parmar and Majumber., (2013);**

Deendarlianto et al., (2015); Rizaldi et al., (2019) and Taukhid et al., (2021) which reduces production cost as they need to be operated most of day time, **Anyadike et al., (2011).**

This study aims to investigate the possibility of using micro-sprinklers as alternative for known normal nozzle aerators and how it can be managed to apply the needs of (DO) for indoor fishing. The study will also evaluate the (DO) effect on water environment quality parameters and how they will affect fish growth and vital activities.

MATERIAL AND METHODS

1- Experiment design:

This study was conducted during the period from 19th October till 12 December 2021 at a private house located at 31.67º N, 31.36º E in Kafr -Saad city, Damietta governorate. Experiments had two phases including primary experiment to choose suitable operating pressure that can provide greatest possible oxygen transfer rate (OTR) and the second phase was to evaluate the performance of micro-sprinkler in providing the oxygen requirements and evaluate the water environment during fish growth season.

2.1 Aeration process

Simulation of aeration process was by filling water into a securit glass tank with dimensions of 600mm length, 600mm width, and 800 mm height, which are nearly 0.29 m^3. Glass thickness was 10 mm. A mix of main canal Nile River irrigation water and fresh tap water with a ratio of 1:1 was used for fish breeding. Physical and chemical properties of both waters are listed in **table 1.**

Table 1. Analysis Chemical and physical properties of the used water.

	Anions (mEq/l)			Cations (mEq/l)				NH_3, mg/l	pH	EC, mS/cm
	Cl^-	HCO_3^-	SO_4^{--}	K^+	Na^+	Mg^{++}	Ca^{++}			
Canal water	7.32	4.56	1.38	0 .37	6.44	1.80	3.99	0.55	7.44	1.15
Tap water	1.32	2.10	1.21	0.36	5.30	0.06	0.14	0.04	7.32	0.61

After making this water mix; there was a 2 hours interval before adding the mix to the tank to avoid chlorine effect on fish and give it the opportunity to volatile. **Figure (1)** shows a schematic diagram for the glass tank. Whenever there was a need to full or partial change for water in the tank, a 1.25 cm diameter ball valve was fitted at the lowest point of the tank to drain water.

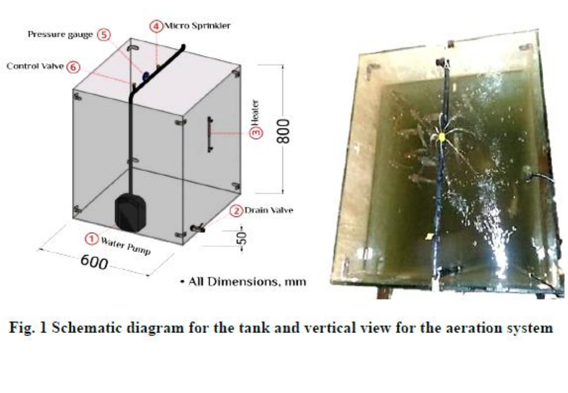

Fig. 1 Schematic diagram for the tank and vertical view for the aeration system

A submersible 90 watts electric pump with 2.2 m^3/h capacity and 2.8 m maximum head, located at the bottom of the glass tank to pump water from the tank to the micro sprinkler. A polyethylene 16 mm inner diameter drip irrigation hose was connected directly to the pump to deliver water to the micro sprinkler which located in the center of the tank and fitted to look at the up side. Specifications of the micro-sprinkler are shown in **table 2.** Shape and design of micro-sprinkler are shown in **figure (2).**

Water inlet pressure head to the micro-sprinkler was controlled by a 16mm inside diameter T-shaped plastic valve. Operating head measurement was with using pressure gauge 0.2 m accuracy. Aeration process management was to keep the (DO) content between 4 to 8 mg/l to avoid oxygen stress on fish and over aeration. As (DO) measurement was three times a day, the operation of aeration system started when (DO) reading was near to 4 mg/l and stopped at 8mg/l.

Table 2. Specifications of used micro-sprinkler

Manufacturer	Metalic plastic
Country of made	Egypt
Material	Polyethylene
Recommended operating head	17 m
Designed flow rate	18 l/h max
Wetting pattern diameter	Max 22-25 cm
Diameter	15mm
Number of outlets	8

2.2 Fish breeding

Homosexual Tilapia Nilotic fingerlings (Oreochromis niloticus) were bought from a special incubator with initial weight 20g/fingerling. Total fingerlings in the tank were 12 which equals a density of 41 fingerlings/m^3 which considered semi dense fish culture. As the experiment is targeting to investigate how successful can be the use of micro-sprinkler in the aeration process, we preferred to start with semi dense density to reduce the risk of fish mortality. A 150 watts aquarium glass water heater was fitted to the water tank side to be used in emergence water heating if the water temperature dropped to the minimum limit. The heater is automatically can adjust the water temperature from 17 to 35º C and it was adjusted to 25º C. A floating feed billets with diameter of 3 mm has raw protein not less than 30%, crude fat not less than 2.44%, crude fiber not more than 6.49%, total energy not less than 3880 (kcal / kg feed). Fish were fed three times a day, at seven in the morning, at eleven in the afternoon, and at exactly two in the afternoon. Feeding time should not exceed an hour because it is the maximum fish feeding time (**Martins et al., 2011)**. An hour after placing the feed, the remaining feed was removed from the surface of the tank in order to prevent the decomposition of the feed so as not to affect the dissolved oxygen content in the water. Feeding during the whole growth period was with a fixed 3 days interval. The feeding and experiment stopped when fish reached a marketable size and weight.

2.3 Aeration management

In order to know the best management practice for the micro-sprinkler; four operating pressure heads namely 15, 18, 20 and 25 m of water were tested to choose the maximum possible (OTR) to obtain. Calculation of (OTR), (mg/h) was according to Equation (1) **Vogelaar et al., (2000).** The system operated under each of the proposed pressure heads to 30 minutes after measuring the initial DO (DO_i) in mg O2. By the end of time the final DO (DO_f) was measured.

$$OTR = \frac{DO_f - DO_i}{T} \quad \text{..(1)}$$

According to the obtained results the 25 m operation head was used during the whole period of the experiments.

2.4 Water quality parameters measurements

The judgment on the quality of water environment for tilapia fish was according to **table 3**. Evaluation of water environment quality parameters extended to the first 21 days of the experiment. Quality parameters included DO, water temperature (T_w), Electric conductivity (EC), Ammonia (NH_3), and turbidity (Tur). There was investigation about the relationship between (DO) and all of (T_w), (EC), (NH_3), (T_{ur}), as they affect the (DO) content in water.

Ammonia concentration measurement and turbidity were the main parameters of changing water in the tank. If one or both of the two parameters were in unacceptable range; the water in the tank was replaced by a new water supply with the same mix of tap and canal water.

Table 3. Maximum and minimum limits of Tilapia breeding water quality parameters

Parameters	Min	Max
Dissolved Oxygen, mg/l	4.0	10.0
pH	6.5	9.0
Temperature, °C	8.0	39.0
Conductivity, µS/cm	150	500
NH_3	3.0	5.0
Turbiditty, NTU	14	23.0

Source: Ali et al., (2020) and Makori et al., (2017)

2.4.1 Dissolved oxygen (DO) and water temperature (T_w)

The Oxygen meter Lutron (YK-22DOA), which measures both (DO) and water temperature. The accuracy of this device was 0.1 mg/l. The same device has the ability to measure water temperature within a range of -20 to 120 ºC, with 0.1ºC accuracy. DO in water was measured three times a day in the following times: 6:00 AM, 12:00 PM and 6:00 PM to act the times of dawn midday, and dawn respectively. Measurement is carried out at a distance of 10 cm from the surface layer of water with the device probe.

2.4.2 Turbidity measurement (T_{ur})

The turbidity meter Lutron (TU-2016), which has a range from 0.00 to 50 NTU (Nephelometric Turbidity Unit). (T_{ur}) level in the tank was measured every 24 hours at 2:00 PM. A sample is taken from the bottom of the tank and filled in the device's package for the recommended limit on the package, then the device is turned on and the reading was recorded.

2.4.3 Ammonia content (NH_3)

The ammonia meter Milwaukee (Mi405), which has a range from 0.00 to 9.99 mg/l, and accuracy of 0.01 mg/l. The level of ammonia in the tank was measured at the same times of the day when measuring DO with 48 hours interval. A sample is taken from the bottom of the tank and filled in the device's package for the recommended limit on the package, then the device is turned on and then record the reading.

2.4.4 Potential of Hydrogen (pH)

The pH meter Adwa (AD1030) was distinguished in measuring pH with accuracy of 0.01. pH level in the tank was measured at the same time daily with the last reading of (DO) measurement time. A water sample of 20 ml taken from the tank and placed inside the device's water holder to measure pH of the water.

2.4.5 Electric conductivity (EC)

The EC measured by the device Lutron (YK-22CTA), daily at a distance of 100 mm from the surface layer of water with one of the (DO) readings.

2.5 Feed conversion ratio (FCR)

The average weight of random 5 fish was used to describe fish weight. Weighing process was every three days using a digital scale with 0.001g accuracy. (DO) is a critical factor to the feed intake of fish. The (FCR, %) index was calculated to express the growth performance and how efficient was the proposed aeration system to keep the fish growth and weight gain in normal trend of increase. (FCR) calculation was according to Equation (2) **Effiong et al., (2009).**

$$FCR = \frac{W_i - W_f}{F_{int}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots.(2)$$

Where F_{int}= feed intake, g.

Feeding rate was according to the recommendations of **GAFRD, (2009)** as a percentage of live fish weight.

2.6 Energy consumption

In order to investigate how can the proposed aeration system save energy, energy consumption calculated by multiplying required power to pump water (P_w, Watts) to the operation hours during the total growth period as shown in Equation (3**) Letey et al., (1990)** and Equation (4) **Ishfaq, (2002).**

$$P_w = \frac{\omega QH}{\text{constant}} \quad \text{..................................(3)}$$

Where ω= Water specific weight kg/m^3; Q= water flow rate m^3/s, H= operation head, m.

$$P_r = \frac{P_w}{\eta_p} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

Where: Pr = Required power, watts; Pw = pump water, watts; η_p = pumping efficiency which was assumed to be 70%. Friction loss was neglected due to the small scale of the system.

2.7 Aeration Efficiency

Aeration efficiency was to compare the proposed aeration system efficiency and the standard values of nozzle sprayer aerators. Equation 6 was applied to calculate standard Aeration efficiency (SAE, kg O_2/kW. h) of nozzle sprayer aerators **Boyd, (1998).**

$$SAE = OTR/p_r \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

RESULTS AND DISCUSSION

3.1 Oxygen transfer rate (OTR)

Data listed in **table 4** showed that by increasing operation head both micro sprinkler flow rate and OTR to the water in the tank increased. Referring to the obtained results, 25m operation head was recommended to operate the micro-sprinkler under the experiment conditions.

Table 4. Effect of operation head on micro-sprinkler flow rate, l/h and OTR, mg/h.

Head, m	Flow Rate, l/h	OTR, mg/h
15	14.6	6.5
18	16.0	6.7
20	18.0	7.3
25	21.0	7.5

3.1. Water environment quality evaluation

3.1.1. Potential of Hydrogen (pH)

Results shown in figure (3), indicated that pH values during the water quality evaluation time period was in the optimal range most of times. The maximum value was 8 which did not exceed the maximum permitted value for pH in Tilapia water environment. The minimum recorded value 5.65 was less than the least recommended value but it tended to increase to reach the recommended values because of partial change of water.

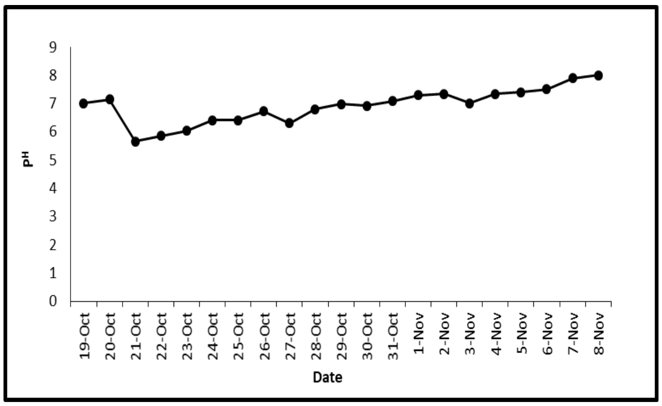

Fig. 3 Variation in pH values during water quality evaluation time period.

3.1.2. Effect of water temperature on dissolved oxygen

Results showed that there was a reverse relationship between DO and water temperature at measuring times. This result was in agreement with **Rajwa-Kuligiewicz et al., (2015).** Figure (4) shows the relationship between water temperature and (DO). Temperature is not the only factor that affects (DO) but also there are other factors like NH_3 content and turbidity. This could be clarified as the increase in water temperature about 2.6ºC led to decrease DO content from 6.6 mg/l to 2.0 mg/l which indicates the role of other factors.

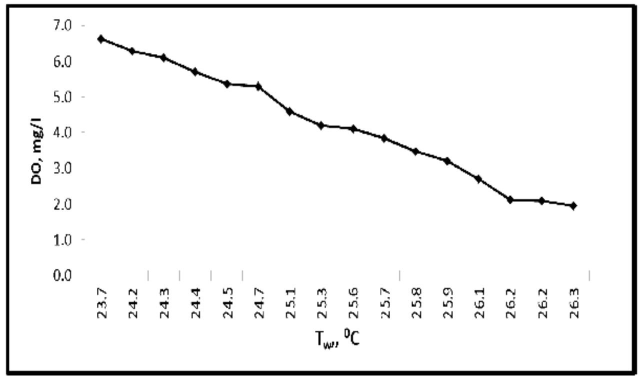

Fig. 4 Relationship between water temperature and DO content under experimental conditions such as (NH_3, pH, Tur).

3.1.3. Turbidity (T_{ur})

Measurements of turbidity shown in figure (5) revealed that there was reverse proportional relationship between turbidity and (DO) content. When turbidity tends to decrease the (DO) tends to increase and vice versa and this was in agreement with **Eze et al., (2021).** Maximum turbidity obtained was 26.10 NTU while the least was 2.86 NTU. Turbidity highest values were directly related to feeding days because of the residues of forage. Least recorded turbidity values were observed at the days of changing water in the tank.

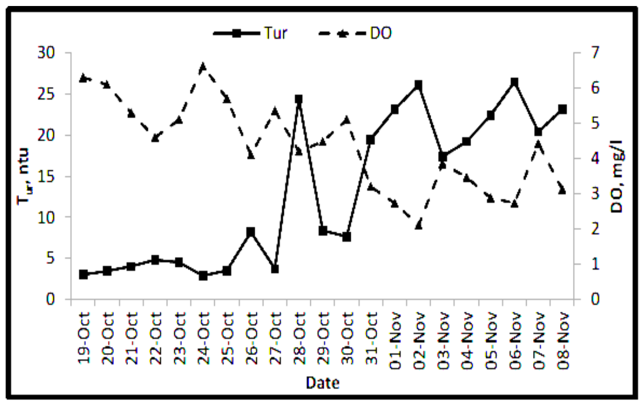

Fig. 5 Values of (DO) and (T_{ur}) over the growing season

3.1.4. Electric conductivity (EC)

(EC) measurement was to describe water salinity. Obtained data of (EC) showed that the relationship between (DO) and EC did not follow a certain trend whether directly or reversely proportional as shown in figure (6). Theoretically there is a reverse relationship between water salinity and (DO), salt water can't absorb oxygen as fresh water. The same behavior of these observations was recorded by **Külköylüoğlu et al., (2007).** This may be because the difference in factors affecting (DO) and salinity which could result the separation in results trends. The least (EC) value was 508 µS/cm while the greatest was 651 µS/cm. These values considered acceptable despite they exceed the recommended values of **Makori et al., (2017)** but in the accepted range of **Stone et al., (2013)** which was between 500 to 2000 µS/cm. Based on the previous recommended values of EC, the EC values during the experiment were high but did not reach a dangerous level that may affect the life of fish.

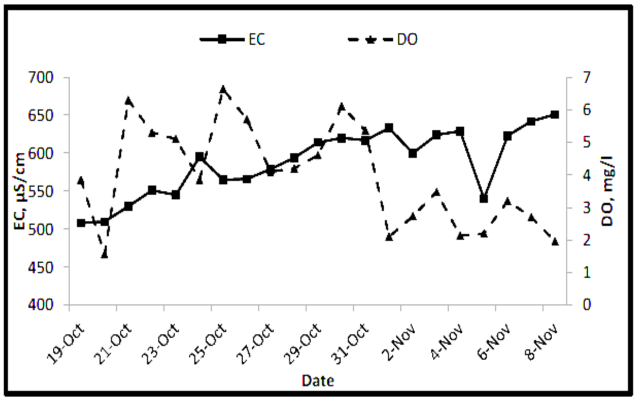

Fig. 6 Relationship between EC and DO values during the experiment period

3.1.5. Ammonia concentration

Figure (7) shows the values of NH_3 over the water environment evaluation period. Results showed that NH_3 was reversely proportional to (DO). Maximum obtained value of NH_3 was 9.7 mg/l which faced the least (DO) content recorded at measuring time which was 2.2 mg/l. NH_3 concentration exceed the maximum recommended limit at days 1st, 2nd, and 5th of November and this was treated by changing water. This might be due to the increase in fish size and the small size of the tank. As behavior of NH_3 versus Oxygen was the same as T_{ur}, it could be mentioned that there was a directly proportional relationship between NH_3 concentration and T_{ur}.

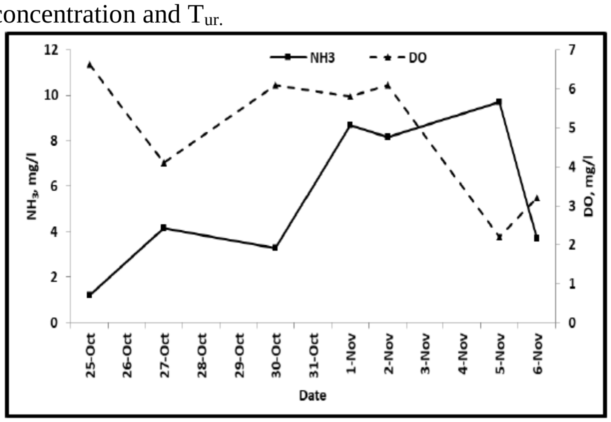

Fig. 7 Relationship between (NH_3) and (DO)

3.2. System ability to provide oxygen and aeration efficiency

Results indicated that the aeration system was able to increase (DO) content in water to the desired value when required. Figure (8) describes the trend of average (DO) content over measuring days. The low content of oxygen as previously mentioned was related to many factors such as EC, T_{ur}, and T_w. but in general, as it is required to increase the (DO) content to the decided concentration when required, these low values were not a measure for the system success or failure specially when the system did succeed to increase DO.

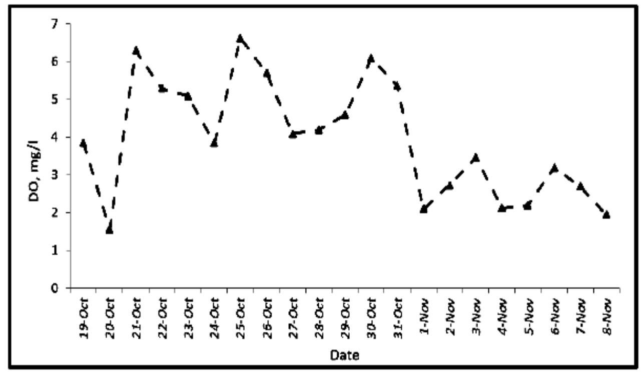

Fig. 8 Average daily DO content and the increase after aeration Process

The required P_r was 1.5 Watt and OTR was 7.5 mg O_2/h then the calculated SAE was 5.0 kg O_2/kW.h with a total energy consumption of 0.498 kW.h with total 332h operation time. Calculated SAE for the proposed system was less than the SAE of the Pump sprayer aerators SAE which is 5.6 kg O_2/kW.h **Boyd, (1998).** The proposed micro-sprinkler aeration system did not go far from the standard of nozzle sprayer (SAE). This might be a success for this system as a prototype and might lead to make improvement in system management procedures like using greater sprinklers or higher operation pressure heads to reach the standard (SAE).

3.3. Growth rate and feed conversion ratio

Figure (9) shows the growth rate of fish during the growing season. The fish weight kept the trend of increase during the whole season with no observations of constant weight or weight loss periods as shown in **table 5**.

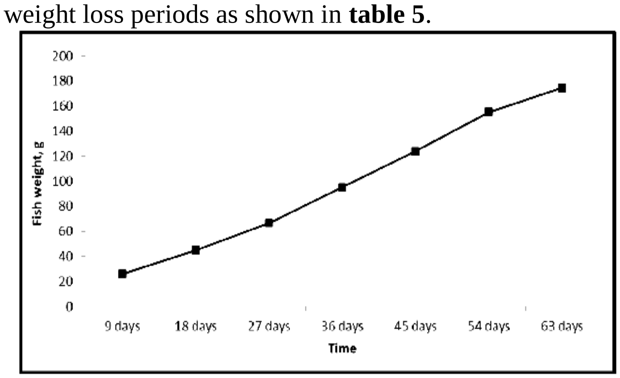

Fig. 9 Rate of increase in fish weight during growing season

Total feed intake per fish was 82.44 g. FCR at the end of growing period was 1.88. This ratio exceeded the ratio mentioned by **Rana & Hassan (2013)** for tilapia fish in cage environment which ranged from 1.0 to 1.71.

The continuous increase in fish weight and (FCR) value might be a reflection for the success of micro-sprinkler aerator management in keeping the (DO) in suitable level for fish growth and water environment quality management procedures to keep water environment in suitable quality.

Table 5. Average weigh per fish during experiment period

Time period, days	Average fish weight, g
0	20
9	26
18	45
27	67
36	95
45	124
54	155
63	175

CONCLUSION

During the experiment water quality parameters were inacceptable limit for fish growth and survival. The system showed acceptable performance indices and could apply the DO demand when required. The results of this study could be concluded in the following points:

1. Water pH was within the acceptable limit during the whole experiment period.
2. There was reversely proportional relationship between (DO) and all of NH_3, EC, and T_{ur}.
3. The turbidity level reached its highest value of 26.50 NTU while the lowest value of the turbidity level in the tank was 2.86 NTU. Turbidity accelerated in increasing with the increase in fish growth and weight.
4. The ammonia level had the highest value at 9.7 mg/l and the least value of the ammonia content was 1.19 mg/l.
5. (OTR) of the system was 7.5 mg O_2/h at 25m operation head.
6. Total energy consumption of the unit was 0.498 kW.h with total 332h operation time.
7. Calculated SAE 5.0 kg O_2/kW.h and considered near to SAE of nozzle sprayer aerators which is 5.6 kg O_2/kW.h.
8. (FCR) reached 1.88 and it exceeds the (FCR) in caged fish farming.

The previously listed results showed the possibility of using micro-sprinklers for indoor fish ponds culturing. Future studies are recommended to investigate better management for the system like increasing operating pressure head or study more suitable number of micro- sprinklers to increase the performance of the proposed aeration system to reach or exceed the value of (SAE) of nozzle sprayers.

FUNDING:

This research was self-funded.

CONFLICT OF INTEREST:

The authors declare that they have no conflict of interest.

AUTHORS CONTRIBUTION

Elnemr, M. K. developed research proposal, shared manuscript preparation and revision.

Eldesoky, F. S. handled the experiment and measurements and shared manuscript preparation.

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تقييم استخدام الرشاش الدقيق لتهوية أحواض الأسماك في الأماكن المغلقة

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أحواض الأسماك في الأماكن المغلقة تساعد على تلبية احتياجات البشر من لحوم الأسماك وتتمتع أيضًا بإمكانية إجراءها بمقاييس مختلفة. الهدف الرئيسي من هذه الدراسة هو إجراء تقييم لاستخدام الرشاشات الدقيقة كبديل لنظم البخاخات التقليدية للحصول على مزايا تتعلق بسهولة التنفيذ وتوفير الطاقة لأحواض الأسماك الداخلية. أجريت الدراسة في خزان زجاجي داخل مكان مغلق على أسماك البلطي النيلي. أظهرت قياسات تقييم البيئة المائية أن تركيز الأمونيا (NH3) ودرجة الحموضة (PH) والتوصيل الكهربائي (EC) والعكارة (Tur) كانت في حدود مقبولة للحفاظ على حياة الأسماك. كانت هناك علاقة عكسية بين محتوى الأكسجين المذاب DO وكلا من العكارة والتوصيل الكهربائي وكذلك تركيزالأمونيا. نجح نظام التهوية المقترح في تلبية متطلبات الأكسجين عند الحاجة مع استهلاك منخفض للطاقة وكفاءة تهوية قياسية بلغت قيمتها 5.0 kgO2/kW.h والتي تقترب من كفاءة التهوية القياسية لنظم البخاخات. بلغت نسبة التحويل الغذائي (FCR) بنهاية موسم النمو 1.88 بمتوسط وزن 180 جرام. كشفت الدراسة عن إمكانية استخدام الرشاشات الدقيقة لتهوية أحواض الأسماك الداخلية وأوصت باستقصاء استراتيجيات الإدارة الممكنة الأخرى لتحسين كفاءة التهوية للنظام والحصول على إنتاجية أعلى للأسماك.

الكلمات المفتاحـية

أحواض الأسماك، الرشاش الدقيق، نظام التهوية، تربية الأحياء المائية في الأماكن المغلقة.


DJAS
of
urnal Agricultural Sciences Damietta Journal
of
Agricultural Sciences
DJAS (2022), Vol. 1, Issue (II)