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Evaluating a Recirculating Aquaculture System Using Magnetized Water for Water Quality Parameters and Growth Performance of the Nile Tilapia (*Oreochromis niloticus*) Fingerlings

Ragaa A. Ahmed [1*], Samir A. Ali[2], Mahmoud I. M. Ismail[3], Tarabye H. H. H.[3]
[1]Aquaculture Department, Faculty of Fish and Fisheries Technology, Aswan University, Egypt
[2]Agricultural Engineering Department, Faculty of Agriculture–Benha University 13736, Egypt
[3]Agricultural Engineering and Biosystems Department, Faculty of Agriculture, Aswan University

[*]**Corresponding Author: ahmed.ragaa@fft.aswu.edu.eg**

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ABSTRACT

The current study was designed to determine the effect of magnetic water technology and different stocking densities in a recirculating aquaculture system (RAS) on water quality parameters and the growth performance of the Nile tilapia (*Oreochromis niloticus*). RAS mainly consists of rectangular tanks for fish rearing, two centrifugal pumps (power = 0.5hp, Hmax = 35m, Qmax = 2m^3/ h) used for recirculating the water in RAS, a mechanical filter, a biofilter, an aeration system, pipes, valves, and other fittings. Magnetic water with a degree of 14,500 gauss (1.45 Tesla) was used in comparison with normal water (0 gauss). The Nile tilapia fingerlings with an average initial weight of 5.4± 0.31g were randomly distributed. The experiment was based on a 3×2×3 factorial design with two stocking densities (50 and 100 fingerlings/ 0.5m^3), and each group was duplicated and reared in three types of water: control water (CW), magnetic water (MW), and non-magnetic water (NMW). The experimental fish were fed a commercial diet (30% protein) at a feeding rate of 4% of body weight for all groups. Water quality parameters, growth performance parameters, feed use, and chemical composition were calculated in all groups at the end of the experiment after six weeks. Results indicated that using a recirculating aquaculture system (RAS) with natural bacteria as a biological filter is highly effective in improving the water quality characteristics, especially eliminating ammonia. However, the use of magnetization technology to treat fresh water culture does not make a significant difference in improving the water quality. Furthermore, the water recycling system not only saves water throughout the production period but also improves the growth performance of the Nile tilapia fingerlings.

INTRODUCTION

Worldwide demand for quality protein is rising as the human population continues to rise. Fish is typically considered to be an especially healthy source of protein when compared to animal sources. Nowadays, aquaculture produces more fish protein than catch fisheries in terms of the world's food supply **(FAO, 2018)**.

A major problem for sustainability and environmental preservation is that the Nile tilapia farming produces a lot of effluent, in addition to using a lot more freshwater than other animal husbandry practices. The recirculating aquaculture system (RAS), which improves the sustainable growth of aquaculture, has grown in popularity as a result **(Ahmed *et al*., 2019)**.

The worldwide expansion of the tilapia industry, along with the scarcity of freshwater and competition for it from agriculture and urban activities, has gradually moved the sector away from conventional semi-intensive systems and toward more intensive production methods **(El-Sayed, 2006)**. Compared to conventional aquaculture systems, RAS generally achieves environmental sustainability by using 90– 99% less water. Recirculating water significantly lowers the risk of pathogens entering the system. While there are few facilities for caring for waste disposed of from marine RAS, waste disposed of from freshwater RAS is typically processed in regional waste treatment facilities or may be used for agricultural purposes as fertilizer **(Van Rijn, 2013)**.

The use of magnets to improve quality is of a significant interest due to its low cost compared to chemical and physical treatments. Magnetically treated water improves some water quality parameters, some blood parameters, feed utilisation, and the growth performance of fish. Using magnetic force has a vital role in the treatment of polluted water and has positive implications for aquaculture. This encourages more research in this field to overcome the negative effects of water pollution **(Ahmed & Abd El-Hamed, 2020)**. The magnetic field affects certain physico-chemical properties of water. The use of magnets to improve water quality is of a significant interest due to their low cost compared to chemical and physical treatments. Magnetic water improves some water quality parameters and the growth performance of the Nile tilapia and the common carp **(Said *et al*., 2022)**.

The primary aim of this study was to investigate the impact of utilizing magnetization technology and different densities in recirculating aquaculture systems (RAS) on water quality characteristics and growth rates.

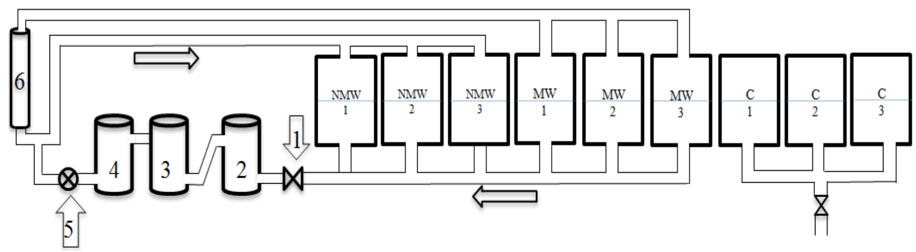
MATERIALS AND METHODS

This study was conducted in fiberglass tanks at the Faculty of Fish and Fisheries Technology, Aswan University, Egypt

The components of a recirculating aquaculture system

Breeding tanks

Rectangular fiberglass tanks with dimensions (length*width*height) of 2000mm*1000mm*1250mm and a volume of 2.5m^3 were used. Each tank was filled to a volume of 1m^3 and drainage holes of 2 inch diameter/ tank that were made near the bottom (Fig. 1).



1: Valve 2: Mechanical filter 3: Biological filter 4: Water collection 5: Pump 6: Magnetic water treatment

Fig. 1. Components of the experiment

Mechanical filter and biological filter

Two plastic barrels (220-liter capacity) were used. One was used as a mechanical filter, while the other was used as a biological filter. The flow from the tanks to the filters was facilitated by gravity.

Bacterial growth media

Irrigation hoses with a diameter of 16mm were used as bacterial growth media. They were cut to a length of 3cm to provide a qualitative surface area of about $250m^2/ m^3$

Magnetic devices

A magnetic rod with a diameter of 2 inches and a magnetic field strength of 14500 gauss (1.45 Tesla) was used as the magnetization device by Delta water, made of stainless steel to treat the water. Water becomes magnetized as it travels through a magnetic field, which affects the structure and composition of water molecules physically.

Water pump

Two 0.5-hp water pumps (OSAB) were utilized, each with a flow rate of $2m^3/ h$ and a maximum lift rate of 35m. The operation was regulated by a self-controller, allowing each pump to run for 30 minutes, and then rest for 30 minutes in an alternating pattern.

Air pumping device

An air blower with a capacity of 1.5hp and a flow rate of $170m^3/ h$ was used. It was turned on for half an hour and turned off for another half an hour.

Water quality

The water quality in the system was monitored daily. Measurements of pH, salinity, and temperature were obtained from the sumps of the system, and the dissolved oxygen was measured in each individual tank using an oxygen meter (Milwaukee Instruments, Range 0.0 to 19.9mg/ l). Additionally, temperature, pH, and TDS were measured using a water quality tester (Range 0- 14pH, 0- 50°C, 0-1999ppm, 0- 19.99ppt). Ammonia was measured using test solution/ indicator (RE0603-A, RE0603-B, RE0603C, RE0603D, range 0– 8mg/ L, volume 15mL).

Experimental conditions

This experiment aimed to investigate the effects of different densities and magnetized water on the Nile tilapia (*Oreochromis niloticus*) fingerlings. The study consisted of two factors, each of which was repeated twice: storage densities (50 and 100 fingerlings/ 0.5m^3) and two types of water, one magnetized and the other not (under the recirculating aquaculture system (RAS)). The control transaction was an open system.

During the six-week experiment, the fish were reared in tanks with an average weight of 5.4± 0.31g/ fish and were fed a daily ration of 4% of their body weight using floating pellets (1mm) containing 30% protein. The daily feeding ration was split equally between the morning (9 AM) and evening (3 PM).

Throughout the study period, the water flow rate was maintained at 33.3 liters per minute. In the control ponds, approximately 8,400 liters of water were replaced to reduce the level of ammonia, whereas 1,324 liters of water were added to compensate for water lost due to evaporation. In the recirculating aquaculture system (RAS), 2,648 liters of water were added during the trial period to compensate for water lost, and an additional 575 liters were added to compensate for water lost during the removal of solid waste from the mechanical filter.

The treatments were as follows:

C50: Control (50 fingerlings/0.5m^3)

C100: Control (100 fingerlings/ 0.5m^3)

MW50: Magnetized water (50 fingerlings/0.5m^3)

MW100: Magnetized water (100 fingerlings/ 0.5m^3)

NM50: Non- magnetized water (50 fingerlings/ 0.5m^3)

NM100: Non- magnetized water (100 fingerlings/ 0.5m^3)

Growth performances parameters

Every two weeks, fish were taken from each tank to determine the growth performance parameters, including weight gain, average body weight (g) expressed as final weight, survival rate (SR) (%), condition factor (K), and feed conversion ratio (FCR), which were calculated according to the following formulas: The weight gain (g/ fish) was calculated using the following equation: Body weight gain (BWG) (g/ fish) = final weight (g) - initial weight (g). Total body length (BL) was measured at the end of the experimental period by the ruler (cm). The condition factor (K) was calculated using the following equation: K = (W /L3) x l00, where W = body weight (g) and L = total length (cm). Feed conversion ratio (FCR) and specific growth rate (SGR) were determined by using the following equations: FCR = feed intake (g) / weight gain (g), SGR = 100 x (lnW2-lnW1) / T, Where W1 is the initial weight and W2 is the final weight (g), T is the number of days in the feeding period, and survival rate (%): Survival rate (%) = {(total number - dead number)/total number} x 100.

Experimental diet

Fish in all experimental groups were fed six days per week with a commercial floating pellet containing 30% crude protein content whose diameter was 1mm. The commercial feed ingredients were: fish meal (65%), yellow corn, wheat flour, wheat bran, soybean meal (48%), fish oil, vitamins, and a mineral mixture. Chemical analyses of the experimental diets are shown in Table (1).

Table 1. Chemical analysis of the experimental diets

Chemical analysis	percentage (%)
Crude protein	30
Gross energy (kcal/kg)	4260
Crude fat	8.15
Crude fiber	5.4

Statistical analysis

All statistical analyses were performed using the SPSS version 22.0 for windows package. All data were expressed as means ± standard error. All of the data obtained were tested for the normality of distribution and homogeneity of variance, and the least significant difference (LSD) test was used to test the differences. The 5% level of probability was considered to be the significance level.

RESULTS AND DISCUSSION

Water quality parameters in fish tanks

The values of water quality parameters are presented in Table (2). There were no statistically significant differences ($P > 0.05$) in the means of DO, and temperature between the CW, MW, and NMW during the study period. Moreover, there were no significant differences in temperature, pH, TDS, dissolved oxygen, total ammonia concentrations between MW and NMW. However, there were significant differences in total ammonia, ph, and TDS in the control water compared with magnetic water, while the non-magnetic water remained ammonia levels within the tolerance range for the growth and survival of the Nile tilapia (*Oreochromis niloticus*). Whereas, the pH values remained relatively constant (ranging from 7.3 to 7.9) and did not change in any system during the study period. The water temperature in the fish ponds was around an average of 30 and 31.7℃.The overall means of TAN, DO,TDS, and PH concentrations in fish tanks did not differ significantly ($P > 0.05$) between the magnetic water and non-magnetic water system. The results of the present study are comparable with the findings of various authors **(Krzemieniewski *et al*., 2004; Hassan *et al*., 2018a; Hassan *et al*., 2019; Irhayyim *et al*., 2020)**, who found no changes in ammonium concentrations between the magnetic field system and the non-magnetic water. However, the results of this study are in contrast with the findings obtained by **Hassan and Rahman (2016)**, **Hassan *et al*. (2018)**, **Ahmed and Abd El-Hamed (2020)** and **Said *et al*. (2022)**, who found a reduction in the ammonium concentrations of the magnetic treatments. Additionally, the findings are in contrast with the findings obtained by **El Hanoum *et al*. (2017)**, **El-Ratel and Fouda (2017)** and **Ahmed and Abd El-Hamed (2020)**, who found that the magnetic field has an influence on certain parameters of water such as dissolved oxygen, pH, total hardness, and ammonium, causing improvements in the water quality. The improvement in water quality characteristics and the decrease in ammonia concentration in magnetized and non-magnetized water compared to the control system in this study is due to both the mechanical filter that removed solids and the biological filter, which oxidized ammonia by bacteria.

Table 2. Means ± SE (standard error) of water quality parameters treated with magnetic water in the recirculating aquaculture system

Water parameter	C		NM		MW	
	First WK	Sixth WK	First WK	Sixth WK	First WK	Sixth WK
DO (mg/l)	5.63±0.57[a]	5.77±0.06[a]	5.49±0.61[a]	5.97±0.11[a]	5.53±0.59[a]	5.82±0.13[a]
TAN(mg/l)	0.80±0.20[a]	2±0.00[a]	0.30±0.07[b]	0.00±0.00[b]	0.30±0.07[b]	0.00±0.00[b]
pH	7.92±0.07[a]	7.61±0.05[b]	7.65±0.10[b]	7.84±0.01[a]	7.56±0.09[b]	7.81±0.01[b]
TDS (ppt)	0.24±0.01[a]	0.30±0.00[a]	0.16±0.01[b]	0.20±0.00[b]	0.16±0.01[b]	0.20±0.00[b]
TEMP(℃)	32.73±0.13[a]	29.86±0.26[b]	33.01±0.11[a]	29.60±0.21[b]	33.01±0.10[a]	30.36±0.23[a]

Growth performance

The values of the growth parameters and nutrient utilization are presented in Table (3). The highest growth parameters were found in fish groups reared at 50 fish/ 0.5m^3, which could be due to comparatively lower stocking density and good water quality than other groups (100 fish/ 0.5 m^3). Despite the fact that most parameters of water were found within a suitable range for fish, the highest means of weight gain (8.3g) were recorded in magnetic water at 50 fish/ 0. m^3 and 7.8g in non-magnetic and control water in fish groups reared at 50 fish/ 0.5m^3, and the lowest values were recorded in magnetic and non-magnetic and control water in fish groups reared at 100 fish/ 0.5m^3. This may be due to density and competition. No significant differences (P> 0.05) were observed between the average values of condition factor (K) and specific growth rate (SGR) in magnetic and non-magnetic water and control water in different groups of storage density. The SR and condition factor (K) values of the reared fish are shown in Table (3). However, no significant differences (P >0.05) were observed between the average values of the feed conversion rate (FCR) (1.6) in fish from magnetized and non-magnetized water and control water in the rearing groups at different densities. The highest survival rate at density of 50 and 100f/ 0.5m^3 was found in the non-magnetized water group compared to the magnetized water and control water. The results indicated that fish growth, nutrients, energy use, survival rate, and feed conversion did not differ or improve with the magnetized water compared to non-magnetized water. The results of this study contrast with the findings of **Tang *et al.* (2015)** and **Hassan *et al.* (2018)**, who concluded that magnetized water improved the growth performance of the tilapia and the common carp. Similarly, **Mabrouk *et al.* (2022)**, **Said *et al.* (2022)** and **Fadel *et al.* (2024)** found that the magnetic water treatments significantly improved growth performance, survival rate, and water quality parameters compared to the normal water, even at different stocking densities.

Table 3. Impact of magnetic treated water and stocking density on the growth performance and feed utilization (means ± tandard error) of the Nile tilapia (*Oreochromis niloticus*)

Growth performance parameter	WG	SGR	FCR	K	SR
Interactions					
C50	7.67±0.55 [a]	2.10±0.8 [a]	1.56±0.08 [a]	0.91±0.05 [a]	85.±1.15 [c]
C100	7.58±0.18 [a]	2.09±0.03 [a]	1.55±0.03 [a]	0.91±0.01 [a]	89±0.58 [b]
NM50	7.80±0.4 [a]	2.35±0.08 [a]	1.60±0.05 [a]	0.94±0.05 [a]	95.33± 1.33 [a]
NM100	7.25±0.42 [a]	2.24±0.09 [a]	1.57±0.07 [a]	0.88±0.06 [a]	94.33±0.33 [a]
MW50	8.30±1.54 [a]	2.42±0.29 [a]	1.60±0.22 [a]	0.92±0.13 [a]	93.33±3.33 [ab]
MW100	7.29±0.2 [a]	2.25±0.04 [a]	1.57±0.03 [a]	0.95±0.04 [a]	91.67±2.19 [ab]
MAGNETIC					
NM	7.80±0.73 [a]	2.33±0.14 [a]	1.59±0.1 [a]	0.94±0.06 [a]	92.50±1.82 [a]
M	7.53±0.29 [a]	2.29±0.06 [a]	1.59±0.04 [a]	0.91±0.04 [a]	94.83±0.65 [a]
DENSITY					
50	7.93±0.49 [a]	2.29±0.1 [a]	1.59±0.07 [a]	0.92±0.04 [a]	90.22±2.34 [a]
100	7.37±0.15 [a]	2.19±0.04 [a]	1.56±0.02 [a]	0.91±0.02 [a]	91.67±1.01 [a]

CONCLUSION

This study concluded that using a recirculating aquaculture system (RAS) with natural bacteria as a biological filter is highly effective in improving the water quality characteristics, especially eliminating ammonia. However, the use of magnetization technology to treat fresh water culture does not make a significant difference in improving the water quality. Furthermore, the water recycling system not only saves water throughout the production period but also improves the growth performance of the Nile tilapia fingerlings.

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