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Effect of Magnetic Water on The Growth of the Nile Tilapia and Lettuce Plant in the Aquaponic System

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ABSTRACT

This research was designed to study the effect of magnetized water on the growth of the Nile tilapia fish (for 70 days) and lettuce plants (for 28 days) using different levels of magnetization intensity (2500, 3400 and 4000 gauss) in the aquaponic system. In addition, the effect was evaluated on some water properties in the system. The length and weight of fish samples, the length of the roots and leaves (the total length) of the lettuce plant, as well as the growth indicators of the fish were all measured. Some properties of the water in the aquarium , such as dissolved oxygen concentration, pH value and total ammonia nitrogen concentration were weekly measured during the experimental period. For fish samples, increases in weight and length with percentages of 26.6 to 31.9 and 14 to 17 were respectively recorded, associated with the magnetization of water in the system during the 70-day experiment. Meanwhile, an increase in the length of the lettuce plant was observed with a percentage fluctuating between 20.4 and 27.5 during the 28-day experiment. Water magnetization showed a slight significant effect on water properties in the aquarium, regarding dissolved oxygen saturation, pH and total ammonia concentration, which makes it within the safe framework for fish growth. Due to the system used, the total ammonia percentage in the biological filter witnessed a decline in the range of 11.2:15.18%, aligned with a decrease in the total ammonia percentage, ranging between 70.3 and 87.1% inside the growing bed, which made the ammonia levels return to the fish tank at their minimal level.

INTRODUCTION

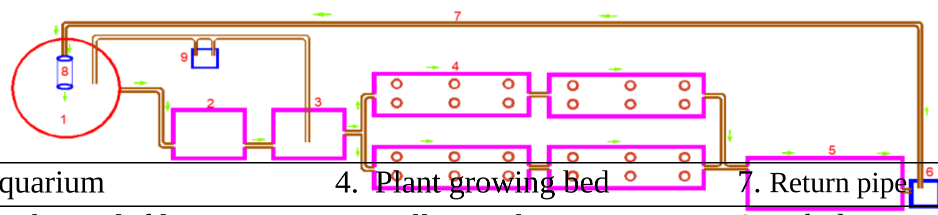
Human population worldwide growth neccessiates searching for new agricultural systems to meet the increasing demand for food **(Molden, 2007; Fedor *et al*., 2010)**. For example, systems that integrate plants with fish production are recognized as environmentally friendly and sustainable **(Rakocy *et al*., 2006)**. Aquaponic involves combining fish and soilless plant production. The Food and Agriculture Organization of the United Nations has emphasized aquaculture as a sustainable food production practice for the future and recently issued small-scale guidelines for the aquaponic system production **(Somerville *et al*., 2016)**. In Europe, numerous start-up companies have taken the initial steps towards commercial aquaponic production **(Thorarinsdottir, 2015)**. Aquaponic offers an opportunity for environmentally sustainable food production, following the circular economy principles by reusing water and nutrients **(Goddek *et al*., 2015)**. The system allows for the continuous production of quality fish and vegetables while minimizing water replacement. In addition, there is a reduced need for formulated fertilizers **(Rakocy *et al*., 2006; Wongkiew *et al*., 2017)**. The advantage of the aquaponic system over recirculating aquaculture systems (RAS) and hydroponic systems include the capability of raising fish, while simultaneously growing edible plants, which remove nutrients from water **(Tyson *et al*., 2011)**. The reliance on the bacterial ecosystem is one features of the aquaponic system. Most fish species retain 20–30% of ingested dietary nitrogen **(Schreier *et al*., 2010)**. While, 70–80% is released into the water as waste **(Krom *et al*., 1995)**. Digested protein is mostly excreted as ammonium ($NH4+$) through the gills **(Tyson *et al*., 2011; Wongkiew *et al*., 2017)**. NH4 + can also accumulate because of the bacterial decomposition of organic matter such as protein and nitrogenous compounds in uneaten feed **(Roosta & Hamidpour, 2011)**. Ammonium nitrogen (NH4 + -N) excreted by fish provides the major form of nitrogen essential for plant growth **(Roosta & Hamidpour., 2011; Wongkiew *et al*., 2017)**. Biological nitrification of the nutrient-rich fish tank water forms nitrate (NO3−), which is assimilated by plants **(Tyson *et al*., 2011)**. Nitrification converts NH4 +, which becomes harmful to fish for increasing pH, to NO3 – by which water quality is maintained. In addition, in weakly buffered water, nitrification can decrease the pH value of the system's water, while bacterial denitrification can increase water pH. Recently, a great attention has been drawn on the possibility of using magnetized water, which has great effects on plant growth, development and production. The magnetic treatment of irrigation water has benefited agriculture via improving germination, growth, yield, water economy, early maturity of crops, reducing plant diseases and salinity stress, promoting crop quality, increasing fertilizers' efficiency and reducing the cost of farm operations **(Maheshwari *et al*., 2009; Yusuf *et al*., 2015)**. In addition, the magnetic water treatment technology has become the focus of researchers' attention compared to physical methods and other chemicals since it provides purity, environmental & health safety and the ease of use. The state of the water molecules within the magnetic field changes or breaks the hydrogen bonds between the molecules. This leads to changing the properties of water such as electrical systems, increasing the percentage of dissolved oxygen in water, increasing the ability to dissolve salts and acids, polymerization, surface tension, changing the speed of chemical reactions, evaporation properties, hygroscopicity, flexibility and electrical insulation in addition to increasing permeability. Thus, water is brought with energy, vitality and flow. Subsequently, these changes will affect the qualities of the material entering the structure through its effect on the physical properties or on the chemical or physiological and biochemical processes. Additionally, the use of magnetic field technology has proven its effectiveness in germination processes in terms of early germination date and germination intensity **(Boraie, 2021)**. Consequently, the magnetic field can be used as an alternative to the chemical methods of plant treatment for improving the production's efficiency. For optimum results, **Terpstra (2015)** determined water quality standards in tilapia aquaponic systems at temperature between 18 & 30°C; dissolved oxygen concentration between 5 & 8mg/ l; pH value between 7 and 9 and unionized ammonia of 1mg/ l. The main objective of the current work was to study the effect of magnetic water on the growth of both the Nile tilapia *Oreochromis niloticus* and lettuce plant in the aquaponic system, addressing some water properties for the aquarium's water during system operation.

MATERIALS AND METHODS

This study was carried out on the Nile tilapia *Oreochromis niloticus* at laboratory of processing engineering, Agricultural Engineering Department, Faculty of Agriculture, Cairo University in 70 days, extending from March till May 2022, while examining the changes in lettuce plant during a period of 28 days in an aquaponic system. This study covered the effect of magnetic water using three different levels of magnetization intensity of 2500, 3400 and 4000 gauss in the aquaponic system on fish weights and lengths, the growth of lettuce in terms of the length of roots and leaves and some physical properties of water such as pH, dissolved oxygen concentration and total ammonia nitrogen concentration, as well as the growth indicators of the fish. At the beginning of the experiment, the average weight of the Nile tilapia fish was about 30 ± 2g/ fish, and the average total length of lettuce seedlings was 12.40cm. Fish feed was offered in a percentage of 3%. The chlorophyll content in lettuce leaves was estimated at the beginning and end of the experiments. A statistical analysis was carried out using the SPSS program for the measurements and calculations of the different treatment experiments.

1. System components and description

The components used for the study were as follows: an aquarium, a mechanical filter, a biological filter and a plant- growing bed. The working mechanism of the system is the flow of aquarium water with 130-liter capacity through a valve to a mechanical filter containing a medium of gravels with 0.5cm- diameter and a wire mesh from oxen to collect the sediment in water. A plastic biological filter with a 19-liter capacity was set inside the design, using parts of plastic pipes with a length of 2cm. The biological filter converts ammonia and nitrite into nitrates through the activity of the living bacteria growing there. Most fish waste is not filterable, and it is directly dissolved in water. Since the size of these particles is too small to be mechanically removed, using a mechanical filter alone is of no benefit. The dynamics and movement of water within the biofilter break up very fine solids passing through the mechanical filter, preventing more residues from accumulating on the roots of the plants. Finally, the water loaded with nitrates moves, making it easier for the plant to absorb it in the four-plant growing bed, with dimensions of 60 x 40cm and 19cm deep. Then, water is drained into a collection plastic basin, with a capacity of 50 liters. A 0.5- HP electric pump is fixed beside the water collection basin, on top of which a 20-meter head suction is fixed to allow water flowing from the water collection basin, which is drained from the plant growing bed, pumping it back to the aquarium, passing through the tubular magnets before the water turns back to the aquarium, where three different levels of magnetization intensity of 2500, 3400 and 4000 gauss were used. The components of recent aquaponic system are shown in Fig. (1)



1. Aquarium	4. Plant growing bed	7. Return pipe
2. Mechanical filter	5. Collection basin	8. Tubular magnets
3. Biological filter	6. Electric pump	9. Air pump

Fig. 1. Aquaponic system components

The experimental study included the effect of different levels of magnetization intensity on the growth of the Nile tilapia fish and lettuce plants during the experimental period. The length and weight of fish samples and the length of the roots and leaves (total length) of the lettuce plant were all measured, as well as the growth indicators of the fish. Moreover, some properties of the aquarium water were measured, such as the dissolved oxygen concentration, the pH value and the total ammonia nitrogen concentration. These measurements were weekly recorded during the experimental period. The total ammonia nitrogen concentration was estimated at the three outlets under different levels of magnetization intensity and during three different periods (3, 6 and 9 weeks) throughout the 10-week experiment in order to determine the percentage of change taken place in the total ammonia nitrogen concentration, both in the aquarium and during its flow through the system, until it turned back into the aquarium.

2. Instruments

A digital balance was used for measuring the weight of fish samples, recording a range value of 0 to 10kg, with an accuracy of 0.01g. An accurate measuring ruler was used to measure the lengths of fish samples and those of the roots and leaves of lettuce, with an accuracy of 0.5mm,. While, pH value was determined in the aquarium water utilizing the pH meter, which is a digital meter measuring the pH value by putting the sensor in the water. The dissolved oxygen concentration was measured by a digital meter having an accuracy of 0.005mg/ l. Chlorophyll content in lettuce was measured using a chlorophyll meter **(SPAD-502, Japan)**. The ammonia concentration in water was measured by the ammonia meter, which has a digital meter to measure the concentration in mg/ l. Finally, the intensity of the magnet was measured by a device Gauss/tesla meter model 5080. Three tubular magnets with a diameter of 0.5 inch and a length of 12cm were used to magnetize the water during the different treatments. Fig. (2) shows the three tubular magnets that were used to magnetize water in the different treatments.

Fig. 2. The three tubular magnets that were used in the different treatments

3. Growth indicators of the Nile tilapia fish

The experimental growth data were used to calculate the value of each growth indicator according to the following mathematical formulas:

Average daily gain in weight "DGW $_i$"

$$\mathbf{DGW}\, i = \frac{(w_{2}\, i - w_{1}\, i)}{t} \quad (1)$$

Where, DGW_i = average daily gain in weight at the end of the growth period (g/ fish. day), and

t = time growth interval within the growth period.

The average daily gain in length "DGL $_i$"

$$\mathbf{DGL}\, i = \frac{(L2\, i - L1\, i)}{t} \quad (2)$$

Where, DGLI $_i$ = average daily gain in length at the end of the growth period (cm/fish. day);

L2 $_i$ = final total length at the end of growth period (cm), and
L1 $_i$ =initial total length at the beginning of growth period (cm).

While, for the specific growth rate in weight "SGRW $_i$",

it was calculated according to the formula used in the study of **Jauncey and Ross (1982)** as follows:

$$\mathbf{SGRW}\,i = \frac{(\ln w2\,i - \ln w1\,i)}{t} \times 100 \quad (3)$$

Where, SGRW i = specific growth rate in weight for fish (% weight / fish), and
Ln = natural logarithm.

To estimate the specific growth rate in length "SGRL $_i$", the following equation was used:

$$\mathbf{SGRL}\,i = [\frac{\ln L2\,i - \ln L1\,i}{t}] \times 100 \quad (4)$$

Where, SGRL $_i$= specific growth rate in length (% length / fish. day).

For the percentage of average daily gain rate in weight "GRWP i", the succeeding formula was implemented:

$$\mathbf{GRWP}\,i\,\% = [\frac{W2i - W1i}{W1i}] \times [\frac{100}{t}] \quad (5)$$

Where, GRWP $_i$= percentage of average daily gain rate in weight (%weight/ fish.day).

The following formula was adjusted to calculate the percentage of average daily gain rate in length "GRLP $_i$"

$$\mathbf{GRLP}\,i\,\% = [\frac{L2i - L1i}{L1i}] \times [\frac{100}{t}] \quad (6)$$

Where, GRLP $_i$ = percentage of average daily gain rate in length (% length/fish .day).

RESULTS AND DISCUSSION

The results obtained throughout the several stages of laboratory experiments are represented and discussed as follows

1. Effect of using magnetized water in aquaponic system on the weight of the Nile tilapia

Fig. (3) shows the weekly mean weights of the Nile tilapia fish for 70 days under three different levels of magnetization intensity (2500, 3400 and 4000 gauss). The obtained results demonstrated that, the weight of fish increased from 30.52 to 79.83g using the water without magnetization. Conversely, by using magnet intensity of 2500 gauss, the weight increased from 30.3g to 101.1g (increasing percentage = 26.64 %). While, by using magnet intensity of 3400 gauss, the fish weight increased from 30.41 to 103.20g (increasing percentage: 29.27 %). Whereas, the use of a magnet intensity of 4000 gauss increased fish weight from 29.8 to 105.3g (increasing percentage: 31.90%). It was noticed that, upon using the intensity of 2500 gauss, a slight significant effect was detected on the weight of fish, whereas the weight increased by increasing the magnet intensity to 4000 gauss (increasing percentage: 4.15 %).

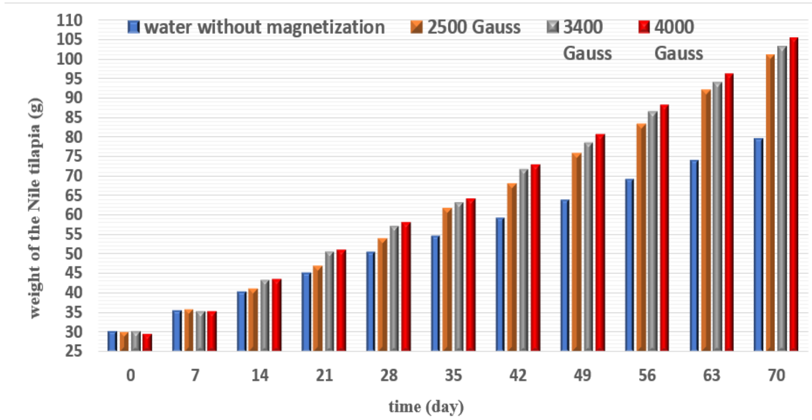


Fig. 3. Effect of using magnetized water on Nile tilapia fish growth in weight

Equations (1, 3 & 5) were applied for the initial conditions of the experimental treatments and the final results at the end of the experiment. The computed results are shown in Table (1). It could be seen that, the best treatment giving the most positive results was that using magnetic intensity of 4000 gauss, while the lowest results were those detected for water without magnetization. The results of the statistical analysis using the SPSS program for fish growth indicators by weight are shown in Table (2). It was noted that, there is only a significant difference between the value of fish weight when using water without magnetization and the average specific weight, while the values of the other indicators showed no significant differences with them.

Table 1. Effect of magnetized water under three level of different magnetic intensities on the computed indicator values for the Nile tilapia fish weight

Evidence	**Water without magnetization**	**Magnetized water**		
		2500 gauss	**3400 gauss**	**4000 gauss**
Average daily gain in weight "DGW" (g/fish.day)	0.704	1.011	1.039	1.070
Specific growth rate in weight "SGRW" (%wight/fish.day)	2.705	2.850	2.860	2.880
Percentage of daily gain rate in weight "GRWP" (%weight/fish.day)	2.300	3.300	3.410	3.610

Table 2. Results of statistical analysis using SPSS program for fish growth indicators regarding weight

Treatment	DGW	SDRW	GRWP
Control	0.6087B	1.1597A	1.7537A
2500	0.8837A	1.4877A	2.5300A
3400	0.911A	1.5017A	2.5900A
4000	0.942A	1.5460A	2.7133A

2. Effect of using magnetized water in aquaponic system on the length of the Nile tilapia fish

Fig. (4) displays the weekly mean length of the Nile tilapia fish for 70 days, with an increase in length values from 12.1 to 15.8cm, using the water without magnetization. While, upon using magnet intensity of 2500 gauss, fish length increased from 12 to18.6cm (increasing percentage: 17.72%). Moreover, using magnet intensity of 3400 gauss, the fish length increased from 12.10 to 19.30cm (increasing percentage: 22.15%), and the fish length increased from 11.9- 19.9cm upon using magnet intensity of 4000 gauss (increasing percentage: 25.94%). Notably, the magnetized water has a role in increasing the length of fish. Furthermore, the intensity of 2500 gauss recorded a simple significant effect on the length of fish, while the length increased by increasing the magnet intensity to 4000 gauss (increasing percentage: 6.98%).

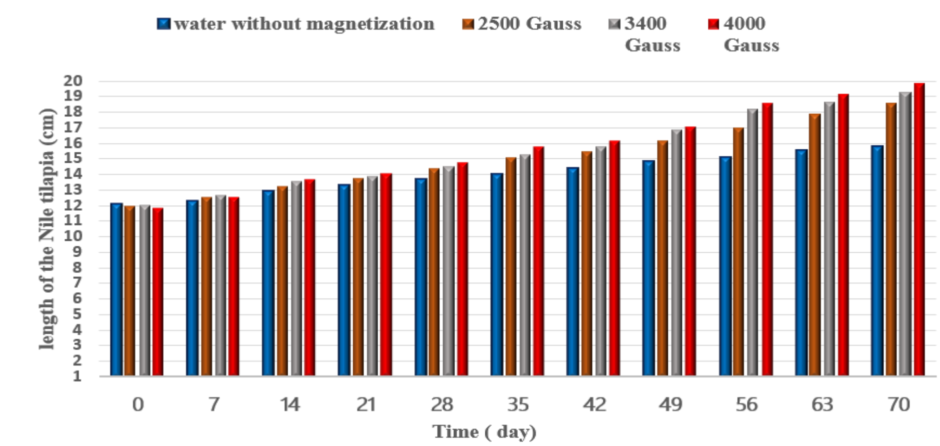


Fig. 4. Effect of using magnetized water on the Nile tilapia fish growth in length

Equations (2, 4 & 6) were implemented for the initial conditions of the experimental treatments and the final results at the end of the experiment. The computed results are presented in Table (3). Eminently, the best treatment with the most positive results was that with an intensity of 4000 gauss, while the lowest findings were recorded for water without magnetization. The results of the statistical analysis using the SPSS program for fish growth indicators by length are shown in Table (4). No statistically significant differences were detected between the indicators when using water without magnetization and under different levels of intensity of other magnetization.

Table 3. Effect of magnetized water under three level of different magnetic intensities on the computed indicator values for Nile tilapia fish length

Evidence	Water without magnetization	Magnetized water		
		2500 gauss	3400gauss	4000 gauss
Average daily gain in length "DGL" (cm/fish.day)	0.052	0.094	0.103	0.114
Specific growth rate in length "SGRL" (% length/ fish.day)	1.600	1.770	1.800	1.820
Percentage of daily gain rate in length "GRLP" (% length / fish.day)	0.430	0.780	0.850	0.960

Table 4. Results of statistical analysis using SPSS program for fish growth indicators considering length

Treatment	DGL	SGRL	GRLP
Control	0.041A	1.14A	0.28A
2500	0.086A	1.36A	0.54A
3400	0.088A	1.43A	0.61A
4000	0.091A	1.52A	0.70A

3. Effect of using magnetized water in aquaponic system on the length of lettuce

Figs. (5- 8) show the weekly mean of the total lettuce length for a period of 28 days in aquaponic system under three different levels of magnetization intensity (2500, 3400 and 4000 gauss). The obtained results demonstrated that the magnetized water has a role in increasing the total length of the lettuce in both roots and leaves. Upon using the magnet intensity of 2500 gauss, the total plant length increased from 12.4 to 27.1cm, recording an increasing percentage of 20.44. While, on using magnet intensity of 3400 gauss, the total plant length increased from 12.30 cm to 28cm, with an increasing percentage of 24.44. On the other hand, using magnet intensity of 4000 gauss recorded a total plant length increase ranging from 12.4 to 28.7cm (increasing percentage: 27.5%). These positive effects of magnetic treatment may be due to some alterations taken place in plant systematic biochemical levels and their possible effects at cell level, while these positive impacts are mainly attributed to the increased water content **(Abedinpour & Rohani, 2017)**.

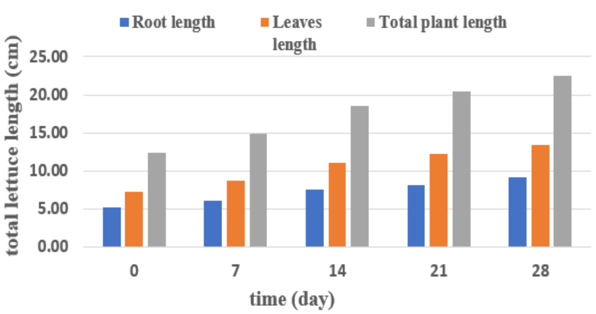


Fig. 5. Total lettuce length with water without magnetization

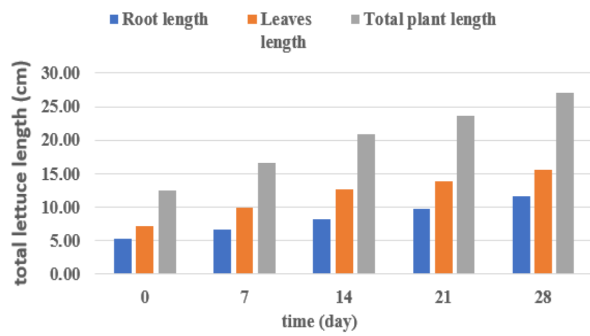


Fig. 6. Total lettuce length; intensity 2500 gauss

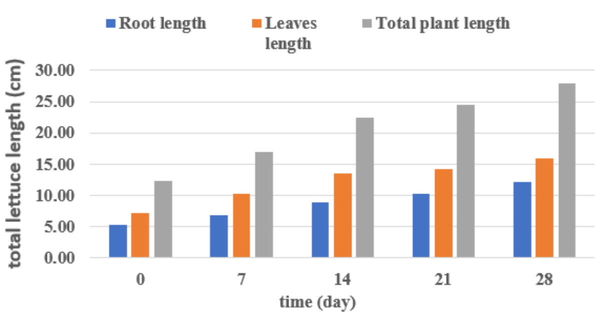


Fig. 7. Total lettuce length in magnet intensity of 3400 gauss

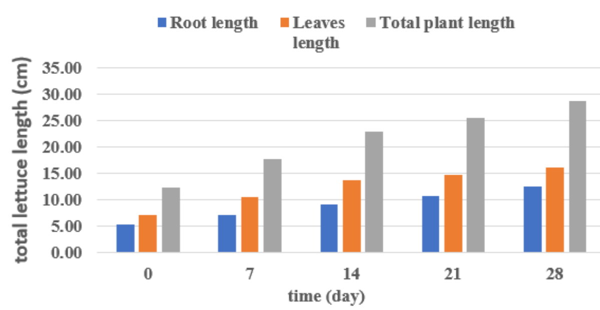


Fig. 8. Total lettuce length in magnet intensity of 4000 gauss

4. Dissolved oxygen concentration (DOC)

Fig. (9) exhibits the dissolved oxygen concentration values for a period of 70 days in the aquarium water. The obtained results showed that the dissolved oxygen concentration during the experiment in water without magnetization was in the range between 7.40 & 5.30mg/ l; whereas, a decrease was recorded with increasing temperature at the end of the experiment, forming the suitable range for the growth and activity of the Nile tilapia fish. In addition, upon using the magnet intensity of 2500 gauss, the dissolved oxygen recorded a range between 7.35 & 5.50mg/ l. While, its range was between 7.40 and 5.80mg/ l on using the magnet intensity of 3400 gauss. On the other hand, the dissolved oxygen ranged between 7.40 & 6.10mg/ l aligned with the use of the magnet intensity of 4000 gauss. It is worthnoting that, water magnetization showed a simple effect on the dissolved oxygen concentration. Notably, the dissolved oxygen concentration increased by decreasing water magnetization and decreased by increasing water magnetization in the aquarium.

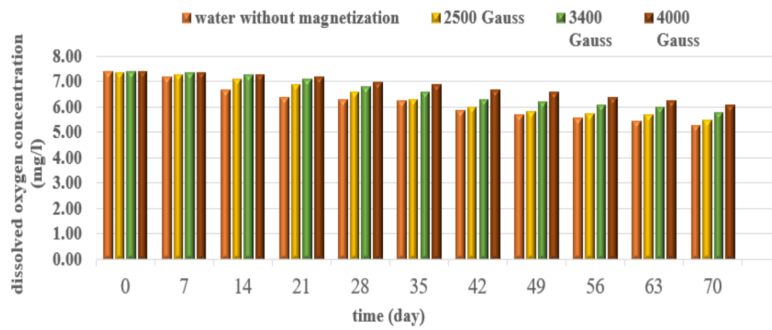


Fig. 9. Effect of using magnetized water on the dissolved oxygen concentration in aquarium water

5. pH- value of aquarium water

Fig. (10) shows the weekly pH- value in aquarium water. The results showed that the pH value during the experiment fluctuated in water without magnetization between 8.20 to 8.48, which was a suitable range for growth and activity of the Nile tilapia fish samples. Additionally, it was noticed that, water magnetization had a slight effect on the pH value, as for instance, on using the magnet intensity of 2500 gauss, the pH value increased from 8.18 to 8.55; upon using magnet intensity of 3400 gauss, the pH value increased from 8.20 to 8.57; while, using the magnet intensity of 4000 gauss, the pH value increased from 8.15 to 8.72. Generally, water magnetization has a simple effect on the pH value; it slightly increased or decreased around the mean value by increasing or decreasing water temperature.

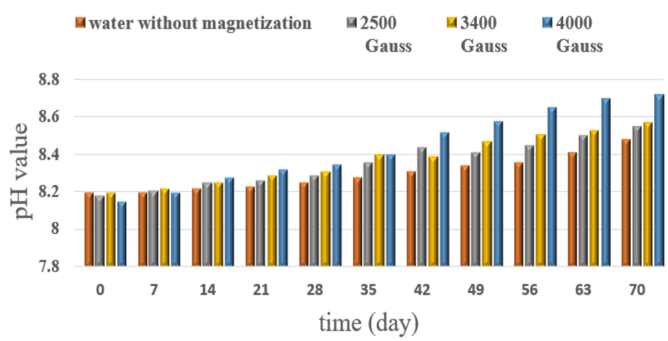


Fig. 10. Effect of using magnetized water on pH- value in aquarium water

6. Total ammonia nitrogen concentration of aquarium water (TAN)

Fig. (11) shows the percentage of total ammonia inside the aquarium water, which was estimated during the experimental period. The results showed that the total ammonia nitrogen concentration during the experiment fluctuated in water without magnetization between 1.74 to 1.95 mg/l. Beside, it was noticed that, the water magnetization had an effect on the total ammonia, where using magnet intensity of 2500 gauss, the total ammonia increased from 1.77 to 1.98mg/ l,; whereas, upon using the magnet intensity of 3400 gauss, the total ammonia nitrogen increased from 1.74 to 2.20mg/ l. On the oter hand, the total ammonia nitrogen increased from 1.75 to 2.43mg/ l in association with the use of the 4000- gauss magnet intensity.

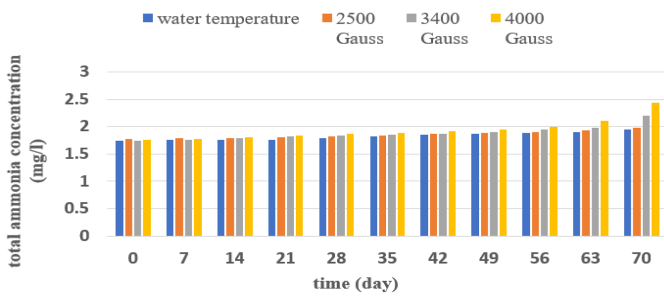


Fig. 11. Effect of using magnetized water on total ammonia nitrogen concentration in aquarium water

7. Total ammonia nitrogen concentration of aquaponic system (TAN)

Figs. (12- 14) display the total ammonia nitrogen concentrations at the three outlets of the system, which are at the outlets of the aquarium, the biological filter and the plant growing bed, respectively. In addition, it shows the total ammonia nitrogen concentration at the three outlets under different levels of magnetization intensity and during three different periods (3, 6 & 9 weeks) along the 10-week experiment. The results show that the concentration of ammonia increased slightly with the increase in the magnetization intensity and the duration of the experiment. Moreover, it was noticed that, the highest concentration of ammonia was recorded for the water leaving the aquarium, then its concentration decreased as it passed through the biological filter, and it decreased to its lowest level after passing through the plant growing bed. The percentage of ammonia reduction in the biological filter during a period of 3 to 9 weeks ranged between 11.42 & 15.18% when using water without magnetization and between 12.63 & 21.32% on using water magnetization. The percentage of the reducing concentration of ammonia in the growth bed was recorded between 70.37 & 78.06% upon using water without magnetization, and it fluctuated between 68.67 & 77% while using water magnetization. Furthermore, it was noted that, the total ammonia nitrogen concentration of the water in the aquaponic system followed the same path when measured after three, six and nine weeks.

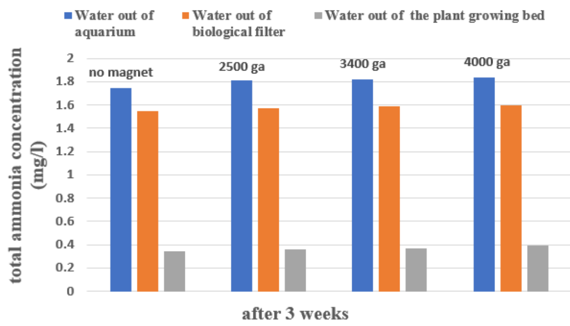


Fig. 12. The total ammonia concentration after 3weeks.

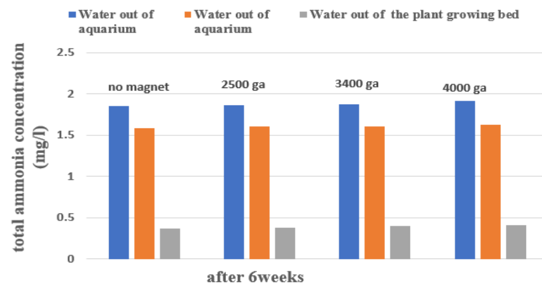


Fig. 13. The total ammonia concentration after 6weeks

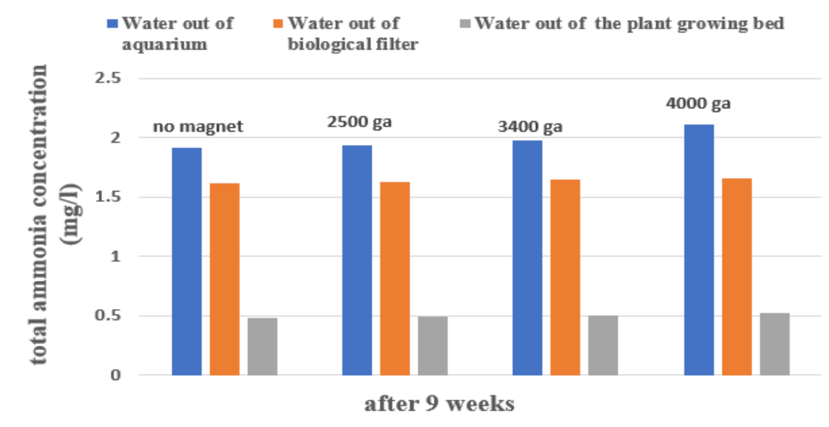


Fig. 14. The total ammonia concentration in aquaponic system after 9 weeks

8. Chlorophyll value in lettuce leaves

Table (5) shows the effect of using magnetized water on the chlorophyll value of lettuce grown in the aquaponic system at the beginning and end of the experiment. It was observed that, the use of magnetized water has a clear and significant role in increasing chlorophyll in lettuce leaves, compared to the use of non-magnetized water, as the percentage of increase ranged between 5.4 & 8.59%, while the increase in the intensity of magnetization led to a slight increase in the value of chlorophyll, where by using the intensity of magnetization of 4000 gauss, the value of chlorophyll increased by 2.9% more than using the magnetization intensity of 2500 gauss.

Table 5. Effect of magnetized water under three level of different magnetic intensities on the values of chlorophyll in lettuce leaves grown in the aquaponic system

Time	**Chlorophyll values of lettuce leaves grown in water without magnetization**	**Chlorophyll values of lettuce leaves grown in magnetized water**		
		2500 gauss	**3400gauss**	**4000 gauss**
At the beginning of the experiment	32.1	32.1	32.1	32.1
At the end of the experiment (after 4 weeks)	34.9	36.8	37.2	37.9

Compared to previous literature studies, the effect of using magnetized water in aquaponic systems is considered a new use, and it is specific to the present study. However, in general, magnetization affects water properties **(Chang & Weng, 2006; Ahmed 2009; Hanafy *et al*., 2017)**, with a subsequent positive effect on the growth of fish in the system. In addition, the growth of lettuce and other plants is affected by irrigation with magnetized water **(Abobatta, 2015; Hozayn *et al*., 2016)**.

CONCLUSION

The effect of magnetized water with different intensities on the growth of the Nile tilapia fish, lettuce plants and some properties of water inside the aquaponic system were tested. The results showed that, the magnetization of water in the system led to an increase in the weight of the Nile tilapia fish at a percentage ratio ranging between 26.6 & 31.9 %, aligned with an increase in the length of the Nile tilapia fish with a range between 17.72 & 25.94 %. It also led to an increase in the growth of the lettuce plant, evidenced with its length increase at a ratio ranging between 20.4 & 27.55 % throughout the experiment period .Additionally, the effect of magnetization water had no significant effect on the properties of aquarium water in terms of pH, dissolved oxygen concentration and total ammonia, making them within the safe framework for fish growth. Furthermore, the results showed that in the system, the total ammonia percentage within the biological filter was reduced to a ratio ranging between 12.63 & 21.3 %. While, the cultivation of the lettuce plant led to a decrease in the total ammonia nitrogen concentration by a ratio ranging between 68.67 & 77 %, which made the total ammonia levels returning to the aquarium in their minimum limits.

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