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EFFECTS OF EXPOSURE TO MAGNETIC FIELD ON WATER PROPERTIES AND HATCHABILITY OF *Artemia salina*

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ABSTRACT

The application of magnetised water in aquaculture is still in its infancy. This study is a step towards gaining a better understanding of the effect of magnetism on water properties and on the biology of culture organisms, such as the brine shrimp, *A. salina*. The present study evaluates the effects of magnetic field exposure on water properties which in turn affect the hatchability of *A. salina*. Water was passed through three magnetic devices of different intensities, i.e. 0.1, 0.15 and 0.2 Tesla, respectively, once at every 5 hour interval. The dissolved oxygen (mg/L) was found to increase (from 3.84 mg/L to 4.51 mg/L). pH also increased from 7.11 to 7.42 which is favourable for *A. salina*. The ammonium (NH_4-N mg/L) and ammonia (NH_3-N mg/L) levels decreased from 0.43 mg/L to 0.28 mg/L and from 0.36 mg/L to 0.19 mg/L respectively. Salinity (ppt), specific conductance (µS/cm) and total dissolved solids (mg/L) were also found to have increased significantly ($P \leq 0.05$) after magnetization. Overall, the exposure of water to a magnetic field was found to have increased the hatchability rate of *A. salina* significantly ($P \leq 0.05$). A much better increase of 39.61% (41.67 to 69.00) in *A. salina* hatchability rate (H%) was attained in water exposed to a magnetic field of 0.15 Tesla for four times. This has positive implications for aquaculture because a higher rate of *A. salina* hatchability means that the brine shrimp can be produced more economically and a good sign for application of magnetic water for other aquaculture procedures such as induced spawning, fertilization, larval rearing and fish grow-out in recirculating aquaculture system.

Keyword: magnetic field, water properties, hatchability, artemia salina.

INTRODUCTION

This study is based on earlier works which discussed the effects of magnetic field exposure on the properties of water. Magnetic water is produced when water is passed through a magnetic field with the purpose of modifying its structure. The magnetic field can cause a hierarchy of changes ranging from the dynamics of electrosolitons to the state of macromolecules of water. Water quality is determined by variables such as transparency, turbidity, water colour, pH, alkalinity, hardness, and the content of carbon dioxide, unionised ammonia, nitrite, and nitrate [1]. Hence, solutions in water treatment are applied to improve water quality.

The changes in physical and chemical properties of magnetised water affect the biological properties of the organisms that consume the magnetic water such as the organism's rate of respiration, which in turn affects its entire metabolic system.

Literature have already shown that exposure of water to a magnetic field has positive effects on its properties and that it makes it better, plant and livestock water uptake, and their metabolism. However, the application of magnetised water in aquaculture is still in its infancy. This study is but one of few other studies aiming at probing the effects of subjecting water to magnetic field on the hatchability of Tilapia (*Oreochromis* app.) and on African Sharptooth Catfish (*Clarias gariepinus*), in addition to the biological effect of this magnetizing of water on aquaculture in general.

The use of live food still remains an integral part of finfish hatchery [2]. Currently, fish larvae cultures still rely heavily on the use of live food organisms during their early life phase. The brine shrimp, *A. salina* occupies a unique position in aquaculture and is given as live feed to over 85% of cultured species around the world [3]. Several methods for assisted hatching of Artemia were developed [4].

Brine shrimp nauplii is convenient food source for larger fish fry. The ability to nutritionally enrich Artemia nauplii provides a delivery platform to specifically target potential predators' nutritional requirements and meet these needs. Feeding and providing proper nutrition to fish larvae is a great hurdle faced by potential fish breeders [5]. Several criteria determine the quality of an Artemia cyst sample for aquaculture application.

The efficient and profitable production of *Artemia nauplii* and other aquatic organisms in aquaculture is dependent on the environment in which they can suitably reproduce and grow. Understanding the source and quality of water for Artemia production is fundamentally important, and deterioration of water quality is the main concern. Optimum *Artemia nauplii* production is mostly dependent on favourable physical, chemical and biological qualities of water and successful pond management requires an understanding of its water quality.

As early as [6] from University of Austin, Texas, noted an accelerated growth in plants treated with magnetized water. Since then, researchers have used a variety of experimental techniques to study the effects of a magnetic field on living organisms. [7]; [8]; [9]; [10]; [11, 12], revealed that exposing water to magnetic field

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influences the water's surface tension, density, viscosity, hardness, conductivity and solubility of solid matters.

The interaction of magnetic energy with water has stimulated research interest which became essential in widening the use of magnetized water in various areas, as well as understanding the fundamental physics of such interactions [13].

This study aims at studying the effects of exposure to magnetic field on both water properties and hatchability of Artemia, focussing on, the magnetic intensity and duration of exposure.

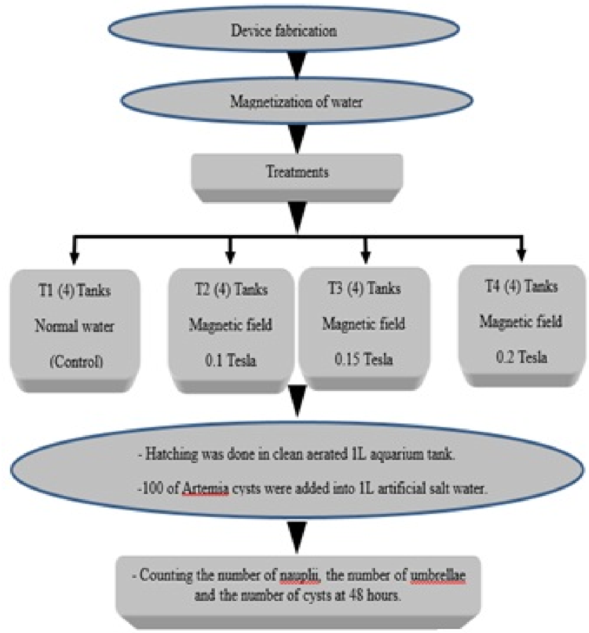
Materials and methods

Magnetic water is water that is produced when it passes through a magnetic field with the purpose of changing its structure. After water passes through a magnetic field of certain strength, it is called magnetically treated water or magnetic water [14].

As an experimental part of the study, a sequence of procedures was followed to implement the magnetization of water to a range of magnetism intensities. The sequence included a set of magnets having different values of intensity of field, and in the order of: 0.1: 0.15 & 0.2 Tesla. Figure-1 shows the magnets used.

Figure-1. The magnetization devices of different intensities used in the experiment (a) 0.1 Tesla (b) 0.15 Tesla (c) 0.2 Tesla.

a) Experimental flow chart



The magnetization of water was carried out at a rate of a single subjection to magnetic flux in intervals, each of which having a duration of five hours. In the first interval, water was magnetized only once. In the second interval, water was magnetized twice during the whole interval. In the third interval, water was magnetized for three times, while in the fourth interval, water was magnetized for four times. The professional Plus Multiparameter Water Quality Meter was the equipment used to measure water quality parameters that pertain to the study, Figure-2. These parameters included water temperature, DO concentration, pH level, NH_4-N level, NH_3-N level, salinity, SPC and TDS. All parameters were measured five times; before of magnetization (control) and after magnetization at (5, 10, 15, and 20 hours).

Figure-2. Professional plus multiarameter water quality meter.

Artemia brine shrimp eggs packed by Ocean Star International, Inc. were used. A total of 100 cysts were incubated in 1 liter of saltwater in each tank. Before introducing *Artemia nauplii* into the tank, salt water was

 ISSN 1990-6145
ARPN Journal of Agricultural & Biological Sciences
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prepared by diluting 3.6 Kg of salt into 100 liter of dechlorinated water in order to obtain 36 ppt saline water. The water was aerated and maintained at room temperature of 27˚C throughout the experiment. The DO (mg/L), pH, NH_4-N (mg/L), NH_3-N (mg/L), SAL (ppt), SPC (µS/cm) and TDS (mg/L) were measured five times; before of magnetization (control) and after magnetization at (5, 10, 15, and 20 hours). Hatching percentage was calculated for each rearing system. Complete hatching is said to have occurred when the larvae came out after breaking the egg membrane [15]. The hatching rate was determined by counting the number of nauplii, the number of umbrellae and the number of cysts after 48 hours using the following equation:

H% = {No. of nauplii / (No. of nauplii + No. of umbrella + No. of cysts)} x 100

See Figure-3 for recognizing the constituents of the equation.

Figure-3. the constituents of the equation.

SAS (SAS 9.0) statistical software which uses the one-way analysis of variance (ANOVA) and Duncan's multiple tests to determine the significance of differences among the water properties and hatchability of Artemia at magnetic intensities of 0.1, 0.15 and 0.2 Tesla, and differences among the hatchability of Artemia in water magnetized intervals at one time, two times, three times and four times respectively. The differences between treatments (magnetic intensities and exposures) are regarded as significant if $P \leq 0.05$.

RESULTS AND DISCUSSIONS

The effect of the exposure to magnetic field on water properties

The dissolved oxygen increases with increasing water magnetization times. The best result shows an increase from 3.84 mg/L to 4.51 mg/L after the water is magnetized with field intensity 0.1 Tesla for four magnetization times. Constant aeration is necessary to keep cysts in suspension and to provide sufficient oxygen level for the cysts to hatch. A minimum of 3 mg/L dissolved oxygen during the incubation is the crucial parameter of water quality because its concentration has effect on metabolism rate. Results of these treatments showed a significant increase in dissolved oxygen percentage compared with the control, as shown in Figure-4.

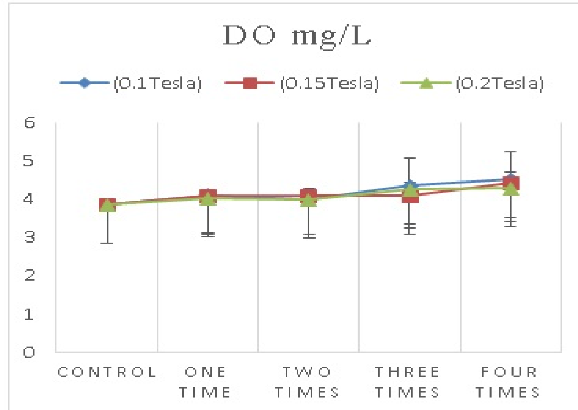

Figure-4. effect of exposure to magnetic field on dissolved oxygen of water magnetized 0.1, 0.15 and 0.2 Tesla and mj hthe magnetization intervals at one time, two times, three times and four times, respectively.

It can be seen that in general, the pH slightly increases with magnetization time. The results show a highest increase from 7.11 to 7.42 units after the water is magnetized with field intensity 0.1 Tesla for fourth magnetization time. This is in agreement with ([13] although he reported a higher 12% increase in water pH after magnetization.

pH affects the metabolism and other physiological processes of the Artemia [3]. Artemia prefers an alkaline pH range for the production of cysts [16]; [17] and [18]. The effect of the exposure to the magnetic field was increased pH of water. The effect depends on the time of exposure to the magnetic field [19]. Results of these treatments showed significant increase in pH level compare with the control Figure-5.

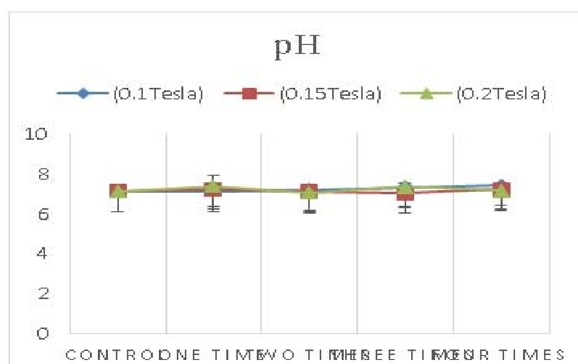

Figure-5. effect of exposure to magnetic field on pH level of water magnetized 0.1, 0.15 and 0.2 Tesla and the magnetization intervals at one time, two times, three times and four times, respectively.

The NH_4-N content showed a general decreasing trend with magnetization time. A best decrease (from 0.43 mg/L to 0.28 mg/L of NH_4-N) was recorded after the water was magnetized four times with a magnetic field intensity of 0.2 Tesla. Results of these treatments

VOL. 11, NO. 11, NOVEMBER 2016 ISSN 1990-6145
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significant decreased in NH4-N Concentration compare with the control are shown in Figure-6.

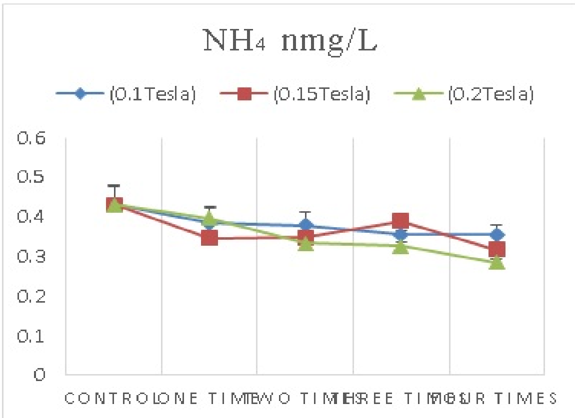

Figure-6. effect of exposure to magnetic field on ammonium (NH4-N) of water magnetized 0.1, 0.15 and 0.2 Tesla and the magnetization intervals at one time, two times, three times and four times, respectively.

The NH3-N content also showed a general decreasing trend with magnetization. A best decrease from 0.36 to 0.19 mg/L of NH3-N was recorded after the water was magnetized four times with a magnetic field intensity of 0.2 Tesla. It is also noted that the NH3-N content decreased from 0.36 to 0.3 nmg/L after the water was magnetized for one time at a magnetic field intensity of 0.1 Tesla. Results of these treatments showed significant decrease in NH3-N concentration compared with the control, as shown in Figure-7.

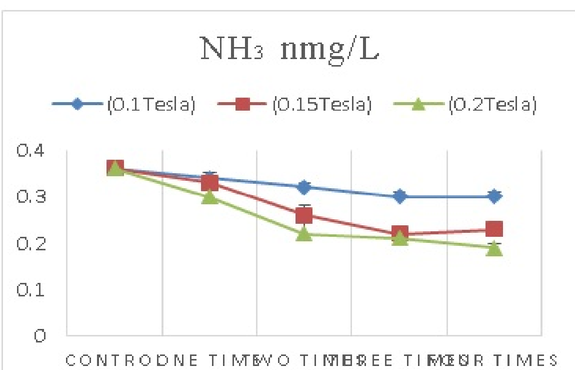

Figure-7. effect of exposure to magnetic field on ammonia (NH3-N) of water magnetized 0.1, 0.15 and 0.2 Tesla and the magnetization intervals at one time, two times, three times and four times, respectively.

The water salinity showed a general increasing trend with magnetization times. This agrees with the works of [20]; [21] and [3]. Results of these treatments significant increase in salinity Concentration compare with the control are shown in Figure-8.

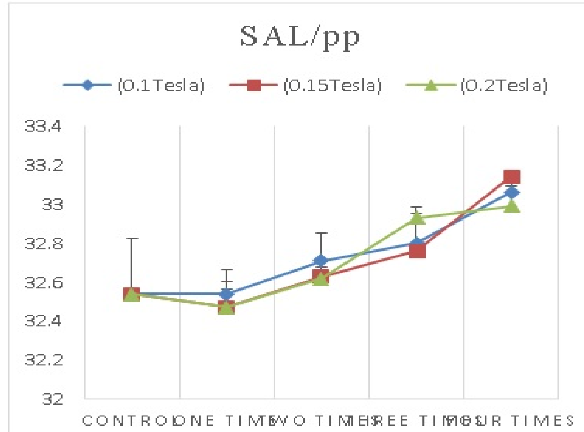

Figure-8. effect of exposure to magnetic field on salinity concentration of water magnetized 0.1, 0.15 and 0.2 Tesla and the magnetization intervals at one time, two times, three times and four times, respectively.

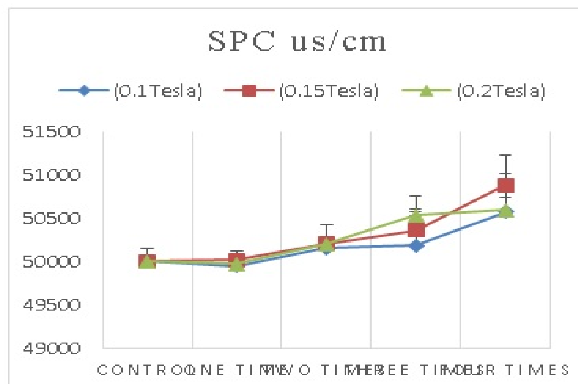

Figure-9. effect of exposure to magnetic field on specific conductance concentration of water magnetized 0.1, 0.15 and 0.2 Tesla and the magnetization intervals at one time, two times, three times and four times, respectively.

The total dissolved solids also showed a general increasing trend with magnetization times. These results are in agreement with those reported by [22]; [16]; [23]; [17]; [18]; [24]; [3] and [22]. As had been seen, water exposure to magnetic field results in softening of that water as well as increasing its pH too. Magnetic flux causes water molecules to get arranged in one. This mode of arrangement is caused by relaxation bonds, then the bond angle decreases to less than 105º, leading to a decrease in the consolidation degree between water molecules, and increase in size of molecules. This change in water molecules composite causes a change in pH and TDS [25]. This is in disagreement with [13] although they reported a decrease in water total dissolved solids after magnetization. Results of these treatments showed significant increase in TDS concentration compared with the control as shown in Figure-10.

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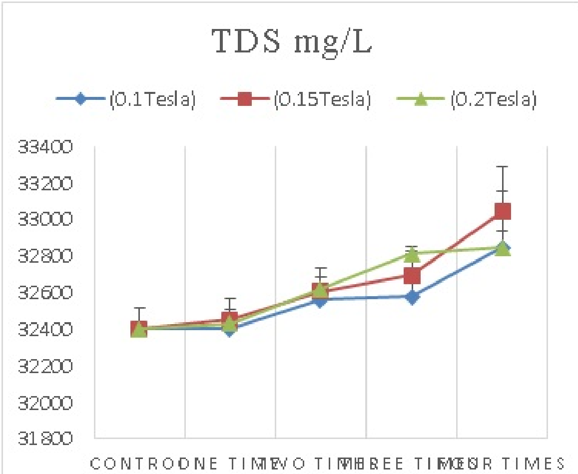

Figure-10. effect of exposure to magnetic field on total dissolved solid concentration of water magnetized 0.1, 0.15 and 0.2 Tesla and the magnetization intervals at one time, two times, three times and four times, respectively.

Effect of the exposure to magnetic field on hatching percentage

The changes in physical and chemical properties of magnetised water seems to affect the biological properties of the organisms that consume the water. As for *Artemia nauplii* hatchability in particular, the exposure to magnetic field has a significant effect here. When Artemia eggs are in water that has been magnetized, the hatching rate is higher than it in the control, and it can also be seen in Figure-11, Figure-12, and Figure-13 that hatchability also increases with the number of magnetization times.

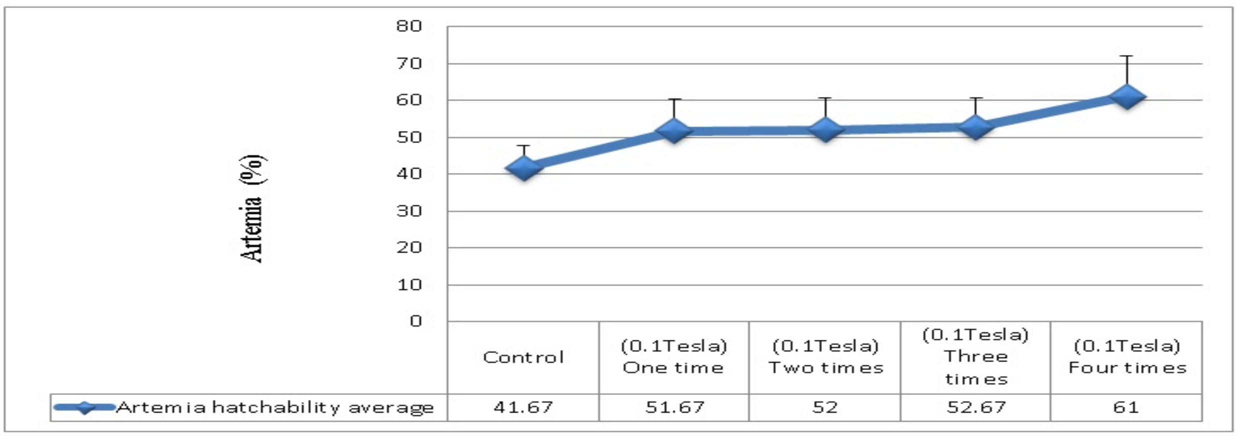

Figure-11. hatchability of Artemia in water magnetized 0.1 Tesla and the magnetization intervals at one time, two times, three times and four times, respectively.

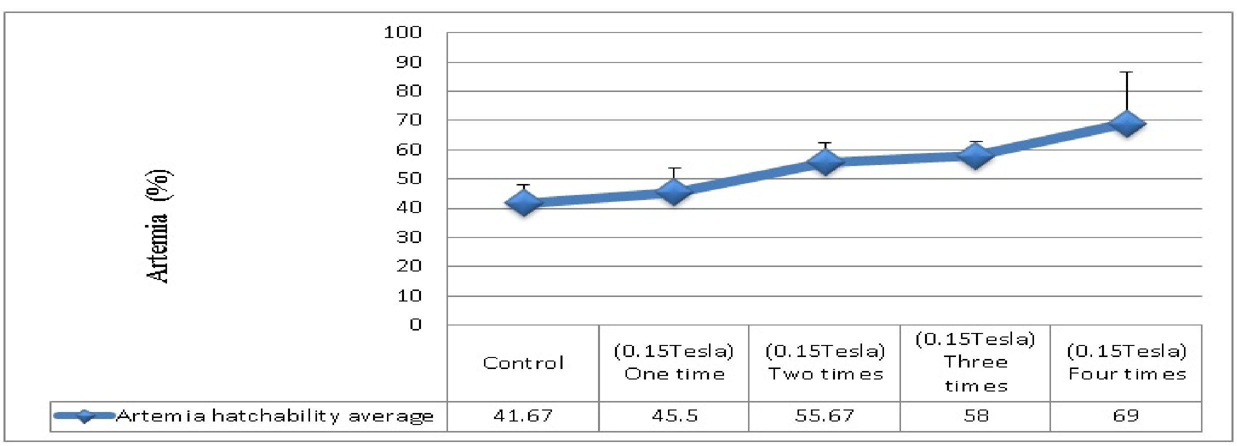

Figure-12. hatchability of Artemia in water magnetized 0.15 Tesla and the magnetization intervals at one time, two times, three times and four times, respectively.

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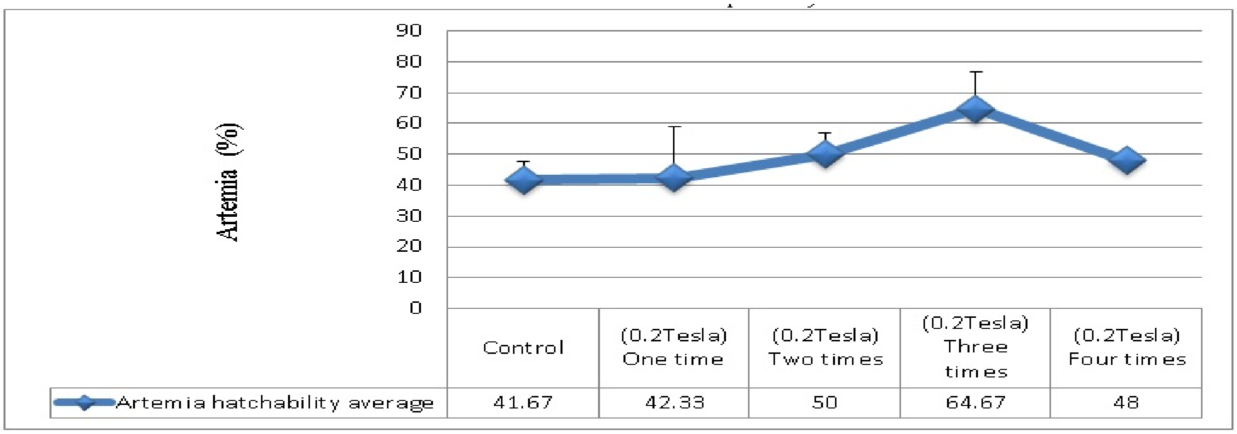

Figure-13. hatchability of Artemia in water magnetized 0.2 Tesla and the magnetization intervals at one time, two times, three times and four times, respectively.

The best average hatching results are achieved in water magnetized with field intensity 0.15 Tesla between one to fourth magnetization times, followed by 0.1 Tesla between one to fourth magnetization times, and then finally 0.2 Tesla between one to fourth magnetization times. The result is also plotted in Figure-14.

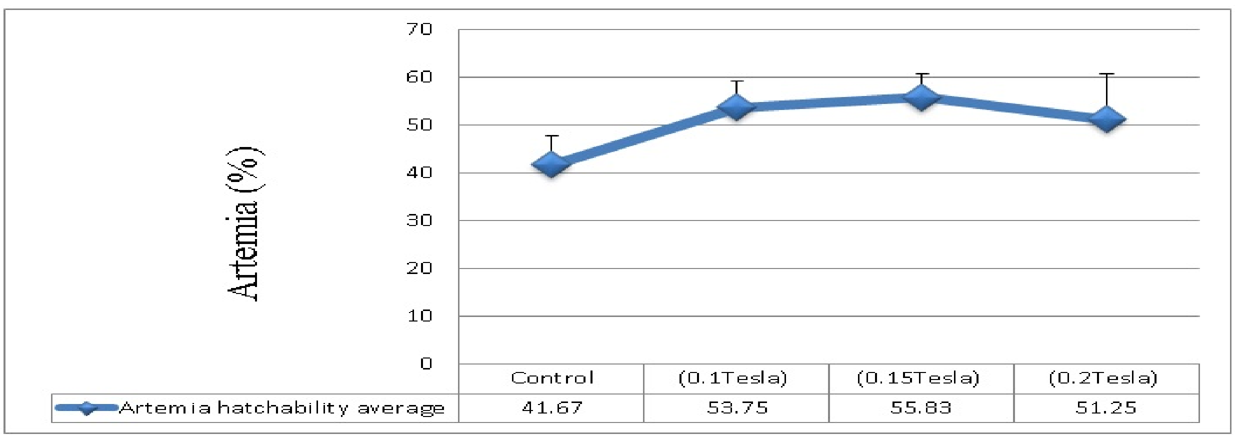

Figure-14. hatchability of Artemia in normal water and water magnetized with intensities 0.1, 0.15 and 0.2 Tesla.

Table-1 summarizes the effect of magnetized water on the hatching percentage of A. salina. It can be seen that the best condition for Artemia to hatch was when the water had been magnetized at 0.15 Tesla for four times.

Table-1. the effect of magnetized water 0.1, 0.15 and 0.2 Tesla and the magnetization intervals at one time, two times, three times and four times on increase of hatching percentage compare with normal water (%).

Magnetization times / Magnetic Field intensities	Magnetization for one time	Magnetization for two times	Magnetization for three times	Magnetization for four times
0.1 Tesla (%)	19.35↑	19.87↑	20.88↑	31.69↑
0.15 Tesla (%)	8.42↑	25.15↑	28.16↑	39.61↑
0.2 Tesla (%)	1.56↑	16.66↑	35.57↑	13.19↑

Table-2 presents the statistical analysis of the effect of magnetized water on the hatching percentage of *A. salina*. It can be seen that the increase in Artemia hatchability are significant ($P \leq 0.05$) when the water has been magnetized at 0.15 Tesla for four times and 0.2 Tesla for three times compare with normal water.

Table-2. effect of the magnetized water 0.1, 0.15 and 0.2 Tesla and the magnetization intervals at one time, two times, three times and four times and the interaction between them on hatching percentage.

Magnetization times / Treatment	Magnetization for one time	Magnetization for two times	Magnetization for three times	Magnetization for four times
Control	41.67 D			
0.1 Tesla	51.67 BCD	52. 00 BCD	52.67 BCD	61. 00 ABC
0.15 Tesla	45.50 CD	55.67 ABCD	58. 00 ABCD	69. 00 A
0.2 Tesla	42.33 D	50. 00 BCD	64.67 AB	48. 00 CD

*Alphabets that same latter in column are not different significant of according Duncan's test ($P \leq 0.05$).

According to [26], a change in physical and chemical properties such as in magnetic water also affects biological properties of water. It increases the solubility of minerals which eventually improves the transfer of nutrients to all parts of the body. The overall yield is an effective and improved organism performance. The following illustration explains how organism performance is improved through water magnetization: Magnetism affects the bonding angle between hydrogen and oxygen atoms within each water molecule, causing the hydrogen-oxygen bond angle within the water molecule to be reduced from 104° to 103° degrees. This in turn causes the water molecules to cluster together in groups of 6-7 rather than groupings of 10-12 molecules and higher. The smaller the clustering; the better is the absorption of water across cell walls ([27]& [28], as shown in Figure-13.

Based on what had been mentioned before, it could be assumed that improved hatchability of *A. salina* may be due to the fact that the magnetic fields can affect membrane functions, not only by a local effect on ion fluxes or ligand binding but also by altering the distribution and aggregation of the intramembranous proteins [29].

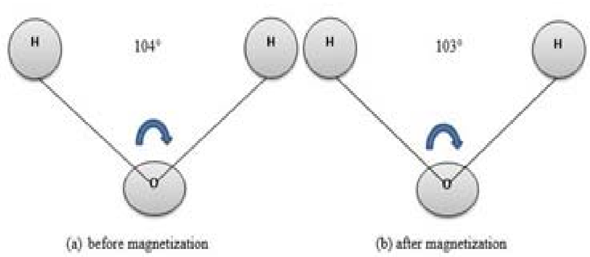

Figure-15. hydrogen angle bond (a) before magnetization (b) after magnetization.

CONCLUSIONS

Based on the above results the followings can be concluded

- Treatments involving the effect of magnetic field of intensity 0.1, 0.15 and 0.2 Tesla with (one, two, three and four magnetization times) have demonstrated a sensible alteration in the physical and chemical properties of water such as dissolved oxygen (mg/L), pH, NH_4-N, NH_3-N, salinity (ppt), specific conductance (µS/cm) and total dissolved solids (TDS mg/l).
- The exposure to magnetic field resulted in higher hatching rate of A. salina.
- The best significant hatching rate was attained in water exposed to 0.15 Tesla at four magnetization times and 0.2 Tesla at three magnetization times compared to normal water.

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