



**POTENTIAL APPLICATIONS OF EXPOSURE TO
MAGNETIC FIELD IN CHANGING WATER
PROPERTIES AND IMPROVING GROWTH
PERFORMANCE OF SELECTED AQUACULTURE
ORGANISMS**

by

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LIST OF ABBREVIATIONS

ALP	Alkaline phosphates
ALT	Alanine aminotransferase
AST	Aspartate aminotransferase
ATP	Adenosinethriphosphate
CD	Conductivity
COD	Chemical oxygen demand
COD	Chemical Oxygen Demand
COR	Concentrations of serum cortisol
CP	Crude protein
DM	Dry matter
DNA	Deoxyribonucleic Acid
DO	Dissolved oxygen
Ec	Electric conductivity
EDTA	Ethylenediaminetetraacetic acid
EMF	Electro-Magnetic field
FAO	Food and Agriculture Organization
FCR	Feed conversion ratio
GLU	Glucose
GOT	Glutamic oxaloacetic transaminase
GPT	Glutamic pyruvic transaminase
Hc	Body depth
Hz	Hertz
INSAT	Institute of Sustainable Agrotechnology

L ₀	Initial length
L ₁	Final length
MCHC	Mean corpuscular hemoglobin concentration
MCV	Mean corpuscular volume
MCV	Mean corpuscular volume
mRNA	Messenger Ribonucleic Acid
mT	Militesla
N ₁	Initial total number of fish
N ₂	Final total number of fish alive
NTU	Nephelometric Turbidity Unit
ORP	Oxidation reduction potential
PCV	Packed cell volume
Ppt	Parts Per Thousand
PVC	Polyvinyl chloride
RAS	Recirculating aquaculture systems
RBC	Red blood cell
SC	Specific conductance
SGR	Specific growth rates
SL	Standard length
SPC	Specific conductance
SpCond	Specific conductivity
SR	Survival rate
T	Time in days
TDS	Total dissolved salts
TG	Triglycerides

TL	Total length
TP	Total protein
TSS	Total suspended solids
W	Weight
W ₀	Initial weight
W ₁	Sample weight
W ₂	Weight of empty dry cup
W ₃	Weight of dry cup + ether extract
WBC	White blood cell
WG	Weight gain
WHO	World Health Organisation
W _t	Final weight

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LIST OF SYMBOLS

CaCO ₃	Calcium Carbonate
Cl	Chlorides
Hb	Hemoglobin
HSI	Hepatosomatic index
μT	Microtesla
NH ₃ -N	Amonia
NH ₄ -N	Ammonium
P-PO ₄	Phosphate
T	Tesla
VSI	Viscerasomatic index

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Potensi Aplikasi Dedahan Medan Magnetik Terhadap Sifat Air dan Fungsi Tumbesaran Organisme Akuakultur Terpilih

ABSTRAK

Kajian ini adalah untuk memahami dengan lebih mendalam kesan medan magnetik terhadap sifat-sifat air dan biologi pembiakan organism akuakultur. Air magnetik dihasilkan apabila air dialirkan melalui medan magnet bertujuan untuk mengubah suai strukturnya dengan perubahan hierarki makromolekul air. Tumpuan kajian terhadap air magnetik adalah berdasarkan kepada kerja-kerja dan laporan-laporan yang menunjukkan terdapat kesan positif medan magnetik terhadap sifat air, pertumbuhan tanaman, percambahan tanaman, kualiti air minuman ternakan dan persenyawaan ikan serta kemungkinan menangani beberapa isu berkaitan kualiti air dalam sistem akuakultur aliran kitar semula air (RAS) yang masih memberi kesan negatif terhadap penetasan dan tumbesaran spesies akuakultur. Pertama, kajian ini menilai sifat dan kualiti air yang terdedah kepada medan magnetik berintensiti 0.10, 0.15, 0.20, 0.10 + 0.15, 0.10 + 0.20, 0.15 + 0.20 dan 0.10 + 0.15 + 0.20. Hasil kajian menunjukkan peningkatan signifikan ($p < 0.05$) terhadap peratusan oksigen terlarut, pH dan konduktiviti masing-masing sebanyak 17.3, 1.6, 3.0% dan penurunan signifikan aras ammonium, ketepatan konduktiviti, jumlah pepejal terlarut dan klorida, masing-masing sebanyak 25.3, 1.1, 1.4, 1.00, 16.9, dan 3.4%. Kajian kesan air magnetik ke atas *Artemia (Artemia salina)* pada intensiti 0.10 + 0.15 + 0.20 T menunjukkan peningkatan kadar penetasan sehingga 89.1, 88.4 dan 69.5%, manakala apabila air magnetik dialirkan melalui medan magnetic berintensiti 0.10 + 0.15, 0.10 + 0.20, 0.15 + 0.20 dan 0.10 + 0.15 + 0.20T kadar penetasan menurun sebanyak 48.6, 42.3, 43.3 dan 42.0%, berbanding dengan 49.3% bagi kawalan. Peningkatan penetasan *Artemia* (H%) sebanyak 64.7% dicapai dalam air yang terdedah kepada medan magnetic berintensiti 0.15 T selama 20 jam berbanding 41.7% bagi kawalan. Peningkatan kadar penetasan (H%) tertinggi 86.3, 86.7 dan 86.3% bagi red tilapia (*Oreochromis sp.*) dicapai dalam air yang terdedah kepada medan magnet 0.10, 0.15, dan 0.20 T selama 5 jam, berbanding 78.6% bagi kawalan. Peningkatan kadar penetasan (H%) ikan keli (*Clarius gariepinus*) meningkat sebanyak 55.0, 59.2, dan 66.8% apabila didedahkan kepada medan magnet masing-masing pada intensiti 0.10, 0.15 dan 0.20 T, berbanding dengan rawatan kawalan (51.7%). Pengurangan ketara ($p < 0.05$) FCR sebanyak 14.9% dan peningkatan berat badan 5.2% berlaku kepada jade perch (*Scortum barcoo*) manakala bagi juvana tilapia merah, telah berlaku penurunan ketara FCR sebanyak 30.7% dan peningkatan berat badan 17.0%. Spesimen histologi tisu hati bagi ikan jade perch dalam tangki kawalan dan yang terdedah kepada medan magnetik 0.10 T mempunyai organisasi sinusoid normal tanpa tanda-tanda luka atau keabnormalan berbanding tisu hati ikan yang berbentuk hepatosit apabila terdedah kepada medan magnetik bertintensiti yang lebih tinggi. Secara ringkasnya, kajian menunjukkan penggunaan air magnetik mnghasilkan kadar penetasan yang tinggi bagi *Artemia*, red tilapia, dan ikan keli. Di samping itu, ikan yang ditenak dalam RAS air magnetik mempamerkan pengambilan makanan yang kurang. Oleh kerana peranti magnet mudah dipasang pada RAS dan berkos rendah, penggunaannya akan dapat meningkatkan produktiviti penternakan ikan oleh para petani.

Potential Applications of Exposure to Magnetic Field in Changing Water Properties and Improving Growth Performance of Selected Aquaculture Organisms

ABSTRACT

This study intends to understand the effect of magnetic field on water properties and on aquaculture organisms. Magnetic water is produced when water is passed through a magnetic field which alters the state of the macromolecules of the water. Changes to the physico-chemical properties of magnetised water affect the biological properties of the organisms that consume or are exposed to it. This study is based on previous works reporting the positive effects of exposure to magnetic field on water properties, plant growth, plant germination, livestock-drinking water, fish fertilisation and against the backdrop of issues pertaining to water quality in recirculating aquaculture systems (RAS), which negatively impacted fish growth and hatchability rate of aquaculture species. First, this work evaluated the effect of exposure to magnetic field intensities of 0.10, 0.15, 0.20, 0.10+0.15, 0.10+0.20, 0.15+0.20, and 0.10+0.15+0.20 T on water qualities. The results showed significant ($p < 0.05$) increase in dissolved oxygen, pH, and conductivity by 17.3, 1.6, 3.0%, respectively, and a significant decrease of the ammonium level, specific conductivity, total dissolved solids, oxygen reduction potential, and chlorides by 25.3, 1.1, 1.4, 1.0, 16.9, 3.4%, respectively. A study on the effect of magnetically charged water on *Artemia* (*Artemia salina*) showed an increase of hatchability rate, from 49.3% for the normal water to 89.1, 88.4, and 69.5% for magnetised water of 0.10, 0.15, and 0.20 T, respectively. However, a decline in *Artemia* hatchability rate to 48.6, 42.3, 43.7, and 42.0% occurred when water was magnetised to 0.10+0.15, 0.10+0.20, 0.15+0.20, and 0.10+0.15+0.20T respectively. An increase of 64.7% in *Artemia* hatchability (H%) was attained in the water exposed to a magnetic field of 0.15 T for 20-hours compared with the control treatment at 41.7%. The increase of 86.3, 86.7 and 86.3% in red hybrid tilapia's (*Oreochromis* sp.) hatchability rate (H%) were attained in water exposed to magnetic field intensities of 0.10, 0.15, and 0.20 T for 5 hours, compared to the control treatment at 78.8%. Increases of 55.0, 59.2, and 66.8% in catfish's (*Clarius gariepinus*) hatchability rate (H%) were attained in water exposed to magnetic fields of 0.10, 0.15 and 0.20 T, compared to the control treatment at 51.7%. Significant decrease ($p < 0.05$) in feed conversion ratio by 14.9% and increase in body weight by 5.2% for jade perch (*Scortum barcoo*) and significant decrease in FCR by 30.7% and increased weight gain by 17.0% for red hybrid tilapia juveniles in RAS. The best results were obtained when using water exposed to magnetic field intensities of 0.10 and 0.15 T, respectively. The liver cells of the fishes grown in the control treatment and those in 0.10 T magnetic water exhibited a normal sinusoid organisation with no indications of lesions or abnormalities of the hepatocytes. In summary, the study demonstrated the benefits of using magnetically charged water for aquaculture due to increased hatchability of artemia, red tilapia, and catfish, and a better growth performance for jade perch and red hybrid tilapia culture in waters exposed to magnetic fields demonstrated significantly lower FCR, hence improve in fish productivity in RAS. Since the installation of the device is simple, low cost, and can be retro-fitted into existing systems, fish farmers can increase their aquaculture productivity.

CHAPTER 1

INTRODUCTION

1.1 Aquaculture & Water Quality

Edible fish is an important source of food and nutrition. It forms the livelihood of most fishermen and industries that process fish. Fish is one of the most traded food commodities worldwide, and more than half of the global fish export, by value, is contributed by developing countries. The world's fish supply reached 20 kg/capita in 2014 due to vigorous growth of the aquaculture industry and improved fisheries management (FAO, 2016).

Aquaculture currently produces half of the total edible fish supply, which is expected to reach 62% by 2030, as wild-caught fish supply will be unable to cope with increasing demand from a growing middle class population. Aquaculture is no doubt an important component in global food security and economic growth (FAO, 2014).

Water quality is paramount in aquaculture. Excellent water quality is necessary for the optimal growth of fish, as it reduces stress to fish and prevent proliferation of diseases. Important water quality parameters in aquaculture include temperature, dissolved oxygen, pH, ammonia, and nitrate and nitrite content (Masser et al., 1999; Al-Salman, 2000; Fadhil et al., 2011; Carbajal-Hernández et al., 2012; Lopez-Luna, 2013; Carbajal-Hernandez et al., 2013).

1.2 Bio-benefits of Magnetisation and Magnets

There are numerous in-vitro and in-vivo studies reporting positive findings on the use of magnetised water or fields on various plant species (e.g. Carbonell et al., 2000; Martinez et al., 2000; Celestino et al., 2000; Yaycili & Alikamanoglu, 2005; Khoshravesh et al., 2011, Maffei, 2014). While the effects of magnetised water can be evident on living organisms, it appears that its effect towards the productivity of aquaculture remains understudied.

Gill et al. (2005) concluded that there are significant gaps in knowledge regarding the use of magnetic fields in aquaculture. There are still many questions pertaining to the use of magnetic device in aquaculture, such as the intensity of the exposure to magnetic field, their effects on water properties, and the effects of these properties on aquaculture water. The effects of exposure to electromagnetic fields rely on the magnetic field's intensity, frequency, and the length of exposure. Considering the simple and inexpensive setup to magnetise water, which consists of water flowing through a magnetic device and requiring no additional electricity or maintenance, it could well be a cost-effective application for controlled aquaculture systems. The proposed study is an effort to further improve aquaculture production using RAS. The proposed technological development, i.e. incorporation of new water treatment device that could improve the physical properties of water, has never been introduced or tested for aquaculture in Malaysia. RAS has been used for culturing high value freshwater species, such as kelah (*Tor spp.*), emperau (*Tor tamroides*), and jade perch (*Scortum barcoo*), as well as marine species such as groupers (Serranidae Family), due to its quick turnaround in terms of its initial investment cost (Hoestenberghé et al., 2013). It is expected that Malaysian fish farmers would find the small cost in incorporating the

magnetic device to RAS agreeable due to the positive affect on their aquaculture production.

Water quality can be improved using magnetic devices. Literature detailed the use of applied magnetic fields to treat water, resulting in its improvement. The construction of magnetic devices is cheap and simple, and can be retrofitted into existing fish rearing systems (Gabrielli et al., 2001; Krzemieniewski et al., 2003; Krzemieniewski et al., 2004a).

Continuous improvement on RAS is important in order to improve its efficiency and production. This research is an effort towards enhancing the performance of RAS without incurring too much cost. The enhancement involves incorporating a magnetic device to create a constant magnetic field for magnetising water in a conventional RAS. The technologies that are used for water treatment are ultraviolet radiation and water ozonation (Bullock, 1997), but these approaches require high investment and is expensive (Krzemieniewski et al., 2004b).

This work intends to study the effects of magnetised water on Artemia's (*Artemia salina*), red hybrid tilapia's (*Oreochromis* sp.), and catfish's (*Clarias gariepinus*) hatchability and the growth performance of red hybrid tilapia and development of jade perch (*Scortum barcoo*) juveniles in RAS.

1.3 Problem Statement

There are water quality issues in rearing fish using recirculating aquaculture system. Certain technologies for water treatment to improve its quality are highly energy intensive and expensive to use, thus implying high investment and operating costs. The need to look for a novel method of water treatment which not only improves

water and fish quality but is also cost effective and energy efficient, resulting in improvement of aquaculture productivity. There is limited knowledge pertaining to the use of magnetic devices in aquaculture, such as the intensity of the exposure of magnetic field and effects on water properties, hatchability and grow-out performance of aquaculture organisms remains. On the other hand, De Graaf et al., (1995) reported low hatching rate for catfish, and the average hatching percentage of the eggs varied between 28.4 ± 4.5 and $59.1\% \pm 3.7$. Thus, there is need to study the optimum magnetic field intensity that is required to improve water quality and aquaculture productivity.

By incorporating a magnetic water-treatment device in RAS, aquaculture may become more attractive in the future.

1.4 Research Objectives

1. To determine the effects of exposure to magnetic field of different intensities and frequency on the physico-chemical properties of water.
2. To study the effect of magnetic field of different intensities and frequency of exposure on Artemia, catfish and red tilapia hatchability.
3. To determine the effects of exposure to magnetic field of different intensities and frequency of exposure on survival rate, growth performance, whole-body Proximate Composition and hematology of red tilapia in RAS.
4. To study the effects of exposure to magnetic field of different intensities on growth performance, whole-body Proximate Composition, hematology, and liver histology of jade perch in RAS.