GROWTH PERFORMANCE AND GONAD MATURATION OF GIANT FRESHWATER PRAWN IN MONOCULTURE, AQUAPONICS AND INTEGRATED MULTITROPHIC AQUACULTURE SYSTEMS

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DECLARATION

I, hereby, declare that this thesis has been composed entirely by myself and that is not been submitted for any other degree or professional qualification. The materials in this thesis are original, except for equations, summaries and references, which have been duly acknowledged.

23 February 2023

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ABSTRACT

This study aimed to measure the growth of giant freshwater prawn (*Macrobrachium rosenbergii*) and green bean (*Phaseolus vulgaris*) in aquaponic systems of different flow rates 0.6 L/min, 1.6 L/min, 2.6 L/min, and 3.6 L/min as the first experiment. While the other aim of the study is to investigate the growth performance and gonad maturation of *M. rosenbergii* in three different culture systems: Monoculture, Aquaponics, and Integrated Multi – Trophic Aquaculture (IMTA) systems in 90 days in the second experiment. The relationship between different water flow rates and various *M. rosenbergii* systems of growth performance and gonad development can impact the systems' uptake of nutrients. Body weight gained (BWG), survival rate (SR), and specific growth rate (SGR) of *M. rosenbergii* were evaluated as the growth performance indicator. At the same time, gonad maturation was observed through histology. Besides, water quality variables such as temperature, pH, dissolved oxygen (DO), and dissolved nutrients (ammonia, nitrite, nitrate, and phosphate) were also monitored every week in each system. The result of different flow rates showed that there was a significant difference in mean (± S.E.) survival rate which is high in flow rate 1.6 L/min with the mean of 96.67 ± 0.26% compared to 0.6 L/min (84.33 ± 0.43%), 2.6 L/min (58.67 ± 1.96%) and 3.6 L/min (87.33 ± 0.43 %). The water flow rate for experiment 2 has been chosen based on the water flow rate that encouraged *M. rosenbergii* to grow at its maximum capacity in experiment 1. Results showed that the growth performance and gonad maturation of *M. rosenbergii* were significantly different ($p<0.05$) due to the water quality changes in the three culture systems. There was a significant difference in SR and SGR of *M. rosenbergii*. The mean (± S.E.) SR of males and females were high in the IMTA system, which was 81.48 ± 5.86 % and 73.15 ± 5.16 % compared to the Aquaponic system (62.94 ± 6.68 % and 50.00 ± 8.56 %) and Monoculture system (48.15 ± 9.80 % and 47.22 ± 8.44 %). The value of pH, DO, and temperature were not significant differences ($p> 0.05$), and there were significant differences ($p<0.05$) in ammonia, nitrite, and phosphate concentration. The lowest ammonia concentration was recorded in IMTA (0.23 ± 0.03 mg/L), followed by Monoculture (0.34 ± 0.03 mg/L) and Aquaponic (0.36 ± 0.03 mg/L). Results of histology of each system showed different stages of maturity, which were 50.00 % of females of stage V for ovarian in the IMTA system, 16.67 % for Aquaponic, and 8.33 % in the Monoculture system. As for the male *M. rosenbergii*, there was 66.67 % of stage IV in gonad maturation of IMTA and Monoculture and 33.33 % in the Aquaponic system. There was a significant difference in the diameter oocyte of stage V of female *M. rosenbergii*. The higher mean (± S.E.) diameter oocyte of stage V in ovarian recorded was 565.86 ± 14.81 µm in the IMTA compared to Aquaponic (483.53 ± 30.94 µm) and Monoculture (482.86 ± 38.98 µm). In conclusion, culturing *M. rosenbergii* in the IMTA system could enhance the growth performance and gonad maturation of *M. rosenbergii*; it could make it more economical regarding water usage and reduce wastewater disposal from the farming system.

ABSTRAK

PRESTASI PERTUMBUHAN DAN PERKEMBANGAN GONAD UDANG GALAH DI DALAM SISTEM MONOKULTUR, AKUAPONIK DAN AKUAKULTUR MULTITROFIK BERSEPADU

Kajian ini bertujuan untuk mengukur pertumbuhan udang galah (Macrobrachium rosenbergii) dan kacang hijau (Phaseolus vulgaris) dalam sistem akuaponik dengan kadar alir berbeza 0.6 L/min, 1.6 L/min, 2.6 L/min dan 3.6 L/min sebagai percubaan pertama. Manakala matlamat lain kajian untuk menyiasat prestasi pertumbuhan dan kematangan gonad M. rosenbergii dalam tiga sistem kultur berbeza: Monokultur, Akuaponik dan Sistem Akuakultur Berbilang Tropik Bersepadu (IMTA) dalam 90 hari ialah eksperimen yang kedua. Hubungan antara kadar aliran air yang berbeza dan pelbagai sistem M. rosenbergii pada prestasi pertumbuhan dan kematangan gonad boleh memberi kesan kepada pengambilan nutrien sistem. Pertambahan berat badan (BWG), kadar kemandirian (SR), dan kadar pertumbuhan khusus (SGR) M. rosenbergii dinilai sebagai kadar pertumbuhan. Pada masa yang sama, kematangan gonad diperhatikan melalui histologi. Selain itu, pembolehubah kualiti air seperti suhu, pH, oksigen terlarut (DO), dan nutrien terlarut (ammonia, nitrit, nitrat dan fosfat) juga dipantau setiap minggu dalam setiap sistem. Keputusan kadar alir yang berbeza menunjukkan terdapat perbezaan yang signifikan dalam SR min (± S.E.) yang tinggi dalam kadar alir 1.6 L/min dengan min 96.67 ± 0.26% berbanding yang lain. Kadar aliran air untuk eksperimen 2 telah dipilih berdasarkan kadar aliran air yang menggalakkan M. rosenbergii berkembang pada kapasiti maksimum dalam eksperimen 1. Keputusan menunjukkan prestasi pertumbuhan dan kematangan gonad M. rosenbergii adalah berbeza secara signifikan ($p< 0.05$) disebabkan oleh perubahan kualiti air dalam tiga sistem kultur. Terdapat perbezaan yang signifikan dalam SR dan SGR M. rosenbergii. Purata (± S.E.) SR jantan dan betina adalah tinggi dalam sistem IMTA iaitu 81.48 ± 5.86 % dan 73.15 ± 5.16 % berbanding sistem Akuaponik dan sistem Monokultur. Nilai pH, DO dan suhu adalah tidak terdapat perbezaan yang signifikan ($p>0.05$) dan terdapat perbezaan yang signifikan ($p<0.05$) dalam kepekatan ammonia, nitrit dan fosfat. Kepekatan ammonia terendah direkodkan dalam IMTA (0.23 ± 0.03 mg/L), diikuti oleh Monokultur dan Akuaponik. Keputusan histologi setiap sistem menunjukkan peringkat kematangan yang berbeza, iaitu 50.00 % wanita peringkat V untuk ovari dalam sistem IMTA, 16.67 % untuk Akuaponik dan 8.33 % sistem Monokultur. Bagi M. rosenbergii jantan pula, terdapat 66.67 % peringkat IV dalam kematangan gonad IMTA dan Monokultur dan 33.33 % sistem Akuaponik. Terdapat perbezaan yang ketara dalam diameter oosit peringkat V M. rosenbergii betina. Purata min (± S.E.) diameter oosit peringkat V yang lebih tinggi dalam ovari direkodkan ialah 565.86 ± 14.81 µm dalam IMTA berbanding dengan Akuaponik dan Monokultur. Kesimpulannya, pengkulturan M. rosenbergii dalam sistem IMTA boleh meningkatkan prestasi pertumbuhan dan kematangan gonad M. rosenbergii; di samping itu, ia boleh menjadikannya lebih menjimatkan dari segi penggunaan air dan mengurangkan pembuangan air sisa daripada sistem perladangan.

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LIST OF SYMBOLS

%	-	Percentage
°C	-	Degree celsius
µm	-	Micrometer
mL	-	Mililiter
g	-	Gram
m	-	Meter
L	-	Liter
L/H	-	Liter/Hour
mg/L	-	Miligram/Liter
nm	-	Nanometer
cm	-	Centimeter
L/min	-	Liter/minute

LIST OF ABBREVIATIONS

ATP	-	Adenosine triphosphate
BC	-	Blue claw
BWG	-	Body weight gain
DIN	-	Dissolved inorganic nutrient
DO	-	Dissolved oxygen
F&PF	-	Feces and pseudo-feces
FAO	-	Food Agriculture Organization
FC	-	Follicles cells
FCR	-	Feed conversion ratio
GSI	-	Gonadosomatic index
IMTA	-	Integrated Multi-Trophic Aquaculture
N	-	Nitrogen
NADH	-	Nicotinamide adenine dinucleotide hydrogen
OC	-	Orange claw
OO	-	Oogonia
P	-	Phosphorus
PL	-	Post larvae
PO	-	Primary oocyte
POM	-	Particulate organic matter
PVO	-	Previtellogenic oocytes
SGR	-	Specific growth rate
SR	-	Survival rate
SM	-	Small male
VO	-	Vitellogenic Oocytes

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CHAPTER 1

INTRODUCTION

1.1 General Introduction

The market rate of giant freshwater prawns (*Macrobrachium rosenbergii*) is always higher than fish. Due to that, the species were cultured globally, thus becoming the most significant contribution to total world freshwater aquaculture production. Due to its high demand, all the tropical and subtropical developing nations in Asia and many other countries already culture *M. rosenbergii* (Tayamen, 2007).

Meanwhile, in Malaysia, *M. rosenbergii* is one of the targeted species in aquaculture, becoming popular as it can generate high income among farmers (Banu & Christianus, 2016). Unfortunately, due to the pandemic of COVID-19, the production of *M. rosenbergii* declined. In 2018, the production was 213.42 metric tonnes, higher than in 2020, with 205.58 metric tonnes sales value of over RM 12,757.12 (Department of Fisheries Malaysia, 2020). The *M. rosenbergii* delayed production results from its poor growth and environmental factors. Since most species of crustaceans cannot grow in captivity, such as mud crabs (*Scylla* sp.), obtaining mature gonads is the primary challenge in aquaculture (Ikhwanuddin & Bachok, 2010). Thus, the matured gonads encourage prawn reproduction. Environmental variables impacted the development of the gonads and the growth performance (Babu & Datta, 2013). Ecological factors, including food availability, temperature, and photoperiod, impact the spawning of *M. rosenbergii* (Mallasen et al., 2008). Besides, external factors such as temperature and

water quality will affect the growth and gonadal maturation of *M. rosenbergii* (Saha & Alam, 2014).

The water flow rate is important for the growth of *M. rosenbergii* culture in different systems because it affects the level of dissolved oxygen in the water. Increased dissolved oxygen levels in the water, crucial for prawn's health and growth, are made possible by increased water flow rates (Qayyum et al., 2005). Second, the water flow rate contributes to water quality preservation by eliminating waste materials from the system, including fish feces, uneaten food, and decomposing plant matter. These waste materials may accumulate in the water, resulting in dangerous concentrations of ammonia and nitrites that may be hazardous to prawns (Estim et al., 2019). In order to maintain the cleanliness of the water and wholesome for the fish and plants, a higher water flow rate aids in the more effective removal of these waste materials. The water flow rate can also impact the system's nutrient absorption rate. Bacteria in the system break down nutrients from the excrement of the fish (Estim et al., 2019).

The various systems will act on water quality, affecting the growth performance and gonad maturation of *M. rosenbergii* (Henry-Silva et al., 2015). Extensive, semi-intensive, or intensive freshwater prawn monoculture are all possible. Semi-intensive monoculture system is the most common system in tropical areas (FAO, 2002). At its most basic level, this monoculture system may offer additional advantages with minimal impact as it is a typical farming technique (FAO, 2002). The culture system generally comprises either freshwater-filled concrete tanks or earthen ponds. The number of prawns to be raised determines the size and form of the pond or tank. As for pond or tank preparation, prawns are cultured at a density of 5–10/m^2. For smaller prawns, the stocking density can be raised to 15-20/m^2 (Trivedi, 2020). Disease outbreaks can be prevented by routinely checking the quality of the water, providing proper nutrition, and maintaining high cleanliness in the culture system. In order to sustain healthy development and high yields, *M. rosenbergii* culture practices primarily concentrate on

providing acceptable water quality, appropriate feeding, and disease management (Trivedi, 2020).

The Aquaponics system is one of the most well-known practices. Aquaponics is a closed system combining hydroponics with aquaculture to produce aquatic plants and animals. The developing plants will receive an organic food supply from the fish waste and extra feed, and the plants will act as a natural water filter. Due to the integrated culture used in the aquaponic system's biodynamic principles and the efficiency of its production results, there is less demand for externalities. Plants may use naturally occurring fertilizer created by the nitrifying bacteria in the system without soil (Estim & Mustafa, 2010). The system's benefits include improved output (of fish or crustaceans and vegetables), reduced nutrient input, and water use (Diver & Rinehart, 2010). The plants grow because of the nutrient supply from the aquatic animal waste. The roots of the plants take up ammonia, nitrites, and phosphate contained in the waste product of prawns. It functions as liquid fertilizer for plants and helps aquatic animals to grow as the water quality contains low ammonia, nitrites, and phosphate concentrations.

The aquaponics would give a desirable pH range for the growth of prawns, especially *M. rosenbergii* (Sace et al., 2013). Additionally, the aquaponic system's dissolved oxygen level will rise due to the plant's photosynthesis, which produces oxygen (Sace et al., 2013). The aquaponics system would give the optimum range of water quality for the growth of *M. rosenbergii* (Sace et al., 2013). Besides, the optimum flow rate in an aquaponic system will maximize the yield growth of *M. rosenbergii* and green beans by improving the water quality through organic farming with a simple and affordable technique which is the Aquaponic system. By adjusting the water flow rate in the tank, the concentrations of metabolites may be changed. For instance, it was discovered that the concentrations of carbon dioxide rose with a decrease in water flow (Fivelstad & Bergheim, 2004).

Another culture system is the integrated multi-trophic aquaculture system (IMTA). Different species are combined in one system, while fed aquaculture will reduce the organic and inorganic wastes (Neori et al., 2014). The different trophic level with

other species helps to utilize the waste from one species as food or fertilizer for another species. Thus, it helps to balance the ecosystem and improve water quality. It is preferable to IMTA compared to the Monoculture system because new food sources are accessible, and there is a synergism between the species (Neori et al., 2014). The IMTA idea is flexible, and it can be practical to open water and land-based systems for marine or freshwater systems. The suitable organisms are selected based on their purposes in the ecosystem and their economic worth or potential. Besides, the production would be more than two outcomes.

Two or more species can ultimately increase the producer revenue that is well accepted in the market as the IMTA (Chopin et al., 2008). Besides, this system would give less feeding as it only feeds the fed aquaculture; the other trophic species, called suspension extractive aquaculture or deposit extractive aquaculture, would benefit each other by feed or nutrient supply. Additionally, prawn stocking densities significantly impacted the IMTA of prawn growth more than in tilapia. This is most probably related to the fact that at higher stocking densities, feed offer decreases due to intra-specific competition for food (Henry-Silva et al., 2015). The somatic and gonadal development of the shrimp is impacted by the higher levels of organic matter and food availability in the IMTA systems (Shpigel et al., 2018). The IMTA system can speed up the process of reaching commercial size, improve the quality and maturation of the gonadal tissue, and lower the FCR in aquatic species (Chopin et al., 2008). This study focuses on *M. rosenbergii* growth performance and gonad maturation in three cultured systems: Monoculture, Aquaponics, and IMTA. These systems would give different water quality dynamics that affect the growth and gonad maturation of *M. rosenbergii*.

1.2 Problem Statement

The production of *M. rosenbergii* during pre and post-pandemic COVID-19 declined (Department of Fisheries Malaysia, 2020). The *M. rosenbergii* delayed development results from poor growth, production, and environmental factors such as water quality. The output of *M. rosenbergii* is reduced because there is a lack of information on the

growth and gonad maturation of *M. rosenbergii* (Paul & Rahman, 2016). Obtaining mature gonads is the primary challenge in aquaculture, especially for crustaceans. The knowledge of gonads as reproductive performance will influence the market demand.

The water quality parameters of *M. rosenbergii* farms are essential because they affect production and because water quality issues are becoming frequent in many regions of the world. Once more, unconsumed feed and other waste products from the culture, primarily feces, sink to the bottom. Freshwater prawn's living environment is ruined by toxic metabolites produced by the mineralization of accumulated organic matter in anaerobic environments. Managing water quality is one of the most critical aspects of culturing freshwater prawns. Poor water quality can result in low profit, product quality, and potential human health risks. So, it requires an excellent system to treat the water. Modern aquaponics and Integrated Multi-Trophic Aquaculture (IMTA) systems can be highly successful but require intensive management and special considerations. The special consideration is how the system's different flow rates can affect freshwater prawn's growth performance.

1.3 Significance of the Study

This study provides a scientific basis for the growth performance and gonad maturation of *M. rosenbergii* with different flow rates in the culturing system. As the market demand for *M. rosenbergii* increases worldwide, growth performance and gonad maturation are the most suitable criteria for improving the production of *M. rosenbergii*. Besides, this study presents water quality dynamics in different culture systems and sustainable approaches, such as Monoculture, Aquaponics, and IMTA systems. The culture system creates a better environment for the growth and gonad maturation of *M. rosenbergii*. This thesis provides valuable baseline water quality and different flow rate data that could improve the growth performance and gonad maturation of *M. rosenbergii*. Information in this thesis is also suitable for farmers, aquarists, the aquaculture industry, and water management strategies required for *M. rosenbergii* production.