Water Quality and Growth Performance of Giant Freshwater Prawn, *Macrobrachium rosenbergii* and Green Bean, *Phaseolus vulgaris* in Aquaponics System at Different Flow Rates

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ABSTRACT This study was assessed to determine the effect of flow rate on growth performance of *Macrobrachium rosenbergii* and *Phaseolus vulgaris*, and the water quality (concentration of nitrite, nitrate, phosphate and ammonia) in aquaponics system. The flow rates were 0.6 L/min, 1.6 L/min, 2.6 L/min and 3.6 L/min. In water inlet, the total mean concentration of nitrite at 0.6 L/min was slightly higher than other treatments. As for the water outlet, the total mean concentration of nitrite at 3.6 L/min was lower than others. Besides, the growth performances of plant which was flower and fruit present were slightly different. The best growth performance in *Phaseolus vulgaris* was at flow rate 0.6 L/min. The result analyzed by One-way Anova showed that there were no significant differences between water quality and growth performance of shrimp and plants at different flow rates in aquaponics system. Due to that, the design of aquaponics system at different flow rate was able to treat the prawn waste water and the plant can grow well. The excess feed and waste from *M. rosenbergii* gave dissolved inorganic nutrients which will be absorbed by the plant for supporting the growth.

KEYWORDS: Water analysis, growth, *Macrobrachium rosenbergii, Phaseolus vulgaris*, flow rate

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INTRODUCTION

Aquaponics is the closed aquaculture system with the combination of aquaculture and hydroponics that aquatic animals and plants grow together in one integrated system. The fish waste and excess feed will provide an organic food source for the growing plants and the plants provide natural water filter for the fish. Biodynamic principles of aquaponics system increase the interest in integrated culture and reduce demand for externalities due to its efficiency in production and operation (Estim and Mustafa, 2010). Plants are able to grow without the presence of soil using natural fertilizer available in the system as a result of nutrients produced from nitrification process by the nitrifying bacteria. The fish water, rich in nutrients is used for plant growth, while the plants are used as biofilters for water regenerations (Estim and Mustafa, 2010). Nutrients strains from the excess feed and waste product of aquatic animal dissolve in the water and change the chemical composition of the media. This nutrient-rich water has ammonia (NH_4), nitrate (NO_3), nitrite (NO_2) and phosphate (PO_4). The good nutrients from the water are absorbed by plant which act as biological filter. Then, the water will recycle back to the prawn tank as it is already being filtered. The water quality being improved in the system, balances the pH, maintains Dissolve Oxygen (DO) and enhances the production of cultured aquatic animals by the nutrient removal of the plant (Nollan *et al*., 1998).

Macrobrachium rosenbergii is important species in South-East Asia countries as it is nutritious delicacy to human. Now, the giant freshwater prawn is becoming an increasingly important target species for aquaculture. There are many published articles cases of success in culturing giant freshwater prawn, *M. rosenbergii* (Wurtz, 2007). In order to increase the world market, the shrimp was widely cultured to satisfy the demand. The production system evolved from extensive toward intensive for increasing inputs of high quality feed and water supply. In traditional intensive shrimp culture, the deteriorated pond water quality is frequently exchanged with new external water supply to maintain desirable water quality for shrimp growth. The researchers and farmer are more attracted to the *M. rosenbergii* due to its nutritional value, taste and demand in the market (Schwantes *et al.*, 2009). *M. rosenbergii* production is economical and more environmentally sustainable compared to conventional intensive shrimp production. Information on stocking density and requirements of *M. rosenbergii* in monoculture systems is available (Marques *et al*., 2000). However, the development and production of freshwater prawn at high level efficiency in aquaculture or agriculture systems still requires the identification and evaluation of specific requirements (food and nutrient) of the different species cultivated in these systems. The species being reared is influenced by the particular selection of technology, site, infrastructure, production management expertise, and other factors (Dunning *et al*. 1998). Noble and Summerfelt (1996) noted that in aquaculture systems that recycle water, the water quality should be maintained at levels sufficient for supporting healthy and fast growing fish.

Vegetables are the most efficient organism in removing nutrients in aquatic ecosystems. Legumes are able to form symbiotic association with *Rhizobium* which have tremendous ability in fixing N and their interaction plays a significant role in the agricultural crop production. Legumes can be used as an alternative of chemical N fertilizer due to its high potential in improving crop growth, quality and yield of grains and cereals by increasing the availability of Nuptake. In agricultural systems, N is known as the imperative factors in plant growth and governs a major constituent of chlorophyll and photosynthetic activity. *Phaseolus vulgaris* is one of the legumes plant as it family is Leguminosae. The edible part for *P. vulgaris* is bean which food grain legume that plays critical role in the lives of people (Masabni, 2010).

The accumulation of fish metabolites in the tank depends on the production rate and the flow rate (Eding and van Weerd, 1999). The metabolite concentrations in the tank can be changed by the flow of water into the tank. To increase reduced water flow, carbon dioxide concentrations for example were found (Fivelstad *et al*., 2004). The effect of different water flow rates is related to nutrients removal, water quality and plant growth. The flow rate value will affect the absorbance of nutrient in plant, due to that, the concentration of ammonia and nitrate can be observed. In Netherlands, producers successfully increased their production by increasing flow rates beyond 1 to 2 tank volumes/h when culturing Anguilla eel (Lupatrsch *et al*., 2010). The current study was designed to measure the growth of *M. rosenbergii* and green bean (*P. vulgaris)* in aquaponics system and to investigate effects of water quality (concentration of ammonia, nitrite, nitrate and phosphate) on the growth performance of *Macrobrachium rosenbergii* and green bean (*P. vulgaris)* at different flow rate.

METHODOLOGY

The experiment was conducted at the Aquaponics and IMTA site of Borneo Marine Research Institute, Universiti Malaysia Sabah for 32 days. Aquaponics system was set up; it consists of one tank for *M. rosenbergii* and on top of the tank, there were two plant tanks which contain of green bean, *P. vulgaris* as showen in Figure 1. The tank water volume was 150 L. The stocking density was 22 tails of *M. rosenbergii* with 100 L in water. The size of *M. rosenbergii* used was 2.54-5.08 cm per tail and body weight of 0.3 g which was suitable to observe the growth rate. *M.rosenbergii* was obtained from the UMS Shrimp Hatchery. The prawn was stocked in the tanks and cultured in the freshwater. There were two plants in each shrimp tank with one plant as shown in Fig.1. The water volume was

100L with the plant tank can occupy two plants in each *M. rosenbergii* tank. The pump power used 2000L/h. Aquaponics system was used in which the waste water was recirculated and the minerals were absorbed by the *P. vulgaris*. The water quality affected the growth of *M. rosenbergii* and *P. vulgaris* at different flow rates. The flow rates were 0.6 L/min, 1.6 L/min, 2.6 L/min and 3.6 L/min with random distribution arrangement. The flow rates were adjusted by the valve. From the previous study, by Endut *et al.*, (2015), the best flow rate in growth performance was 1.6 L/min. Thus, the interval of each flow rate at 1.0 L/min was used. Besides, the stocking of *M. rosenbergii* in one tank were lower, thus the flow rate should be slowed. Type of aquaponics system being used was media filled bed. In addition, the gravel acts as a media because it is very good for supplying nutrient to the plant.

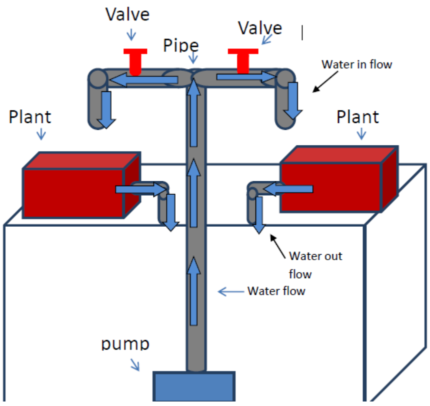

Figure 1. Experimental design of flow rate system in aquaponics

Water Analysis

Water quality was measured using in-situ water quality measurement. The experimental period was 32 days. A multi –parameter (Hanna - YSI) was used for in situ water quality. The reading was taken in the morning and evening to observe the dynamic of water quality throughout the day. The parameter measured include dissolved oxygen (DO) level, water temperature and pH level. Water analysis was conducted in chemical oceanography laboratory. The water was analyzed with the limnological analysis introduced by Wertzel and Liken (1991) such as nitrate, nitrite, ammonia and phosphate.

Growth rate in Macrobrachium rosenbergii and Phaseolus Vulgaris

As for the *M. rosenbergii*, the growth was tested by this formula:
The length (cm) and weight (g) of *M.rosenbergii* were measured every 10 days.

$$\text{Survival rate (\%)} = \frac{\text{No. of } M.\ rosenbergii \text{ at the end of experiment}}{\text{No. of } M.\ rosenbergii \text{ at the start of experiment}} \times 100$$

$$\text{Specific growth rate (SGR)} = \frac{\ln W_1 - \ln W_0}{T_1} \times 100$$

(Muralisankar *et al.*, 2015)

$$\text{Body weight gain (BWG)} = W_2 - W_1$$

Where, W_1 = initial mean weight (g), W_2 = final mean weight (g), T_1 = duration of experiment (days) and ln = natural log. (Seenivasan *et al.*, 2012)

The growth of *P. vulgaris* was measured by growth of rate with following formula:

Height of plants = Final height of plants – Initial height of plants (cm)

$$\text{Growth rate} = \frac{\text{Height of plants (cm)}}{\text{Culture period (days)}}$$

Statistical Analysis

The Statistical Package for the Social Sciences (SPPS) software version 22.0 was used for the statistical analysis. One way ANOVA was used to determine the differences in the nitrite, nitrate and phosphate concentration at different flow rate tank culture. The treatment means were then compared using Duncan's comparison in the SPSS.

RESULT AND DISCUSSION

Growth in Macrobrachium rosenbergii and Phaseolus vulgaris

Table 1. Mean body weight (BW), length (L), specific growth rate (SGR), body weight gain (BWG) and survival rate (SR) of *Macrobrachium rosenbergii* in aquaponics system (mean ± standard deviation)

Flow rate (L/min)	N	BW (g)	L (cm)	SGR (%)	BWG (g)	SR (%)
0.6	60	0.73 ± 0.33	4.54 ± 0.77	3.69 ± 0.750	351.67 ± 135.09	84.33 ± 9.45
1.6	60	0.77 ± 0.37	4.52 ± 0.71	4.19 ± 0.176	435.00 ± 37.75	96.67 ± 5.77
2.6	60	0.75 ± 0.35	4.62 ± 0.76	3.80 ± 0.414	361.10 ± 78.76	58.67 ± 43.09
3.6	60	0.71 ± 0.33	4.40 ± 0.65	3.97 ± 0.717	402.77 ± 132.33	87.33 ± 9.29

Table 1 showed the mean body weight (BW), length, survival rate, body weight and specific growth rate (SGR) of *M. rosenbergii* in each of the aquaponics system at different flow rate. For BW, the highest mean was 0.77 ± 0.37 g at 1.6 L/min flow rate and for the length, the highest mean was 4.62 ± 0.76 cm at 2.6 L/min flow rate. There was no significantly difference in growth performance of *M. rosenbergii*) between other treatments ($p>0.05$). Survival rate and SGR at flow rate 1.6 L/min was higher compared with others treatments. Table 2 showed the mean growth performance of *P.vulgaris* and the highest height was 75.80 ± 52.73 cm at the 3.6 L/min of flow rate. The highest total leaf was 16.80 ± 14.60 cm at the 0.6 L/min of flow rate. For the total flower and total fruit, the flow rate of 0.6 L/min showed the highest mean compared others. There was no significantly difference in RGR of *P. vulgaris* ($p>0.05$). The production of fruit was taken about one month and a half for *P. vulgaris.*

Table 2. Mean height (HGT), total leaves (TL), length of width (LW), total flower (TFL), total fruit (TF) and relative growth rate (RGR) of *Phaseolus vulgaris* in four different flow rate of aquaponics system (mean ± standard deviation)

Flow rate (L/min)	N	HGT (cm)	TL (cm)	LW (cm)	TFL	TF	RGR (%)
0.6	60	70.33±57.11	16.80 ± 14.60	7.50 ± 4.04	0.87 ± 1.81	0.73 ± 1.58	18.39 ± 38.09
1.6	60	71.77 ± 52.29	16.73 ± 13.66	7.47 ± 4.79	0.53 ± 1.25	0.67 ± 1.50	18.36 ± 38.01
2.6	60	57.90 ± 43.33	12.13 ± 12.93	6.82 ± 4.53	0.20 ± 0.56	0.07± 0.26	18.29 ± 37.85
3.6	60	75.80 ± 52.73	14.20 ± 11.25	6.45 ± 4.29	0.07 ± 0.26	0.07± 0.26	18.41 ± 38.12

Concentration of nitrite, nitrate, ammonia and phosphate in water inlet and outlet

In water inlet, the flow rate of 1.6 L/min was higher concentration for the nitrite and nitrate concentration compared others (Table 3). There was no much different in the ammonia concentration at different flow rate of 0.6 L/min, 1.6 L/min, 2.6 L/min and 3.6 L/min. Phosphate level was the highest at flow rate of 2.6 L/min; 1.58 mg/L concentration. While for water outlet, the lower concentration of nitrite was 0.09 ± 0.07 mg/L at flow rate of 3.6 L/min and the higher concentration of nitrate was 6.54 ± 4.38 mg/L at flow rate of 2.6 L/min (Table 4). The ammonia concentration was nearly the same at all flow rates. The highest concentration of phosphate was 1.64 ± 0.76 mg/L at flow rate of 0.6 L/min. There was no significantly difference in concentration of nitrite, nitrate, ammonia and phosphate ($p>0.05$).

Table 3. Mean nitrate, nitrate, ammonia and phosphate of water inlet in aquaponics system (mean ± standard deviation)

Flow rate (L/min)	N	Nitrite	Nitrate	Ammonia	Phosphate
0.6	60	0.29 ± 0.293	5.63 ± 4.353	0.15 ± 0.180	1.62 ± 0.841
1.6	60	0.40 ± 0.383	6.38 ± 5.037	0.16 ± 0.333	1.54 ± 0.623
2.6	60	0.24 ± 0.451	5.77 ± 5.187	0.15 ± 0.173	1.58 ± 0.905
3.6	60	0.29 ± 0.360	5.99 ± 5.968	0.11 ± 0.098	1.49 ± 1.511

Table 4. Mean nitrate, nitrate, ammonia and phosphate of water outlet in aquaponics system (mean ± standard deviation)

Flow rate (L/min)	N	Nitrite	Nitrate	Ammonia	Phosphate
0.6	60	0.46 ± 0.861	5.75 ± 3.929	0.10 ± 0.120	1.64 ± 0.758
1.6	60	0.52 ± 0.544	6.24 ± 3.724	0.14 ± 0.171	1.54 ± 0.650
2.6	60	0.44 ± 0.670	6.54 ± 4.381	0.14 ± 0.154	1.62 ± 0.868
3.6	60	0.09 ± 0.067	5.89 ± 4.447	0.10 ± 0.114	1.51 ± 0.595

DISCUSSION

Growth of Macrobrachium rosenbergii and Phaseolus vulgaris

The competition occurred in aquaponics system due to the different size of prawn. The growth rate of individual *M. rosenbergii* was from variation of growth. They kept competing to get space which is called as territorial behavior and compete to get food due to that cannibalism happened (Anonim, 2009). The frequency of molting process is an indicator of the growth of *M. rosenbergii* (Nandlal and Pickering, 2005). One of the factors of mortality in the present study was observed during cannibalism activities. Molting of *M. rosenbergii* was higher percentage for the attack by the other shrimp. In addition, the shrimp are more active at night and hide the copying process usually at night. *M. rosenbergii* is easier to attack the small and large size shrimp molt when food shortages (Murtidjo, 1992). Furthermore *M. rosenbergii* was also eating the skin after change it (Nandlal and Pickering, 2005).

In the present study, there was no significantly difference in *P. vulgaris* between 0.6 L/min to 3.6 L/min of flow rate in growth rate. The growth rate is not much with range between 18.29 ± 37.85 to

18.41 ± 38.12. The best flow rate in total flower and total fruit was 0.6 L/min. The slow flow rate showed the increase of total flower and total fruit. It is due to the rate of nutrient absorption in plant (Estim and Mustaffa, 2010).

Concentration of Nitrite, Nitrate, Ammonia and Phosphate

There was no significantly difference in nitrite, nitrate, ammonia and phosphate ($p>0.05$). The results showed nitrite has significantly difference at flow rate water inlet 1.6 L/min, which the nitrite was higher compared to others and the flow rate water outlet 3.6 L/min, which is lower compared to others. The concentrations slightly increase from culture tank to plant tank. The nitrite was slightly increasing at the flow rate of 1.6 L/min. This was due to the high of over feed because, being a closed system, the high nitrogen accumulated within the system (Allan *et al*., 1995).

The nutrients were filtered by the plant for the plant tank in RAS with plant treatment (Estim and Mustafa, 2010). Besides, all the nutrients were filtered by the plant, where the mechanism in the plant converted nitrogen to be the good nutrients for supporting their growth during nutrients deficiencies in the aquaponics system (Harrison and Ward, 2001). In the plant tank, green beans are legume that derives much of their nitrogen for growth by bacteria which is living in nodules at the root system. The bacteria reduce ammonia, which is then incorporated into amino acids. These amino acids are then used by the plant or stored in the seed (Boyd and Tucker, 1998). Thus, study by Boyd and Tucker (1998) concluded that it may be that at least three factors that interact to control the occurrence of the products of nitrification in aquaculture ponds which are water temperature, ammonia availability as affected by phytoplankton metabolism, and dissolved oxygen status also affecting by the phytoplankton metabolism.

Several mechanisms were responsible for the removal of nitrate from the wastewater. Nitrate is the preferred form of inorganic nitrogen taken up by the roots of higher plants. It may also be assimilated by microorganism in the water column or by biofilms associated with the root mats of plants. Organic-bound nitrogen (proteins, amino acids and urea) was ammonified by microbial processes, which can be either aerobic or anaerobic. Nitrification or oxidation of ammonia (ammonified and excreted ammonia) to nitrate as an oxygen demanding process occurred in two steps involving microbial species, e.g., *Nitrosomonas* and *Nitrobacter*. The importance of nitrification reported primarily in production of nitrate, which then participates in denitrification reactions, the conversion of nitrate to nitrogen gas (Endut *et al.,* 2009). However, this does not happen in nitrite concentration. The plant was not fully utilized. The stocking density of *M. rosenbergii* was low due to that, the excess feed occurred because the shrimp did not eat much. Thus, it increased the nitrite concentration.

CONCLUSION

The design of aquaponics system at different flow rates was able to treat the prawn waste water and the plant can grow well. The excess feed and waste from *M. rosenbergii* gave dissolved inorganic nutrients which passed through the plant and absorbed by the plant for supporting the growth. Besides, the prawn and plant yield production of this integrated system is suitable for human consumption. The best growth performance in *P. vulgaris* was at flow rate of 0.6 L/min. However, there was no best treatment in terms of growth performance for *M.rosenbergii* between the four flow rates.

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REFERENCES

[1] Allan, G. L., Moriarty, D. J. W. & Maguire, G. B. 1995. Effects of pond preparation and feeding rate on production of *Penaeus monodon* fabricius, water quality, bacteria and benthos in model farming ponds. *Aquaculture*, **130**(4), 329-349.

[2] Anonim. 2009. *Standard Prosedur Pengolahan Pisang. Direktorat Pengolahan Hasil Pertanian* Direktorat jenderal pengolahan dan Pemasaran hasil pertanian Departemen pertanian. Jakarta.

[3] Boyd, C. E. & Tucker, C. S. 1998. *Pond Aquaculture Water Quality Management*. Kluwer Academic Publishers, Boston, doi:10.1007/978-1-4615-5407-3

[4] Dunning, R. D., Losordo, T. M. & Hobbs, A. O. 1998. *The Economics of Recirculating Tank Systems: A Spreadsheet for Individual Analysis.* SRAC Publication No. 456, 8 p.

[5] Eding, E. H. & van Weerd, J. H. 1999. Grundlagen, aufbau und management von kreislaufanlagen. *In:* Bohl, M. (ed). *Zucht und Produktion von Siibwasserfischen.* Frankfurt, Germany DLG-Verlagsgesellschaft-GmbH.

[6] Endut, A., Jusoh A., Nor'aini, A. & Nik W. 2009. Effect of flow rate on water quality parameter and plant growth of water spinach (*Ipomoea aquatica*) in an aquaponics recirculating system. *Desalination and Water Treatment*, **5**(1-3), 19-28.

[7] Estim, A. & Mustafa, S. 2010. Aquaponics application in a marine hatchery system. *Aquaponics Journal*, **57**(2), 26-34.

[8] Fivelstad, S., Bergheim, A., Holland, P. M. & Fjermedal, A. M. 2004. Water flow requirements in the intensive production of Atlantic salmon (*Salmo salar* L.) parr–smolt at two salinity levels. *Aquaculture*, **231**(1-4), 236–277.

[9] Harrison, P. & Ward, S. 2001. Elevated levels of nitrogen and phosphorus reduce fertilization success of gametes from scleractinian reef corals. *Marine Biology*, **139**(6), 1057-1068.

[10] Lupatsch, I., Santos, G. A., Schrama, J. W. & Verreth, J. A. J. 2010. Effect of stocking density and feeding level on energy expenditure and stress responsiveness in European seabass, *Dicentrarchus labrax*. *Aquaculture*, **298**(3-4), 245-250.

[11] Masabni, J. 2010. *Easy Gardening - Beans, Green Beans* (https://cdn-ext.agnet.tamu.edu/wp-content/uploads/2014/09/how-to-grow-green-beans.pdf). Accessed on 26 November 2018.

[12] Marques, H. L. de A., Lombardi, J. V. & Boock, M. V. 2000. Stocking densities for nursery phase culture of freshwater prawn, *Macrobrachium rosenbergii* in cages. *Aquaculture*, **187**(1-2):127-132.

[13] Muralisankar T., Saravana Bhavan P., Radhakrishnan S., Seenivasan C., Srinivasan V. & Santhanam, P. 2015. Effects of dietary zinc on the growth, digestive enzyme activities, muscle biochemical compositions, and antioxidant status of the giant freshwater prawn, *Macrobrachium rosenbergii*. *Aquaculture*, **448**(2015), 98–104.

[14] Murtidjo, B. A. 1992. *Pedoman Beternak Ayam Broiler*. Yogyakarta: Kanisius.

[15] Nandlal, S. & Pickering, T. 2005. *Freshwater prawn Macrobrachium rosenbergii farming in Pacific Island countries. Volume one. Hatchery operation.* Noumea, New Caledonia: Secretariat of the Pacific Community.

[16] Noble, A.C. & Summerfelt, S. T. 1996. Diseases encountered in rainbow trout cultured in recirculating systems. *Annual Review of Fish Diseases*, **6**(1996), 65-92.

[17] Nollan, B. T., Ruddy, B. C., Hitt, K. J. & Helsel, D. R. 1998. A National Look at Nitrate Contamination of Groundwater. *Water Conditioning and Purification*, **39**(12), 76-79.

[18] Schwantes, V.S., Diana, J. S. & Yi, Y. 2009. Social, economic, and production characteristics of Giant River prawn *Macrobrachium rosenbergii* culture in Thailand. *Aquaculture*, **287**, 120-127.

[19] Seenivasan, C., Bhavan, P. S., Radhakrishnan, S. & Shanthi, R. 2012. Enrichment of Artemia nauplii with Lactobacillus sporogenes for enhancing the survival, growth and levels of biochemical constituents in the post-larvae of the freshwater prawn, *Macrobrachium rosenbergii*. *Turkish Journal of Fisheries and Aquatic Sciences*, **12**(1), 23 - 31.

[20] Wetzel, R. G. & Likens, G. E. 1991. *Limnological analysis*. Springer Science & Business Media.

[21] Wurts, W. A. 2007. Low Input Shrimp Farming in Kentucky, *Macrobrachium rosenbergii*. *World Aquaculture Journal*, **38**(4), 44-49.