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Biofiltration potential of macroalgae for ammonium removal in outdoor tank shrimp wastewater recirculation system

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ABSTRACT

Shrimp wastewater usually contain high amount of nitrogen that causes eutrophication, a phenomenon of algae bloom. It is harmful for shrimp growth and needs to be addressed if the objective is to improve water quality and make it suitable for shrimp growth. This paper addresses ammonium removal in tiger shrimp wastewater by using two macroalgae species: *Ulva lactuca* (*U. lactuca*) and *Gracilaria edulis* (*G. edulis*). To achieve this, an outdoor macroalgae with shrimp integrated system was developed. This integration was completed in two shrimp growth periods; 60 days and 120 days. The mean growth rates of *G. edulis* and *U. lactuca* were found as 4.0% day^{-1} and 3.6% day^{-1}, respectively. The mean ammonium removal rates for *G. edulis* and *U. lactuca* were found to be 70% and 45%, respectively. Thus, both species are suitable as biofilter and their valuable biomass has a great commercial value. The potential applications of the findings include improvement of shrimp wastewater quality which will ultimately enhance shrimp and macroalgae productivity to meet growing demands of the market.

1. Introduction

Intensive shrimp production expands rapidly in most of the south-east Asia countries [1,2]. Malaysia is one of the top ten shrimp producers in the world with production capacity of 2.8% in total world production of shrimp. In 2003, 70% of total aquaculture production in the country was generated by brackish water aquaculture species [3] where shrimp production alone stood at 30, 000 tonnes [4] and in 2012 this figure has increased to 65, 000 tonnes for meeting shrimp demand for local consumption and export targets [5,6]. The trend of total aquaculture production (including shrimp) in Malaysia is increasing (Fig. 1).

In shrimp culture ponds, nutrients such as phosphorus and nitrogen progressively accelerate with the culture period due to accumulation of excess feed materials and excretory products. Thakur and Lin [7] revealed that for nutrient budget in a closed shrimp culture system, shrimp could only assimilate 23–31% nitrogen and 10–13% phosphorus of the total inputs. Consequently, shrimp wastewater has high load of excess nutrient and also organic matter in dissolved forms

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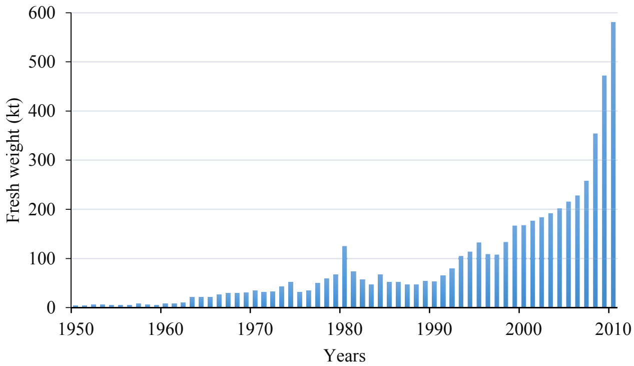

Fig. 1 – Total aquaculture production in Malaysia [3].

that deteriorates water quality for shrimp culture [8,9]. It also potentially causes environmental impact such as eutrophication [10,11] and cultivated shrimps are usually susceptible to diseases [12–14]. Integration of macroalgae cultivation in aquaculture wastewater is considered an ecologically sound aquaculture practice since macroalgae are known as potential nutrient strippers to assimilate the excess nutrient from wastewater [15,16]. Macroalgae biomass also contributes to the economic development with valuable by-products such as phycocolloid agar [17,18], human food [19,20], animal feed [21] and biofuel [22,23]. The macroalgae genera most common in mariculture biofiltration are *Ulva* and *Gracilaria* which have been utilized in a few studies integrated with aquaculture animals in open sea, in ponds and as well as in tank culture systems [24–29].

Fei [24] found that the *Gracilaria* can solve the eutrophication problem with 6.6% of growth rate. Troell et al. [25], stated that a considerable reduction in dissolved ammonium and phosphate can be achieved in an integrated culture of the *Gracilaria chilensis*-salmon, which ultimately reduce the risk of eutrophication. In addition, Buschmann et al. [26], found that in an integrated salmon-*G. Chilensis* tank cultivation system, the macroalgae was capable of removing 95% of ammonium and 32% of orthophosphate. Tank cultivation of *Gracilaria caudata* and the filter feeder *Artemia franciscana* had biofiltration capacity for ammonium of 29.4% [27]. The *Ulva rotundata*, a type of *Ulva* genera, removes 54% of the total dissolved inorganic nitrogen in 600 L effluents of gilthead seabream in 70 days [28]. Msuya et al. [29] found that *Ulva reticulata* can remove total ammonia nitrogen (TAN) of 6.5 g m^{-2} day^{-1} with 65% removal efficiency, which is a significant figure.

The hypothesis of the study was that the *Ulva lactuca* and *Gracilaria edulis* can remove ammonium from shrimp wastewater effectively and can result in higher biomass production of the shrimp and macrolagae. Thus, in the present study, *G. edulis* and *U. lactuca* were selected as biofilters and the ammonium removal efficiencies were determined. Both experiments were aimed to observe the potential of the selected macroalgae as biofiltration agent. The growth rate was also monitored since its biomass has great value to be commercialized into other useful by-products (e.g. fertilizers, animal feed and biofuel).

2. Materials and methods

Two types of experiments were conducted to assess the biofiltration capacity for removing ammonium by macroalgae. The first experiment was a laboratory scale where only shrimp wastewater with macroalgae was used. In the second experiment an outdoor experimental setup was designed and built to monitor the growth of both shrimp and macroalgae, as well as the ammonium removal efficiency by the macroalgae in shrimp wastewater.

2.1. Experimental design for outdoor shrimp recirculation system

G. edulis was collected from canals at Brackishwater Culture Research Centre, Gelang Patah, Johor Bahru, Malaysia and *U. lactuca* collected during low tide at Danga Estuary, Johor Bahru, Malaysia. Healthy thalli of the macroalgae were collected and transported to the laboratory in a polystyrene box filled with water samples from the respective site. In the laboratory the macroalgae were washed under running water and cleaned of epiphytes. Healthy thalli of macroalgae were separated to reduce the risk of contamination during the experiments. Snapshots of the outdoor experimental setup are displayed in Fig. 2.

Three treatments were set up using glass aquarium (45 cm × 32 cm × 32 cm), which were stocked with three prawns. The initial mean weight was 2.2 ± 0.1 g in each aquarium, each one containing 0.04 m^3 brackish water (22–28 PSU). Salinity is calculated as a conductivity ratio of the water sample to a standard KCl solution on Practical Salinity Scale (PSS) and this is referred to PSU (Practical Salinity Unit) in this paper. Forty-five day-old post larvae of *Panaeus monodon* (PL_{45}) were purchased from a hatchery with an average weight of about 2.0 g for acclimatization in the aquarium with light intensity of 80 μmol m^{-2} s^{-1}, before the outdoor experiment. Two experiments in different combination of shrimp growout period and the initial weight of shrimp were conducted. The first combination (Experiment 1) was of 60 days of growout period and initial weight of shrimp of 2.0 g. The second combination (Experiment 2) was of 120 days of growout period and initial weight of shrimp equal to 10.0 g.

Macroalgae were placed in an inert plastic aquarium with volume of 0.03 m^3 above the shrimp aquaria to allow continuous vertical flow of shrimp wastewater in this recirculation system. The experiment consisted of three treatments in triplicate: 1) stocked with *G. edulis*; 2) stocked with *U. lactuca*; and 3) control, without any macroalgae.

The stocking density (fresh weight) of *G. edulis* and *U. lactuca* was 2.0 kg m^{-3}. The treatment was observed for 2 weeks and the nutrient uptake rate by macroalgae was measured. Shrimp were fed 6% of its body weight per day with commercial shrimp feed (dry weight) composed of 40% crude protein, 21.2% carbohydrate, 6% crude fat, 6% crude fiber, 11% moisture, 15% ash and 0.8% phosphorus. During the experiment, evaporation losses of water were compensated by the addition of deionized water to maintain the salinity level. The experiments were conducted outdoor so that light and temperature conditions would be similar to that in the field and

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