Aquacultural Engineering 72–73 (2016) 70–76

Contents lists available at ScienceDirect

Aquacultural Engineering

journal homepage: www.elsevier.com/locate/aqua-online

Effect of microalgae with semicontinuous harvesting on water quality and zootechnical performance of white shrimp reared in the zero water exchange system

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ARTICLE INFO

Article history:
Received 16 November 2015
Received in revised form 22 April 2016
Accepted 22 April 2016
Available online 27 April 2016

Keywords:
Litopenaeus vannamei
Marine feed microalgae
Nutrient removal
Vibrio counts
Shrimp growth performance

ABSTRACT

Microalgae cannot only provide nutrients for aquatic animals but also be useful in wastewater treatment in aquaculture. Up to now, little is known on the potential biological and economic benefits of microalgae application in intensive culture mode of shrimp. To evaluate the effects of 3 marine feed microalgae in *Litopenaeus vannamei* culture, a 84-day experiment was performed in this study, and water quality, *Vibrio* counts in water and shrimp, and shrimp growth performance in cement tanks seeded with *Platymonas helgolandica* (T1), *Chlorella vulgaris* (T2) and *Chaetoceros mulleri* (T3) at 0.02 mg Chl-a l^{-1}, respectively, were compared with that in tanks without microalgae (Control). At 06:00 DO in all treatment tanks was significantly higher than that in control tanks ($p < 0.05$). Whereas DO at 18:00 in treatment tanks was significantly higher than that in control tanks ($p < 0.05$). The TAN concentration was significantly higher ($p < 0.05$) in the control than that in the treatments. At day 42, day 56, day 70 and day 84, the NO_2-N concentration mean values were significantly higher ($p < 0.05$) in the control, followed by T1, T2 and T3. At the end of the experiment, Water pH in the control (7.4) was significantly lower than that in the treatments (8.44, 8.53 and 8.45 respectively) ($p < 0.05$). Significantly lower *Vibrio* counts were generally observed in the treatment tanks ($p < 0.05$), and the counts of presumptive *Vibrio* in shrimp stomach and intestines were significantly higher in the control compared to that in the treatments ($p < 0.05$). The highest final average weight (18.04 g) was observed in T1, which was significantly higher than that in the control ($p < 0.05$). T1 had the highest shrimp yield (4.41 kg m^{-3}) at harvest, and the difference was significant ($p < 0.05$). T1 tended to have the highest average weight gain (1.5 g $week^{-1}$) and lowest feed conversion ratio. The shrimp survival was significantly higher in T1, T2 and T3 (81.50%, 79.44% and 77.69%, respectively) than in the control ($p < 0.05$). The present study showed that all three microalgae in no water exchange system had positive effects on water quality and shrimp productive performance. Therefore, all three species are suitable as biofilter in situ in shrimp culture system, suggesting that microalgae have a promising potential for shrimp culture with no water exchange. Further research is needed to demonstrate the harvest and the potential applications of the microalgae.

1. Introduction

Shrimp aquaculture industry is a high-value activity and accounts for 15% of the total seafood production worldwide (FAO, 2013). However, in intensive shrimp culture system only 23–31% of nitrogen from applied feed could be transformed into shrimp biomass (Thakur and Lin, 2003) and much of the nutrient inputs retained and degraded in the system, which will in turn to be a potential cause for deterioration of water quality (Tran et al., 2013). The degenerated environmental conditions have been considered result in the outbreak of various infectious diseases such as the white spot syndrome (Sánchez-Martínez et al., 2007) and the acute hepatopancreatic necrosis disease (AHPND) which is thought to be caused by *Vibrio* in the intensive shrimp culture (Jyoti et al., 2014). *Vibrio* is autochthonous in the shrimp cultured environment at low levels, and Vibriosis outbreak when deteriorated environment factors lead to the rapid multiplication of these bacteria (Johnson et al., 2010). Therefore, various water quality control techniques for regu-

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http://dx.doi.org/10.1016/j.aquaeng.2016.04.006
0144-8609/

lation of environment have been developed in shrimp aquaculture, especially those with a closed culture system, to guarantee the success of production.

Reduced or no water exchange in shrimp culture is an effective way to minimize the introduction and spread of infectious pathogens (Burford et al., 2003). High shrimp yields have been reported at high density with minimal water exchange (Samocha et al., 2015; Burford et al., 2003; Cohen et al., 2005; Cruz-Suárez et al., 2010; Wasielesky et al., 2006). An aquaculture technology which is becoming relevant specifically to the shrimp industries is biofloc technology (BFT) (Rodrigo et al., 2013). In a biofloc system, when there are enough degradable organic carbon sources, some probiotics perform nitrification during which ammonia is oxidized to form less toxic nitrite, which is then oxidized to form nitrate (Rodrigo et al., 2013). Compare to either of the preceding compounds, nitrate is much less toxic; however, high concentrations of nitrate can reduce shrimp growth and survival (Kuhn et al., 2010). Moreover, nitrate removal can be complicated (Van Rijn, 1996). Another promising method to control water quality to reduce water exchange is the use of microalgae. In the system, microalgae provide oxygen during photosynthesis that is used by cultured shrimp and bacteria metabolisms, whereas shrimp and bacteria release CO_2 needed for microalgae growth and recycle the nutrients responsible for eutrophication into potentially valuable biomass (Cheng et al., 2013), and microalgae present in wastewater system can be used in nutrient sequestration and removal of other contaminants from wastewaters (Ruiz-Marín et al., 2010; Wang et al., 2010). By far, microalgae are widely used in wastewater treatment. Rawat et al. (2010) used microalgae to treat aquaculture wastewater, and the efficiency of nutrient removal was satisfactory. Benjamas et al. (2003) used *Spirulina platensis* in shrimp culture tanks to control water quality, and he found *S. platensis* was effective to reduce nitrogenous compounds regardless of shrimp density. However, most research in such reports is about the application of algal monoculture in high-rate algal tank system (HRAP) or stabilization ponds (Metaxa et al., 2006; Phang et al., 2000). Whereas these technologies need big spatial footprint so they are used mainly in small communities.

Microalgae are rich sources of nutrition for fish, such as vitamins, essential amino acids, lipids, minerals and essential fatty acids (Ju et al., 2012; Takeuchi et al., 2002). In feeding trials with aquatic animals, lots types of microalgae have been observed to promote growth, feed utilization and survival (Charles et al., 2012; Medina-Félix et al., 2014). So far, little study focus on integrated systems cultured both microalgae and shrimp and the effect of microalgae on shrimp growth performance and water quality. In the present study, 3 marine feed microalgae, *Platymonas helgolandica*, *Chlorella vulgaris* and *Chaetoceros mulleri*, were co-cultured with white shrimp (*Litopenaeus vannamei*) in no water exchange system, and their effects on water quality and the productive performance of shrimp were evaluated.

2. Materials and methods

2.1. Experimental setting

This project was conducted at Qingdao Baorong Aquatic Products Co., Ltd., located in Shandong Province in eastern China. Twenty-four indoor cement tanks (r = 0.97 m, h = 1.0 m) filled with 2.67 m^3 seawater were used as experimental culture units and the salinity was between 20.66 and 20.90‰. To maintain the microalgae in suspension, water surface aeration and bottom micropore aeration (Fig. 1) were provided and dissolved oxygen remained within the recommended range for growth of shrimp. The tanks were kept in a plastic house and received only artificial lighting. The light regime was set at 12 h light/12 h dark and the light intensity was about 9000 lx (Vinatea et al., 2010).

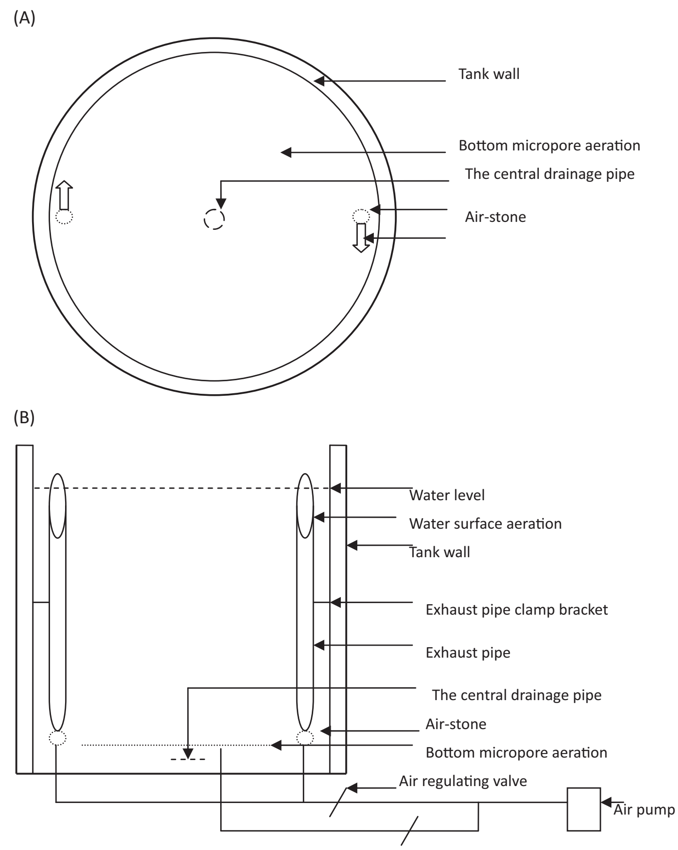

Fig. 1. (A) Plain view of the tank showing the aeration, and (B) a cross-sectional view of the tank showing the aeration.

2.2. Shrimp source, nursery and feeds

Specific pathogen-free post-larvae (PLs 5) of *L. vannamei* obtained from a commercial breeding station (Haiyi, Hainan) were cultured at a stocking density of 8000 PLs m^{-2} in a nursery tank until the animals reached a mean weight of 0.05 g. Thereafter, shrimp were randomly distributed in the tanks at a density of 800 shrimp $tank^{-1}$ (300 shrimp m^{-3}) and fed with a commercial feeds containing 42% of crude protein (Chia-Tai, Qingdao) five times daily. The feeding level was determined at 7% on wet body weight weekly and the daily feed amount was adjusted to the biomass in the tanks.

2.3. Algal strain and pre-culture conditions

The microalgae were provided by the Laboratory of Genetic Resources and Breeding, Yellow Sea Fisheries Research Institute, Chinese Academy of Fishery Sciences, and maintained in the f/2 culture medium (Guillard and Ryther, 1962): $NaNO_3$ 500 mg, $NaH_2PO_4{\cdot}2H_2O$ 8.8 mg, 1 mL F-Si trace metal solution, 1000 mL distilled water. The culture conditions were maintained at 28 °C under the continuous illumination of 175 μmol m^2 s^{-1}. Working algal culture in exponential growth phase was prepared by transferring stock algal culture into 3-L Erlenmeyer flasks with air injection.

2.4. Experimental design

Microalgae densities were measured using cells counts and chlorophyll-a (Chl-a) concentration. Cells were counted using a haemacytometer with light microscope, while at the same time