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Reduction of Ammonia and Nitrite in Shrimp Larviculture in a Recirculation System

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Abstract

Shrimp *Penaeus monodon* postlarvae (PL12) were cultured in a static and a recirculation system with and without adding nitrifying bacteria, respectively. Ammonia, nitrite, nitrate, sulfide, chemical oxygen demand (COD), and growth and survival of the shrimp were monitored. The concentrations of total ammonia-N, nitrite-N, nitrate-N, sulfide and COD in the recirculation systems were much lower than those in the static systems. The appropriate use of nitrifying bacteria could help reduce ammonia and nitrite concentration in both static and recirculation systems. The postlarvae reared in the recirculation systems had better growth and survival than those in the static system. A new system employing recirculated water for commercial hatchery and growout use is suggested.

Introduction

Ammonia is the main end-product of protein catabolism and comprises 40-90% of nitrogenous excretion in crustaceans (Parry 1960; Hartenstein 1970). Ammonia is oxidized to nitrite and nitrate by nitrifying bacteria (Sharma and Ahlert 1977). The accumulation of ammonia and its intermediate product nitrite during nitrification in recirculation systems is a potential threat to cultured fish and crustaceans (Colt and Armstrong 1981).

The culture of *Penaeus monodon* in Taiwan has increased dramatically in recent years with an annual production of 30,000 tonnes in 1988 (Chen et al. 1989). Efforts have been made to increase production in a small impounding area due to the limited availability of arable lands

and international market demand. Shrimp culture methods using stocking densities of 100,000 PL·m^{-2} in the hatchery and more than 100 PL·m^{-2} in growout ponds have been developed (Chen et al. 1986, 1989). Ammonia and nitrite are the most common toxicants which can increase to 0.81 mg·l^{-1} total ammonia-N, 0.12 m·l^{-1} nitrite-N in the hatcheries and 6.497 mg·l^{-1} total ammonia-N, 4.611 mg·l^{-1} nitrite-N in the growout ponds even with frequent water exchange (Chen et al. 1986, 1989).

Ammonia and nitrite in the static culture system also reduce the growth of penaeid shrimps (Wickins 1976; Jayasankar and Muthu 1983a, 1983b; Chin and Chen 1987). The "safe level" of total ammonia-N and nitrite-N are 1.15 mg·l^{-1} and 1.36 mg·l^{-1}, respectively for larval rearing of *P. monodon* (Chin and Chen 1987; Chen and Chin 1988). Mevel and Chamroux (1981) reported that *P. japonicus* reared in a marine closed system was sensitive to a concentration of nitrite-N higher than 0.10 mg·l^{-1}.

Water management has been recognized as the primary factor for better shrimp farming. During the culture period, experienced farmers add groundwater to prevent increase in salinity and water deterioration. However the unlimited pumping of underground water has also resulted in geological subsidence (Chen et al. 1989). Shrimp culture in such intensive systems requires high energy inputs and water consumption. It is estimated that 10 tonnes of seawater are needed to produce 1,000 juveniles of *P. monodon*. Therefore, development of water reuse and recirculation systems to prevent increased ammonia and nitrite levels are research priorities.

Ion exchange and microbiological filters are the two main methods for removing ammonia (Nemoto 1957; Johnson and Sieburth 1974; Turner and Bower 1982). However, removal of ammonia by ion exchange is limited to freshwater because the capacity of ion exchangers is reduced considerably by competing ions in seawater. Nitrification through microbiological filtration is the most practical method for removing ammonia from seawater and is commonly employed in closed-system culture (Spotte 1979).

Nitrification is the conversion of ammonia to nitrite and nitrate by aerobic nitrifiers which attach to filter substrates. Various designs of filter systems have been used to purify culture systems (Bower and Turner 1981; Bower et al. 1981; Paller and Lewis 1982; Kruner and Rosenthal 1983). However, only one paper has documented shrimp culture (on-growing) in a recirculation system (Wickins 1985). This paper sought to determine differences of water quality in both static and recirculation systems used for the culture of *P. monodon* postlarvae.

Materials and Methods

Four culture systems were used in this study: recirculation system (RS), recirculation system with added nitrifiers (RSN), static system (SS), and static system with added nitrifiers (SSN) (Fig. 1). Each group had two replicates. In the recirculation system, the upper two tanks held shrimp; the lower part consisted of three compartments: head chamber, biological filter and reservoir (Fig. 1). The biological filter consisted of 9-cm pebbles, overlaid by 9-cm charcoal and coral sand (Table 1). Each layer was separated by a sheet of nylon window screen. The head chamber was divided into five small compartments with four ladder-shaped polyvinylchloride panels to precipitate particles. A U-shaped pipe was buried in the biological filter through which water was recycled and discharged into the reservoir.

For the RSN, 1 l and 500 ml of commercial available nitrifier (Fritz-Zyme No. 9, Fritz Company, Texas, USA) were added in the filter bed one day before the experiment and one week later, respectively. For the SSN treatment, 100 ml of the same solution was added every week after siphoning off feces and replacing one third volume of the water. For the RS treatment, no chemical was added in the recirculation system. For the SS treatment, feces were removed and one third volume of water replaced only every 2 weeks to prevent water deterioration.

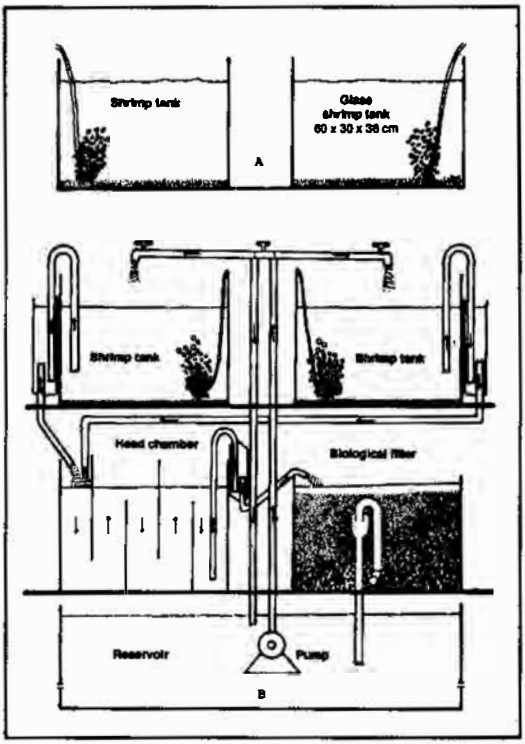

Fig. 1. Diagram of a static sytem (A) and a recirculation system (B) showing two shrimp tanks, a head chamber divided with four panels, a biological filter and a reservoir.

Seawater pumped from the Keelung coast was passed through gravel and sand filters and aerated three days before use. Fresh water was added only to replace losses due to evaporation during the experiments.

Table 1. Dimensions of experimental units in the recirculation systems.

Description	Length (cm)	Width (cm)	Depth (cm)	Water depth (cm)	Area (m^2)	Volume (m^3)
Tank*	60	30	36	30	0.18	0.050
Head chamber	60	30	36	27	0.18	0.050
Biological filter	60	45	30	29	0.27	0.0783
Coral sand	60	45	9	29	0.27	0.0243
Charcoal	60	45	9	29	0.27	0.0243
Pebble	60	45	9	29	0.27	0.0243
Reservoir	50	38	28	39.5	0.19	0.075

*Water was recirculated at a constant rate of 2 $l \cdot min^{-1}$ using a submerged 0.25 hp pump in the reservoir.

P. monodon postlarvae obtained from a commercial hatchery at Tungkang were shipped to the laboratory and acclimatized for six days in the stocking tanks before use. Sixty postlarvae (PL12) were randomly sampled from the stocking tanks and released in each experimental holding tank and reared for 2 months. During the first 2 weeks, the animals were fed newly hatched *Artemia* nauplii and later fed with commercially formulated larval feed (President Company, Taipei, Taiwan) four times a day.

During the experiment, water temperature of 29-30°C, pH value 8.1-8.3, salinity 28-32 ppt and DO 5.6-6.2 $mg \cdot l^{-1}$ were maintained in all systems and the parameters of ammonia, nitrite, nitrate, sulfide and chemical oxygen demand (COD) were determined every 3-9 days following the methods described by Strickland and Parsons (1976). Mortality and growth were recorded every 20 days. Since some chemotherapeutic agents inhibit nitrification, no drug or chemical was applied to any of the systems (Bower and Turner 1982).

Results and Discussion

Figs. 2-6 show the concentrations of total ammonia-N, NO_2-N and NO_3-N, sulfide and COD over time. The results indicate that these five factors in the SS and SSN systems were significantly higher than in the RS and RSN treatments. Total ammonia-N and nitrite-N levels in both with added nitrifiers were lower than those without. Nitrate-N in the RSN was higher than in the RS treatment. The results suggest that adding nitrifiers could help reduce ammonia and nitrite and would increase the nitrate in a marine recirculation system.

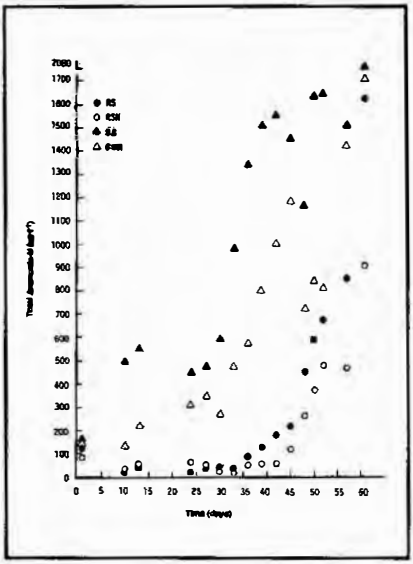

Fig. 2. Fluctuations of total ammonia-N concentration ($\mu g \cdot l^{-1}$) in the tanks of different culture systems; 60 *Penaeus monodon* postlarvae (PL12) wre reared in each tank for 60 days.

RS : Recirculation system
RSN : Recirculation system with added nitrifier
SS : Static system
SSN : Static system with added nitrifier

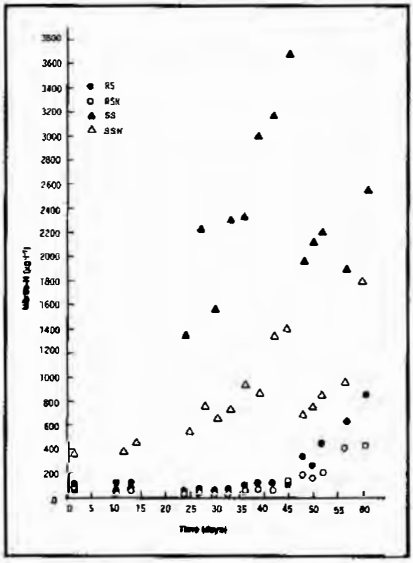

Fig. 3. Fluctuations of nitrite-N concentration ($\mu g \cdot l^{-1}$) at the tanks of different culture system; 60 *Penaeus monodon* postlarvae (PL12) were reared in each tank for 60 days.

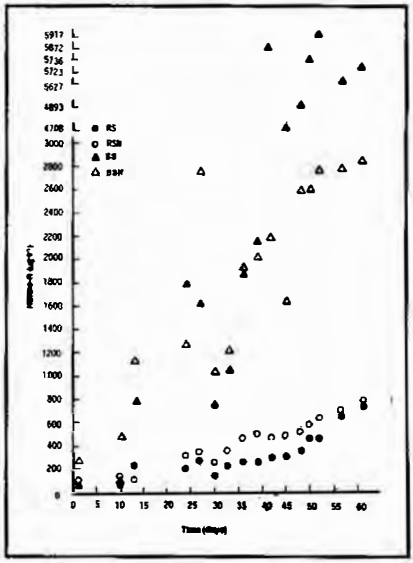

Fig. 4. Fluctuations of nitrate-N concentration ($\mu g \cdot l^{-1}$) at the tanks of different culture systems; 60 *Penaeus monodon* postlarvae (PL12) were reared in each tank for 60 days.

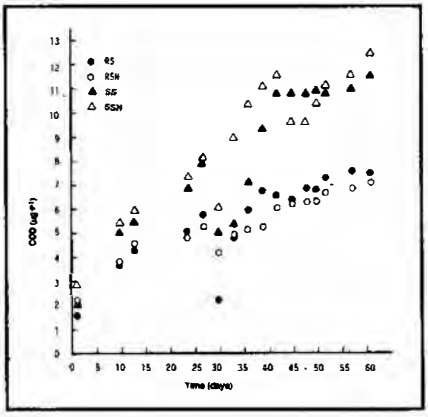

Fig. 5. Fluctuations of sulfide concentration ($\mu g \cdot l^{-1}$) at the tanks of different culture systems; 60 *Penaeus monodon* postlarvae (PL12) were reared in each tank for 60 days.

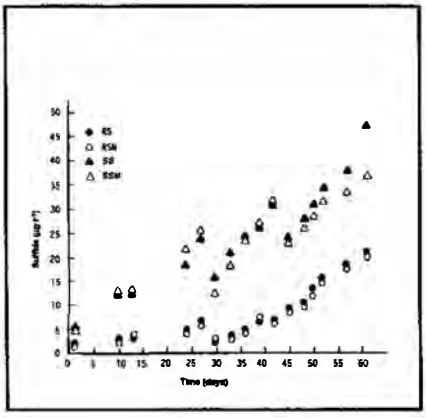

Fig. 6. Fluctuations of chemical oxygen demand (COD) concentration ($\mu g \cdot l^{-1}$) at the tanks of different culture systems; 60 *Penaeus monodon* postlarvae (PL12) were reared in each tank for 60 days.

Figs. 7-8 show that the shrimp in the recirculation systems had significantly higher survival and better growth ($P < 0.01$) than those in the static systems. In both systems, more shrimp survived when nitrifiers were added ($P < 0.05$).

Based on the present results and previous studies (Bower and Turner 1981; Manthe et al. 1984; Chen et al. 1986), a biological filter bed suspended over or adjacent to the culture ponds is recommended (Fig. 9). A submerged pump installed inside the filter net moves the pond water to a biological filter divided into three compartments filled with

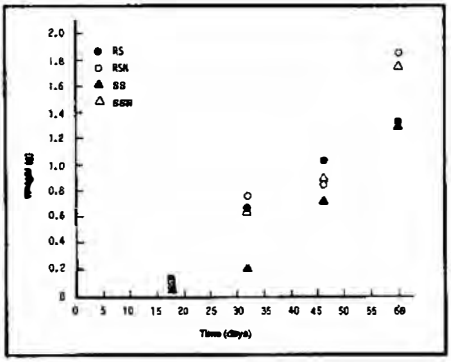

Fig. 7. Fluctuations of the body weight (g) of the shrimps at the tanks of different culture systems; 60 *Penaeus monodon* postlarvae (PL12) were reared in each tank for 60 days.

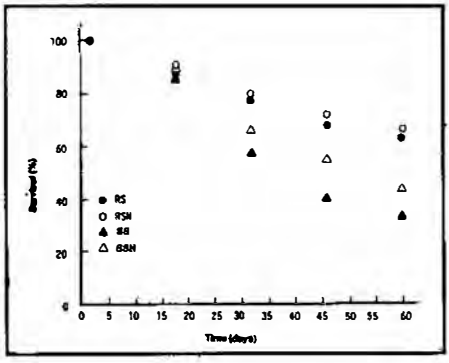

Fig. 8. Fluctuation in shrimp survival (%) in different culture systems; 60 *Penaeus monodon* postlarvae (PL12) were reared in each tank for 60 days.

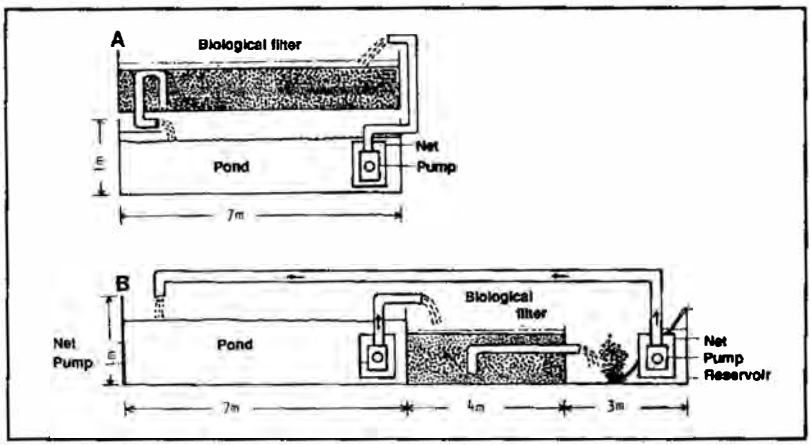

Fig. 9. Diagram of the recirculation system suggested for larval culture in the shrimp hatchery. A: top system in which biological filter is located above the shrimp pond; B: biological filter located adjacent to the shrimp pond.

pebbles, coral sand and charcoal. Ammonia excreted in the shrimp pond will be rapidly oxidized to nitrate by nitrification when water is passed through the biological filter. This system would not interfere with the feeding and harvest processes. The nitrifying bacteria develop naturally or can be seeded and remain as long as the water level is maintained over the filter bed. This system would save time in the troublesome work of water exchange, enhance the elimination of ammonia and nitrite, and increase the survival of postlarvae.

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References

Bower, C.E. and D.T. Turner. 1981. Accelerated nitrification in new seawater culture systems: effectiveness of commercial additives and seed media from established systems. Aquaculture 24: 1-9.

Bower, C.E., D.T. Turner and S. Spotte. 1981. pH maintenance in closed seawater culture systems: limitations of calcareous filtrants. Aquaculture 23: 211-217.

Bower, C.E. and D.T. Turner. 1982. Effects of seven chemotherapeutic agents on nitrification in closed seawater culture systems. Aquaculture 29: 331-345.

Chen, J.C. and T.S. Chin. 1988. Acute toxicity of nitrite to tiger prawn *Penaeus monodon* larvae. Aquaculture 69: 253-262.

Chen, J.C., T.S. Chin and C.K. Lee. 1986. Effects of ammonia and nitrite on larval development of the shrimp *(Penaeus monodon)*, p. 657-662. *In* J.L. Maclean, L.B. Dizon and L.V. Hosillos (eds.) The First Asian Fisheries Forum. Asian Fisheries Society, Manila, Philippines.

Chen, J.C., P.C. Liu, Y.T. Lin and C.K. Lee. 1989. Highly-intensive culture study of tiger *Penaeus monodon* in Taiwan, p. 377-382. *In* N. De Pauw, E. Jaspers, H. Ackefors and N. Wilkins (eds.) Aquaculture - a biotechnology in progress. European Aquaculture Society, Bredene, Belgium.

Chin, T.S. and J.C. Chen. 1987. Acute toxicity of ammonia to larvae of the tiger prawn *Penaeus monodon*. Aquaculture 66: 247-253.

Colt, J.E. and D.A. Armstrong. 1981. Nitrogen toxicity to crustaceans, fish and molluscs, p. 34-47. *In* L.J. Allen and E.C. Kinney (eds.) Proceedings of the Bio-engineering Symposium for Fish Culture. Fish Culture Section, American Fisheries Society, Northeast Society of Conservation Engineers. Bethesda, Maryland.

Hartenstein, R. 1970. Nitrogen metabolism in non-insect arthropods, p. 298-372. *In* J.W. Cambell (ed.) Comparative biochemistry of nitrogen metabolism. Vol. 1. The invertebrates. Academic Press, London/New York.

Jayasankar, P. and M.S. Muthu. 1983a. Toxicity of ammonia to the larvae of *Penaeus indicus* H. Milne Edwards. Indian J. Fish. 30(1): 1-12.

Jayasankar, P. and M.S. Muthu. 1983b. Toxicity of nitrite to the larvae of *Penaeus indicus* H. Milne Edwards. Indian J. Fish. 30: 231-240.

Johnson, P.W. and J.M. Sieburth. 1974. Ammonia removal by selective ion exchange, a backup system for microbiological filters in closed-system aquaculture. Aquaculture 4: 61-68.

Kruner, G. and H. Rosenthal. 1983. Efficiency of nitrification in trickling filters using different substrates. Aquacult. Eng. 2: 49-67.

Manthe, D.P., R.F. Malone and S. Kumar. 1984. Limiting factors associated with nitrification in closed blue crab shedding systems. Aquacult. Eng. 3: 119-140.

Mevel, G. and S. Chamroux. 1981. A study of nitrification in the presence of prawns *(P. japonicus)* in marine closed system. Aquaculture 23: 29-43.

Nemoto, C.M. 1957. Experiments with methods for air transport of live fish. Prog. Fish-Cult. 19: 147-157.

Palier, M.H. and W.M. Lewis. 1982. Reciprocating biofilter for water reuse in aquaculture. Aquacult. Eng. 1: 139-151.

Parry, G. 1960. Excretion, p. 341-366. *In* T.H. Waterman (ed.) The physiology of crustacea. Vol. I. Academic Press, New York.

Sharma, B. and R.C. Ahlert. 1977. Nitrification and nitrogen removal. Water Res. 11: 879-925.

Spotte, S. 1979. Seawater aquariums: the captive environment. John Wiley, New York.

Strickland, J.D.H. and T.R. Parsons. 1976. A practical handbook of seawater analysis. Fish. Res. Board Can. Ottawa, Canada.

Turner, D.T. and C.E. Bower. 1982. Removal of ammonia by bacteriological nitrification during the simulated transport of marine fishes. Aquaculture 29: 347-357.

Wickins, J.F. 1976. The tolerance of warm-water prawns to recirculated water. Aquaculture 9: 19-37.

Wickins, J.F. 1985. Ammonia production and oxidation during the culture of marine prawns and lobsters in laboratory recirculation system. Aquacult. Eng. 4: 155-174.

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