Development of Sustainable Shrimp and Crab Culture Technology Utilizing Effective Microorganisms

Zhou Xin[1] and Bu Jutsu[2]

[1]Freshwater Fisheries Research Center of Chinese Academy of Fishery Sciences, Jiangsu, China
[2]Jiangsu Ouna Biological Technology Co., Ltd., Nanjing, China

***Abstract*—Aquaculture production in China grew dramatically from less than 1.3 million tons in 1970 to approximately 47.8 million tons in 2010, accounting for 61.2% of the total global aquaculture production by weight. By value, aquaculture production within China has increased over 21-fold, from US$ 2.94 billion in 1984 to US$ 61.7 billion in 2010. Today, China as the largest aquaculture producer and exporter produced 61.7 % of the global aquaculture production.**

Aquaculture practice has been contributed significantly to development in rural and urban areas by improving family income, providing employment opportunities and reducing problems of food supply and security. However, excess use of antibiotics as disease control agents and growth promoter in aquaculture recently has raised significant concerns recently because of the potential threats to human health. Also many studies reported the impacts of aquaculture on the environmental pollutions such as water contamination with nitrogen, phosphorus and other pollutants.

In order to develop sustainable aquaculture technology, a microbial technology, effective microorganisms (EM) technology, has been introduced and adjusted for shrimp and crab culture in China. These efforts resulted in quality improvement, marked increase in productivity and economic profit with much reduced use of antibiotics. Through technological innovation and scientific management, EM has become an effective means for aquaculture in terms of improvement of environment, promotion of ecological and overall level of aquaculture industry and the safety of aquatic products. These results may contribute enormously to sustainable, healthy and steady development of aquaculture industry in China.

***Keywords* — Aquaculture, antibiotics, China, contamination, crab, effective microorganisms, shrimp, sustainable**

I. INTRODUCTION

China is the largest aquaculture producer and exporter and produced 61.7 % of the global aquaculture production [1]. The total area devoted to aquaculture production increased from 2.86 million hectares in 1979 to 5.63 million hectares in 2008 [2]. China produced over 17 million tons of carp and around 1.2 million tons of tilapia, accounting for about 90 % of the global carp production and about 36 % of the global tilapia production [3]. The farming of Chinese mitten crab (*Eriocheir sinensis*) also expanded very rapidly since the 1990s in China. It is now an important component of the freshwater aquaculture industry in China. Consumers in China and some other Asian countries favor it. Increasing market demand played an important role in the rapid expansion of mitten crabs culture since the late 1980s.

However, rapid expansion of aquaculture brought about some serious problems in the productivity and to the surrounding environment as well. Effluents from aquaculture ponds typically abound in suspended organic substances containing carbon, nitrogen and phosphorus, originating primarily from leftover feed and fecal material. For example, the shrimp production discharged as much as 3.73 million tons of the shrimp sewage, including 5,589 tons of COD, 658 tons of nitrogen and 307 tons of phosphorus in Fujian province in 1998 [4]. In 2002, shrimp production (79,000 tons) in Bohai Sea and Yellow Sea areas indicated that more than 120,000 tons of leftover feed was discharged into the sea [5].

Furthermore, it was estimated that bacterial infections cause 15–20 % loss of annual total production of aquaculture in China [6]. In order to reduce the loss, antimicrobials, including various antibiotics, are heavily used. Overuse of the antibiotics results extensive amount of antibiotics in the aquaculture products and in the surrounding aquatic environment. This situation definitely leads not only to the decrease in the immunity of the cultured animals, but also to the consumers' microbiota, thus rendering them more vulnerable to infectious diseases [7]. Possible alternatives to antibiotics should be promoted and used.

The technology of effective microorganisms (EM) was originally developed in Japan in 1980s [8]. EM consists of mixed cultures of beneficial and non-pathogenic microorganisms such as lactic acid bacteria, photosynthetic bacteria and yeast. EM does not contain any genetically engineered organisms. At its initial stage, EM technology was utilized in agriculture as microbial inoculants to increase the microbial diversity and to improve soil [9]. Its application gradually expanded to other fields because of safety, low cost and easy handling in addition to its effect. EM is now being used in agriculture, livestock farming, aquaculture, wastewater treatment, environmental conservation, healthcare and other fields [10]. EM has been used in aquaculture, especially in shrimp breeding, in such countries as Thailand, Vietnam and Ecuador with a number of positive results. They are, (1) improved productivity and quality of the products, (2) improved quality of water as regards dissolved oxygen and pH, (3) reduced production of harmful gases such as ammonia, hydrogen sulfide and methane, (4) reduced quantity of sludge, (5) reduction of the pathogenic microorganisms in water, (6) lower costs with reduced frequency of water exchange, and (7) reduced use of antibiotics [11].

EM technology also has been applied in aquaculture in China. Chinese mitten crab, also known as the Shanghai hairy crab, is one of the well-known aquaculture products in China. It has been known that the crab possesses a remarkable ability to survive even in polluted water, and readily tolerates and uptakes heavy metals, such as cadmium and mercury. Accordingly, the proper management in crab breeding is the utmost necessity from the standpoint of food safety. Unfortunately so far, only limited studies have been conducted to examine the effect of EM on Chinese mitten crab culture. The present communication describes the results of the experiments regarding the effect of EM on aquaculture system in China.

II. METHODS

1) Evaluation of effect of EM on water quality of shrimp pond

Two freshwater shrimp ponds of around 15mu (1mu = 666.67m^2) in Gaochun District, Yanxi County were selected for the experiments. EM was applied into one pond and not into the other. Time-dependent change of chemical oxygen demand (COD), NH_3^+-N, total phosphorus (TP), and turbidity of water sampled from each pond were measured.

2) Evaluation of effect of EM on water quality in combination with water hyacinth

Water from freshwater aquaculture pond was used for the experiments. Four experimental plots, 1) control, 2) addition of EM, 3) addition of EM and 10% of water hyacinth, 4) addition of EM and 20% of water hyacinth, were set up. Time-dependent changes of total nitrogen (TN), NH_4^+-N, NO_2-N, chemical oxygen demand (COD) and total phosphorus (TP) of waster sample from each plot were measured.

3) Evaluation of effect of EM on Shanghai hairy crab culture

To evaluate the effect of sustainable crab production system, which utilizes EM technology, we conducted a comprehensive survey at crab culture ponds of around 15,000 mu in Gaochun District in Nanjing. Parameters such as pH, potassium permanganate consumption, suspended solids, ammonia nitrogen, TN and TP, were measured in June and September in 2015. For comparison, these parameters were also measured in traditional crab culture pond as control and intensive crab culture pond utilizing chemical agents. Nutritional component of crabmeat was analyzed after harvest. To evaluate effect of EM against pathogenic bacteria in sediment soil and water from crab culture pond, coliform group, *Escherichia coli* and vibrio were counted at different EM concentration used (0, 500, 1000, 1500ppm).

4) Evaluation of effect of EM in shrimp culture

To evaluate the effect of EM in shrimp culture, parameters such as pH, DO, COD, NH_4^+-N and nitrite were measured with EM or without EM. Shrimp production yield and water changing times were checked.

III. RESULTS AND DISCUSSION

1) Evaluation of effect of EM on water quality of shrimp pond

Parameters such as COD, NH_4^+-N, TP and turbidity of shrimp pond water to which EM was applied were improved compared with those of control. The positive effect continued during the experiment periods. Figs.1a and 1b show the changes in NH_4^+-N and turbidity, respectively.

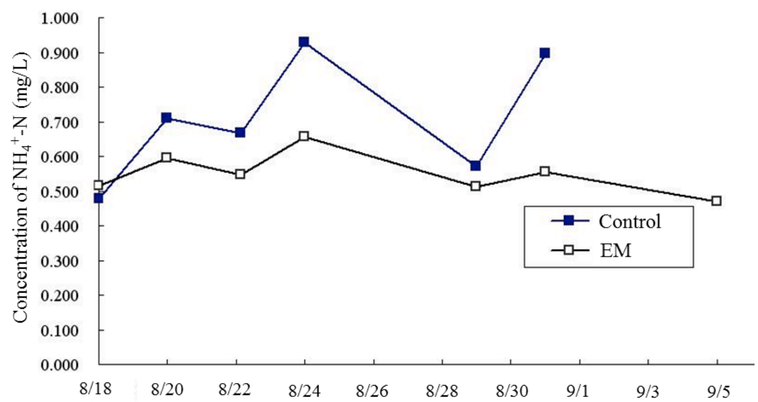

Fig. 1a. EM treatment improved NH_4^+-N concentration

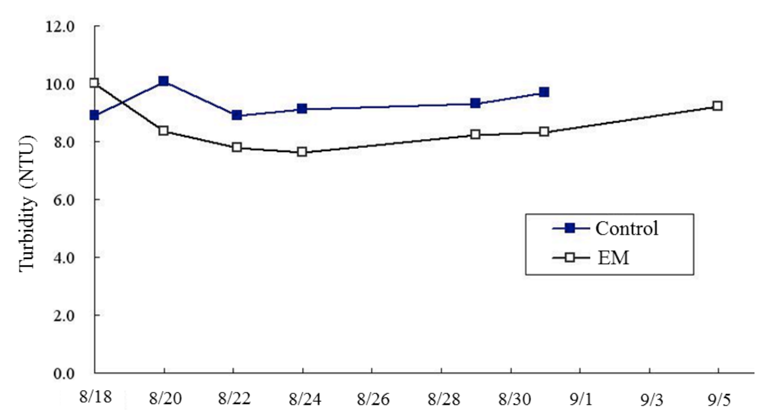

Fig. 1b. EM treatment improved Turbidity. Turbidity was quantified by using NTU (Nephelometric Turbidity Unit).

2) Evaluation of effect of EM on water quality in combination with water hyacinth

Results showed that combination of EM and water hyacinth exhibited more cleansing effect than EM only in terms of such parameters as TN, NH_4^+-N, NO_2^--N, TP and COD. As shown in Figs.2a and 2b, the concentration of NH_4^+-N and NO_2^--N reached freshwater aquaculture pond water discharge level I. Namely, $NH4^+$-N level reduced to below 0.6 mg/L and NO_2^--N level reduced to below 0.1 mg/L.

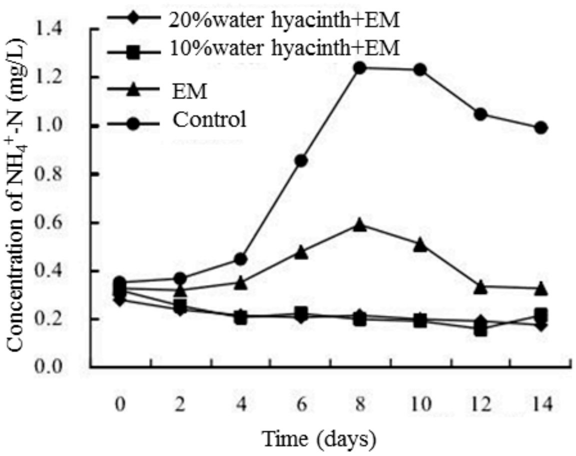

Fig. 2a. The effect of water hyacinth + EM on NH_4^+-N concentration

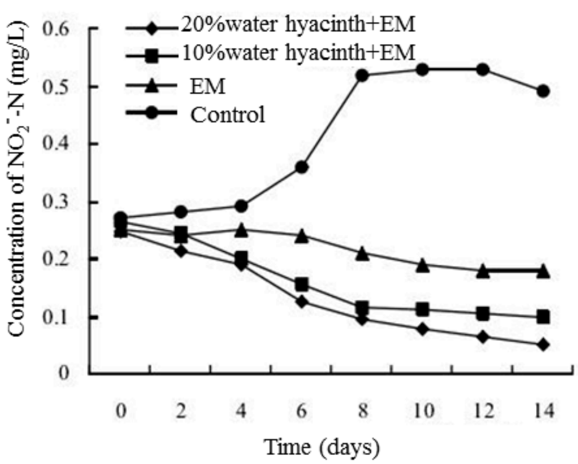

Fig. 2b. The effect of water hyacinth + EM on NO_2^--N concentration

3) Evaluation of effect of EM on Shanghai hairy crab culture

Pond water quality indices such as pH, potassium permanganate, suspended solid, NH_4^+-N, TN and TP were improved where EM was applied. As shown in Table 1, the quality of pond water treated with EM reached level I discharge standard whereas water quality in control and intensive crab culture pond only reached level II. Nutritional component of crabmeat produced with EM technology was better than control (Table 2).

TABLE 1
EFFECT OF EM ON MAKERS OF WATER POLLUTANT

No.	Group	pH	Permanganate Index (mg/L)	Suspended solid (mg/L)	Ammonia nitrogen (mg/L)	TP (mg/L)	TN (mg/L)
1	Control	8.1	7.79	14.0	1.50	0.25	2.32
2	EM	8.03	6.25	7.0	0.50	0.05	0.92
3	Chemical agents	7.21	19.45	20.4	2.50	0.52	4.37
Class I standard		6.0-9.0	≦8.0	≦50	≦1.5	≦0.3	≦2.0
Class II standard		6.0-9.0	≦12	≦100	≦2.0	≦0.4	≦3.0

TABLE 2
EFFECT OF EM ON CRABS NUTRITIONAL INGREDIENT IN 2015

Group	Protein g (100g)	Fat g (100g)	Water g (100g)	Ash g (100g)	Carbohydrate g (100g)
Control	7.40	3.7	77.6	1.8	16.0
EM	10.8	6.0	56.4	2.5	24.3

4) Evaluation of effect of EM in shrimp culture

In cases where EM was applied, $NH4^+$-N in water decreased by 57% on average compared with control. Reduction in parameters such as COD and $NO2^-$-N was also observed. Diseases and death rate of shrimp were greatly reduced, thus leading to the increase of final products.

IV. CONCLUSIONS

Our studies suggest that technology of effective microorganisms (EM) can contribute to the development of sustainable aquaculture including shrimp and crab culture in China.

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