Development of the water quality stabilizer Ceraclean® for aquaculture

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1. Introduction

With the world population increasing and climate change putting pressure on the supply of crops, food security is increasingly threatened while demand for fishery products is on the rise worldwide. World fishery production, however, has been hovering around 90 million tons in the last 20 years. In particular, marine production is said to have reached its limit. Aquaculture production, therefore, is growing at home and abroad to compensate for the production of high-demand fishery products[1]. Among others, shrimp culture, which is more feed efficient than livestock farming (cattle, hog and poultry), is receiving growing attention in landlocked developing countries faced with food shortages. At the same time, shrimps are growing in significance as a source of animal protein. World shrimp production has been increasing in recent years (Figure 1); it stood at about 3.8 million tons in 2010, 71.8% of which were white shrimps[2]. White shrimps are the world's most successful species in the aquaculture industry, with 77.9% produced in Asia.

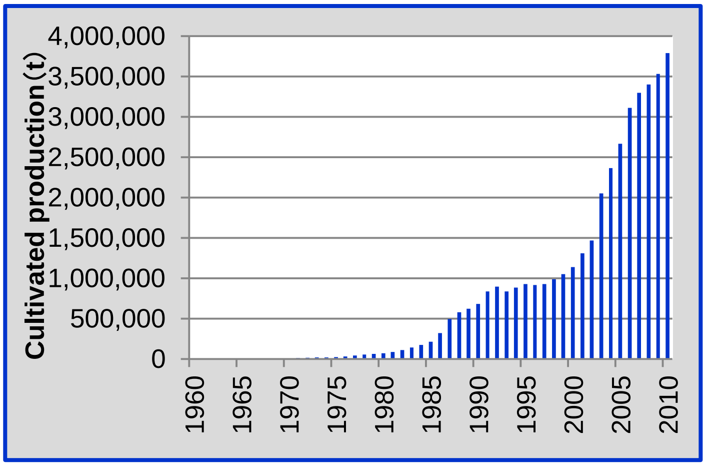


Figure 1. World aquaculture production of shrimp

Intensive shrimp culture is common in Southeast Asia, where fries are released into large artificial ponds and fed intensively with compound feeds. The excrement and leftovers, however, are deteriorating the cultural environment while the wastewater is polluting the surrounding environment.

Shrimp culture has been repeatedly damaged by the prevalence of diseases. For example, EMS (Early Mortality Syndrome), which results in the mass mortality of fries[3], began to become widespread in China in 2009 and has been reported in some Southeast Asian countries (Figure 2)[4,5]. In particular, Thailand has been the hardest hit, where shrimp production plunged from 600,000 tons in 2011 to 300,000 tons in 2013. As a result, the international market price of white shrimps at the end of 2013 almost doubled from 2012 levels, which also had an impact on the Japanese market. Shrimp pond water should therefore be purified with its quality stabilized to prevent diseases like EMS and to increase the productivity of shrimp culture.

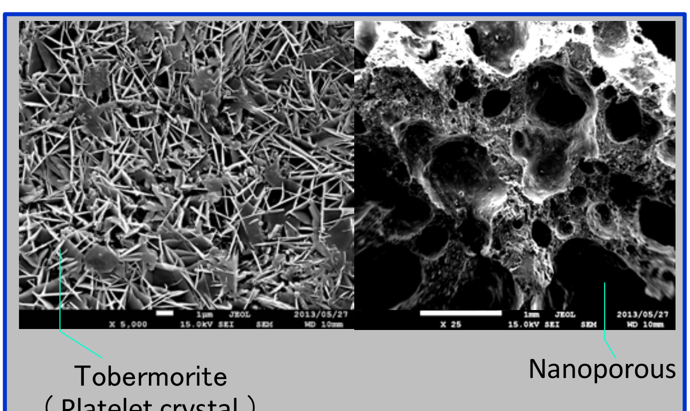
Figure 2. Geographical distribution of (EMS/AHPND) in the world

Taiheiyo Cement Corporation set up the Aqua Business Group in the Environmental Business Development Department in October 2012 to develop and commercialize water treatment materials, working on technologies to improve the aquaculture environment. This report concerns the use of the water quality stabilizer Ceraclean for an improved shrimp culture environment, the summary of which is given below, along with its development status.

2. Overview of water quality stabilizer Ceraclean

Ceraclean (Picture 1), an artificial calcium silicate hydrate with numerous micropores, is designed to improve pond water quality. Consisting primarily of a mineral called tobermorite, it stabilizes pH and alkalinity with its strong buffering capacity, with useful bacteria growing in the pores (Picture 2). While the excrement and leftovers accumulate on the bottom of shrimp ponds, causing water pollution, Ceraclean helps useful bacteria grow, which in turn reduces the amount of sludge and purifies the water. It's being marketed in Taiwan for use primarily in shrimp culture. In addition, R&D is under way on its other properties to boost its sales and develop new markets in Southeast Asia and other parts of the world.

Picture 1. Ceraclean



Picture 2. SEM images of Ceraclean

3. Development history and status

3.1 Review of the increase in the productivity of shrimp culture

The authors, Tokyo University of Marine Science and Technology and Walailak University in Thailand (where shrimp culture is widely practiced), launched a joint program in 2013 to study the effects and mechanism of Ceraclean for use in shrimp culture. First, white shrimps were kept in tanks at Walailak University for laboratory experiments, where tests were conducted with four parameters on two groups – with Ceraclean (application of 60mg/L every three days) and without Ceraclean (control). Specifically, 350 L tanks were used for 60-day feeding, with each containing 20 white shrimps, to determine the average daily growth (hereinafter, "ADG") and survival rate. Table 1 shows the growth and survival rate of the shrimps after 60 days. The ADG, with Ceraclean applied, was 0.02g higher compared to the control, which proves its effectiveness in improving the growth rate. Likewise, the survival rate increased by 24.2%, resulting in a 95% increase in the yield, which suggests the potential for a significant increase in the productivity. To shed light on its mechanism, calcium eluted from Ceraclean was measured in terms of its concentration in the tank water; it stabilized between 300-400mg/L (see Figure 3) while the calcium concentration in the control fluctuated significantly, followed by a gradual decrease. Calcium is an essential mineral that helps shrimps grow healthily and form their shells, which could increase their resistance to diseases and survival rates. Picture 3 shows how the tank water looked; the control turned green while that with Ceraclean applied, turned brown. Microscopic examinations found the growth of green algae (such as toxic dinoflagellates) in the control and of diatoms (rich in unsaturated fatty acids, serving as nutrient sources for shrimps) in the water containing Ceraclean. A continuous supply of silicate eluded from Ceraclean (an essential nutrient for diatoms) may have contributed to the steady growth of diatoms.

Table 1. Effect of Ceraclean on growth and survival rate of white shrimp (60 days)

Parameter	Control	Ceraclean
Initial weight (g)	2.37 ± 0.35	2.35 ± 0.38
Final weight (g)	6.07 ± 1.29	7.28 ± 1.30
Weight gain (g)	3.71 ± 1.30	4.74 ± 1.26
ADG	0.06 ± 0.02	0.08 ± 0.02
Survival (%)	37.5 ± 20.6	61.67 ± 17.6

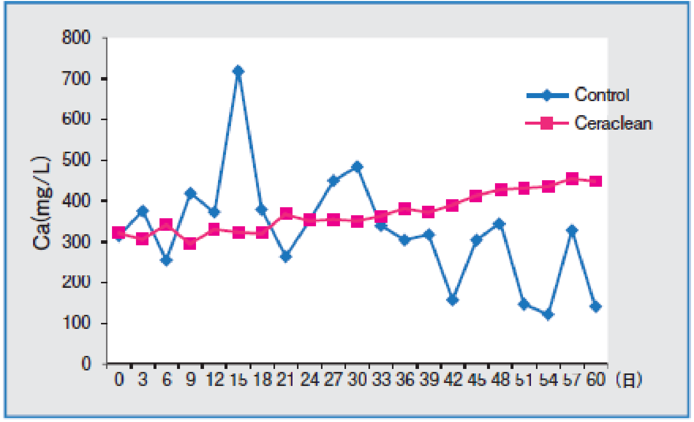
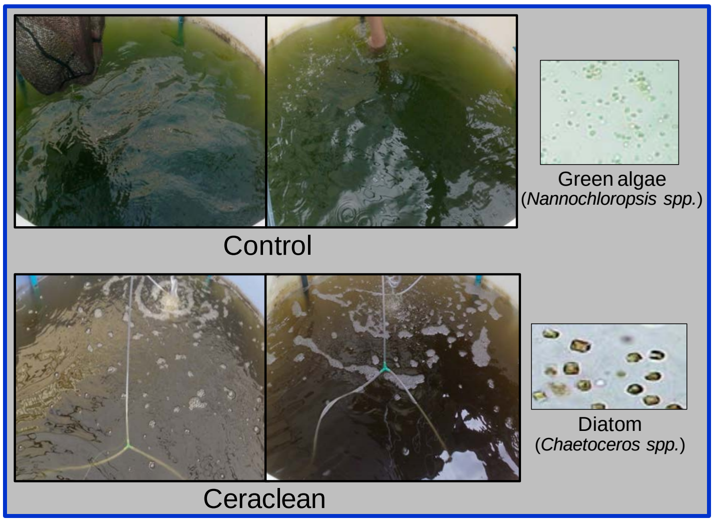


Figure 3. Effect of Ceraclean on Calcium in water of white shrimp culture



Picture 3. Color of water and types of algae in tanks

3.2 Effects of Ceraclean associated with Biofloc technology

A shrimp culture technique called Biofloc technology is gaining attention in South Korea, Thailand and other parts of Southeast Asia. Biofloc technology involves the use of artificially flocculated bacteria (Biofloc) that reduce the amount of ammonia and nitrous acid (toxic compounds produced from the excrement and leftovers) in the culture water. Biofloc itself serves as a source of protein for shrimps[6]. Other effects for shrimp culture include: appropriate turbidity controls that reduce stress and cannibalism; establishment of a stable biota to maintain the water quality and prevent the intrusion of pests; and production of diatoms to feed shrimps (Figure 4).

As the results of the laboratory tests above suggest that Ceraclean helps diatoms propagate steadily, scaled-up tests were conducted subsequently, given that the combination of Ceraclean and Biofloc technology is expected to increase the productivity of shrimp culture. Specifically, the tests were conducted with four parameters on four groups – with Ceraclean, with Biofloc, with Ceraclean and

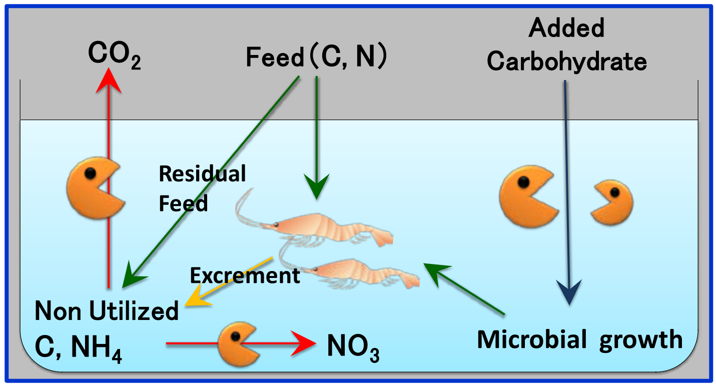


Figure 4. Scheme of Biofloc technology system

Biofloc, and the control – using 500L tanks for 60-day feeding, with each containing 60 white shrimps; Ceraclean was applied every 7 days at a concentration of 60mg/L. Table 2 shows the growth and survival rate of the shrimps after 60 days – both the ADG and the survival rate were highest in the group with Ceraclean and Biofloc, showing a 0.02g increase and an 18% increase, respectively, compared to the control. Ceraclean, therefore, contributes to further increasing productivity when combined with Biofloc technology.

Table 2. Effect of Ceraclean on growth and survival rate of white shrimp (60 days)

Parameter	Control	Ceraclean	Biofloc	Ceraclaen +BioFloc
Initial weight (g)	1.65 ± 0.07	1.47 ± 0.09	1.80 ± 0.25	1.47 ± 0.09
Final weight (g)	6.45 ± 0.10	6.87 ± 0.49	7.20 ± 0.70	7.52 ± 0.42
Weight gain (g)	4.8 ± 1.30	5.4 ± 0.26	5.43 ± 0.70	6.05 ± 0.63
ADG	0.08 ± 0.01	0.09 ± 0.01	0.09 ± 0.01	0.10 ± 0.01
Survival (%)	63.5 ± 9.7	74.5 ± 1.2	77.1 ± 5.1	81.5 ± 3.4

4. Overview

The above is a summary of the water quality stabilizer Ceraclean and its development status. Because of their high feed conversion efficiency, shrimps are expected to play a crucial role in dealing with the food crisis while in Southeast Asia, where most of them are produced, the prevalence of diseases is threatening their production. The culture water should thus be stabilized and purified to prevent diseases. It's been proven that Ceraclean maintains the chemical quality of the water, strengthens the shells of shrimps through the release of minerals (calcium, silicate, and so forth), improves the survival rate with the biota stabilized primarily by diatoms, and increases the ADG through feeding of diatoms, which together increase the productivity of shrimp culture (Figure 5).

It's being tested at commercial shrimp ponds in Thailand to demonstrate its performance and elucidate its mechanism.

As shrimp culture is also expected to become widespread in Japan, Ceraclean will be tested for use in land-based shrimp culture. In addition to shrimps, Ceraclean could be effective for other crustaceans (crabs, and so forth) and bivalves (clams, and so forth). The role of silicon circulation in the global environment, meanwhile, is increasingly revealed with the "silica deficiency hypothesis" advocated[7]. At the same time, it's been pointed out that a decrease in silicate causes red tides, having detrimental effects on ecosystems.

Ceraclean is expected to contribute to the conservation of the water ecosystem, providing it with silicate in a sustainable manner.

Ceraclean, for that matter, has the potential of alleviating the food crisis and changes in the global environment, going beyond its primary functions.

("Ceraclean" is a registered brand of Taiheiyo Cement Corporation.)

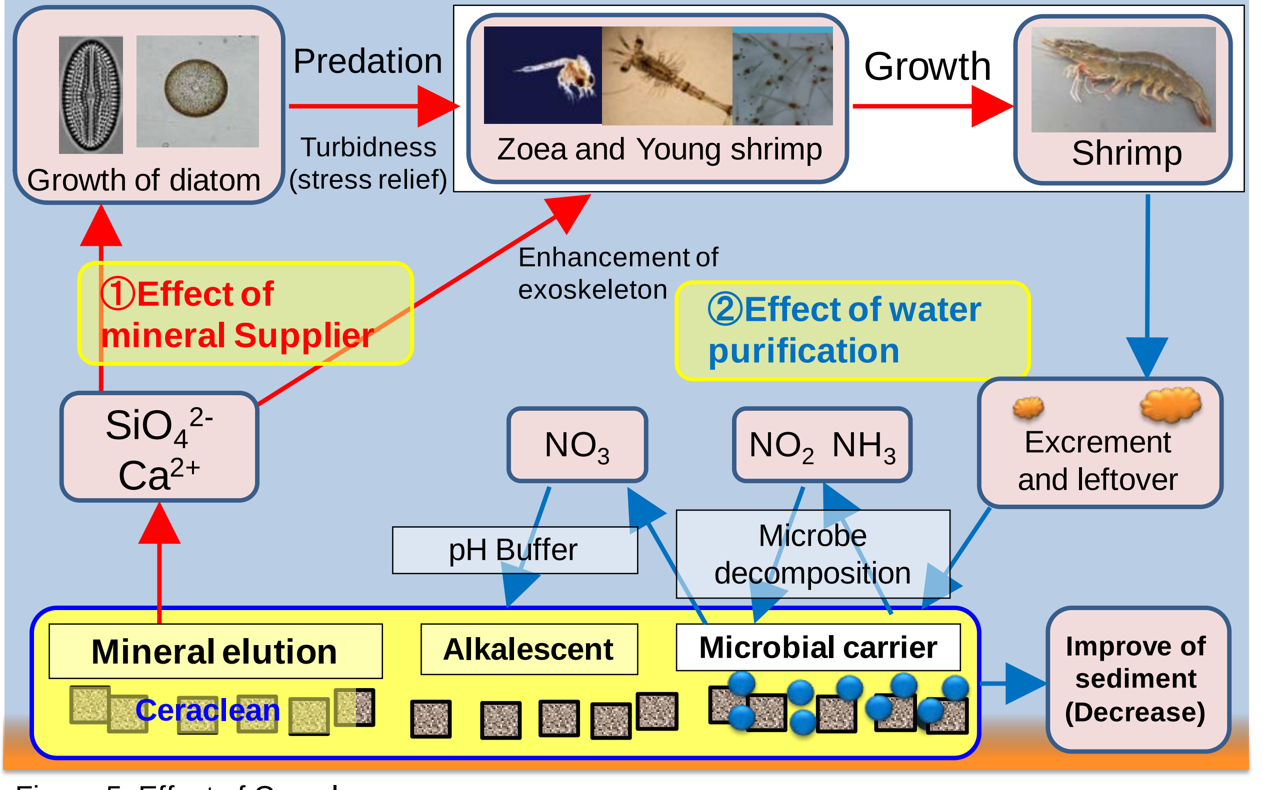


Figure 5. Effect of Ceraclean

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