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Utilization of Chitosan for Organic Shrimp Production

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Abstract

Chitosan is a bio-originated polymer which is widely applied in many fields. This research applied chitosan in the shrimp culture system. The shrimp growth as well as water quality of the effluent was significantly improved with chitosan application. Applying chitosan to the integrated culture system can reduce phosphate concentration in the effluent. Our results show that utilization of chitosan for organic shrimp production can play an important role in organic shrimp farming in aspects to improve feed quality, water quality management, the shrimp health and the culture system sanitation.

Keywords : Chitosan, Shrimp production, Water quality

Introduction

The Principal Aims of Organic Production Now a days, consumers in developed countries are increasingly interested in organic farming products, since, it was found that products from chemical processes are harmful and also cause environmental impacts and lead to un-sustainable agriculture and husbandry. In contrast, organic farming products are not only solving toxic reside problems, but also revive an environmental ecosystem. Although organic agriculture products have been interested for some years. However, organic aquaculture production has just been started.(www.firheries. Go.th/law)

Thailand has become the leading country in marine shrimp production from farming since 1991 (Kongkeo, 1994) Due to the commercial importance of this commodity and the increased demand for organic shrimp, both guidelines and regulations to produce in such a way have been adopted. The overall objective for the organic aquaculture production must be consideration for the environment and the thriving and health of both wild and cultured organisms. The production system must be managed in such a way that the environmental integrity of the surrounding water and land areas is preserved through:

a) Minimizing possible effects on local biological processes.

b) Maintaining healthy water conditions.

c) Managing the production so that infectious organisms, parasites, and input factors have minimal impacts on wild organisms in the surrounding environment.

d) Providing for poly-culture in the production system in order to close nutrient cycles where possible.

e) Prohibition for antibiotics and genetically engineered organisms in the feed.

The proposed guidelines for organic shrimp farming practices include farm management and feeding management aspect. Good pond management will prevent not only the deterioration of soil and water quality but also prevent disease outbreak to nearby coastal areas. The overall aspect is to reduce environmental impacts and enhance production efficiency without using antibiotic and chemical eagents. www.nicaonline. Com/articles 10/site). The proposed guidelines are :

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1) There should be a treatment pond of at least 30% of total farm area, which can receive 100% of effluents at harvesting period.

2) Farm system should be a closed system or closed re-circulating system to minimize waste discharge. Water exchange rate should not exceed 5% at harvesting period.

3) Effluent water quality (ammonia, biological oxygen demand, dissolved oxygen, phosphate, and suspended solids) has to be appropriately treated.

4) Settled particulate organic matter must be removed and brought to adequate re-usage, e.g. as fertilizer in agriculture unit.

5) All feed ingredients must be derived from certified organic ingredients.

6) Feed must only be offered in a way that allows natural feeding behavior and minimizes loss of feed to the environment.

Chitin and Chitosan

Chitin and chitosan are naturally prevalent biopolymers, which are the main components in the cuticle structure of crustaceans, insects and mollusks, included in the cell walls of fungi and some microorganisms. The main building units of chitin are N-acetyl-D-glucosamine, which are connected to each other by β (www.firheries.go.th/law; Kongkeo (1984); www.nicaonline.com/articles 10/site ; and Hirano, 1997) linkages to form long chain biopolymers. Chitosan is partially deacetylated forms of chitin which compose of the two common sugar derivative units of mainly dominant part of D-glucosamine connected with less quantity of N-acetyl-D-glucosamine in the polymer chain. Chitin and chitosan are naturally occurring cationic amino polysaccharide of biologically reproducible, non-toxic and biodegradable materials on the earth. Chitin and chitosan have biologically multifunction activities in organs, tissues and cells of animals and plants (Hirano, 1997).

Utilization of chitosan in shrimp culture in Thailand could develop into an economically successful application. There are many problems hindering the successful production of shrimp culture. The two major problems in intensive shrimp culture are feeds water quality management and diseases (Fast, 1992). Shrimp are susceptible to many pathogens particularly during the intensive culture that either lowers their resistance or enhances the pathogenicity of the pathogens. Therefore, chitosan utilization should be able to lower these risks, since it has antiviral immunopotentiating and antimicrobial functions in animals (Hirano, 1997). Furthermore, chitosan can play an important role in organic shrimp farming in aspects to improve feed quality, water quality management, the shrimp health and the culture system sanitation.

Improvement of Feed by Chitosan

Applying chitosan was found to positively affect the shrimp growth, frequency of molting, and chitin development process in all measured aspects (Table 1 and 2). The chitosan feed additive dose at 100 ppm promoted the shell chitin had higher contents of 21.02% at the 115th day than the control set at 20.85% (Table 2). The analyzed composition of pacific white shrimp (*Litopenaeus vannamei*) was used to determine the flux of chitosan in feed which provided a better understanding of the feed utilization and growth of shrimp. Effect of chitosan on shrimp production was shown in Table 3. The results reflect that chitosan can promote the shrimp growth.

Table 1. Effect of chitosan on shrimp sizies at the 40th, 80th and 115th cultivation date

Description	Control	Chitosan 100 ppm coated on feed
Day 40th, 80th, 115th		
Total weight (g)	2.04, 8.23, 16.30	2.41, 9.45, 19.04
Total length (cm)	3.60, 7.20, 11.25	4.15, 8.75, 12.18
Meat weight (g)	1.11, 4.65, 8.54	1.30, 4.95, 9.88
Shell weight (g)	0.67, 2.55, 5.91	0.84, 3.23, 6.72
Waste weight (g)	0.26, 1.03, 1.85	0.27, 1.27, 2.44
Hepatopancreatic weight (g)	0.16, 0.36, 0.60	0.18, 1.01, 1.70

Table 2. Quantitative analysis of components in shell

Description	Control	Chitosan 100 ppm coated on feed
Day 40th, 80th, 115th		
Crude protein (%)	15.63, 15.91, 16.08	15.68, 15.96, 16.52
Calcium (%)	26.40, 26.92, 27.05	26.50, 27.00, 28.42
Fat (%)	0.40, 0.50, 0.61	0.48, 0.57, 0.66
Fiber (%)	20.05, 21.15, 21.58	20.02, 21.08, 21.47
Chitin (%)	18.00, 19.60, 20.85	18.95, 20.15, 21.02
Ash (%)	63.10, 64.58, 65.22	63.45, 64.95, 65.40

Table 3. Effect of chitosan on shrimp production

Description	Control	Chitosan 100 ppm coated on feed
Total weight of production (kg/pond)	1,496.38	1,898.12
Feed conversion rate [FCR]	1.44	1.03
Average daily gain [ADG] (g/head-day)	0.1122	0.1356
Survival rate [SR] (%)	74.21	77.82

Pond-Water Quality Improvement by Chitosan

The effects of chitosan solution (coating-on and adding into shrimp feed) on the reduction of feed stuff dissolution and wastewater quality was studied at both laboratory level (concrete pond, size 3.20 m^2) and field test (soil pond, size 3200 m^2). The solution of 1% chitosan (Degree of Deacetylation (DD) 85$\pm$2% and Molecular Weight (MW) 40,000-400,000 g/mole) in 1% acetic acid was used at 400 ppm concentration for both modified shrimp feed for every 3 days and 2 meals a day. It was found that chitosan could reduce the stuff dissolution and improve the wastewater quality in the experiment pond comparing to the control pond. Better results than the laboratory test were found in the field test. The control pond produced totally 1,778.00 kg of shrimp at feed conversion ratio (FCR) 1.63 and survival rate (SR) 46.52%. Using chitosan as the feed additive resulted in higher total weight of production at 2,689.50 kg, (FCR 1.30 and SR 76.62%). The highest total weight, 2,704.50 kg, of production was achieved when chitosan was used as feed coating, where FCR and SR were 1.29 and 74.00%, respectively (Table 4).

Chitosan had attractively grown as an alternative synthetic flocculants. The protonization of amino groups in solution makes chitosan positively charged and since most natural colloidal particles, including bacteria and macromolecules, are negatively charged, attractive electrostatic interactions may lead to flocculation. This is one of the reasons that it has been used in various areas of water treatment, such as removal of organic substances from drinking water, treatment of wastewater from distillers, removal of oil from wastewater, treatment of food processing wastes, as well as other applications (Jill *et al.*, 1999).

Application of Chitosan in Recirculating System

Based on positive results in the previous study, a new study was conducted to test the efficiency of chitosan improvement together with the integrated aquaculture system. If addition of this bio-origined polymer into the integrated system could improve the system performance, this can lead to a new concept for sustainable shrimp production. The tested integrated system consisted of several ponds as described as below.

Table 4. Effected of chitosan solution on the reduction of feed stuff dissolution and wastewater quality at field test (115 days)

Description	Control	Chitosan 400 ppm coated on feed	Chitosan 400 ppm added into feed
Salinity effect (ppt)	15 to 8.7	15 to 5.5	15 to 6.1
pH effect	7.7 to 13	7.7 to 9.6	7.7 to 9.7
Alkalinity effect (mg/L as $CaCo_3$)	80 to 56	80 to 42	80 to 40
D.O. effect (mg/L) ; at day time	7.5 to 2.9	7.5 to 4.3	7.5 to 4.1
; at night time	4.0 to 1.5	4.6 to 3.1	4.6 to 3.0
Turbidity effect (NTU)	40 to 155	40 to 80	40 to 70
Total Suspended Solid effect (mg/L)	45 to 210	45 to 105	45 to 115
BOD effect (mg/L)	0 to 520	0 to 250	0 to 230
COD effect (mg/L)	0 to 625	0 to 285	0 to 295
TKN effect (mg/L)	0 to 680	0 to 190	0 to 170
Ammonia effect (mg/L)	0 to 0.06	0 to 0.13	0 to 0.02
Nitrite effect (mg/L)	0 to 0.04	0 to 0.04	0 to 0.02
Nitrate effect (mg/L)	0 to 0.06	0 to 0.03	0 to 0.03
Hydrogen sulfide effect (mg/L)	0 to 0.05	0 to 0.03	0 to 0.04
Harvesting:			
Total weight of production (kg/pond)	1,778.00	2,704.50	2,689.50
FCR	1.63	1.29	1.30
SR (%)	46.52	74.00	76.62

Shrimp Pond

The two commercially valuable aquaculture species in Thailand, i.e. black tiger shrimp (*Penaeus monodon*) and giant freshwater prawn (*Macrobrachium rosenbergii*), were grown in the two same dimension earthen-ponds, with 1,600-m^2 surface area and 1.2-m depth. Aeration was supplied via 1-HP electric paddle wheels aerator. The salinity at starting period was set at 10 ppt both ponds. *P. monodon* were stocked at the rate of 80,000-postlarva/pond (50- postlarva/m^2). A commercial diet was fed at the rate of 3% of shrimp body-weight per day. *M. rosenbergii* were stocked at the rate of 30,000-heads/pond (18.75-heads/m^2) and feeding rate was set at 2% on body-weight per day.

Fish Pond

Red tilapia (*Oreochromis sp.*) is one of the most popular cultured species in many tropical countries because of its resistance to poor water quality and diseases, tolerance to a wide range of environmental conditions and good growth rates. Algae and detrital matter in the extensive aquaculture are already sufficient nutrient sources for red tilapia. In this study, red tilapias, with 90-g in average weight were stocked in the 400-m^2 earthen-pond, at the rate of 5-fishes/m^2. Aeration was supplied via a 0.5-HP electric paddle wheels aerator. No artificial feed was added.

Sedimentation Pond

The suspended solid may cause effects on photosynthesis of aquatic plants by attaching to its leaves. Hence, the 400-m^2-sedimentation pond was applied to reduce suspended solid in fishpond-effluents prior to discharge to seaweed-pond.

Seaweed Pond

In this study, the green algae genus *Enteromorpha* was chosen to be an aquatic plant in the treatment system. This seaweed had potential for commercial exploitation because of its abundant and varied chemical composition, and quality and concentration of basic nutriments for other living organisms (Aguilera *et al.*, 2004). Seaweed was stocked in the 400-m^2 earthen-pond, at the rate of 2.5 kg/m^3.

Recirculating System

Water exchange rate was set at 10% of shrimp-pond volume per day. Chitosan was added into *M. rosenbergii* pond at the rate of 10 mg/L every 10 days. Water samples were collected for analysis every 4 days. (APHA, 1985; Brock *et al.*, 1994; Clesceri *et al.*, 1989; Hakan *et al.*, 2003; Jones *et al.*, 1991; McDonald, 1987; Na-ana, 1999; Parsons *et al.*, 1989; Phillips *et al.*, 1993; Primavera, 1994; Qian *et al.*, 1996; Shpigel *et al.*, 1993; Wang, 1990; and Wang *et al.*, 1990). A schematic diagram of this study was shown in Figure 1.

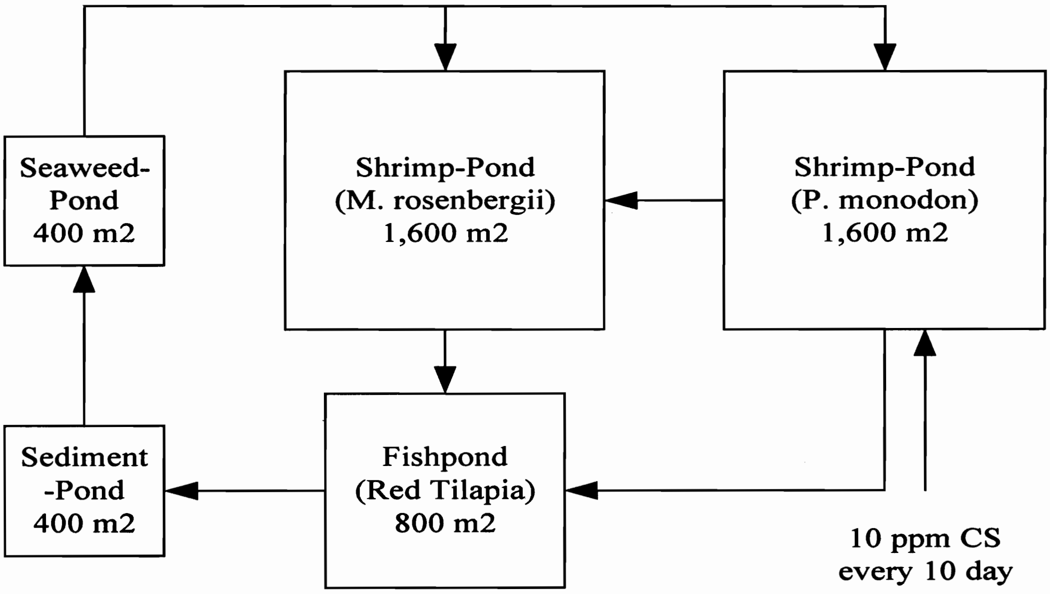

Figure 1. A schematic diagram of integrated system based on shrimp-fish-seaweed with an application of chitosan

Water quality trends in shrimp-ponds in a recirculating system with application of chitosan and control set, without addition of chitosan, were shown in Figure 2.

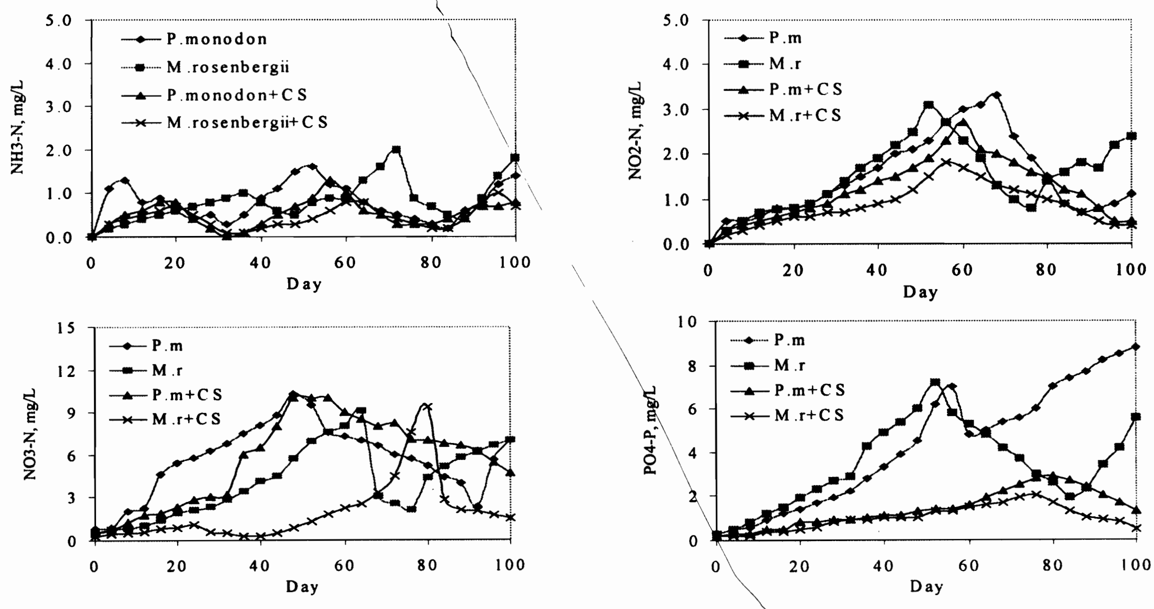

Figure 2. Water quality in shrimp-ponds with and without application of chitosan

The changes of water quality in shrimp-pond were quite similar, independent of the application of chitosan, however, the PO_4-P levels were lower in chitosan applied sets. The integrated system could efficiently control NH_3-N levels in both shrimp and treatment ponds. The NH_3-N levels in treatment ponds are always maintained at a low level (below 1.0 mg/L). However, NO_2-N levels are high in both shrimp-ponds and treatment ponds, i.e. the range of 0.5-4.0 mg/L. The reduction of NO_2-N, in shrimp-ponds at the end of the experiment, might come from the growth of available phyto-plankton. Although application of chitosan did not clearly show the effect on water quality, but it slightly improved the shrimp growth rate and survival rate (Fig.3). Moreover, an application of chitosan also improved the production of fish and seaweed in the integrated aquaculture system.

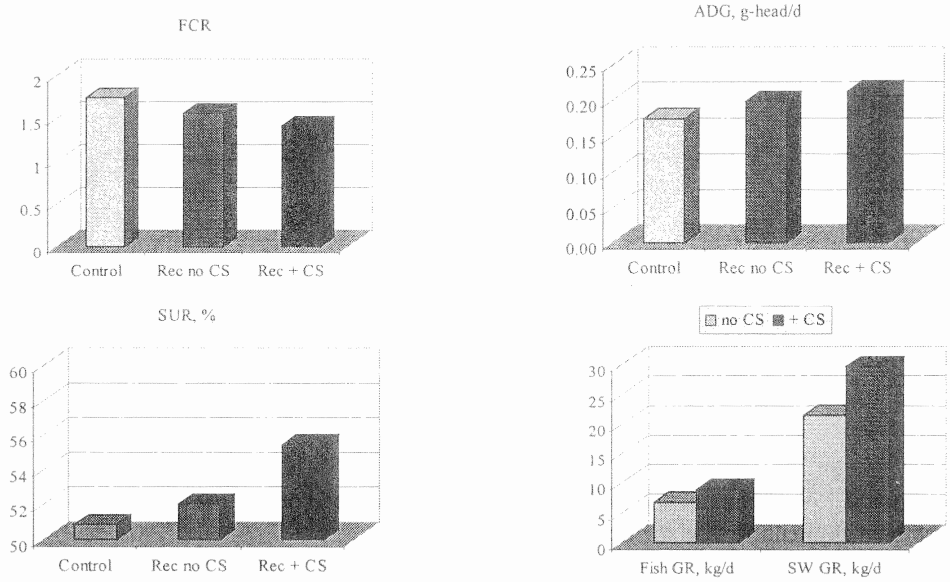

Figure 3. Average daily growth (ADG), survival rate (SUR), feed conversion ratio (FCR), and growth rate of fish and seaweed in the integrated system with and without chitosan

Conclusions

Chitosan is highly practical for the improvement of shrimp growth and water quality. The highest total weight of production was achieved when chitosan was used as feed coating. The results also reflect that chitosan can promote the shrimp growth. Chitosan could also reduce the stuff dissolution and improve the wastewater quality in the experiment pond. Though application of chitosan in integrated aquaculture system did not significantly affect water quality of shrimp-farming effluents, but shrimp growth yield, i.e. average daily growth and survival rate were slightly higher with chitosan. Hence, it can be concluded that chitosan is potentially an alternative organic material for the improvement of both production and water quality in organic shrimp farming.

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