Application of bioflocculant-producing bacteria, heterotrophic nitrogen-removal bacteria, poly-phosphate bacteria and water-hyacinth (*Eichhornia crassipes*) for wastewater treatment of My Tho rice-noodle factories, Tien Giang province, Vietnam

Le Thi Loan[1*], Tran Vu Phuong[2], Cao Ngoc Diep[3]

[1]Dept. Educational high school, Dept. Education - Training, Tien Giang province, Vietnam
*corresponding author
[2]Department of Microbiology Biotechnology, Can Tho University, VIET NAM
[3]Department of Microbiology Biotechnology, Can Tho University, VIET NAM

Abstract— *Rice-noodle wastewater represents a serious problem regarding environmental degradation and human health protection. The aim of the study was to create the application of bioflocculant-producing bacteria, heterotrophic nitrogen-removal bacteria, poly-phosphate bacteria and water hyacinth (Eichhornia crassipes) for wastewater treatment of My Tho rice noodle factories, Tien Giang province, Vietnam in order to get an insight into number of entities that discharge polluted water into environment. An experiment was carried out with containers having different capacities from 100-mL, 1-L, 10-L, 100-L and 1000-L and 3 replications to select best strains of bioflocculant-producing bacteria, heterotrophic nitrogen bacteria, poly-P bacteria and water-hyacinth for removing toxic element to wastewater before releasing to river/canal. Application of two bioflocculant-producing bacterial strains PO.01.C and PRO.03.B (protein and polysaccharide) into rice-noodle wastewater, aeration in 3 hours, held on 21 hours, supernatant moved to other container, adding heterotrophic nitrogen removal bacterial strain and poly-P. strain 064.B, aeration 8 hr/24hr during 7 days and wastewaters were transferred other containers containing water-hyacinth (Eichhornia crassipes) in 2 days, the results recorded that pH of wastewater increased from 4.68 to 6.13, TSS and BOD_5 concentration of wastewater reduced from 369 and 1200 mg/L to 17 and 23 mg/L, respectively. TKN and TP decreased from 45 and 6.3 mg/L to 7.57 and 4.56 mg/L, respectively. All targets reached to 40/2011 standard / Ministry of Natural Resource and Environment of Viet nam.*

Keywords - Bioflocculant-producing bacteria, Heterotrophic Nitrogen Removal Bacteria, Poly-Phosphate bacteria, Rice-noodle, wastewater, water-hyacinth.

I. INTRODUCTION

Rice noodles are the most consumed form of rice product next to cooked rice grain in Asia [1]. Noodles may either be served by frying and mixing with vegetables and meats or served as a soup noodle by boiling in a broth. Rice protein lack gluten; hence lack the functionality of continuous visco-elastic dough.

My Tho city, a city locates in the Mekong Delta, Vietnam, has many traditional technologies and "My Tho rice noodle" is among famous technology for a long time. Rice noodle has been produced from special local rice variety and there are seven manufacture factories have gathered in a cooperative and they have a "HU TIEU MY THO" trademark. However these factories work in the traditional condition therefore they have no wastewater treatment plant and wastewater have irrigated to canal or river directly. Especially wastewater from rice noodle factories contain many toxic elements as ammonium, orthophosphate,… and high TN, TP, BOD_5, TSS concentrations [2].

Wastewater generated from these industries depicts wide variation in strength and characteristics. Variation due to the amount of water usage, type of vegetable and fruits used type of product and different additives like salt, sugar, gelatin, colors, oil and preservatives added also leads to the pollution load in the wastewater but this wastewater is non toxic in nature because it comprises less hazardous compounds. Almost 50% of the water utilized in food processing industry is for washing and rinsing purposes. Water being the primary ingredient is widely used as a cleaning agent in food processing industry [3].

After cellulose, starch is the second polysaccharide found in nature, produced by plants as reserve material. The main cultivated actually plants for the starch industrially production are cereals, especially corn, followed by wheat and potato [4].

Generally, rice noodles are made from flour containing high amylose concentration (> 22%), which contributes to the gel network. It provides firm structure and desirable properties to noodle [1,5]. There is significant association found between amylose and acceptability of rice noodles [6].

Physicochemical wastewater treatment is a frequently used technique in the area of wastewater treatment [3]. Physicochemical wastewater treatment techniques are applied for the removal of heavy metals, oils and greases, suspended matter and emulgating organic substances, organic and inorganic components, difficult to decompose, non polar organic substances, toxic pollutants or high salt concentrations, phosphorus [7].

Under food processing industry, Palm oil refining wastewater has been successfully treated by physicochemical treatment using chitosan, alum and PAC and reported [8].

Flocculants are divided into inorganic flocculants such as aluminium sulfate (Alum) and polyaluminium chloride (PAC), organic synthetic high polymer flocculants such as polyacrylamide (PAA) derivatives, polyacrylic acids and polyethylene imine and naturally occurring bio-polymers flocculants such as chitosan, sodium alginate and microbial flocculants or bioflocculant [9,10,11]. Bioflocculant is a kind of biodegradable macromolecular flocculant secreted by microorganisms. Because of their biodegradability, harmlessness and lack of secondary pollution, bioflocculants have gained much wider attention and research to date [12]. Most of research focused on screening for microorganisms, culture conditions, mechanism of flocculation, chemical structure, and so on [13,14,15,16,17].

The aims of this study were (i) applying bioflocculant-producing bacteria to reduce organic and inorganic components, (total suspended solids = TSS) (ii) using heteroytophic nitrogen removal bacteria and poly-phosphate bacteria to decrease total kjeldahl nitrogen (TKN) and Total phosphorus (TP) and (iii) application of water hyacinth to remove or reduce (Bio-Oxygen Demand) BOD_5 concentration in wastewater reaching to 40:2011 standard of Ministry of Natural Resources and Environment Vietnam.

II. MATERIALS AND METHODS

2.1 Materials

Wastewater from rice-noodle factories at My Tho city, Tien Giang province with characteristics as follows (Table 1)

TABLE 1
PH AND PHYSICAL AND CHEMICAL CHARACTERISTICS OF WASTEWATER FROM RICE NOODLE FACTORIES OF MY THO CITY, TIEN GIANG PROVINCE, VIETNAM+

Treatment	1-L and 10-L Experiments	100-L Exp.	1000-L Exp.	40/2011 Standard*
pH	4.13	3.84	4.68	5.5 – 9.0
Total kjeldahl nitrogen (TKN) (mg/L)	99.82	26.71	45,11	40
Total phosphorus (TP) (mg/L)	2.64	5.43	6.31	6
Total of Suspended solids (TSS) (mg/L)	4544	620	369	100
Biochemical Oxygen Demand (BOD_5) (mg/L)	6160	950	1200	50
Total Ammonium (TAN) (mg/L)	4.55	7.12	6.31	10

+ ***data from Centre for Teqnique and Biotechnology, Tien Giang Science and Technology, Department.***
****Ministry of Natural Resource and Environment***

2.1.1 Environmental bacteria:

- Bioflocculant-producing bacteria: six strains as *Bacillus subtilis* PRO.01C, *Bacillus subtilis* PRO.03B, *B. tequilensis* PRO.07.04, *B. megaterium* PRO.04.01, *B. tequilensis* PO.08A and *Bacillus subtilis* PO.03.05 [2] were grown in culture media [18] (Deng *et al*.,) and [19], Hazana *et al*. separately.
- Heterotrophic nitrogen-removal bacteria: as four strains: *Bacillus altitudinis* HNi03DL, *Stenotrophomonas maltophilia* HNa03C, *Enterobacter hormaechei* HAm05C, *Achromobacter xylosoxidans* HNa07B were grown in nitrogen medium [20] and poly-phosphate bacteria: *Bacillus megaterium* POLY.P. 064B was grown in poly-P medium [21], the heterotrophic nitrogen removal and poly-P bacterial strains were selected from previous experiments [2].

All of strains were contained in suitable containers as flasks 500-L or 2000-mL on rotary with 120 rpm in 24 h or 72 h, until they reached to >10^9 CFU/ml and they were used as inoculation in all experiments.

2.2 Methods

Wastewater were used in these experiments from Mr. Truong Van Thuan's rice noodle factory (in all experiments from 1-L, 10-L, 100-L and 1000-L) and pH, physical together with chemical in these experiments were presented in Table 1

2.2.1 Experiment layout

Wastewater was filtered through filterable equipment to deplete material having big size (>1 mm) out of wastewater.

2.2.1.1 Bioflocculant-producing bacteria

The aim of this experiment was selection of bacterial strain having high flocculation

2.2.1.2 Experiment 100-mL, 1-L and 10-L

A. Experiment 100-mL:

The experiment was completely randomized design with three replications, the treatment composed of control (without bacteria) and the bioflocculant-producing (protein and/or polysaccharide) bacterial strains (*Bacillus subtilis* PRO.01C, *Bacillus subtilis* PO.01C, *B. tequilensis* PRO.07.04, *B. megaterium* PRO.04.01, *B. tequilensis* PO.08A and *Bacillus subtilis* PO.03.05).

Wastewater were distributed in the flask-250 mL containing 100 ml wastewater, inoculated 0.1 ml bacterial inoculation, adjusted pH=7; put the flasks on the rotary, 60 rpm in 60 sec, after that these flasks were hold on in 1 hour, supernants of each flask were measured flocculating activity. The good bioflocculant-producing (protein or/and polysaccharide) bacterial strains were selected for the next experiment.

B. Experiment 1-L:

The experiment was completely randomized design with three replications, the treatment composed of control (without bacteria) and bioflocculant-producing (protein or/and polysaccharide) bacterial strains

Wastewater were distributed in the flask-2000 mL containing 1000 ml wastewater, inoculated 1 ml bacterial inoculation, adjusted pH=7; put the flasks on the rotary, 60 rpm in 60 sec, after that these flasks were hold on in 1 hour, supernants of each flask were measured flocculating activity. The good bioflocculant-producing (protein or/and polysaccharide) bacterial strains were selected for the next experiment.

C. Experiment 10-L:

The experiment was completely randomized design with three replications, the treatment composed of control (without bacteria) and bioflocculant-producing (protein or/and polysaccharide) bacterial strains.

Wastewater were distributed in the container 20-Litre containing 10 liters wastewater, inoculated 10 ml bacterial inoculation, adjusted pH=7; put the flasks on the rotary, 60 rpm in 60 sec, after that these flasks were hold on in 1 hour, supernants of each flask were measured flocculating activity. The good bioflocculant-producing (protein or/and polysaccharide) bacterial strains were selected for the 100-L and 1000-L experiments.

2.2.1.3 Heterotrophic nitrogen removal bacteria and poly-P bacteria

The aim of this experiment was selecting of best heterotrophic nitrogen removal bacterial strains

A. Experiment 1-L:

The experiment was completely randomized design with three replications, the treatment composed of control (without bacteria) and heterotrophic nitrogen removal bacterial strains as *Bacillus altitudinis* HNi03DL, *Stenotrophomonas maltophilia* HNa03C, *Enterobacter hormaechei* HAm05C, *Achromobacter xylosoxidans* HNa07B [2]. The experiment was done in 3 days, aeration.

In the poly-P bacteria, the experiment composed of control and *Bacillus megaterium* POLY.P. 064B, with and without aeration, it was done 3 days with three replications.

Ammonium and Orthophosphate were measured by color metric method.

B. Experiment 100-L:

The experiment was completely randomized design with three replications, each treatment was a container 120-litre containing 100 liters wastewater. The experiment divided two stages:

- wastewater treated with bioflocculant-producing bacteria (as described above)
- supernatant treated with heterotrophic nitrogen removal bacteria and poly-P bacteria

Wastewater added with selected bioflocculant-producing bacteria from experiment 10-L of bioflocculant-producing bacteria, inoculated 100 ml bacterial inoculation, adjusted pH=7; aeration by air-pump in 1 hour, after that these containers were hold on in 3 hours, supernatants of each container were transferred to another container, added 50 ml selected heterotrophic nitrogen removal bacteria and 50 ml poly-P bacteria strains from result of experiment 1-L heterotrophic nitrogen removal bacteria and poly-P bacteria, aeration 8/24 h during 4 days (see flowchart) (Figure 1).

C. Experiment 1000-L

The experiment was the same as the experiment 1000-L but container 1200-litre containing 1000 litres wastewater, aeration in 3 hours and held on 21 hours, supernatants of each container were transferred to another container, added 500 ml selected heterotrophic nitrogen removal bacteria and 500 ml poly-P bacteria strains from result of experiment 1-L heterotrophic nitrogen removal bacteria and poly-P bacteria, aeration 8/24 h (two times per day, 4 hours in the morning and 4 hours in the afternoon) during 7 days and wastewaters were transferred other containers containing water-hyacinth (*Eichhornia crassipes*) in 2 days and water samples were collected to measured ammonium, orthophosphate, TKN, TP, TSS, BOD_5 and pH (see flowchart).

2.2.2 Analytical methods

Flocculation was determined by measuring the absorbance of the upper phase of suspension at 550 nm. A control experiment using 0.5 ml of distilled water was used instead of the cultures broth was added to the suspension performed in the same manner and the absorbance was measured. Determination of the flocculating activity and flocculation rate was determined using following formula [19].

$$\text{Flocculating activity} = (1/A - 1/B) \quad (1)$$

$$\text{Flocculation rate (\%)} = B - A \times 100/B \quad (2)$$

A = absorbance of the samples

B = absorbance of the control

NH_4^+-N (Colometric method or Phenol nitroprusside method) [22], BOD_5, Orthophosphate (Colormetric method), TP, TKN and pH (pH meter) were determined by Advanced Analyses Laboratory, Can Tho University, Viet Nam.

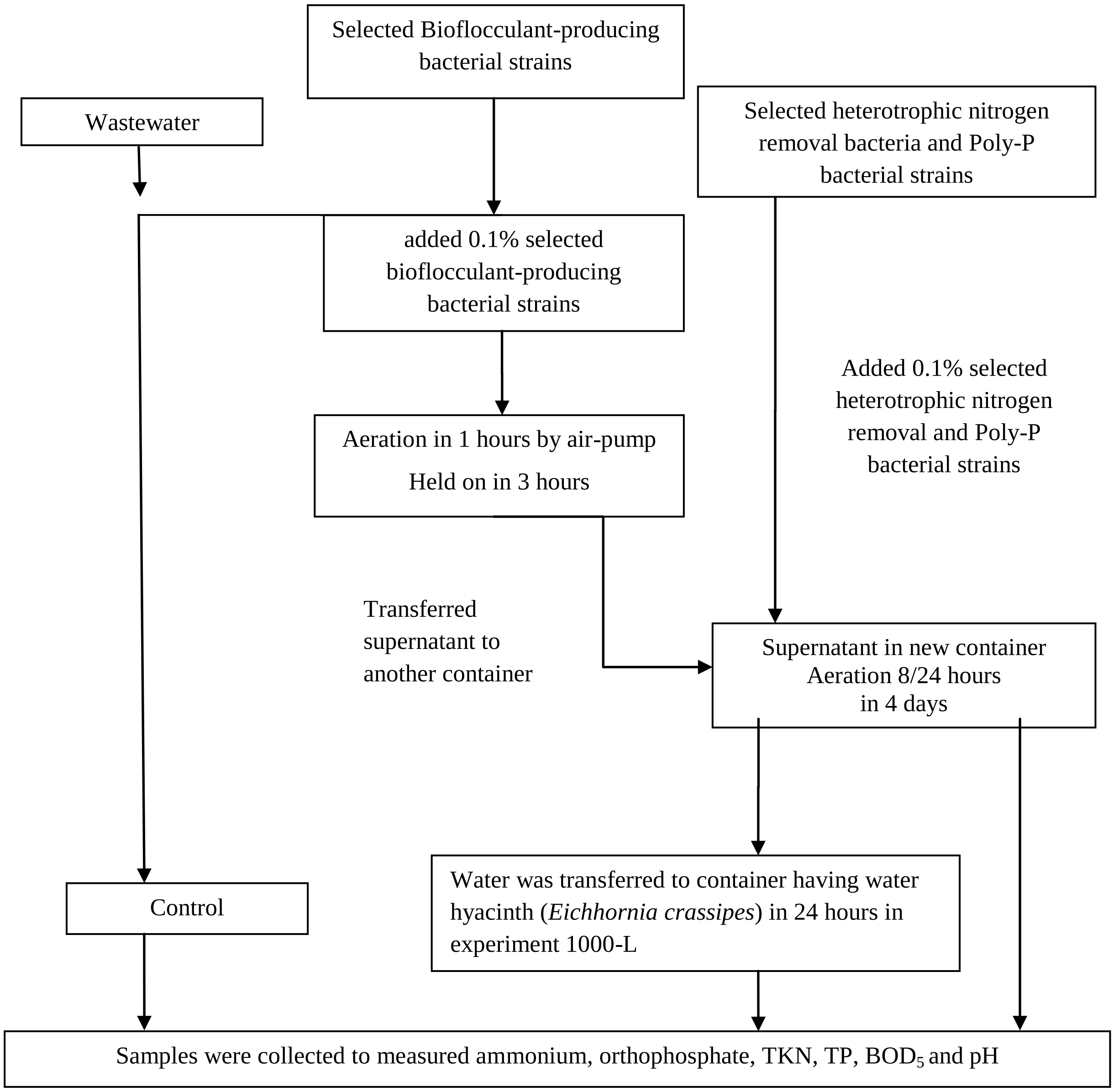

FIGURE 1. Flowchart presented the process of application bacteria and water-hyacinth for rice noodle wastewater treatment

2.2.3 Statistical Analysis

The experiment was analyzed as a two-way ANOVA with the isolates and with levels of flocculating rate (%), N as ammonium, P as orthophosphate. All analyses were conducted using the programme MSTATC, Minitab 16. The data were considered significantly different at $P<0.01$.

III. RESULTS AND DISCUSSION

3.1 Bioflocculant-producing bacteria

3.1.1 100-mL experiment, 1-L and 10-L experiments

The result from figure 2 showed that strains as PRO.07.04, PRO.01.C and PRO.03.B were the best polysaccaride-producing bacterial strains, and PO.01.C was the best protein-producing bacterial strain in comparison to 2 other strains. Combination of two strains [PRO.03.B + PO.01.C] had the highest flocculant rate (%) in comparison to two other combinations (Figure 3).

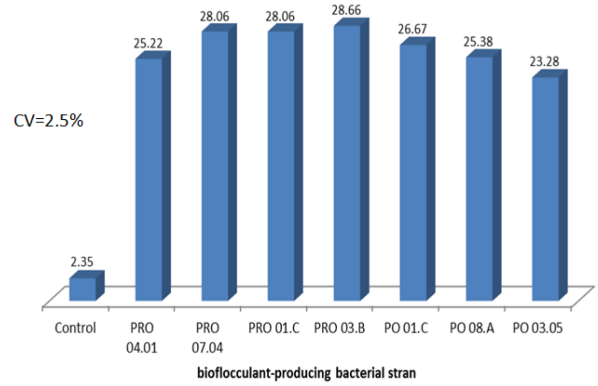

FIGURE 2. Ability of flocculant activity of 7 bioflocculant-producing bacterial strains in rice noodle wastewater

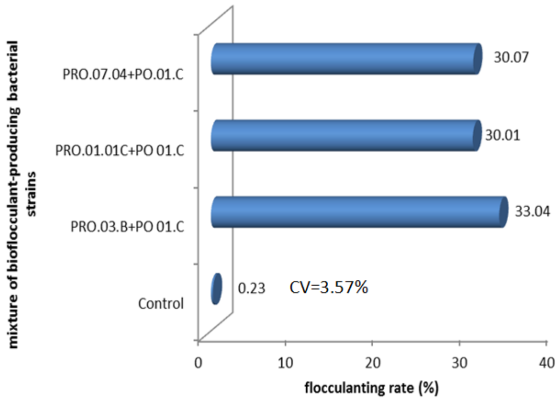

FIGURE 3. Ability of flocculant activity of combination of 2 bioflocculant-producing bacterial strains in rice-noodle wastewater

This combination [PRO.03.B + PO.01.C] applied in wastewater in 1-L and 10-L containers gave good results (Figure 4).

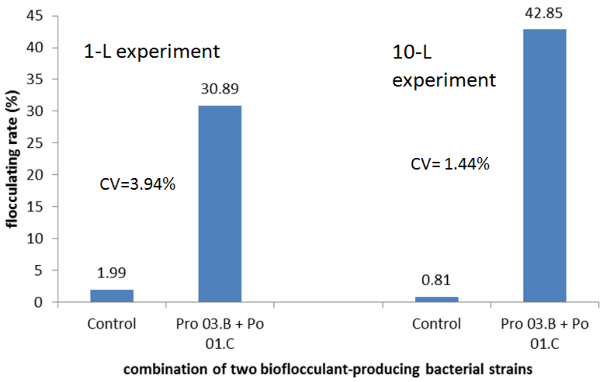

FIGURE 4. Ability of two flocculant- producing bacterial strains PRO.03.B + PO.01.C in the rice-noodle wastewater

The mixture of two strains [PRO.03.B + PO.01.C] was used in the next experiment.

3.2 Heterotrophic nitrogen removal bacteria and poly-P bacteria

3.2.1 Experiment 1-L:

The results from Figure 5 and Figure 6 showed that HNa03C strain reduced ammonium and orthophosphate concentrations in rice-noodle wastewater better than other strains after 3 days aeration continuously.

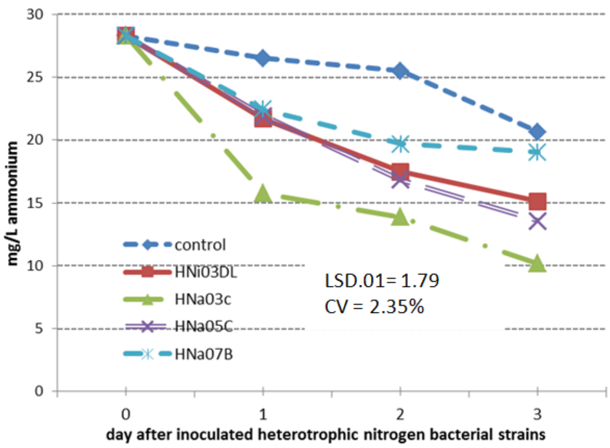

FIGURE 5. Effects of heterotrophic nitrogen on ammonium concentration (mg/L) in rice-noodle wastewater in 1-L experiment

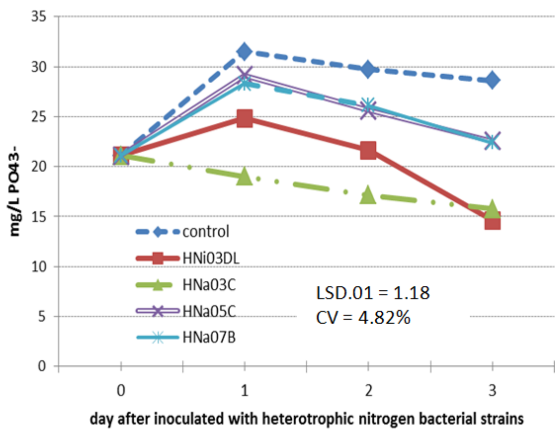

FIGURE 6. Effects of heterotrophic nitrogen on orthophosphate concentration (mg/L) in rice-noodle wastewater in 1-L experiment

In aeration condition, poly-P 064.B strain reduced ammonium and orthophosphate concentrations in rice-noodle wastewater clearly in comparison to without aeration and control (without bacteria) (Figure 7 and Figure 8).

Therefore, two strains, HNa03C and poly-P 064.B were chosen to use to next experiment.

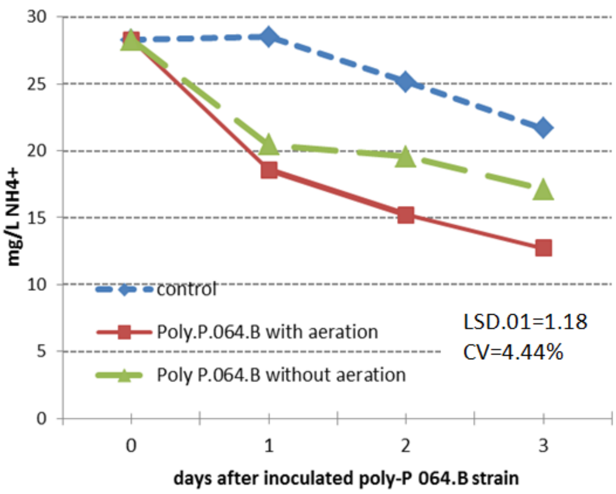

FIGURE 7. Effects of poly-P bacteria on ammonium concentration (mg/L) in rice-noodle wastewater

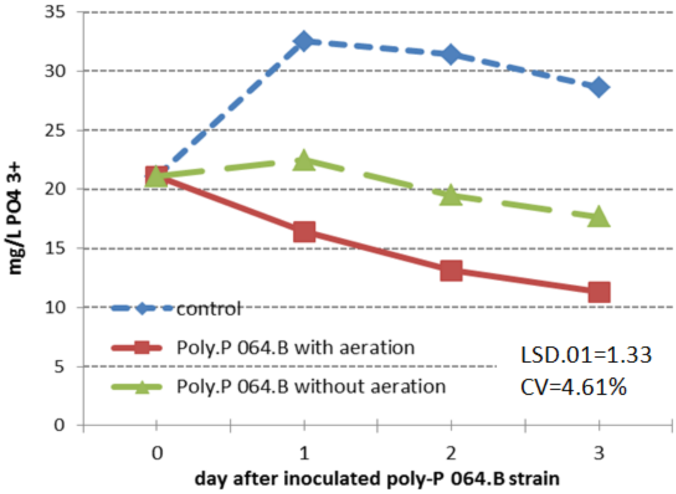

FIGURE 8. Effects of poly-P bacteria on orthophosphate concentration (mg/L) in rice-noodle wastewater

3.2.2 Experiment 100-L:

The result from Table 2 showed that pH of wastewater at initial stage was 3.84 and in control treatment (without bacteria) pH of wastewater increased to 4.61 but adding bioflocculant-producing bacteria and heterotrophic nitrogen removal, poly-P bacteria into wastewater supported pH of wastewater. Total of Suspended Solids (TSS) and Biochemical Oxygen Demand (BOD_5) in wastewater were very high (620 and 950 mg/L, respectively) and TSS and BOD_5 concentration wastewater reduced strongly after 4 days especially in bacterial application treatment, BOD_5 concentration wastewater decreased down one third (in comparison to initial stage). Total Kjeldahl Nitorgen (TKN) in wastewater decreased but total phosphorus (TP) in wastewater increased.

TABLE 2
EFFECTS OF BIOFLOCCULANT-PRODUCING BACTERIA AND HETEROTROPHIC NITROGEN REMOVAL, POLY-P BACTERIA ON PH AND PHYSICAL AND CHEMICAL OF RICE-NOODLE WASTEWATER

Treatment	Initial	control	Bacterial application*	Effectiveness (%) compared to initial
pH	3.84	4.61	6.02	30.56
Total of Suspended Sodids (TSS) mg/L	620	58	55	510.00
Biological Oxygen Demand (BOD_5) mg/L	950	450	300	216.66
Total Kjeldahl Nitrogen (TKN) mg/L	26.7	11.1	10.5	154.26
Total Phosphorus (TP) mg/L	5.4	6.2	17.6	-

biofloccculant-producing bacteria and heterotrophic nitrogen removal, poly-P bacteria

3.2.3 Experiment 1000-L

pH of wastewater in bacteria treatment increased strongly through bioflocculant-producing bacteria stage and heterotrophic nitrogen removal, poly-P bacteria stage from 4.89 to 6.98, after that pH of wastewater reduced slowly (to 6.13) while pH wastewater in control treatment also increased to 5.71 (Figure 9). BOD_5 concentration of wastewater in bacteria treatment reduced strongly in two stages (bioflocculant-producing bacteria and nitrogen removal & poly-P bacteria) (more than 2.4 times compared to initial), in water-hyacinth stage, after that BOD_5 concentration of wastewater almost did not change. In control treatment, BOD_5 concentration only reduced in nitrogen removal and poly-P bacteria stage (Figure 10). The same as BOD_5 case, TSS concentration of wastewater also only reduced strongly in bacteria stage (more than 23.6 times compared to initial).

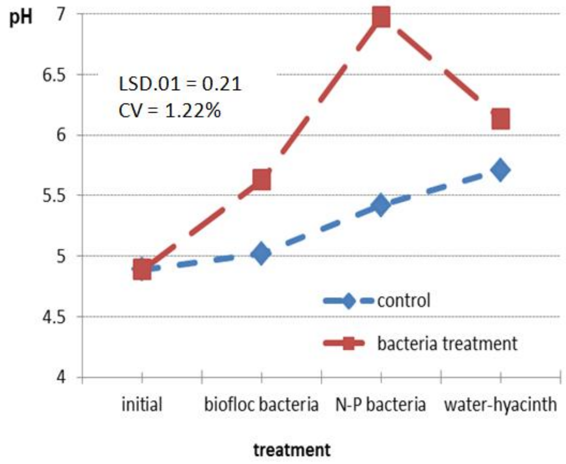

FIGURE 9. Effects of bacteria and water hyacinth on pH of rice-noodle wastewater

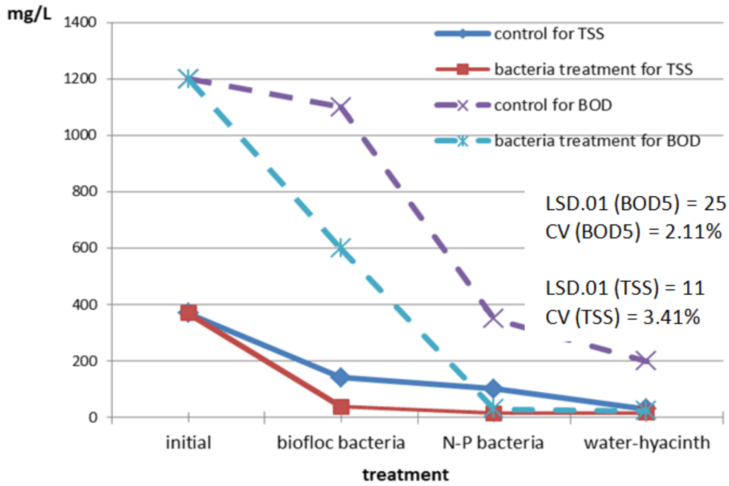

FIGURE 10. Effects of bacteria and water hyacinth on TSS and BOD_5 of rice-noodle wastewater

Application of bacteria in rice-noodle wastewater, TKN concentration of wastewater reduced during 3 stages while TKN concentration of wastewater in control treatment increased in all stages (from 45 mg/L decreased to 7.57 mg/L (reduced 49.44%). Applying bioflocculant-producing bacteria decreased TP concentration of wastewater but adding heterotrophic nitrogen removal, poly-P bacteria increased TP concentration and TP concentration only reduced when wastewater moved into container containing water-hyacinth (in 2 days). On the contrary, TP concentration on wastewater of control treatment only enhanced during 3 stages (from 6.3 decreased to 4.76 mg/L, reduced 32.35%) (Figure 11).

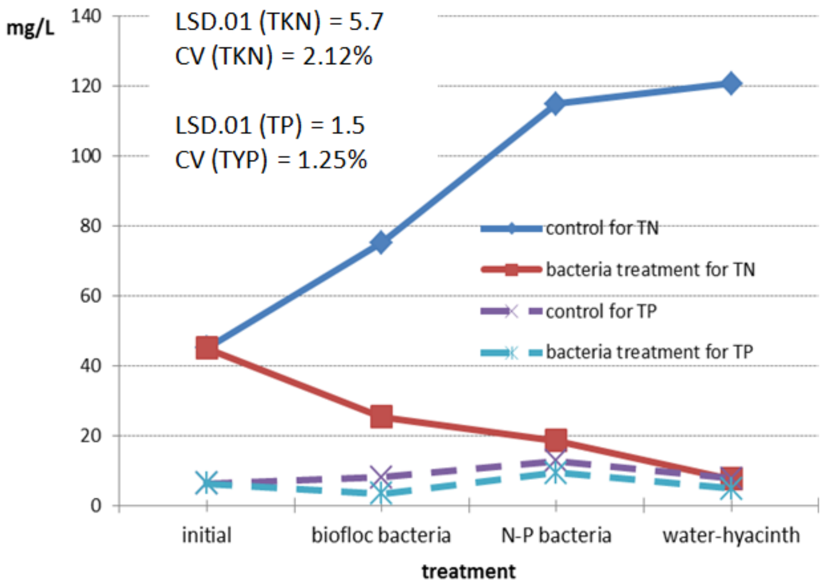

FIGURE 11. Effects of bacteria and water-hyacinth on TKN and TP concentrations of rice-noodle wastewater

Rice-noodle has been used for Thai cooking [23] and many countries in Asia (7). According to Pimpa [23], the manufacture of noodle using rice starch as a raw material produces a large volume of wastewater. The wastewater causes a considerable disposal or treatment problem because of its high biological oxygen demand (BOD) and total suspended solids (TSS).

After cellulose, starch is the second polysaccharide found in nature, produced by plants as reserve material. The main cultivated actually plants for the starch industrially production are cereals, especially corn, followed by wheat and potato [24]. Russ and Meyer-Pittroff, [25] recommend to appreciate the food waste by measuring the specific amount of waste production and determining the “specific waste index” which represent the mass of accumulated waste divided by the mass of the saleable product. Mironescu [26] recognized that starch and protein in wastewaters at potatoes processing worked for pH of wastewater decreased by fermentation of lactic bacteria. In rice-noodle processing, soaking rice for a long time is essential for producing naturally fermented rice-noodles. During this procedure, rice is soaked not only to absorb water, but also to allow natural fermentation to occur. Fermentation is facilitated by various microbes, especially lactic acid bacteria (LAB) [27] and yeast [28].

The effect of LAB and other bacteria during fermentation is a decrease in pH. The rice and soaking water have an initial pH of 7 (neutral) and this decrease to a pH of 4 when fermentation is complete [27] and in this study, pH of the supernatant decreased to 4.68 after 24 hr or 4.13 and 3.48 after 48 hr (Table 1). The main organic acids in the supernatant were lactic acid and acetic acid; Lactic acid was predominant [27], this indicated that some of the LAB involved were heterofermentative [29], pH of supernatant (or wastewater) will be good medium for heterotrophic bacteria releasing H_2S (a kind of not available gas).

Bioflocculant is a kind of biodegradable macromolecular flocculant secreted by microorganisms. Because of their biodegradability, harmlessness and lack of secondary pollution, bioflocculants have gained much wider attention and research to date (12). The actual application of this bioflocculant in rice noodle wastewater dewatering was investigated under a variety of conditions. Bioflocculants are widely useful in the treatment of water and wastewater, in downstream processing, and in processing of food and chemicals (30). In this study, application of bioflocculant-producing bacteria into rice-noodle wastewater supported organic matter solids as starch and/or protein precipitating down bottom. Gong *et al.* [31] observed that flocculating activity (%) reached to over 80% when pH of food wastewater (as meat, brewery, soy sauce brewing and river wastewater) was over 6.0 at 36 hr time with *Serratia ficaria* SF-1 strain. This led TSS concentration in wastewater decreased strongly (Figure 10) and pH of wastewater increased (Figure 9) and this result also helped heterotrophic nitrogen removal bacteria and poly-P bacteria acting effectively to remove nitrogen and orthophosphate out of wastewater (Figure 11). Besides, BOD_5 concentration reduced strongly due to the good action of the group bacteria effectively (Figure 10).

Bacteria with the ability of simultaneous heterotrophic nitrification and aerobic denitrification have been reported periodically [32]. Thus, the conventional nitrogen removal with the cooperation of different microorganisms under different conditions has been challenged. Ample literatures have been published on different strains such as *Pseudomonas stutzeri, Alcaligenes faecalis, Paracoccus denitrificans* and *Thiosphaera pantotropha* [33-35]. This kind of bacteria may have the potential to overcome the problems inherent in the conventional nitrogen removal process. The studies on heterotrophic nitrification and aerobic denitrification have focused on a low ammonium concentration that is discharged from domestic wastewater, and research on the treatment of high-strength ammonium wastewater is rare [36].

Alcaligenes faecalis strain No.4, which has heterotrophic nitrification and aerobic denitrification abilities, was used to treat actual piggery wastewater containing high-strength ammonium under aerobic conditions. In a continuous experiment using a solids-free wastewater (SFW) mixed with feces, almost all of the 2000 NH_4^+–N mg/L and 12,000 COD mg/L in the wastewater was removed and the ammonium removal rate was approximately 30 mg–N/L/h, which was 5–10 times higher than the rates achieved by other bacteria with the same abilities. The denitrification ratio was more than 65% of removed NH_4^+–N, indicating that strain No.4 exhibited its heterotrophic nitrification and aerobic denitrification abilities in the piggery wastewater [37].

Application of *Pseudomonas stutzeri* and *Acinetobacter lwoffii* to remove ammonia in wastewater of biowaste was carried out to evaluate their ability of ammonia removal at different concentrations with and without aeration condition in laboratory condition. The results showed that these species had ammonia removal ability effectively at both 50 mg/l and 100 mg/l ammonia concentrations. *Pseudomonas stutzeri* strain D3b and *Acinetobacter lwoffii* strain TN7 are the best bacterial species to remove ammonia. Besides that, both of species removed ammonia in aeration condition better than non-aeration condition. In three days, the ammonia removal efficiency of *Pseudomonas stutzeri* strain D3b were 97.2% and 98.57% and *Acinetobacter lwoffii* strain TN7 were 96.32% and 98.31% in 50 mg/l and 100 mg/l ammonia concentrations in wastewater of biowaste, respectively [38].

IV. CONCLUSION

Application of bioflocculant-producing bacteria, heterotrophic nitrogen removal bacteria, poly-P bacteria and water-hyacinth treated My Tho rice-noodle wastewater effectively and safety.

Treatment	Initial	control	Bacterial application*	40/2011 Standard (B level) Ministry of Natural Resource and Environment
pH	4.89	5.71	6.13	5.5 – 9.0
Total of Suspended Sodids (TSS) mg/L	369	31	17	100
Biological Oxygen Demand (BOD_5) mg/L	1200	200	23	50
Total Kjeldahl Nitrogen (TKN) mg/L	45.0	120	7.57	40
Total Phosphorus (TP) mg/L	6.3	7.57	4.76	6.0

REFERENCES

[1] B.O. Juliano, and J. Sakurai. "Miscellaneous rice products. In: Rice: Chemistry and Technology. Jouliano, B.O. (Ed.)." American Association of Cereal Chemists, St. Paul, Minnesota, USA, 1985. pp. 569-618.

[2] L.T.Loan, T. V. Phuong, and C. N. Diep. "Isolation and identification of bioflocculant-producing bacteria, heterotrophic nitrogen removal bacteria and poly-phosphate bacteria in wastewater from "My Tho rice noodle" factories, Tien Giang province, Vietnam." International Journal of Innovations in Engineering and Technology (IJIET). Vol. 10(2), 2018,pp. 185-198.

[3] A.P. Vanerkar, S, Sanjeev and S. Shanta. "Treatment of Food Processing Industry Wastewater by a Coagulation/ Flocculation Process." International Journal of Chemical and Physical Sciences. Vol.2, Special Issue 2013, pp. 63-72.

[4] M. GonzalezJ, J.B. Lindamood, and N. Desai. "Recovery of protein from potato plant waste effluents by complexation with carboxymethylcellulose," Food Hydrocoll. Vol. 4(5), 1991, pp. 35-1363, doi:10.1016/S02681 005X(09)8013118

[5] M.J.M., Fari, D. Rajapaksa and K.K.D.S. Ranaweera. "Quality characteristics of noodles made from selected varieties of Sri Lankan rice with different physicochemical characteristics." Journal of National Science Foundation Sri Lanka. Vol. 39, 2011, pp. 53-60.

[6] S. Yoenyongbuddhagal, S. A. Noomhorm. "Effect of raw material preparation on rice vermicelli quality." Starch/Starke. Vol. 54. 2002, pp. 534-539.

[7] B. Rusten, A. Lunder, O. Elde, and H. Odegaard, Water Sci. Tech., vol. 28(2), 1993, pp. 67-76.

[8] T. P. Silva, V Pacheco-Salazar, J.C Sanchez-meza, G. Roa-Morales and A. Colin-Cruz. J of Envi. Sci. and Hlth., Part A, vol. 44, 2009, pp. 108-115.

[9] H.H. Suh, G.S. Kwon, C.S. Lee, H.S. Kim, H.M. Oh, and B.D. Yoon, "Characterization of bioflocculant produced by *Bacillus* sp. DP-152." J. Ferment. Bioeng., vol. 84(2), pp.108-112, 1997. [doi:10.1016/S0922-338X(97)82537-8]

[10] H. Salehizadeh, M. Vossoughi and I. Alemzadeh, "Some investigations on bioflocculant production bacteria." Biochem, pp.39-44, 2000.

[11] I.L. Shih, Y.T Van, L.C. Yeh, H.G. Lin and Y.N. Chang. "Production of a biopolymer flocculant from *Bacillus licheniformis* and its flocculation properties". Bioresource Technology, vol.78 (3), 2001, pp. 267–272.

[12] Y. Li, N. He, H. Guan, G. Du, and J. Chen, "A novel polygalacturonic acid bioflocculant REA-11 produced by *Corynebacterium glutamicum*: a proposed biosynthetic pathway and experimental confirmation." Appl. Microbiol. Biotechnol. vol.52, 1999, pp.698–703.

[13] J.H. Jang, M. Ike, S.M. Kim, and M. Fujita. "Production of a novel bioflocculant by fed-batch culture of Citrobacter sp." Biotechnol. Lett. vol.23, 2001, pp.593–597, 2001

[14] H. Salehizadeh, and S.A. Shojaosadati. "Extracellular biopolymeric flocculants: recent trends and biotechnological importance". Biotechnology Advances, vol.19 (5), 2001, pp. 371-385, 2001.

[15] N. He, Y. Li, and J. Chen. "Production of a novel polygalacturonic acid biofloccualnt REA-11 by *Corynebacterium glutamicum*." Bioresour. Technol., vol. 94(1), 2004, pp. 99-105. [doi:10.1016/j.biortech.2003.11.013]

[16] S. Deng, G. Yu and Y.P Ting. "Production of a bioflocculant by *Aspergillus parasiticus* and its application in dye removal." Colloids and Surfaces B: Biointerfaces, vol.44, 2005, pp.179-186, 2005.

[17] J.Y. Wu, and H.F. Ye. "Characterization and flocculating properties of an extracellular biopolymer produced from a *Bacillus subtilis* DYU1 isolate". Process Biochem., doi:10.1016/j.procbio.2007.05.006.

[18] S. Deng, R. Bai and X. Hu. "Characteristics of a bioflocculant produced by *Bacillus mucilaginosus* and its use in starch wastewater treatment." Appl microbial biotechnol, vol. 60, 2003, pp.588-593, 2003.

[19] R. Hazana, I. Norli,. M. H. Ibrahim, and A. Fazilah. "Flocculating Activity of Bioflocculant Producing Bacteria Isolated from Closed Drainage System (CDS) at the Prai Industrial Zone, Penang, Malaysia." International Conference on Environmental Research and Technology (ICERT 2008), 2008, pp.422 – 425.

[20] C.N. Diep, C. N.**,** P. M. Cam, N. H. Vung, T. T. Lai and N. T. Xuan My. "Isolation of *Pseudomonas stutzeri* in wastewater of catfish fish-ponds in the Mekong Delta and its application for wastewater treatment". Bioresource Technology, vol. 100, 2009, pp. 3787-3791.

[21] L.Q. Khoi, and C. N. Diep. "Isolation and phylogenetic analysis of polyphosphate accumulating organisms in water and sludge of intensive catfish ponds in the Mekong Delta, Vietnam." *American Journal of Life Sciences.* Vol. 1, No. 2, 2013, 61-71. doi: 10.11648/j.ajls.20130102.17 (online). ISSN 2328 - 5737

[22] D.R. Keeney, and D. W. Nelson. "Nitrogen-inorganic forms." In: Page, A.L.R.H. Miller and D.R. Keeney (eds.) Methods of soil analysis. Part 2-Chemical and microbiological properties. (2nd Ed.). Agronomy 9, 1982, pp.643-698.

[23] W. Pimpa. "Potentail Application of wastewater from rice noodle manufacture in α-Amylase production." Suranaree J. Sci. Technol. Vol. 11, 2004, pp.151-157.

[24] H. de Baere. “Starch policy in the European Community”, Starch/Stärke vol. 51(6), 1999, pp. 18-1193, doi: 10.1002/(SICI)15211379X(199906)51:6<189:: AID1STAR189>3.0.CO;21G

[25] W. Russ, and R. Meyer Pittroff. “Utilizing waste products from the food production and processing industries,” Critical Reviews in Food Science and Nutrition. Vol. 44, 2004, pp. 57–62.

[26] M. Mironescu. ”Investigations on wastewaters at potato processing and starch recovery and characterisation” Journal of Agroalimentary Processes and Technologies. Vol. 17(2), 2011, pp. 134-138.

[27] Y. Li., J.F. Liang, M.Y. Yang, J.Y. Chen and B.Z. Man. “Traditional Chinese Rice Noodles: History, Classification and Processing Methods.” Cereal Foods World/ 2015, pp. 123-128.

[28] X.X. Liu. “Reconstruction of rice industry and technical innovation in China (in Chinese)”. Cereal Food Ind. Vol. 14. 2007.pp.1-14,

[29] Z.H. Lu, H.H. Peng, W. Cao, E. Tatsumi, and L.T. Li. “Isolation, characterization and identification of lactic acid bacteria and yeast from sour mifen, a traditional feremntated rice-noodle from China.” J. Appl. Microbiol., vol. 105, 2008, pp. 893-899.

[30] H. Salehizadeh, and S.A. Shojaosadati. “Extracellular biopolymeric flocculants: recent trends and biotechnological importance”. Biotechnology Advances, vol.19 (5), 2001, pp. 371-385, 2001.

[31] W-X. Gong, S-G., Wang, X-F Sun, X-W Liu, Q-Y Yue, and B-Y Gao. “Bioflocculant production by culture of *Serratia ficaria* and its application in wastewater treatment”. Bioresource Technology. Vol. 99, 2008, pp. 4668–4674.

[32] D. Castignetii, and T. C. Hollocher, “Hetetotrophic nitrification among denitrifiers”, Appl. Env. Micro., vol.47, 1984, pp. 620-623.

[33] J. J. Su, B. Y. Liu, and C. Y. Liu, “Comparison of aerobic denitrification under high oxygen atmosphere by *Thiosphaera pantotropha* ATCC 35512 and *Pseudomonas stutzeri* SU2 newly isolated from the activated sludge of a piggery wastewater treatment system”, J. Appl. Microbio., vol. 90, 2001, pp. 457-462.

[34] H. S. Joo, M. Hirai, and M. Shoda, “Characteristics of ammonium removal by heterotrophic nitrification-aerobic denitrification by *Alcaligenes faecalis* No.4.”,J. Biosci. Bioeng., vol.100, 2005, pp.184-191.

[35] A. H. Stouthamer, A. P. N. de Boer, J. van der Oost, and R. J. M. van Spanning, “Emerging principles of inorganic nitrogen metabolism in *Paracoccus denitrificans* and related bacteria”, Antonie van Leeuwenhoek, vol.71, 1997, pp. 33-41.

[36] Gupta, A. B. and Gupta, S. K. “Simultaneous carbon and nitrogen removal from high strength domestic wastewater in anaerobic RBC biofilm.” Water Res., vol. 35, 2001, pp. 1714–1722.

[37] H-S. Joo, M. Hirai, and M. Shoda1.”Characteristics of Ammonium Removal by Heterotrophic Nitrification-Aerobic Denitrification by *Alcaligenes faecalis* No. 4”. J. of BIOSCIENCE and BIOENGINEERING. Vol. 100,(20), 200p, pp. 184–191.

[38] C.N. Diep, and N. T. H. Nam. “Ứng dụng vi khuẩn *Pseudomonas stutzeri* và *Acinetobacter lwoffii* loại bỏ amoni trong nước thải từ rác hữu cơ.” Tạp chí Khoa học Trường Đại học Cần Thơ 22b: 2012, pp. 1-8. (Vietnamese)