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ENERGY RECOVERY FROM ACTIVE SLUDGE OF WASTEWATER TREATMENT PLANTS

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ABSTRACT

Due to fast growth of industrial sector, the volume of sludge from wastewater treatment systems increases, and this becomes a big problem to the environment. The cost for treatment of sludge is high and requires typical landfill for disposal. This study suggested recovering energy from the sludge of wastewater treatment plants through an anaerobic fermentation process. Sludge from wastewater treatment plants of fish processing factory (C) and shrimp processing factory (T) were collected for the testing of this study. The 20 L lab-scale batch anaerobic digesters were used to ferment sludge which has different humidity of 85 - 90 % and of 95 - 98 %. The biogas yield of the treatment C 85-90 is 305.3, C 95-98 is 444.2, T 85-90 is 144.4, and T 95 - 98 is 171.1 L/kg $ODM_{fermented}$. After 10 operation days, the percentage of CH_4 in the produced biogas was around 50 % which is high enough for energy purposes. The result clearly confirms that sludge from wastewater treatment plants not only is possible treated in anaerobic digesters but also is able to be applied as input material to produce biogas for energy consumption.

Keywords: batch anaerobic digestion, fish processing factory, sludge wastewater treatment plants.

1. INTRODUCTION

Due to the advantage of natural conditions, fishery and aquaculture are considered as major career for local people in the Mekong River Delta [1]. In 2014, production from fisheries and aquaculture reached 2.92 million tons and 3.41 million tons [2], in which shrimp and catfish are two of the major aquatic products in the region. Currently Vietnam's fishery products are available in more than 120 countries and territories in five continents with earned exports around $7.84 billion in 2014 [3]. In line to this fact, such of fish and shrimp processing enterprises were established in all overthe Mekong Delta's provinces. By employing 9 % of labour source (~ 3.4 million workers), Vietnam becomes one of top ten countries for aquaculture export. However, besides the economic benefits from aquaculture exporting, aquaculture processing factories discharge a huge volume of wastewater, which contains polluted parameters. According to Circular No. 77/2015/TT-BTNMT issued by the Vietnam's Ministry of Natural Resources and Environment stipulating the national technical regulation on the effluent of aquatic products processing industry, aquaculture processing factories must treat their wastewater to reach QCVN 11-MT:2015/BTNMT before discharging the wastewater into surrounding watersources. Then the sludge produced from aquaculture processing has to be treated to meet the National technical regulation on hazardous thresholds for sludges from water treatment process QCVN 50:2013/BTNMT.

A big barrier that affects building wastewater treatment system at aquaculture processing factories is high investment, operation and maintenance cost. Because of this barrier aquaculture processing factories often build a simple wastewater treatment system or they operate the system occasionally. Moreover, aquaculture processing factories mainly install wastewater treatment systems with aeration biological component, which produce more sludge. The sludge highly contains organic matters, nitrogen and phosphorus, which are suitable for anaerobic fermentation. This study suggested an integration of anaerobic digestions into wastewater treatment systems to treat the sludge generated from fishery and aquaculture processing through anaerobic fermentation process. This is a new approach that could bring dual benefits of anaerobic digesters as it can be a solution to both sludge crisis and energy recovery.

2. METHODOLOGY

2.1. Material preparation

According the real situation from aquaculture processing factories, almost issued sludge colleting in two places: from sedimentation tank (after aeration process), and from the sludge dehydrator. So the sites for sludge collection will be:

- Sludge from fish processing wastewater treatment system, in which C 95-98 was sludge collected from sedimentation tank with humidity of around 95 - 98 % and C 85-90 was sludge collected from sludge dehydrator with humidity of around 85 - 90 %.

- Sludge from shrimp processing wastewater treatment system, in which T 95-98 was sludge collected from sedimentation tank with humidity of around 95 - 98 % and T 85-90 was sludge collected from sludge dehydrator with humidity of around 85 - 90 %.

Table 1. The initial components of testing sludge

Parameters	T 85-90	T 95-98	C 85-90	C 95-98
TP (mgP/L)	4639.6	2971.5	1812.2	1154.9
COD (mg/L)	84000.0	60800.0	70400.0	15200.0
BOD_5^{20} (mg/L)	5360.0	2760.0	3040.0	1680.0
TKN (mg/L)	872.2	306.6	784	500.5
C (mg/L)	36.4	35.5	44.4	39.4
N (mg/L)	1.0	1.3	2.6	5.2

2.2. Experiment set-up

The experiments were conducted in batch system of the 21 L digesters which were made from plastic. The cap of each bottle was drilled to make a hole to install a plastic pipe which transport generated biogas to a containing aluminium bags. Each digester was loaded with 18 L sludge, while 3 L left for gas production. All digester was shaken daily to avoid formulation of scum and at the same time to improve fermentation condition. The experiments were carried out based on the various humidities of sludge: C 95-98, C 85-90, T 95-98, T 85-90. The experiment fomulae were random assigned with three repetitions.

2.3. Recorded parameters

The temperature of the substrate was recorded every three days through monitoring pipe by a medicine thermometer.

The biogas produced was collected every three days to measure total volume (by Ritter gas-meter) and the gas compositions (by Biogas Pro 5000).

The substrates were collected at input and output pipes everyday to analyze for TVFA values by HPLC equipment, and collected every five days to analyze for BOD_5, COD, TKN, TP, and total *Coliform* according to the procedures suggest by standard methods [5]. All experiences were processed at Biogas Laboratory, College of Environment & Natural Resources - Can Tho University.

3. RESULTS AND DISCUSSIONS

3.1. Control parameters

The temperature of substrate from the treatments ranged from 26.5 - 33.0 ^{o}C, which was rather lower than the outside temperature. The temperature from this study was suitable for the development of thermopholic condition of 20 - 40 ^{o}C [6]. Due to small volume of the digester, the temperature of substrate inside the digester easily adapt to the outside temperature. However, in case of using a digester with a big volume or the digester buried into the ground, there will be less effect from outside temperature into the substrate's temperature.

At the first ten days, TVFA values from almost treatments were higher than the TVFA values of the later days. This fact is inline with the stated of McCarty (1964), at the first phase of anaerobic fermentation process, the hydrolysis condition is dominated and bacteria transform the particulate organic substrate into liquefied monomers and polymers, while carbohydrates and fats are transformed to amino acids, mono-saccharides and fatty acids [7].

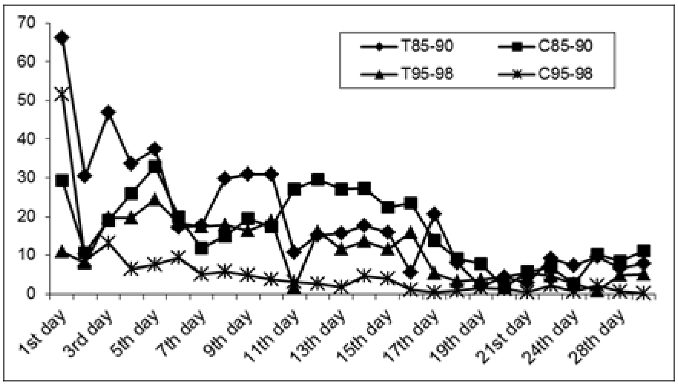

Figure 1. TVFA values of treatments.

3.2 Biogas production

In the first steps of hydrolysis and acidogenesis in fermenation process, the soluble organics transformed into volatile fatty acids which caused low pH in the substrate and had negative effects to the activity of methanogenic bacteria. This fact explains for less of gas produced in the first 5 days of the study, only from 2.7 - 12.1 L from each treatment. On the 8th day the gas produced was maximum at the treament T 85-90 (6.9 L) and the treament C 85-90 (12.1 L); while the maximum gas production of the treament C 95-98 (3.5 L) happened on the 14th day and the treatment T 95-98 (2.47 L) on the 17th day. The lower humidity is, the shorter time for gas produces. From the 20th day, all treatments produced less gas, slightly change from 1.2 - 4.5 L due to less organic remained in substrate. The figure also shows that the hydraulic retention time of anaerobic digestion sludge could be around 14 days.

The biogas yields from treatments of C 95-98, C 85-90, T 95-98 and T 85-90 were 444.2 L, 305.3 L, 171.1 L, 144.4 L/kg $ODM_{fermented}$, respectively. The biogas yield in this result was lower than the biogas yield from another study of Carvalho *et al*. (2010). By added micro-organism (around 480 mL/L) to waste sludge which collected from fish processing factory, the biogas production from sludge up to 1069 L/kg VS [8]. Yet the micro-organisms in this study grew by themselves.

The sludges with high humidity of 95 - 98 % produced more gas than the lower humidity ones of 85 - 90 %. Actually, high humidity sludges are fresh sludges which are just sedimented in sedimentation tank and remain rich of nutrients and organic matters. Meanwhile low humidity sludges are older sludges which are processed by sludge dehydrator.

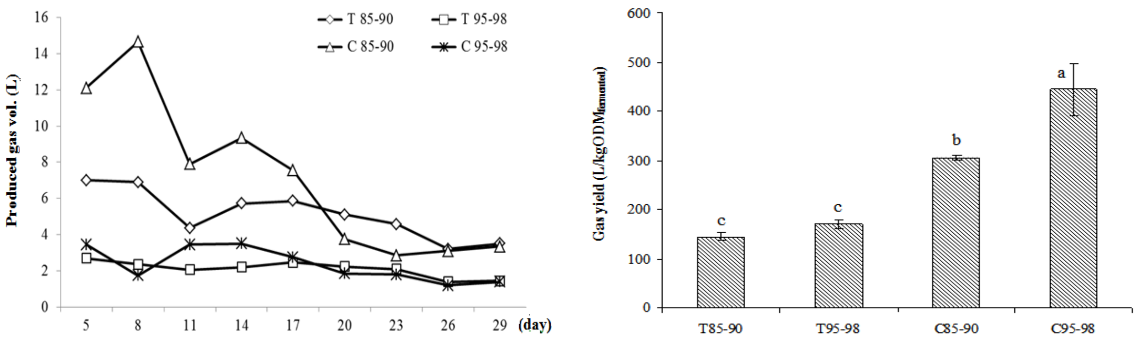

Figure 2. Trend of biogas production (left) and biogas yield from treatments (right).

The biogas yield from the treatment of aquaculture processing factory was lower than that of fish processing factory. This result could be due to the salinity remained in the aquaculture raw materials the factory brought. Within the substrate containing more than 10 g/L of salinity, the methanogenis bacteria could not grow well to produce biogas [9]. Thus, it is needed to test for salinity content in the wastewater of aquaculture processing factory in case a anaerobic digester is combined to the processing system.

3.3. Gas composition

In the first 10 days, the CH_4 composition of treatments with humidity of 95 - 98 % was very low (18.3 - 34.8 %), while %CH_4 ranged from 50.3 - 53.7 % of treatmens with humidity of 85 - 90 %. Even at the same time, the biogas produced from treatments with humidity of 95 - 98 % was higher than that of 85 - 90 %. The reason could be the fresh sludge in treatments of 95 - 98 % humidity needed more time to adapt to new anaerobic conditions and to increase the density of methanogenis bacteria inside the digester.

From the 11th day, the percentage of CH_4 from all treatments ranged from 46.8 to 57.6 %, which was high enough for energy purposes such as cooking. However, other studies mentioned that the CH_4 composition of biogas could be ranged from 57.8 to 60.0 % [10, 11]. The difference in CH_4 composition could be due to the difference of components from input materials.

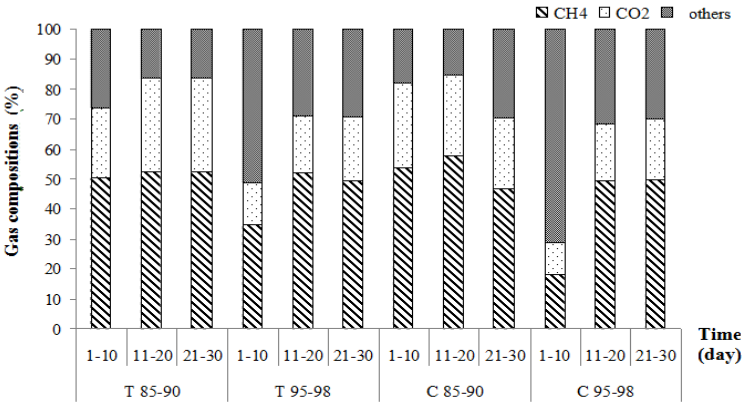

Figure 3. Biogas compositions.

3.4 Sludge treatment efficiency

Anaerobic fermentation process not only creates biogas for energy using purposes but also reduces pollutted parameters from sludge. In this study, the sludges were collected (on the 1st day, 5th day, 10th day, 15th day, 20th day, 25th day, and 30th day) and analysed for BOD_5, COD, TKN, TP, and total Coliform (this parameter was analysed only on the 1st and 30th day).

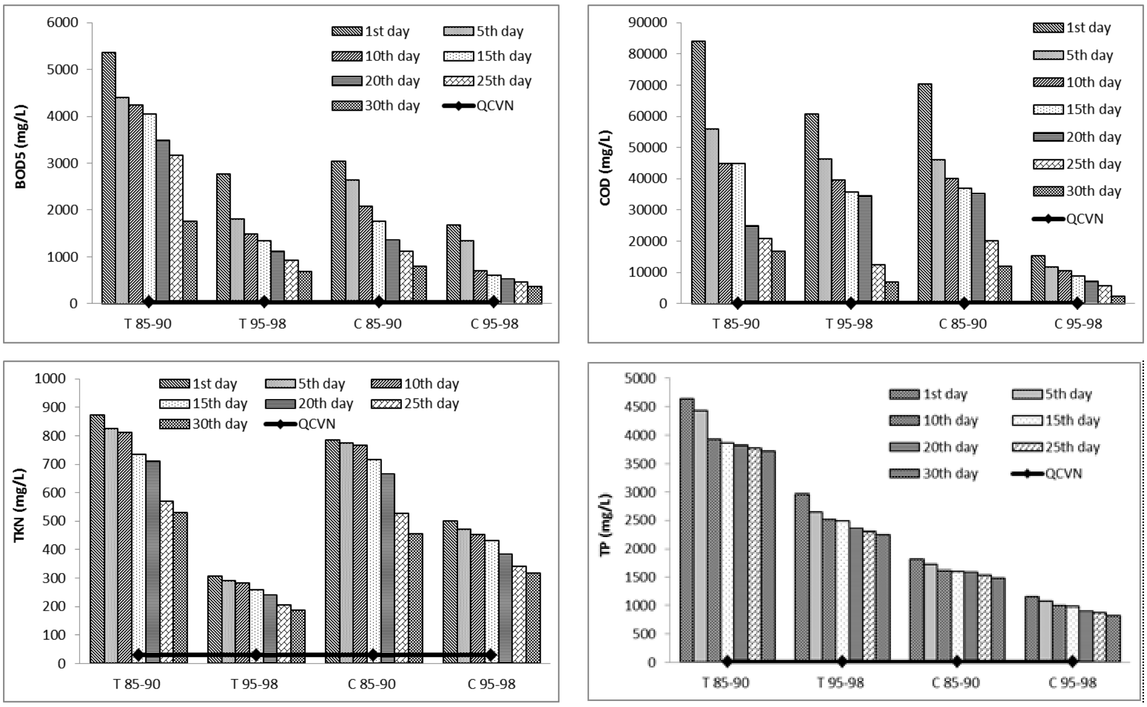

Figure 4. Trends of polluted parameters in treatments.

The results show that all polluted parameters reduced after fermented through anaerobic process, but the treatment efficiency was different between the parameters. The highest treatment efficiency of total *Coliform* was 99.5, 94.2, 99.2, and 99.7 % for treatment of C 95-98, C 85-90, T 95-98, T 85-90, respectively; followed with COD (84.2, 88.8, 82.9, and 80.0 %), BOD_5 (78.6, 75.4, 73.7, and 67.2 %), TKN (36.6, 38.8, 41.8, and 39.2 %) and TP (28.3, 18.1, 24.0, and 19.7 %).

In comparision to the national technical regulation on effluent of aquatic product processing industry, all the polluted parameters were higher than the standard values of wastewater; therefore, the treated sludge should not discharge directly into open water sources. However, some studies reported that effluent from anaerobic digester or anaerobic co-digester could apply as organic fertilizers for both agriculture and aquaculture cultivation [12].

4. CONCLUSIONS AND RECOMMENDATIONS

The testing of applying anaerobic digestion process as an additional step to a wastewater treatment system at aquatic product processing factories showed the following results:

- The biogas yield after 30 days of treatments with sludge from fish processing factory was from 305.3 to 444.2 L/kg $ODM_{fermented}$ in treatment of C 95-98 and of C 85-90. The yield was higher in the treatment with high humidity content.
- The CH_4 composition from the 11^{th} day onward was from 49.4 to 57.6 %, which is good for energy using purposes.
- The treatment efficiency was good, but the quality of the treated sludge could not meet the standards to discharge directly into open water sources.

The intergation of an anaerobic digestion into wastewater treatment systems of fishery and aquaculture processing factories can bring environmental and economic benefits. It can help recover energy from sludge discharged during the processing while its by-product, the effluent, can apply as organic fertilizer for gardening.

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