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Integrated Biogas-Microalgae from Waste Waters as the Potential Biorefinery Sources in Indonesia

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Abstract

Microalgae can produce not only bioenergy (e.g. bioethanol, biodiesel, biogas, and hydrogen) but also other value products (e.g. paraffin, olefin, glycerol, protein, anti-oxidant, pigment, plastic, etc.). To reduce the production cost, we could utilize the waste water streams as the growth medium. Microalgae cultivation can also be integrated with biogas system from agricultural waste waters (e.g. tapioca waste, palm oil mill effluent, and other agricultural wastes).

Keywords: microalgae; biogas; biorefinery; bioproduct; waste water

Nomenclature

BOD	Biological Oxygen Demand
COD	Chemical Oxygen Demand
CPO	Crude Palm Oil
GHG	Green House Gas
POME	Palm Oil Mill Effluent

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1. Introduction

The Indonesian agricultural industries have grown rapidly and become one of the strongest agricultural industries in the world. Unfortunately, the waste water streams from these industries have not been fully utilized. The COD and BOD levels are still significantly high. Thus, it will give bad impact to environment local community.

The waste water production from the agricultural processes can be treated by microalgae cultivation. Biotreatment will reduce the investment and operating costs compared to conventional chemical and mechanical waste water treatments. It will definitely reduce BOD levels, heavy metal contents, and other pollutant values significantly.

Moreover, waste water from agricultural processes also can be converted into biogas. This will reduce COD level from the waste water and reduce contamination from the evaporated methane and other Green House Gases (GHGs). The biogas production can be cleaned and expected can be used for electricity generation, heating supply, and biofuel production (e.g. compressed biogas, cooking stove).

In palm oil industry, for instance, this industryis currently moving towardseither harnessing biogas from POME or producing value-added products such as fertilizer which avoids methane generation.This move is visible with the gradual annual increase in the number of palm oil mills capturing biogas [1]. While the biogas itself consists of about 65% CH_4, 35% CO_2, and traces of H_2S [2].

The integration between microalgae cultivation and biogas production is a unique symbiosis mutualism. Microalgae need carbon source that can be supplied from the excess carbon dioxide from biogas. More green products and clean energies (i.e. biofuel and bioenergy) can be produced from this integration system. Therefore, the integrated microalgae-biogas in waste water could be one of the options for the potential biorefinery sources [3].

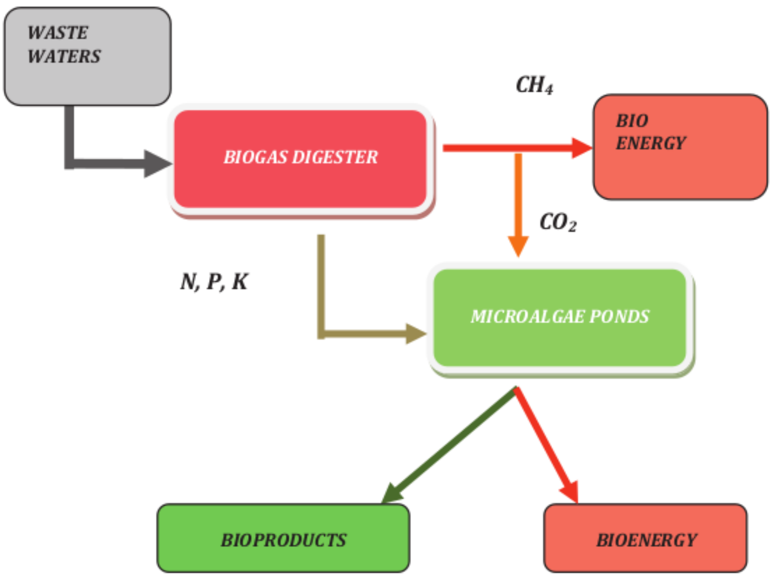

Fig. 1. Integrated biogas-microalgae system from waste waters.

2. Biochemical composition

Microalgae contain mainly protein, carbohydrates, and lipid (see Table 1). Protein serves as the building block for the syntheses of proteins and other cellular macro molecules. Carbohydrates compound have been used as carbon and energy source. Lipids have been used as membrane components, storage products, metabolites, and sources of energy [4].

Table 1. Biochemical composition in some microalgae [4].

Microalgae strain	Protein (%)	Carbohydrates (%)	Lipids (%)	Nucleic acid (%)
Scenedesmusobliquus	50 – 60	10 – 17	12 – 14	3 – 6
Chlamydomonasrheinhardii	48	17	21	-
Chlorella vulgaris	51 – 58	12 – 17	14 – 22	4 – 5
Dunaliellabioculata	49	4	8	-
Spirulina maxima	60 – 71	13 – 16	6 – 7	3 – 4.5

Biogas itself is an intermediate product that produced by biological degradation of the organic matter using bacteria in anaerobic environment. The decomposition process is divided into four steps (see Table 2). Each of them is accompanied by different bacteria groups. The methanogenic bacteria are the main driven for methane production. There are several types of methanogenic bacteria: *methano bacterium*, *methano bacillus*, *methanococcus*, and *methanosarcina*. Each of them can grow in a specific environment condition. If they could not meet the optimal condition, growth may at a lower rate or the bacteria may die, depending on species and conditions [4].

Table 2. Decomposition process steps of biogas production [4].

Process	Bacteria involved	Output
Hydrolysis (Step 1)	Anaerobic hydrolysis bacteria	Monosaccharide, amino acids, and fatty acids
Acidity increased (Step 2)	Acids former bacteria	Organic acids and carbon dioxide
Acetic acid formation (Step 3)	Acetic acid bacteria	Acetic acid, carbon dioxide, and hydrogen
Methane formation (Step 4)	Methanogenic bacteria	Methane

3. Technology concept

Currently we are constructing a pilot project for the integrated biogas-microalgae system from Palm Oil Mill Effluent (POME). The produced carbon dioxide will be used for the carbon supply during the photosynthesis of microalgae.

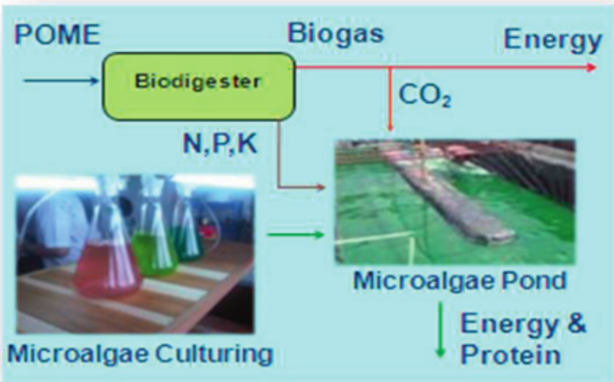

Fig. 2. Integrated biogas-microalgae system from POME.

POME is well known one of the main aquatic pollution sources. This is due to the fact that it has high content of COD value Table 3). Indonesia is the biggest Crude Palm Oil (CPO) producer in the world with more than 16 million tons CPO per annum. Each ton palm oil fruit will produce approximately 0.2 ton of CPO and 0.6 ton of POME. Thus, Indonesia has high threat for POME pollution [3].

Table 3. Typical characteristics of Palm oil mill effluent (POME) [3].

Parameters	Value	Unit
pH	4 – 6	-
COD	50,000	mg/L
BOD	25,000	mg/L
Total solids	40,500	mg/L
Total nitrogen	750	mg/L
Phosphor	180	mg/L

In terms of POME utilization for bioenergy and bioproducts, integration of CO_2biofixation and waste water treatment concept can be used. Biofixation is a process to reduce CO_2 concentration at the atmosphere using a biological process. Microalgae are currently used for biofixation of flue gas since it has ability to absorb CO_2. Due to microalgae ability to capture nutrient in the waste water, the POME treatment can be integrated with microalgae cultivation.

Other pilot project will be constructed soon in this year to utilize waste water from a tapioca plant. Tapioca plant is highly potential for microalgae cultivation and biogas production. In Lampung, there is a tapioca plant that already produced biogas for electricity generation. It becomes interesting to integrate this running facility with microalgae cultivation.

4. Result and discussion

Three microalgae strains have been selected and used for cultivation: *Spirulina sp.*, *Chlorella sp.*, and wild algae. *Spirulina sp.* can be used as protein source (i.e. fish, shrimp, and cattle feed) while *Chlorella sp.* can be used as bioenergy source (i.e. bio-oil/biodiesel). The wild algae have been used for the pre-treatment of the waste waters before *Spirulina sp.* and *Chlorella sp.* can be cultivated in that medium. Other strains can be investigated later on for other bioenergy targets (e.g. bioethanol, hydrogen, etc.).

In this research, the result is more focusing on the microalgae cultivation itself. The biogas production has not been integrated in a bigger scale. The original target is to produce 1 MWe from the produced biogas next to the microalgae cultivation ponds. Due to unreliable feedstock condition, this biogas plant has not been constructed in this year. It is expected in the coming year, this commercial biogas plant will be built. A small biogas model, has been constructed earlier to show that the integration between biogas-microalgae can be realized. In fact, it is also well-know that the biogas production will produce CO_2 as the by-product. This CO_2 can be used for microalgae as the building block for their biomass via photosynthesis process.

Microalgae can easily growth (Fig. 3) in fresh water, saline water, and waste waters (e.g. POME and mixed of POME and rubber waste). The growth speed of microalgae strain (*Spirulina sp.*) depends on the growth medium (Fig. 3). The growth of this strain in the saline water is the highest one. It follows by fresh water, POME, and mixed of POME-rubber waste respectively. The saline water is the original growth medium of *Spirulina sp.* By special culturing and pre-treatment methods, *Spirulina sp.* can also be cultivated in the waste waters.On the other hand, The *Chlorella sp.* growth at waste water medium 20% POME has the highest biomass content compared to other concentrations. The biomass forming and the lipid content of *Chlorella sp.* in various waste water concentrations can be seen in Fig. 4.

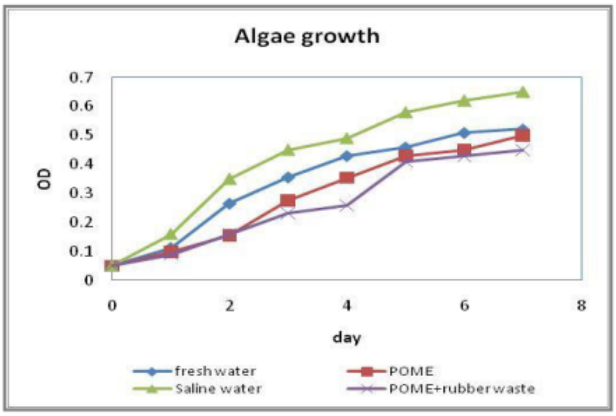

Fig. 3. Growth of Spirulina sp. in various medium of waste waters.

This research was conducted in various waste water concentrations to find the optimum growth medium for microalgae strain subjects. POME was the most extreme waste waters that have been tested. Moreover, various nutrient concentrations to achieve the optimum production rate was observed.

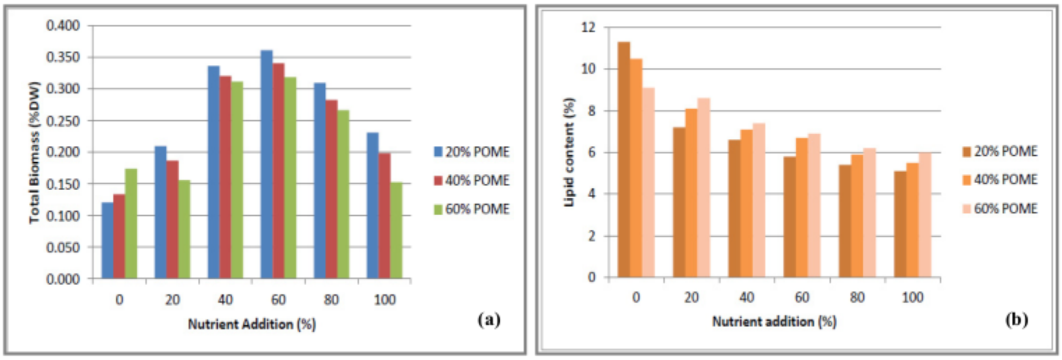

Fig. 4. Biomass forming (a) and lipid content (b) of Chlorella sp. in various medium of waste waters.

In this research, the COD and BOD reduction by introducing wild algae in the waste water had been investigated. They had been compared in various volume ratios, as shown in Table 4.

Table 4. BOD and COD reduction in various volume ratios of microalgae.

Volume ratio (POME : microalgae)	BOD (*mg/L*)	COD (*mg/L*)
1:1	79.00	330.00
1:2	89.53	368.33
1:3	84.27	388.33
1:4	61.66	173.33
1:5	65.58	181.67

5. Conclusion

Integration of biofixation and waste water treatment considered as the most efficient and cost effective ways to reduce agricultural waste pollutions. Bioenergy and bioproduct can be recovered from the waste treatment. There are various microalgae can be used to reduce waste water pollution, depending on the waste water quality (e.g. pH, COD, BOD, etc.).

Palm Mill Oil Effluent (POME) is the most extreme waste water compared to other waste waters. The high COD value in POME can be converted into biogas production. Recently, the biogas system from POME has been utilized in several palm oil mills in Indonesia. Based on our findings, it is also possible to integrate the biogas system with microalgae cultivation. The microalgae can growth in different POME concentrations. The integration of biogas-microalgae from POME will bring additional benefits for the palm industry, local community, and environment. Thus, a sustainable production in palm oil industry can be established.Other waste waters, with high COD values, could also be converted into biogas. Further research observation is needed before an integration system of biogas-microalgae could be implemented.

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