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Preliminary Studies of Biorefinery: Integration of Slurry and CO_2 Gas as Biomethane Digester Waste for Microalgae *Scenedesmus* sp. Growth

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ABSTRACT

Bio-methane as renewable energy can generate slurry waste and CO_2. Utilization of slurry has been examined in previous studies. Slurry digester which is made from seed cake *Jatropha curcas*, JatroMas cultivars can improve the growth of microalgae *Scenedesmus* sp. compared to standard media. CO_2 gas as a biochemical process in the digester is the impurities to be minimized. A number of purification or enrichment technologies have been available for CO_2 capture in order to improve the bio-methane quality. But adsorbs and / or chemical or physical absorption technology is relatively expensive. Microalgae reportedly are able to reduce CO_2 levels in flue gas factory. Even the exhaust gas is spurring the microalgae growth. Related to this, a preliminary study has been conducted in ability of microalgae *Scenedesmus* sp. for CO_2 capture in bio-methane. The study was conducted at the microalgae Laboratory of SBRC - IPB (Surfactant Bioenergy Research Center - Bogor Agricultural University) Indonesia in March-April 2011. *Scenedesmus* sp. was cultivated in 1 000 mL erlenmeyer compared to standard medium as the control solution of 50 % slurry seed cake JatroMas cultivars. Bio-methane gas was inserted into the bottom of the erlenmeyer. Biomethane that came out from *Scenedesmus* sp. media was captured in the gas holder. Observation of *Scenedesmus* sp. growth curves has carried out in accordance, while medium levels of CO_2 measurement is conducted with simple apparatus orsat. Studies were arranged in CRD, with three replications. The result showed that rate of *Scenedesmus* sp. growth in slurry is higher than the control for 0.10/day. The highest peak is in the seventh day of growth for 2.65×10^6 cells / mL. The average of bio-methane CO_2 levels in slurry is lower than the control which is 21 % compared to 24 %. It can be concluded that the integration of slurry and CO_2 gas waste from bio-methane digester that made from seed cake *Jatropha curcas* can spur *Scenedesmus* sp. growth.

Keywords:
Biorefinery, biomethane/ biogas, *Jatropha curcas* seed cake, microalgae *Scenedesmus* sp., CO_2 capture

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1. Introduction

Soerawidjaja [1,2] said that the world is on transition from fossil-based economy in 20th century into bio-based economy because oil is getting more expensive and rare and also quality of the environment is getting worst. Bio resources in bio-based economy are not only food and feed resources but also provide energy and industrial products. Bio-methane / biogas that produced from anaerobic digestion technology will take a part in all scenario of renewable energy or bio-based economy because it can provide fuel or electricity. It can be applied on small scale (lighting, stove fuel and small medium enterprise in village) or medium and big scale (electricity for industry, steam energy generator, gas pipeline and gas fuel for vehicle). It is also can provide raw material for chemical industry (propionate acid, butyrate acid, valerate acid which can be used as raw material for making propane, butane and pentane alcohol).

Bio-refinery is management based on zero waste. Waste of a process can be feed stock for another process with the purpose to increase efficiency [3]. Bio-methane that produced from anaerobic digestion is bio-refinery process because it applies reuse and recycling of waste like manure or agricultural industry waste (plantation, husbandry, forestry, fishery and farming). The positive impact of bio-refinery digestion technology is reported by Hasanudin and Haryanto [4] in Self Sufficient Village, Way Isem, North Lampung that there is increase in farmer income by usage of Jatropha curcas seed cake as bio-methane raw material. In relation with energy efficiency, Soerawidjaja [1] and Sivasamy *et al*. [5] said that bio-methane is most efficient biomass conversion process.

Bio-methane process produces wastes such as slurry, sludge and CO_2 gas. Some research has expressed positive impact of slurry and sludge as organic fertilizer and animal feed. Kawaroe *et al*. [6, 7] reported a positive impact of the usage of digester slurry with Jatropha curcas seed cake as raw material for microalgae growth media. Kawaroe *et al*. [6] said that digester slurry with *Jatropha curcas* cultivar JatroMas as raw material is capable to support the growth of microalgae *Scenedemus* sp.

Microalgae are 3rd generation of renewable energy source. Microalgae cultivation does not compete with food crop and feed because it does not require land, microalgae growth speed is 50 times than crop, microalgae biomass can be two times in 24 h, microalgae efficiency is 20 % compared to crop efficiency which is only 0.5 % and microalgae processing is categorized into green process and green product. Those positive descriptions can be achieved if microalgae photosynthetic growth can be supported by water, light, inorganic salt and carbon dioxide [8, 9].

Verina [10] reported positive impact of microalgae *Botryococcus braunii* growth with input of carbon dioxide (CO_2), both cultivated in laboratory and also cultivated outdoor. Kawaroe *et al*. [11] said that impact of CO_2 input on microalgae *Nannochloropsis* sp. growth that cultivated in laboratory. Microalgae density at the end of research with treatment of non addition of CO_2 is two times than density in beginning of research; meanwhile density of microalgae with treatment of addition of CO_2 at the end of research is four times than beginning of research. On specific growth speed, it is being reported that *Nannochloropsis* sp. which is being cultivated in media with addition of CO_2 is 0.38 ind/d and cultivation specific growth speed without addition CO_2 is 0.17 ind/d.

The above mention researches used pure CO_2. On the usage of flue gas, Sheehan *et al*. [12] said that microalgae are able to absorb 90 % CO2 directly in flue gas of factory. The study which conducted by Down [13] found that microalgae growth is better with CO_2 input from flue gas than pure CO_2. Power Plant CCS – PPCCS [14] supported Down [13] study. It was said that plant flue gas with content of 2 % to 5 % CO_2 can be put into photo bioreactor algae cultivation system directly. It was reported that microalgae are not only absorb CO_2 but also NOx and SOx that can be used as nutrient for its growth.

Bio-methane contains 20 % to 50 % volume of CO_2 beside minor and trace elements such as O_2, N_2, H_2S, NH_3, toluene, benzene [15, 1]. Impurity gas and non energy especially CO_2 must be eliminated if bio-methane will be used as pipeline gas or vehicle fuel. Soerawidjaja [16] suggested application of electrochemical reduction technology as enrichment or purification upgrade action in order to increase content of CH_4 until ≥ 90 % volume. Tentscher [17] proposed some adsorbs and absorb technology as scrubbing / striper / capture CO_2. Hulu, et al. [18] and Vijay [19] recommended application of high water pressure in village of developing countries. Soehardjianto [20] suggested simple physic system based on pressure difference.

With consideration of microalgae ability in capturing of CO_2 especially in flue gas then it was conducted beginning study as stated in this paper as third research of research series of integration of biogas and microalgae study. The objective of this study is to enhance development of renewable energy such as bio-methane, bio-fuel from microalgae and bio-fuel from *Jatropha curcas.*

2. Methodology

Preliminary study of bio-methane biology purification with microalgae was conducted in Laboratory of SBRC – IPB, Bogor from March until April 2011. Research material related to bio-methane and slurry was taken from digester with *Jatropha curcas* cultivar of JatroMas seed cake as raw material in Research Farm PT. Bumimas Ekapersada, Bekasi, West Java. Microalgae was being used is *Scenedesmus* sp. which was reported by Hanagta *et al*. able to capture 80 % of CO_2 [14].

Scenedesmus sp was cultivated in 1 000 mL erlenmeyer flask. As growth media, slurry and water was being used with concentration 50 % volume + 50 % volume compared to standard media (30 ppm ZA fertilizer, 30 ppm Urea fertilizer and 15 % SP-36 fertilizer) as control. Growth media was stirred every morning and evening with magnetic stirrer for 10 min. Bio-methane gas inserted into bottom of erlenmeyer used 20 L of plastic drum filled by *Jatropha curcas* seed cake substrate. Released bio-methane gas from growth media was captured by gas holder in form of plastic bag.

The measurement of CO_2 content was used by simple orsat apparatus and growth observation of *Scenedesmus* sp was conducted by accordance. The erlenmeyers were put in a room where one of the sides got sunlight exposure approximately 8 h to 10 h / day. The research used Randomized Complete Design in three replications.

3. Result and Discussion

The sequence of 3^{rd} study was started with growth observation of *Scenedesmus* sp. in media of 50 % slurry compared to standard media as shown in Fig. 1.

Figure 1 shows growth of *Scenedesmus* sp which was measured by density (cell/ml) is higher in media of 50 % slurry than standard media. The growth rate is higher 0.1 / day and growth highest peak is on 7^{th} day in the amount of 2.65×10^6 cell / mL. This data supports previous study conclusion that mix of Jatropha slurry cultivar JatroMas + water was able to support and increase growth of *Scenedesmus* sp [6, 7]. As explained before, slurry contains nutrient (inorganic salt) relatively complete compared to standard media that only contains N. P and S. Detail of nutrients in slurry can be seen in Table 1.

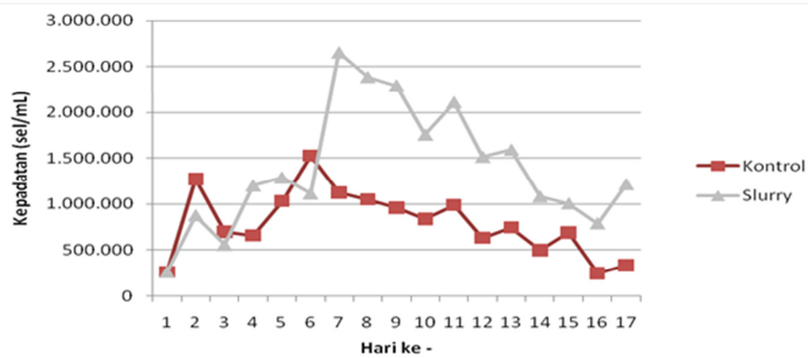

Fig. 1. Graphic curve of *Scenedesmus* sp density in media of 50 % slurry compared to control

Table 1
Nutrient content of digester slurry with Jatropha cultivar JatroMas as raw material

Nutrients	Before (A) (ppm)	After (B) (ppm)	$\frac{A-B}{A} x\ 100$
N Tot	634.7	75.9	88.0
P	112,3	44.3	60.5
K	629.6	317.4	49.1
Mg	107.8	64.7	40.0
Ca	115.6	53.1	54.0
Cu	0.18	0.16	11,0
Zn	0.21	0.10	51,7
Na	45.9	40.9	10.89
Cd	trace	trace	--
Pb	0.17	0.01	94.11
Cr	0.006	0.003	50.0
Mn	0.68	0.24	65.3
Fe	2.12	1.81	31.0
B	0.55	0.33	40.0
Cl	87.75	63.02	28.2

Figure 1 shows increase of *Scenedesmus* sp. growth in slurry media happened in 3rd day compared to standard media. But, in previous study, the increase happened in 14th day as shown in Fig. 2.

Increasing growth as shown in Fig. 1 compared to data in Fig. 2, is assumed because of positive impact of CO_2 gas intake (in bio-methane) that was conducted in research series of this 3rd study. As being reported, pure CO_2 gas intake can increase growth of microalgae *Botryococcus braunii* and *Nannochloropsis* sp [10, 11]. Down [15] said that CO_2 (and other gases) in flue gas has higher capability in increasing of microalgae growth than pure CO_2. Flue gas contains CO_2, O_2, N_2, SO_2 and NO_x [21] while bio-methane contains CO_2, NH_4, O_2, N_2, H_2S, NH_3, toluene and benzene [1, 16].

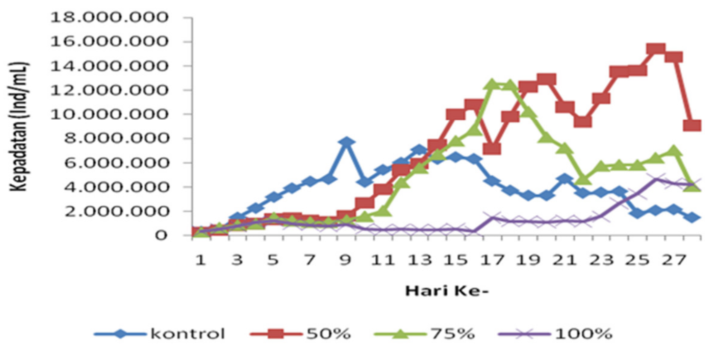

Fig. 2. Growth density of *Scenedesmus* sp in 3 kind of slurry solution compared to control

Microalgae *Scenedesmus* sp. response to CO_2 in bio-methane is shown in Fig. 3. Content of CO_2 gas is measured by simple orsat equipment on released bio-methane from growth media and infiltrate to gas holder.

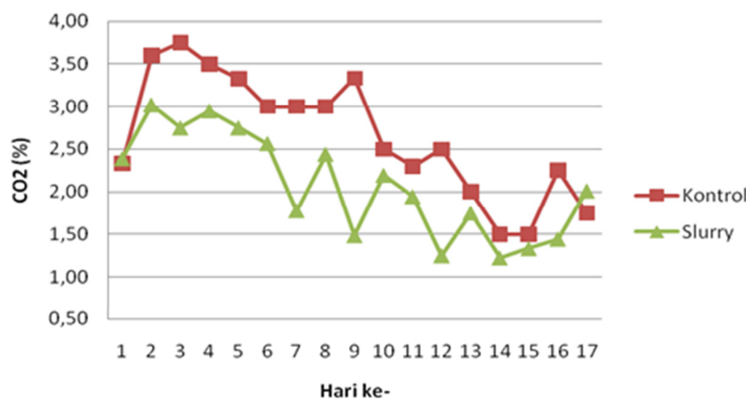

Fig. 3. Content of CO_2 in released bio-methane from slurry media compared to control

Figure 3 shows average of CO_2 content in bio-methane in slurry media is lower than control, 21 % compared to 24 % respectively. As mention above, the CO_2 content data in this study is only measured on bio-methane gas that infiltrate into gas holder. Unfortunately, there is no measurement on CO_2 in inlet bio-methane. But, in general fact, CO_2 content in bio-methane is around 30 % to 50 % [1, 15] then data in Fig. 3 can be concluded:

a. Microalgae *Scenedesmus* sp in two growth media, standard media and 50 % slurry + 50 % water media is able to capture CO_2 in bio-methane
b. Microalgae *Scenedesmus* sp. in 50 % slurry media is able to capture CO_2 higher than standard media. It happened because density of *Scenedesmus* sp. is higher as result 50 % slurry media contains complete nutrient as stated in Fig. 1 and Table 1.
c. There is mutualism symbiosis among slurry, bio-methane gas and microalgae *Scenedesmus* sp.

4. Conclusion and Recommendation

From some series of previous research about integration of bio-methane and microalgae in 3rd study, it can be concluded:

a. Digestion slurry with seed cake JatroMas cultivar as raw material is able to increase growth of microalgae *Scenedesmus* sp. higher than standard media.
b. Microalgae *Scenedesmus* sp. is able to capture CO_2 gas in bio-methane.
c. With integration of slurry and bio-methane intake, there is tendency *Scenedesmus* sp. growth is more increasing.
d. Mutualism symbiosis among slurry, bio-methane and microalgae *Scenedesmus* sp. will give impact to increasing of CH_4 content in bio-methane. In other word, microalgae can be work as purification biologic from bio-methane.

It is recommended that this study to be continued not just stop in this study, especially to completing quantity and quality bio-methane data particularly CO_2 gas that was infiltrated compared to bio-methane that release and being captured in gas holder. It should to be conducted same study with slurry media of *Jatropha curcas* husk as raw material because there is tendency seed cake cannot be used as digestion raw material.

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