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Potential of Microalgae as Biofuel Feedstock

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ABSTRACT

Microalgae are photosynthetic microorganism capable to produce biomass fraction such as lipids, proteins and carbohydrates. Microalgal biomass can be converted to biofuel such as bioethanol, biodiesel and biogas. Biofuel derived from microalgae considered as third generation of biofuel. Microalgal biomass can be converted to energy by biological or chemical methods. Carbohydrate-enriched microalgal biomass can be used for bioethanol raw material. Biomass with high carbohydrate content can be made by manipulating environment factors such as cultivation medium, nutrition limitation, light intensity, salt stress, and temperatures. Biofuel derived from microalgal can replace biofuel derived from terrestrial plants because microalgal biomass has a high caloric value, low viscosity, low density, and lack of lignin that make it easy for converting it into biofuel like bioethanol.

Keywords: *Bioethanol, Biomass, Fermentation, Microalgae.*

1. INTRODUCTION

Energy is an ever-increasing needs of the user at the time of modern society. So, energy consumption is needed to help the advancement of technology in the world (Purnamasari et al, 2012).

Increasing needs that use of fuel causing shortages and had to look for alternatives as a replacement, fuel from based fossil fuels is unrenewable so it can make crisis of the energy. Biofuels will be the answer to existing problems in sufficient energy from biomass that are potential to be made a bioethanol (Putnarubun et al., 2012).

Bioethanol is a renewable energy source that can be replace fossil energy, substance making of bioethanol with natural materials/ biomass by fermentation microorganisms to produced alcohol, It is usually mixed with gasoline to produce gasohol (khrisna et al, 2013) in Indonesia bioethanol needed requirement at 2015 reached 35.250 tons / year (BPS, 2017).

Process of making bioethanol consists of three generations, the first generation that are used food grade, the process is considered less promising because it will affect the food product and the price is relatively high. And then development using the second generation that is making bioethanol from biomass. biomass is enough and sufficient in Indonesia (digilib.unila.ac.id), The last generation is based on *microalgae,* it's more useful because microalgae had many carbohydrate based.

2. DISCUSSION

2.1 Bioethanol from microalgae

Third generation bioethanol production from algae feedstock is an important renewable energy source (Chaudhary at al., 2014). One of the older microorganism live in earth is microalgae (Song et al. 2008). Several types of microalgae are dinoflagellates, green algae, golden algae and diatoms. Light, temperature, nutrient content, pH, O_2 and CO_2 level, salinity and toxic chemicals are several factors that affecting lipid and carbohydrate contents of microalgae (Jambo et al., 2016). Microalgae can grow really fast,, hundred time faster than land based-plants and it can double their biomass in less than one day (Tredici, 2010). Microalgae protein, carbohydrate and lipid contents are varies by species. Most microalgae can content highly lipid, 70 % by weight of dry mass. Microalgae carbohydrate content is up to 50 % of dry weight for some species, (i.e. *scenedesmus, chlorella and chlamydomona*) (Jambo et al., 2016). Microalgae with high content of carbohydrates can be used as carbon source for produce bioethanol (Harun et al., 2010; Radakovits et al., 2010).

Some species of microalgae with high levels of carbohydrates and lipid (i.e. *spirulina* and *porphyridium purpureum)*. It has been estimated that microalgae can produced bioethanol for around 5000-15,000 gal of ethanol/acre/year (Chaudhary at al., 2014).

Production of bioethanol using microalgae as feedstock can be produce with this following procedure. First, released the starch from microalgae cell using mechanical equipment or an enzyme, then add yeast to the biomass for fermentation process. Final product from fermentation is bioethanol (Chaudhary at al., 2014).

2.2Microalgae species for bioethanol production

In hydrolysis reaction, the carbohydrate hydrolyzed to fermentable sugar. The fermentable sugar will be converted to bioethanol in fermentation process. (Harun et al., 2010). The carbohydrate content for some microalgae species are show in Tables 1.

Table 1. Carbohydrate Content of Some Microalgae Species

Microalgae Species	Carbohydrate content (% dry weight)
Chlamydomonas rheinhardii	17
Chlorella pyrenoidosa	26
Chlorella sp.	19
Chlorella vulgaris	12-17
Chloroccum sp.	32.5
Dunaliella bioculata	4
Dunaliella salina	32
Euglena gracilis	14-18
Isochysis galbana	7.7-13.6
Isochysis sp.	5.2-16.4
Mychonastes afer	28.4
Nannochloropsis oculata	8
Porphyridium creuentum	40
Prymnesium parvum	25-33
Scenedesmus abundans	41
Scenedesmus dimorphus	21-52
Scenesdesmus obliquus	15-51.8
Spirogyra sp.	33-64
Synechoccus sp.	15
Tetraselmis maculate	15
Tetraselmis sp.	24
Tetraselmis suecica	15-50

References : Lam K. Man, 2015

As show in Table 1, *Porphyridium cruentum, Prymnesium parvum, Scenedesmus abundans, Scenedermus dimorphus, Scenesdesmus obliquus, Spirogyra sp.,* and *Tetraselmis suecica* are microalgae species that have high carbohydrate content and suitable for bioethanol production. It has been considered that carbohydrate content in dry weight of microalgae biomass (i.e. 21%-64%) is higher than carbohydrate content in lignocellulosic biomass(Lam K. Man et al., 2015)

Table 2 represents the protein, carbohydrate and lipid content of some microalgae species.

Table 2. Compositions of different species microalgae

Microalgae species	Compositions (% weight dry basis)		
	Protein	Carbohydrate	Lipid
Chlamydomonas rheinhardii	48	17	21
Chlorella vulgaris	41-58	12-17	10-22
Porphyridium creuntum	28-39	40-57	9-14
Prymnesium parvum	28-45	25-33	22-39
Scenedesmus dimorphus	8-18	21-52	16-40
Scenedesmus obliquus	50-56	10-17	12-14

2.3 Bioethanol from microalgae

There are two processes to producing bioethanol from microalgae, via dark fermentation or yeast fermentation. Dark fermentation occur when microalgae consuming its intracellular starch in anaerobic condition. Yeast fermentation is using yeast metabolism to convert monomer glucose derived from starch to bioethanol (Gouveia. 2011).

2.4 Factors affecting carbohydrate content in microalgae biomass

Known that some of microalgae strain could contain large amount of starch (>50% of dry weight), glycogen and starch, which are raw materials for bioethanol (Cuellar-Bermudeza et al. 2014). *Spirogyra sp.* and *Porphyridium cruentum* are some examples of microalgae species that have high innate carbohydrate content 33-64% and 40-57%, respectively (Harun et al. 2010). Productivity is the key to enhance the economic feasibility of using microalgae carbohydrate for biofuel production. Accumulation of carbohydrate in microalgae usually occurs when the microalgae cells exposed to environmental stress (e.g. *nutrients limitation*) (Chen et al. 2013). Cultivation strategies that can enhanced the carbohydrate content of microalgae are irradiance, nitrogen depletion, temperature, pH, and CO2 (Chen et al. 2013). Not much different, Markou et al. (2012) also stated that environmental factor that could affecting carbohydrate content of microalgae are nutrient starvation, salt stress, light intensity, temperature, and metabolic mode.

Nutrient limitation or starvation is practically feasible because it is easy to control the nutrient in the cultivation medium (Markou et al. 2011) and considered as an affordable strategy to produce rich carbohydrate microalgae (Dragone et al. 2011). Optimization of the limited nutrients is important to support adequate biomass composition and act as limiting factor to control the biomass production (Markou et al. 2012). Example, when *C. vulgaris* cultivation medium at phosphorus, nitrogen, or sulphur limiting conditions, the starch content increased 83, 50 and 33%, respectively (Douskova et al. 2008).

Since microalgae is considered as photosynthetic organism, it's important to supply sufficient light. Biomass composition and growth rate of microalgae can be affected by quality and quantity of the light. Growth rates of microalgae increase as the irradiance increase, up until light-saturation occur. Most of microalgae saturated under light flux 200–400 μmol photons m−2s−1. When increasing density of microalgae occurred and above level of biomass density, there will be deficient of photosynthesis process caused by self-shading effect (Markou et al. 2012). But still the increasing of the light intensities can be considered resulting more carbohydrate content (Hu, 2004). Known that, there are synergistic connection between light and temperature affecting biomass composition (Markou et al. 2012). Temperature can affect the light inhibition and nutrition uptake. Increasing temperature to the optimum condition will improve microalgal growth rates, above the optimum condition the growth rates will decrease. Some reported research certain that biomass composition affected by temperature still contradiction (Markou, 2012).

Microalgae can exist in elevated salinities due to their respond by accumulating intracellular low molecular weight carbohydrate as internal osmotica. The increase of carbohydrate content protect them from salt harms (Markou 2012; Warr et al 1985; Reed et al. 1984).

2.5 Harvesting carbohydrate encriched microalgae biomass

Common harvesting techniques are gravity sedimentation, filtration and micro screening, centrifugation, ultra-filtration, flotation, combined flocculation-flotation, electrolytic separation (Uduman et al. 2010).

Properties of microalgae that must be considered when selecting harvest method are density, size, and value of the desired product (Brennan and Owende. 2010). Example, *Spirulina platensis* with carbohydrate enriched biomass has bio-flocculation capability which make it easy to harvest (Markou et al. 2012) or with micro screen method that refer to cost and energy efficient (Brennan and Owende. 2010).

2.6 Converting carbohydrate enriched microalgae biomass to bioethanol

Biochemical conversion, chemical reaction, direct combustion, and thermodinamical conversion are several ways to convert microalgal biomass to energy feedstock for producing biodiesel and bioethanol (Dragone et al. 2010). Pre-treatment before converting carbohydrate into bioethanol could improve the conversion (Cheng et al. 2012). Another author, Harun (2010) said that it is essential to doing pre-treatment stage to release the complex carbohydrates to simple sugars before fermentation.

Scarification is the rate limiting step in biofuel production with lignocellulosic material. Two major carbohydrate in microalga are starch and cellulose. Microalgae cells are lack of lignin so it simplifies the scarification process (Markou et al. 2012; Chen et al. 2013). Scarification process can be divided into enzymatic and chemical scarification.

Enzymatic scarification use *cellulases, amylases* and *glucoamylases* to hydrolyze carbohydrate in microalgae biomass to simple sugars. Chemical scarification process occur in fast reaction and high reaction condition, in this process acid or alkali used to hydrolyzed the algal biomass (Chen et al. 2013).

After the starch hydrolysis to monomeric or simple sugars, it will be ready for fermentation process. The fermentation process is biochemical conversion that use organism such as *Saccharomyces cerevisiae* and *Zymomonas mobilis*. Altough, *Z. mobilis* is considered as the most effective organism to convert the sugar to ethanol, it is still not commercially used. Resulting ethanol then purified from the mixture by dehydration and distillation (Gouveia, 2011).

3. CONCLUSION

For producing bioethanol derived from microalgal biomass, it is necessary to maximize the microalgal biomass carbohydrate content by manipulating its cultivating medium, nutrition limitation, temperature, and light intensity. Known that, microalgae has advantages compared to terrestrial plants. Microalgae has lack of lignin that make it easy for converting it into bioethanol through simple hydrolysis. After all, the treatments of microalgae for producing biofuel are species dependent because different species have different content of biomass.

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