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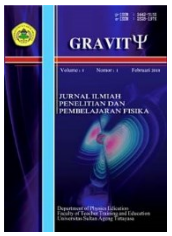

The utilization of microalgae as an agent for converting CO_2 to O_2 in a photosynthesis reactor to mitigate CO_2 emissions

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ABSTRACT

A closed photobioreactor design has been fabricated, aimed to determine the basic concept for microalgae *Chlorella vulgaris* development. This study employed a flat-plate type with dimensions of 16x20x25 cm with the effectiveness of 3000 ml culture media and two 20 watt 220 volt tungsten halogen lamps, which were placed on the right and left sides of the reactor with a light intensity of 1000 lux. This study employed two photobioreactors, type-I without CO_2 supply and type-II with CO_2 supply as much as 25%. The initial cell density of *Chlorella vulgaris* culture was 14,694 x10^5 cells/ml; then observations were made every day using a Haemocytometer. O_2 concentration data were collected every day 3 times with irradiation time of 1, 6, and 9 hours using the O_2 gas sensor (KE-50 type). The determination of the O_2 concentration value in the photobioreactor on the 3rd day was 0.69%.

Keywords: Closed system photobioreactor, CO_2 gas, microalgae, O_2 concentration

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INTRODUCTION

Global warming is an environmental crisis problem that is still happening today. It could be interpreted as a phenomenon of increasing earth temperature caused by the greenhouse effect. The greenhouse effect is an increase in the concentration of greenhouse gases such as water vapor (H_2O), methane (CH_4), carbon dioxide (CO_2), and nitrogen (N_2). Carbon dioxide gas has a significant increase compared to other greenhouse gases. Intergovernmental Panel on Climate Change (IPCC1991) in the pre-industrial period (the 1800s) state that the concentration of CO_2 in the earth's atmosphere had increased from 280 to 353 ppmv, the largest source of emissions came from CO_2 gas (90%), followed by CH_4 (9%) and N_2O (1%).

This condition causes a reduction in the concentration of CO_2 in the air to tackle global warming. The reforestation method is commonly used; this is because plants are effective in converting carbon dioxide into oxygen through photosynthetic reactions. However, there is a better method than reforestation, namely using a photobioreactor.

The use of photobioreactors requires microorganisms, namely algae, because (1) it

is non-toxic, (2) able to live everywhere, (3) reproduce rapidly in growing conditions, (4) able to produce oxygen in the photosynthesis process, (5) can live in a polluted environment (Amaral et al., 2020).

Algae are widely known as algae, including phytoplankton, including Tallophyta (Talus Plants) because they do not have real roots, stems, and leaves. Algae are chloroplast organisms that produce oxygen through the photosynthesis process. Its abundance and easy breeding methods make it possible to make algae a renewable energy source. It is considered useful in reducing CO_2 emissions because of its ability to reduce CO_2 in the photosynthesis process (Bani et al., 2021).

A photobioreactor is an integrated bioreactor with a certain light source for energy intake into the reactor. It uses a closed system of a biotechnological process. Bioreactors provide a stable environment for optimum optimization of organism growth and metabolic activity.

At optimal lighting,photosynthesis rate will be directly proportional to light intensity, limiting too high illumination intensity, damaging the photosynthetic receptor system within minutes, called photoinhibition. In the predominance of microalgae conditions, optimal photosynthesis in radiation is around 1,700-2,000 µE/m^2 (Nielsen & Hansen, 2019).

Several phytoplankton species grow at optimal rates at 50µE/m^2 and will undergo photoinhibition at 130 µE/m^2. In the flat-plate photobioreactor type, with a surface-to-volume ratio (SVR) of 20-80 m^2/m^3 and lighting up to 1.15 µE/(m^2s), with a layer thickness of up to 5 mm, productivity can reach up to 2-5 grams of dry weight per day.

Although biotechnology research has developed rapidly, there is still little written information regarding the short-term adaptation process to light (photoadaption), namely light inhibition or the effect of light saturation effect in translucent bioreactors. Adaptation to light generally takes about 10-40 minutes, and this is an explanation for the mismatch between the productivity of the algae culture medium at optimum lighting and the productivity of the algal culture medium in open systems that experience natural light-dark cycle lighting (Farahdiba et al., 2020; Oostlander et al., 2020b; Thoisen et al., 2018; Sabri et al., 2020)

RESEARCH METHOD

This photobioreactor consists of 2 flat plate glass pools with the same dimensions, namely 16 cm x 20 cm x 25 cm, with an adequate 3000 ml media volume. This reactor is a flat plate closed photobioreactor (Figure 1); this design is relatively cheap and more comfortable to clean. Besides, the distribution of light as an energy source can be more evenly distributed. The use of glass as a material for the reactor is because glass can absorb visible wavelengths of light, namely in the range 400 nm -750 nm, where at these wavelengths, microalgae can live and reproduce well. Before selecting the lamp used for the photobioreactor system, the *Chlorella vulgaris* sample was tested for absorbance using a UV-vis spectrometer. From the results obtained, it was concluded that *Chlorella vulgaris* almost absorbs all visible wavelengths as well as in the infrared region so that halogen lamps are used (Nurrahmawati et al., 2018; Trofimchuk et al., 2020; Ak et al., 2019; Oostlander et al., 2020a; García Cañedo, 2020).

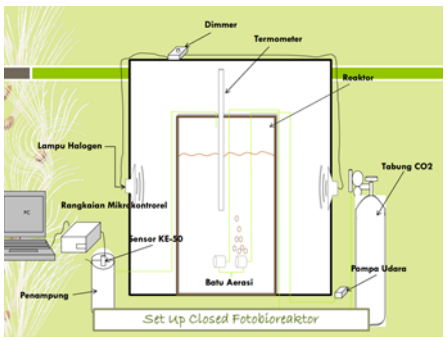

Figure 1. A Set of photobioreactor

The media used in this research is river water (a water hyacinth plant near the ITSNU Pasuruan Campus), sanitized by boiling at a temperature of 130^{o}C; the water is filtered before. The water medium is given nutrition in 120 gr Urea fertilizer, diluted with 120 ml distilled water at 1 ml / 1 liter doze. After that,

it is aerated for about 30 minutes so that the nutrients dissolved in the water are evenly distributed. The *Chlorella vulgaris* was given as much as 300 ml into the culture media as much as 2700 ml (Figure 2), that the sufficient volume of the medium became 3000 ml. This medium's pH was measured with indicator paper at the beginning and end of the photobioreactor process. Then the photobioreactor operating conditions are measured, and the temperature is maintained in the range of 25°-35°C with a tube thermometer (Banerjee et al., 2020; Cahyonugroho & Nindhita, 2018).

Figure 2. Culture media / nutrients

The reactor is placed in a light chamber measuring 30x40x40 cm with a halogen light source of 20 watts 220 volts on the right and left sides, which is connected to a dimmer to control the intensity of the light given to the system. The inside of the light chamber is coated with aluminum foil so that the intensity of the light produced can be quantized so that the photobioreactor gets maximum exposure (Zhou et al., 2020).

Type-I of the reactor, the photobioreactor, is not supplied with CO_2 gas. There are three channels at the top of the photobioreactor; the first channel is the output channel for the gas produced by the photobioreactor system to the container to measure its concentration. A hose connects for the second channerl for aeration from the air pump, and the end is connected to an aeration stone. The third channel is for sampling algae to calculate the density once every 2 days. This photobioreactor is placed in the light chamber to make the light is quantized, and there is no influence on the intensity of the outside, apart from the light source of the halogen lamp which is given to the photobioreactor. To avoid gas leakage, the resulting gas can flow into the gas reservoir, each connection is coated with Vaseline. The temperature at the photobioreactor is measured using a tube thermometer every day. For air circulation in the light chamber, a fan is directed to the hole as air circulation so that the air in the light chamber does not reach the highest temperature of the photobioreactor.

For the Type-II photobioreactors, principally, it is almost the same as the first type, the only difference is that there is an additional channel for the supply of CO_2 gas to the reactor by 25% as an additional carbon source for the photosynthesis process where O_2 is produced which is connected to a CO_2 gas cylinder. This channel is a hose whose tip is given an aeration stone to break down the gas that enters the photobioreactor, allowing CO_2 gas to dissolve in water.

In this study, CO_2 is given periodically by measuring using a flowmeter attached to the CO_2 regulator. CO_2 gas is then injected into a batch scale to determine the O_2 concentration resulting from photosynthetic microalgae during one phytoplankton life cycle of about 12 days. The 4-liter capacity photobioreactor is filled with 3000 ml of culture medium. CO_2 gas flows into the reactor with a closed system from the bottom of the reactor using water from an aerated rock. Before the photobioreactor process takes place, a gas leak test is carried out (Figure 3) the output of the reactor by using an air pump that is inserted into the reactor and then the output hose connected to the reactor is inserted into the methylated spirits, and the output is the same as the output in the reactor. If the output produced is the same as the air pump output, the reactor can be used (Lee et al., 2020; Zhao et al., 2020).

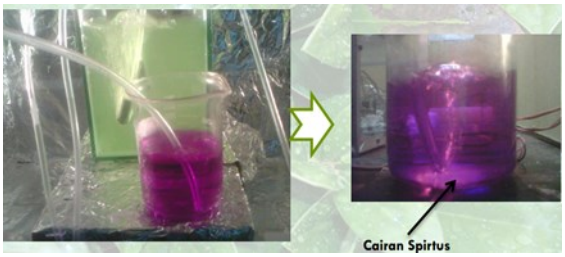

Figure 3. Gas leak test

The absorption test of *Chlorella vulgaris* microalgae was carried out using a UV-Vis spectrometer. It was obtained absorption graph, as shown in (Figure 4). It can be seen that the wavelength range that experiences optimal absorbance ranges from 2OD – 3OD is in the 400 nm-1000 nm wavelength range. It means that the optimal wavelength absorbed is in the visible to infrared light.

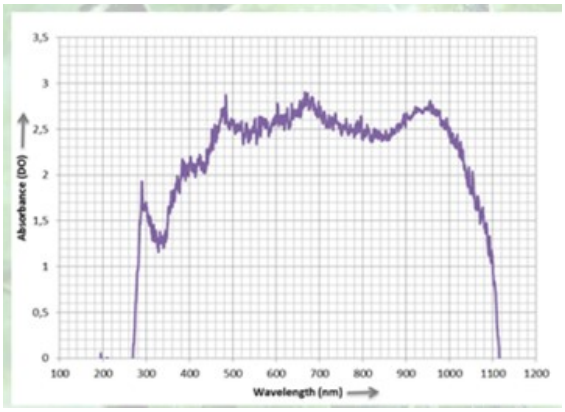

Figure 4. Spectrometer UV-Vis *Chlorella vulgaris*

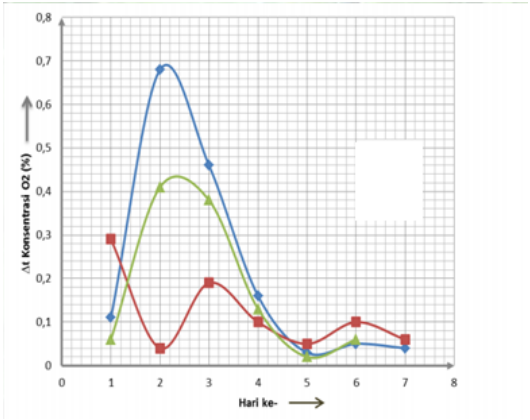

Figure 5. Delta of oxygen concentration in reactor

Figure 5 presents the data about the relationship between the supply of CO_2 gas to the photobioreactor (photobioreactor II) and the one without supply (photobireactor I). It can be seen that although the O_2 concentration value of the system in photobioreactor II is relatively low compared to photobioreactor I, the resulting value is relatively stable and continues to operate until the 9th day, where the value decreases even under free air. The O_2 concentration value at the initial 5 days was relatively high and experienced a phase lag.

However, if it is compared with photobioreactor I, this concentration value is lower, this is due to the presence of CO_2 supply in the morning where due to the limitations of the gas bubbles supplied are too large so that only part of the CO_2 gas is dissolved in water and the rest is still gas and flows into the reservoir, so it is urgent. O_2 gas produced, and the detected O_2 concentration is less than the concentration in photobioreactor II. From the data on the duration of irradiation, it can also be seen; because CO_2 supply is given in the morning, which is when the initial radiation is given, then on the 1st day with a 6 hour irradiation time, it can be seen that the resulting O_2 concentration value is higher than in the 1 and 9 hours irradiation time.

CONCLUSION

The analysis revealed that the closed flat-plate photobioreactor design produced O_2 gas, which was detected by the O_2 gas sensor (KE-50). The O_2 concentration value with an intensity of 1000 lux in photobioreactor II is more stable than photobioreactor I due to the supply of CO_2 in the photobioreactor II system. The delta of the optimum concentration of O_2 on the 3rd day of the photobioreactor was 0,69%.

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