Contents list available at JESE website

Journal of Emerging Science and Engineering

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Research Article

# Feasibility study of utilization of palm oil mill effluent (POME) as a source for microalgae nutrients

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**Abstract.** As palm oil productivity increases, the waste produced will increase. Every palm oil industry produces liquid waste known as palm oil mill effluent (POME). POME contains very high BOD and COD so that it can inhibit microalgae growth. Therefore, comprehensive research is needed to find pre-treatment steps to reduce the COD and BOD content in POME before it is used as a medium for the growth and development of microalgae. The experimental mixture procedure carried out POME and microalgae according to the specified ratio. Research shows that Pond IV POME waste can be used as wild microalgae to grow, thereby reducing the BOD and COD levels of POME waste. Variable modifiers were applied to the volume of POME to the ratio of microalgae volume and the amount of nutrients provided. Microalgae growth with a ratio of 1:4 resulted in a decrease in BOD and COD to 61.66 ppm and 173.33 ppm from 110.6 ppm and 496.67 ppm. On the effect of providing C nutrition (120 ppm), resulted in lower BOD and COD at 65.33 ppm and 186.67 ppm, while the effect of providing N (40 ppm) nutrition resulted in lower BOD and reached 55.41 ppm and 158.33 ppm.

**Keywords:** BOD, COD, microalgae, POME,



Received: 10th July 2023; Revised: 15th August 2023; Accepted: 1st Sept 2023; Available online: 5th Sept 2023

## 1. Introduction

Market demand for palm oil reached 71.48 million tons in 2019 and is predicted to increase by 2.3% every year until 2027 (Low et al., 2021). The palm oil industry produces palm oil mill effluent (POME) of 2.80-2.39 tons per ton of crude oil produced from the sterilization process of the bunches after separating the kernels from the shells and after clarifying the oil (Fernando et al., 2021; Garritano et al., 2018; Lam & Lee, 2011). POME contains biological oxygen demand (BOD) and chemical oxygen demand (COD), which are 100 times higher than municipal waste (Fernando et al., 2021). The high levels of BOD and COD require the processing of POME before being discharged into the environment. General steps taken to treat POME waste, such as adsorption and membrane filtration (Parthasarathy et al., 2016). However, both methods are considered less effective and require high costs. Due to its high lipid, nitrogenous compound, protein, and mineral content, the majority of POME treatments involve biological processing (Tan & Lim, 2019). The majority of palm oil manufacturers prefer the anaerobic digestion, biodiesel feedstock, and decomposition methods. (Low et al., 2021).

Due to the global energy security issue, POME treatment using microalgae to produce biofuel has emerged as a highly competitive instrument in recent years (Chai et al., 2021). The application of microalgae as a liquid waste bioremediation agent has been implemented and reported to be successful (Hadiyanto et al., 2017). Microalgae are microorganisms that are promising as biomass producers (Chisti, 2007). Microalgae show the potential to be applied as raw materials in the production of cosmetics, pharmaceuticals and food (Mahlia et al., 2020). Biomass produced by microalgae contains carbohydrates (11-56%), lipids (8-70%), proteins (40-70%), pigments (3-5%), and various other contents (Roy & Pal, 2015). When compared with plants which also produce biomass, microalgae are considered superior because of their high photocatalyst rate, fast growth, high biomass content, and good resistance to polluted environments (Chisti, 2007).

Microalgae-based wastewater remediation is an eco-friendly method that can eliminate pollution. Microalgae have the potential to be used in the treatment of POME because algae grow using solar energy via photosynthesis, and converting them into biomass can generate a profit by utilizing the nitrogen and phosphorous compounds found in POME. Due to their tenfold greater photosynthetic efficiency than terrestrial plants, microalgae have a tremendously rapid growth rate. Furthermore, using microalgae to treat POME is very cost-effective, as the biomass of microalgal growth in POME has the potential to be a significant source of biodiesel (Show et al., 2017). Microalgae can also be grown on non-agricultural land [28], which is another advantage of their use. Using microalgae to manage POME can also aid in reducing BOD and COD, thereby aiding in pollution prevention (Nur & Buma, 2019).

In this research, the optimum pretreatment steps will be investigated in reducing BOD and COD levels by maintaining the mineral content (N, P, K) contained in POME. Pretreatment carried out includes comparing the volume of POME with wild algae such as

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Chlamydomonas. In this research, several things will be obtained, including: the optimum ratio and amount of nutrients to reduce BOD and COD content with mineral content (N, P, K) that is still high enough to be able to utilize POME as a medium for growth and development of microalgae.

## 2. Materials and Methods

### *2.1 Materials*

The materials used in this research include POME (PT Perkebunan Nusantara VII, Lampung, Sumatra), NaHCO3, urea, and wild microalgae. Wild microalgae were obtained from the waste processing laboratory pond of the chemical engineering department at Diponegoro University. Based on observations, the microalgae found in the pond was a type of *Clamidomonas*.

### *2.2 Experimental procedure*

This research was carried out by acclimating POME and microalgae by adding the nutrients urea and NaHCO3. This process is carried out with a stirrer at scale speed 4. Microalgae concentration analysis is carried out using Optical Density (OD). The analysis is carried out up to a fixed OD value (14 days). After 14 days, carry out biomass analysis. Then, separate the microalgae from the mixture with alum at a concentration of 30 ppm and add 2M NaOH to pH 11. The mixture is settled for one day. The filtrate was analyzed for COD and BOD content, while the sludge was analyzed for oil content.

## 3. Results and Dicsussion

### *3.1. Calibration Curve of Microalgae Cell vs Optical Density (OD)*

To determine the number of microalgae cells present in the sample, first a correlation curve was made between the cell number and the optical density value. The calculation of the number of microalgae cells is done using the counting chamber calculation system, while the calculations of optical density values are done using spectroscopic photometry. In calculating the number of cells by chamber counting, the sample of the microalgae is not diluted because of the small number of observed cells. The procedure is performed twice in order to obtain a high degree of precision. The calibration curve is obtained by making a plot between the number of microalgae cells and the optical density value (Fig. 1).

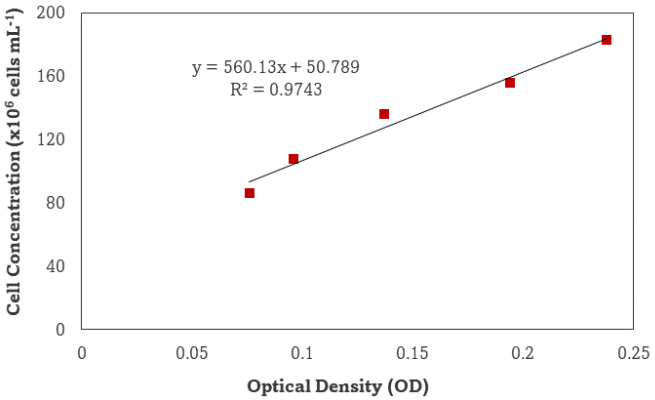


**Figure 1**. Standard plot of cell concentration versus optical density

Figure 1 shows the standard curve obtained from the plot result between cell concentration and optical density. The standard curve forms a straight line with the line equation y = 0,0881x + 0,0002 with a linear regression determination coefficient (R2) of 0,9743. A value of R2 approaching 1 indicates that an independent variable can determine a dependent variable perfectly. Thus, the line equations generated on such standard curves are worthy of use.

### *3.2. Microalgae Growth at Various Concentration of Microalgae Cells in POME medium*

Figure 2 shows the effect of comparing the volume ratio of POME and microalgae on microalgae growth. Observations up to 15 days show increased cell concentrations, indicating that microalgae growth is ongoing well. Until the 6th day, microalgae growth appears to be very steep, indicating the phase of adaptation of microalgae to grow and thrive in the POME medium. Microalgae growth increased significantly from day 6 to day 14, indicating that microalgae growth has reached a lag phase.

Good fluctuations in microalgae cell growth were shown in ratios of 1:1, 1:2, and 1:3. In these three comparisons, microalgae growth looks almost the same. Meanwhile, at a ratio of 1:4 and 1:5, microalgae growth looks very slow, and the number of cells formed is much smaller. A comparison of the volume of POME with microalgae shows that the initial number of microalgae cells influences the final number of microalgae cells. The greater the number of cells in the initial condition, the more microalgae can divide. The best conditions were obtained at a ratio of POME and microalgae 1:3, producing 752,067 x 106 cells.mL$^{-1}$ of microalgae within 14 days.

### *3.3 Microalgae Growth at Various Concentration of UREA*

Nitrogen makes up about 12% of the protoplasm of microalgae and 5-6% of the protoplasm of molds or microorganisms. In wastewater, nitrogen is found in the form of ammonium nitrate (Li et al., 2017). Figure 3 shows that the more urea added, the slower microalgae growth. The addition of more and more urea will result in an acidification process due to increasing levels of ammonia (NH3) being formed. This acidification process will change the stability of the optimum pH, which will disrupt microalgae growth.

When adding urea of 40, 45, and 50 ppm, it was seen that the stationary phase of the microalgae growth curve tended to decrease. This is caused by high ammonia levels, which results in the death of microalgae. The optimum conditions for adding urea were obtained at an addition of 30 ppm. Nitrogen is very important for the metabolism of microorganisms because nitrogen is an important element in forming amino acids and nucleic acids. Proteins are composed of amino acids, while nucleic acids are one of the components that form DNA and RNA. The carbon-to-nitrogen ratio also depends on the contaminants, microalgae, and the type of nitrogen used.

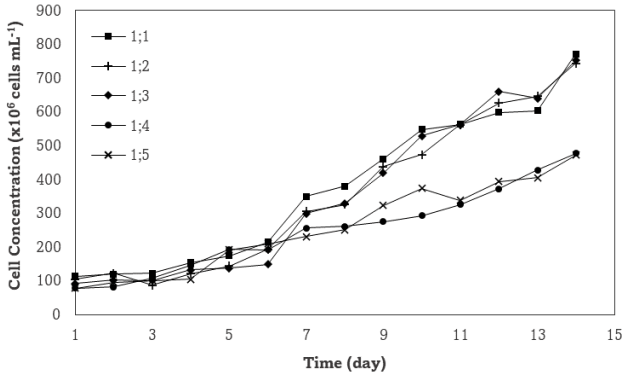


**Figure 2**. The growth of microalgae at various volume ratios of POME and microalgae

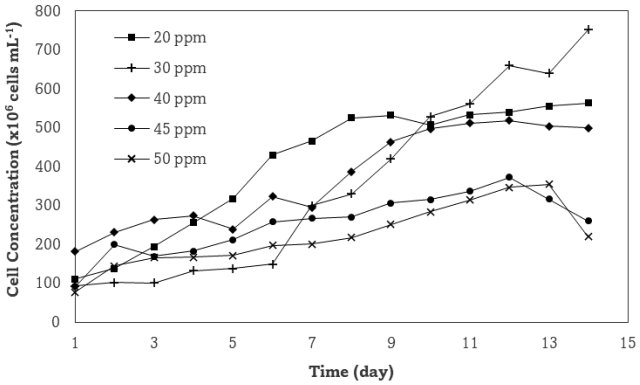


**Figure 3**. The growth of microalgae at various concentration of UREA

*3.4 Microalgae Growth at Various Concentration of $NaHCO_3$*

The addition of the nutrient sodium bicarbonate functions to increase the carbon element (C) content in the POME growth medium (Mokashi et al., 2016). Carbon is an important source of nutrients for the growth of microalgae (Chauhan et al., 2022). Figure 4 shows the best NaHCO3 concentration obtained by adding 100 ppm. At this concentration, a good ratio of carbon, nitrogen, and phosphorus nutritional content will be obtained in the POME media so that the nutrients needed by the microalgae are well met. The Carbon is converted to glucose in photosynthetic reaction (G. Li et al., 2023).

$$CO_2 + H_2O \rightarrow (CH_2O)_n + O_2 \quad (1)$$

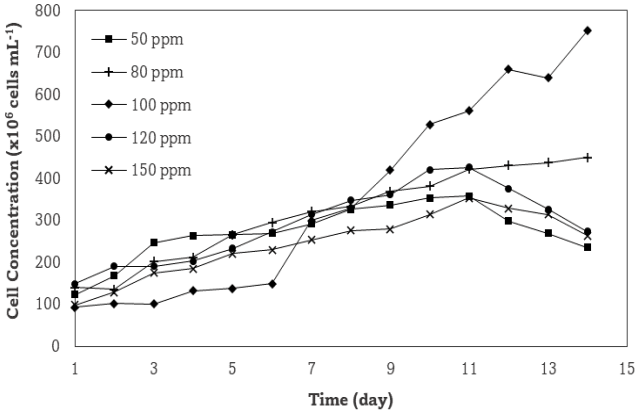


**Figure 4**. The growth of microalgae at various concentration of $NaHCO_3$

### *3.5 COD and BOD Removal*

Figure 5a shows the effect of the volume ratio of POME and microalgae on reducing COD and BOD. The best COD and BOD reduction were obtained in a ratio of 1:4. In this volume comparison, the number of microalgae cells is smaller than other comparisons because the basis for cell calculation used is a counting chamber. In the counting chamber calculation technique, not only living cells are counted, but also dead cells. Thus, in the 1:4 volume ratio variation, the number of active microalgae is greater than in the others. The greater the number of living microalgae, the better the microalgae activity will reduce BOD and COD levels. The reduction in COD and BOD levels by microalgae with variations in the addition of urea nutrition is presented in Figure 5b. Adding urea at a concentration of 40 ppm resulted in the best reduction in COD and BOD values. This is because microalgae degrade the chemical substances in the samples. Meanwhile, adding sodium bicarbonate can reduce COD and BOD levels significantly. The best conditions were obtained with the addition of 120 ppm sodium bicarbonate (Fig. 5c). Adequate carbon requirements for microalgae result in a better ability to degrade chemical substances in the media so that COD and BOD values can be reduced.

Central Java provincial regulation no. 10 of 2004 has determined the levels of COD and BOD that can be released into the environment, respectively, at 150 mg/L and 75 mg/L. The previous analysis showed that the final COD content had not met the specified quality standards, while the final BOD content had met the specified quality standards.

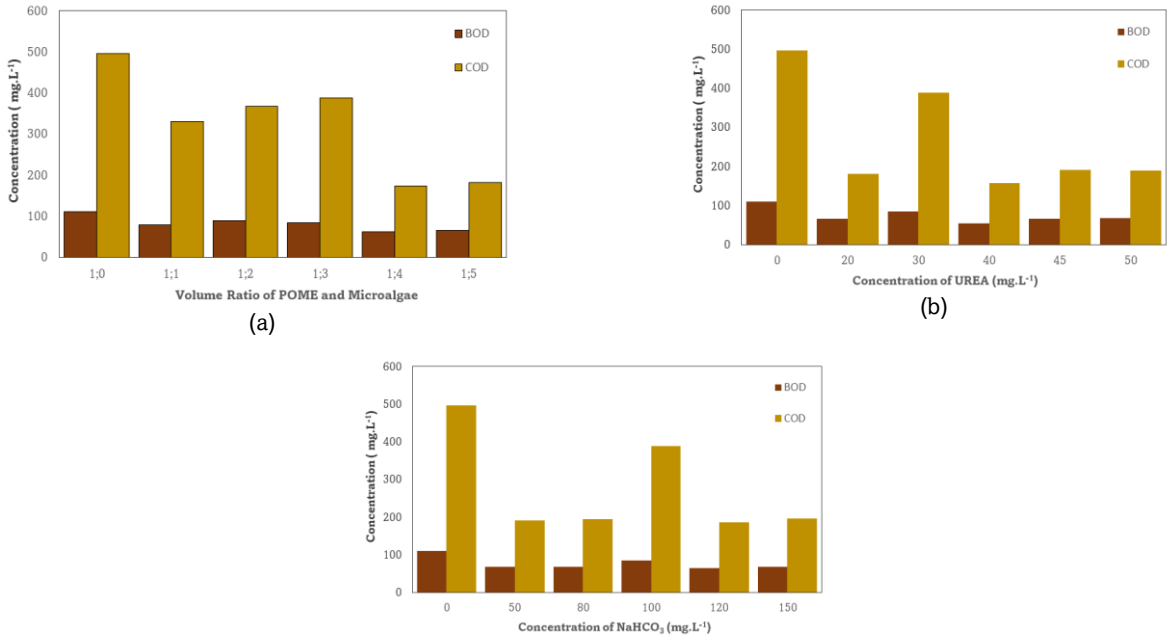


**Figure 5.** Effect of (a) volume ration of POME and microalgae, (b) concentration of UREA, (c) concentration of $NaHCO_3$ on COD and BOD removal

### *3.6 Lipid Content*

Lipid content is obtained from the analysis of oil produced from dried microalgae. The highest lipid content was obtained at a volume ratio of POME and microalgae at 1:3. This ratio produces the highest number of microalgae cells compared to other ratios. The higher the number of microalgae cells, the higher the biomass obtained and the higher the lipids produced.

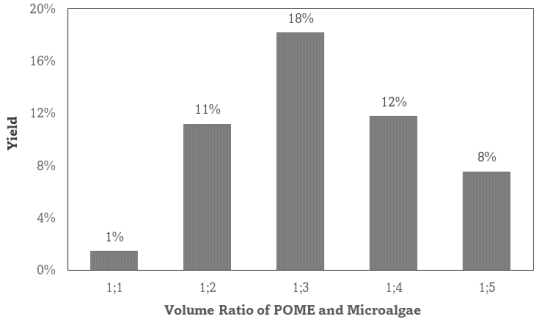


**Figure 7.** Effect of volume ration POME and microalgae on lipid content

## 4. Conclusion

The use of POME as a microalgae growth medium has been successfully carried out for the growth and development of *Clamidomonas* microalgae. The addition of nutrients C (NaHCO3) and N (urea) can fulfill the nutritional needs of microalgae to live in POME media. Utilization of POME as a medium for growing microalgae is also a form of liquid waste bioremediation. COD levels contained in POME waste are reduced significantly and are below established quality standards.

**Acknowledgement**

The authors would like to express our sincere gratitude to our supervisor, Professor Hadiyanto, for his valuable guidance and support throughout the research process. His expertise and insights were invaluable in shaping our research and helping us to overcome challenges.

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