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Full paper

Micro-Macro Algal Mixture as a Promising Agent for Treating POME Discharge and its Potential Use as Animal Feed Stock Enhancer

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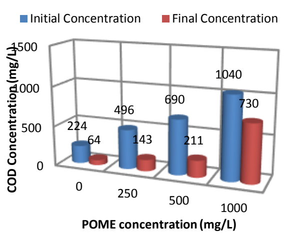
Graphical abstract



Abstract

Algae are well known photosynthetic organisms that are able to grow at various environmental conditions. Microalgae and macrophytes are two categories of algae generally having similar biological activities with several industrial advantages. In recent years, micro and macro algae have been increasingly used as animal fodder supplements for farm animals. The main aim of this study is to propose the micro and macroalgae obtained from Palm Oil Mill Effluent (POME) waste water discharge as a promising low-cost-treatment and high-energy method for harvesting the nutritional supplements in order to enhance the animal feedstock production. The mixed micro and macro algal sample was collected from POME and Desa Bakti river. Then it was characterized for nutritional content as appropriate animal feed stock by diluting POME to various concentrations (0, 250, 500, 100 mg/L) in order to enhance their growth and to increase its nutritional value. It was found that a maximum of 23% COD reduction rate was obtained, while the COD concentration above 500 mg/L affected the growth of biomass. The potential use of algae as cheapest aquaculture diets can be considered to be as appropriate source for overcoming the problem of food scarcity and thereby minimizing the negative environmental impacts.

Keywords: Micro-macro algae; POME; waste water treatment; feed stock; nutrient supplement

1.0 INTRODUCTION

The Malaysian palm oil industry has grown rapidly over the years, which turn it to be the world's largest producer and exporter of palm oil and its derivatives [1]. During the last century, a great deal of research studies as well as different trials has been devoted for the wastewater treatment related issues. POME contains a high amount of degradable organic matter, and the discharge of improperly treated POME though creates adverse impact to the environment [1]. The POME is a thick brownish viscous liquid waste and non-toxic as no chemicals are being added during oil extraction but has an unpleasant odor. It is predominantly organic in nature and highly polluting [1]. POME is a colloidal suspension consisting of 95–96%water, 0.6–0.7% oil and 4–5% total solids, including 2–4% suspended solids originating from a mixture of sterilizer condensate, separator sludge and hydro cyclone wastewater [1]. POME is one of the major sources of a water pollutant in Malaysia. For example, in a conventional palm oil mill, 600–700 kg of POME is generated for every 1000 kg of processed FFB (fresh fruit bunches) [2]. However, the substances in POME could be able to support the growth of microbial as well as microalgae.

Microalgae naturally existed in many of the Palm Oil Mill processes, as algae bloom, decreasing the water quality and particularly in Malaysia, daily industrial production of massive amount of effluent, which is released into river, is an important issue that causes huge negative environmental impacts, especially in Malaysia; the release of massive amount of effluent into the river is an prominent issue that causes immense negative environmental impacts. Regrettably, the related industries fail to meet the regulation and discharging the materials with high level of BOD into rivers. The common conventional treatment facilities (e.g. holding ponds, decanter, anaerobic digesters and aerated lagoons) are unable to meet the regulations set by the Department of Environment (DOE) by the level of BOD at 100 mg/L [3]. Therefore, high-rated system is necessary to treat discharged POME in order to decrease water pollution. Based on the points mentioned above, the aim of this study is to introduce the method for culturing the mixture of algal species (microalgae and macrophytes) in the existing pond treatment system of Palm Oil mill Effluent (POME) to achieve high efficient wastewater treatment and to suggest a specific nutritious and valuable diet using the mixed cultural products of algae to enhance the animal and/or fish feeding quality.

It is also seen that algae can grow in the wastewater even in the heavy metal contaminated waters, which means that no primary farm land is required for cultivation [4]. Hence, algae do not compete with food crops. In addition, algae can grow much faster compared to the traditionally grown oil crops such as sunflower and oil palm [5]. Microalgae were grown in 1950's, when they were identified as a potential food source for humans and animals [4, 6]. Later, because of fuel crisis in the 1970's, researchers began to evaluate the potential for using algae in the production of bio-diesel [6, 7]. Now, microalgae have been re-discovered as fuel source, waste water polisher and CO_2 sink. For the fish ponding system, it can be used as an efficient strategy for CO_2 intake from the pond water which, will help to concentrate more oxygen to the system. Thus, it will improve the growth condition required for fish present in the pond water. Moreover, its potential as a carbon dioxide sink may be interesting in the context of a carbon trading system [6, 8]. Research shows that microalgae require less water than terrestrial plants and is because the cells are grown in suspension; hence they have more efficient access to water [7, 9, 10]. For the same reason they perform well in taking up CO_2 and other nutrients .

This study was aimed to propose a new approach of combining micro and macro algae for the uptake of nutrient from wastewater discharge (Palm Oil Mill Effluent) and further to be used as feedstock. Based on the literature survey, there is no research being carried out for the combination of macro and micro algae in treating wastewater and converting the product to feedstock. Furthermore, the significant advantages of this study are to treat the wastewater with zero chemical usage by applying micro and macro algal species.

2.0 ANALYTICAL PROCEDURE

The promising aspect of the methodology used in the current study is for the strategic development of open pond system using mixed culture of Macroalgae and Macrophyte are summarized in Figure 1. The sample of palm oil mill effluent (POME) was collected from the final pond of a Palm Oil Industry (FELDA palm oil mill, located at Kulai and Kahang, Johor, Malaysia) before it is discharged into the Desa Bakti river. The samples were stored in plastic containers with proper labeling for preservation and until further use. Then, the collected samples were analyzed according to the standard methods [3].

a)Abundance growth of Macroalgae existing in POME pond (PPNJ, Kahang)

b) Abundance growth of macrophyte existing in wastewater treatment plant (UTM, Desa Bakti)

Figure 1 Blooms of micro and macroalgae

After which the micro algae and macrophyte were grown in a fabrication tank of 30 L capacity along with the different concentrations of POME, after sufficient growth they were harvested and cleaned then dried and considered ready to be used as an animal feed stock.

3.0 RESULTS AND DISCUSSION

3.1 Chemical Oxygen Demand (COD)

The standard protocol for COD measurement was to measure the amount of organic compounds in the sample. It was performed according to the standard methods for the examination of water and wastewaters [3]. The aim of the estimation was to study the potential of microalgae in reducing the COD in wastewater.

The microalgae cells were homogenized thoroughly using vortex and later added into the COD vials. The reactor block was pre-heated to ensure an accurate digestion at 150^0C for 2 hours. After 2 hours, the samples were allowed to cool to room temperature. Measurements were taken using Hach DR Spectrophotometer, according to method 5220 B [3].

Table 1 Consumption rate by algae at different concentrations of POME

COD consumption rate (mg/L.day)				
Concentration (mg/L)	0	250	500	1000
Initial Overall Concentration (mg/L)	124	396	590	940
Final Concentration (mg/L)	33	37	40	480
Rate	4.55	17.95	19.64	23.00

The concentration of COD decreased with time for varying concentration of substrate as can be seen in Figure 2 and summarized in Table 1. It was found that algae could be able to remove 71.43%, 71.16%, 69.42%, 29.81% of COD with concentrations of 0, 250, 500 and 1000 mg/L, respectively. These result shows that algae is very effective in removing organic matter at range of 250 mg/L. The COD removal at 500 mg/L was comparable to that of 250 mg/L, while at COD 1000 mg/L, the rate was drastically decreased.

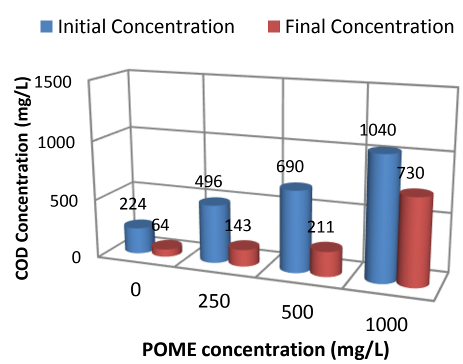


Figure 2 Initial with final COD removal in different POME concentration

It is worth noting that Both COD removal and COD consumption in the control achieved the highest removal percentage. Micro and macro algae could able to achieve optimum growth in the absence of POME. In addition, effect on the concentration of a limiting nutrient, both at low or high nutrient concentrations. In heterotrophic cultures with dense algae, the carbon substance in the medium is depleted very rapidly, and thus a large quantity of carbon source is needed for batch culture to extend the growth period. Therefore, it is necessary to determine what concentration can be used without inhibiting growth.

The substrate removal efficiency achieved in this study is almost similar compared of other studies previously published. For instance, *chlorella vulgaris* grown in batch mixed cultured using piggery wastewater uptake organic matters were 88%, 55.6% and 20.6% for various COD concentrations 250, 520 and 1100 mg/L, respectively [11]. Similar to that of COD removal, Figure 2 shows slight decrease in terms of substrate consumption, with the lowest value achieved at the end of the experiment. There is an uptake of substrate for the storage of algae species.

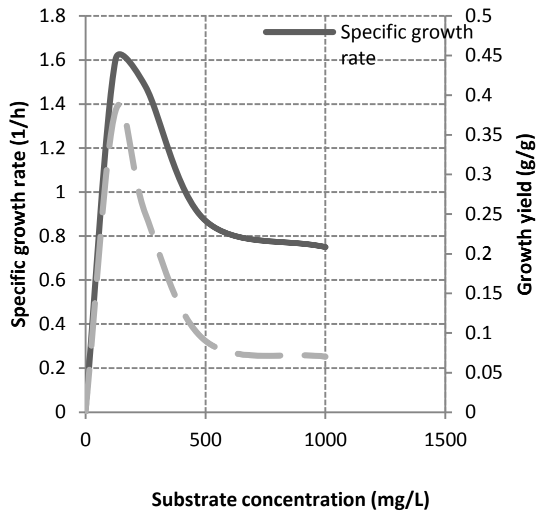


Figure 3 Effect of COD concentration on the growth of micro and macro algae

The results obtained in Figure 3 shows that specific growth rate decreased with increasing substrate concentration, its means substrates could be inhibitors at higher concentrations. The results proved algae can perform heterotrophic growth besides the common autotrophic growth. The organic substances may function directly as an essential organic nutrient or act as an accessory growth factor [12]. This is shown in Figure 3**,** which shows the decrease in growth yield and growth rate of algae when the substrate concentration was increased.

Growth was slow with apparent COD inhibition at concentrations above 500 mg/L. COD concentration above 500 mg/L greatly affects the efficiency of biomass production. In all cultures, algae were green, clearly indicating chlorophyll synthesis. More than 85% of palm oil mills depend solely on ponding systems due to their low costs. Hence a higher probability of algae blooms in the pond, which can be taken advantage of to increase the biomass production of microalgae [13].

3.2 Harvesting of Micro-Algae and Macro Phyte

Conventional processes used to harvest micro-algae include concentration through centrifugation [14], foam fractionation [15], flocculation [16-17], membrane filtration [18] and ultrasonic separation [19]. Harvesting costs may contribute 20- 30% to the total cost of algal biomass [20]. The micro-algae are typically small with a diameter of 3–30 μm, and the culture broths may be quite diluted at less than 0.5 g l^{-1}. Thus, large volumes must be handled. The harvesting method depends on the species, on the cell density, and often also on the culture conditions. Filtration and centrifugation techniques for harvesting of microalgae were applied in this research. This kind of methods could be used for determining of various tests for animal feedstock. On the other side, we used the net techniques as an easy and efficient method for macrophyte harvesting, which is helpful to decrease the cost of biomass production.

There are a number of positive effects that favor algae harvesting. Formerly, the only way to collect the seaweeds (macro algae) was to pick them one by one from the nets, a cold, tedious, and slow job. There is main criterion required to be met by algae harvester: “it must be able to harvest floating algae in water deeper than 30 cm without disturbing the bottom or plant and animal life to any considerable extent.

■4.0 CONCLUSION

The findings of this research show the application of industrial waste POME to serve as a useful nutrient for micro-micro algae to treat wastewater and produce (waste to valuable product). The different concentrations of POME used during the experiment greatly increased the biomass yield that can be used as a potential feedstock for animals. The new approach of combining micro-macro algae of nutrient uptake from waste water was achieved. Moreover, over all it can be concluded that the abundance growth of algae in the palm oil mill effluents of Malaysia will provide dual benefit; it attaining the cost reduction for waste water treatment method and for the production of feed stock to be used for animals which will be considered to be a low cost procedure, and also algae will absorb and remove all hazardous particles present in POME that can create impact on the environment.

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