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Bioenergy Production and Nutrients Removal by Green Microalgae with Cultivation from Agro-Wastewater Palm Oil Mill Effluent (POME) - A Review

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Environmental pollution specifically wastewater is gaining attention both in the developed and developing countries. Malaysia is considered as one of the major palm oil producers in the world. Therefore, it is important to develop an environmental friendly and economic method to treat palm oil mill effluent (POME). The wastewater can serve as an economical nutrient source or substrate that can support the cultivation of microalgae. This can be a great nutrient for algal cultivation at the same time as remediating effluent and generating biomass. Nowadays, many microalgae species are being investigated to determine their potential and effectiveness for phytoremediation application, especially high growth rate. However, using synthetic media for growing microalgae in a mass scale is costly. It is acknowledged that POME (as nutrients enriched media) assisted enhanced microalgae growth under certain condition can considerably reduce the presence of organic and inorganic compounds. In this review, the potential of wide range of the predominant microalgae species with main focus on green microalgae (high removal efficiency): *Chlamydomonas sp* and *Chlorella sp* were investigated. Moreover, we discussed about the history, methods and future prospects in nutrients removal by green microalgae comprehensively. This review discusses several potential strategies for tackling the environmental issue generated by agro-waste water POME with enhancement of biomass productivity which can be used as an alternative for energy production.

1. Introduction

According to international data, the supply of water usage is 22 % in industry, 8 % local and 70 % in agriculture (UNESCO, 2003). A substantial part of this water is released into the environment as wastewater (Zeraatkar et al., 2016). Palm oil industry produces a large volume of palm oil mill effluent (POME) though contributing significantly to the economy of several ASEAN countries (Tan et al., 2018). In Malaysia, the palm oil industry contributes tremendously to the pay of the nation, since palm plantations represent 77 % of agricultural land and around 15 % of the aggregate land region (Bakar et al., 2018).
As indicated by Malaysia Palm Oil Board (MPOB), around 35 Mt of unrefined palm oil was created in 2016 that brought about the arrival of 6 Mt of POME to the earth (Igwe and Onyegbado, 2007). POME is a destructive waste that ought to be dealt with before it can securely be discharged to the environment (Lam et al., 2018). It was evaluated that, for every 1 t of rough palm oil created, 5 - 7.5 t of water are required, and over half of the water will wind up as POME, which is the significant wellspring of water contamination in Malaysia (Kamyab et al., 2017). POME creates a lot of very contaminated wastewater. POME is a thick and brownish slurry squander that has water-dissolvable segments of palm organic product (Zangeneh et al., 2018). POME has a high biochemical oxygen demand (BOD) and synthetic oxygen Demand (COD), which is 100 times more than

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municipal sewage. On the other hand, POME is a non-toxic waste but contribute to environment ecological issues because of its expansive oxygen exhausting capacity in aquatic frameworks, for example, natural and supplement substance. As one of the significant waste delivered from palm oil industry, treatment of POME has been given attention for two fundamental reasons: (i) POME has high natural and oil content that does not take into account guide release to watercourses and (ii) because of the high natural substance, POME is an appropriate material to be utilized for bioenergy production (Tan et al., 2018). It is likewise known to be a decent wellspring of supplements for green growth algae cultivation (Kamyab et al., 2018). Since it is rich in minerals and contains vitamins that may give significant supplements to animate cell culture (Habib et al., 1997). In addition, the profoundly moved nitrogenous mixes in POME could be advantageous for the development of different kinds of microorganisms (Islam et al., 2018). Photosynthetic organisms (macroalgae and microalgae) require daylight, water, and CO_2 to create biomass (Stylist, 2009).

Expanding concerns about environmental change and manageability of petroleum products based economies have brought enthusiasm to microalgae for the potential to set up the bio-based economy, for the most part, because of their higher areal productivity over conventional biomasses (De and Francisci et al., 2018). All things considered, algal biomass generation cost is as yet one noteworthy obstruction for commercialization of algae as bioenergy items, particularly for the low-value ones, for example, biofuels. As an outcome, current use of algal biomass is fixated on high-value items (De Francisci et al., 2018). It is unequivocally prescribed to deliver biofuel at the same time with value-added by-products, following a biorefinery technique (Rawat et al., 2013). The combination of microalgae with wastewater treatment for evacuation of supplements and dangerous components can also prompt a further advance towards a cost-effective process, by saving the cost for N and P manures when utilizing supplement rich streams (Abdelaziz et al., 2013).

The supplement expulsion is essentially an impact of absorption of nutrients as the microalgae growth, however, other supplement stripping marvels additionally happen (Larsdotter, 2006) and income from wastewater treatment would help the general procedure economy. Determination of proper algal species is vital: the capacity of the species to grow in particular wastewaters and afterwards create biomass appropriate for assist change to high by-products directly affects the potential incomes. The utilisation of wastewater as the culturing media includes stricter necessities for robustness of microalgae against adverse conditions, for example, contamination with a dangerous component and competition with unwanted microorganisms (Osundeko et al., 2014). A few studies managing algal consortia recommended *Chlamydomonas* and *Chlorella sp*. as moderately vigorous species that can grow in wastewater (Kamyab et al., 2015).

Aside from the chose species, biomass generation combined with wastewater treatment relies upon an assortment of activity parameters, for example, kind of wastewater, light intensity and cycle, pH, temperature, etc (Larsdotter, 2006).

Utilizing microalgae in POME treatment is a known idea (Lam et al., 2011), and the microalgae biomass extraction for lipid can be utilized as biofuel. However, literature regarding this subject is as yet constrained. Kamyab et al (2016) researched biomass and lipid generation of *Chlorella pyrenoidosa* utilizing POME. Kamyab et al. (2016) considered the impact of POME on lipid efficiency of *C. pyrenoidosa* in hybrid photobioreactors (HPBR). Kamarudin et al. (2013) revealed that bioremediation of POME utilizing *Chlorella vulgaris* has evacuation effectiveness of ammoniacal nitrogen 61.0 %, ammonium 53.8 %, Phosphorus 84.0 %, Phosphate ion 66.2 %, COD 50.5 % and BOD 61.6 %. Ding et al. (2016) investigated a recently confine microalgae named *Chlamydomonas sp* UKM 6 in POME and decided the capability of microalgae production and expulsion of nutrients. As indicated by Kamyab et al. (2015) the ideal accomplishment rate of nutrient evacuation with *C. incerta* was around 67.35 % of COD for 250 mg/L of POME concentrations in 28 d. As expressed by Nur (2014) POME has been examined for their potential as a medium wellspring of green growth algae particularly *Chlorella sp*. Nur and Hadiyanto (2015) explained cultivation of *C. vulgaris* in 40 % POME with the expansion of various carbon sources can be an elective technique for microalgae development in POME medium for the age of biomass to be utilised as a biofuel feedstock.

There is still a need to research an effective microalgae possibility to apply in wastewater treatment technique for remediation and at the same time deliver lipid. Using microalgae into the treatment framework cause to a few invaluable contain improving treatment strategy, microalgae growth, diminishing nutrients, decreasing expense and efficient. This paper expects to expand the utilisation of microalgae in expelling organic particle could lead to the clean and feasible generation of palm oil process.

The goal of this research is to give a better image of the most elevated potential uses of microalgae particularly in a tropical locality like Malaysia. As history has appeared, research studies on microalgae have been vast and varied but they have not always resulted in specific regions with specific species of microalgae. Hence, our motivation is to clear up the real circumstance by just talking about genuine pertinent and to outline them with cases of *Chlamydomonas* and *Chlorella* for even commercialized reason and bioenergy production.

2. Industrial wastewater and POME treated by microalgae

According to global statistics, the distribution of water usage is 22 % in industry, 8 % domestic and 70 % in agriculture (UNESCO, 2003). A big fraction of this water is discharged into the environment as wastewater. It has been estimated that 5- 7.5 t of water is required for producing 1 t of crude palm oil and more than 50 % of the water ends up as POME (Ahmad et al., 2003). It is necessary to have a modern approach to treat the industrial effluents. Disposal of such huge effluent volumes to surface waters has major implications for the environment and freshwater sources have forced authorities to regulate standards for discharging industrial wastewater (IW). The initial composition of the IW largely determines the technical and economic requirements for treatment to meet regulated discharge criteria. The composition of the IWWs is as diverse as the sources and sites of IWWs. Industrial wastewaters mostly contain heavy metals as well as organic toxins and surfactants (Ahluwalia and Goyal, 2007).

Nowadays there is a great and continuous increase in industrialisation, infrastructure and urban expansion in Asia, which has contributed to significant waste treatment demand and water shortage due to water pollution (Prinz and Brontowiyono, 2015). Recent industry including agro-based industry as one of the major sectors discharge a large amount of wastewater annually affecting the other water sources and human life. The palm oil industry in Malaysia is producing the largest amount of organic pollutant loads into rivers (Abdullah et al., 2009). Indonesia and Malaysia are the two largest palm oil producing countries and is rich with numerous endemic, forest-dwelling species (Abdurahman et al., 2011). Malaysia has a tropical climate and is prosperous with natural resources. Oil palm currently occupies the largest acreage of farmed land in Malaysia (Chin et al., 2013). POME is considered to be a highly polluted waste having an unpleasant odour. There is a greater need to find an alternative way to utilize these organic pollutants for the benefit of both human beings and the environment (Kamyab et al., 2017).

Hence, characterization of the IW in order to determine the type of pollution and available nutrients is important as it directly influences the algae growth and IW treatment (Komolafe et al., 2014). In living algae cells, the ability to treat IW is dependent on the growth rate; growth rate directly determines the biomass concentration, and it, in turn, influences the total biosorption capacity of metal ions (Volesky, 2007). Furthermore, to date, no detailed techno-economic feasibility on such process has been conducted. It is to be noted that sustainable reliability of any proposed process, must be tested at pilot and demonstration scale prior to commercialization.

Palm oil mill Effluent (POME) is the wastewater generated by processing oil palm and consists of various suspended materials. Meanwhile, a nitrogen source (usually appears in nitrate form) plays an important role in promoting microalgae growth. In order to grow microalgae effectively, the basic nitrate concentration required is in the range of 200-400 mg/L (Li et al., 2008). Other minerals such as Fe, Zn, P, Mg, Ca and K, which are required for microalgae growth, also exist in POME. POME emerged as an alternative option as a chemical remediation to grow microalgae for biomass production (Lam et al., 2011). When compared to the conventional wastewater treatment process which introduces activated sludge and biological floc to degrade organic carbonaceous matter to CO_2, microalgae can assimilate organic pollutants into cellular constituents such as lipid and carbohydrate and achieve pollutant reduction in a more environmentally friendly way (de Andrade et al., 2016). Moreover, parameters such as temperature, irradiance and, most markedly, nutrient availability have been shown to affect both lipids composition and content in many microalgae (Karpagam et al., 2015a).

3. Bioenergy production and nutrients removal by green microalgae

Microalgae research has gained much interest in recent years as it does not displace food crops for bioenergy production. Certain microalgae species have been reported to contain high amounts of oil to biomass ratio, which could be extracted, processed and refined into transportation fuels, using currently available technology. Microalgae are photosynthetic, aquatic plants that utilise inorganic nutrients such as nitrogen and phosphorus (Alvarez et al., 2000). Algae have several industrial applications that can lower the cost of biofuel co-production. Among these co-production applications, environmental and wastewater bioremediation are increasingly important (Zeraatkar et al., 2016). These algae normally have fast growth rate and their production are not seasonal and can be harvested on daily basis. Microalgae structures are primarily for energy conversion without any development beyond the cells, and their simple development allows them to adapt to the prevailing environmental conditions and prosper in long term. The selection of appropriate microalgal strain is an important factor for the overall success of the by-product resulting from the microalgae (Rosenberg et al., 2008). The ideal algal strain for waste water treatment and biodiesel production should: (a) have high lipid productivity; (b) be robust and able to survive the shear stresses common in photobioreactors; (c) be able to dominate wild strains in open pond production systems; (d) have high CO_2 sinking capacity; (e) have limited nutrient requirements; (f) be tolerant to a wide range in temperatures resulting from the diurnal cycle and seasonal variations; (g) provide valuable co-products; (h) have faster productivity cycle (i) display self flocculation characteristics.

Lipid from microalgae is one of the putative oil resources to facilitate the biodiesel production during this era of energy dissipation and environmental pollution (Karpagam et al., 2015b). The average lipid content of algal cells varies between 1 % and 70 %, but can reach 90 % of dry weight under certain conditions (Xin et al., 2010). The total content of lipids in microalgae may vary from about 1 - 85 % of the dry weight, with values higher than 40 % is typically achieved under nutrient limitation. The interest in microalgae for biodiesel production is due to the presence of high amount of lipid content in some species, and also due to the fact that lipid synthesis, especially of non-polar TAGs (triacylglycerols), which are considered to be the best substrate for producing biodiesel, can be modulated by varying the growth conditions (Monari et al., 2016). Lipid accumulation in microalgae occurs when a nutrient is exhausted from the medium or becomes the growth limiting factor. Cell proliferation is prevented but carbon is still assimilated by the cell and converted to TAG lipids that are stored within the existing cells thereby increasing the concentration of lipid (Meng et al., 2009). Up to now, *Chlorella sp.* And *Botryococcus braunii* were determined as potential microalgae to biomitigate CO_2 from flue gas while producing high lipid content for subsequent biodiesel production (Yoo et al., 2010).

Biodiesel can serve as an alternative diesel fuel that offers some advantages to the environment, such as being biodegradable, non-toxicity, better lubricity, low SO_x and CO emission (Jacobson et al., 2008). Biodiesel from renewable sources can be an alternative to reduce our dependency on fossil fuel and assist to maintain the healthy global environment and economic sustainability. However, they are also some disadvantages as NOx emissions. Production of biofuel from food stock generally consumed by humans or animals can be also problematic and the root cause of worldwide dissatisfaction. Biofuels production from microalgae can provide some distinct advantages such as their rapid growth rate, fast greenhouse gas fixation ability and high production capacity of lipids (Alam et al., 2012). Relative to terrestrial biofuel feedstocks, algae can convert solar energy into fuels at higher photosynthetic efficiencies and can thrive in salt water systems. There has been recently considerable progress in identifying relevant bioenergy genes and pathways in microalgae, and powerful genetic techniques have been developed to engineer some strains via the targeted disruption of endogenous genes and/or transgene expression. Collectively, the progress that has been achieved in these areas is rapidly advancing our ability to genetically optimise the production of targeted biofuels (Beer et al., 2009).

4. Conclusion

The use of wastewater for the growth of microalgal cultures is considered beneficial for minimising the use of freshwater, reducing the cost of nutrient addition, removing nitrogen and phosphorus from wastewater and producing microalgal biomass as bioresources for biofuel or value-added by-products. This review has shown that the integration of POME treatment with microalgae growth for useful by-products. It could be a beneficial alternative to using wastewater as a source to grow algae to be processed to obtain bioenergy. Various aspects need to be studied for microalgae cultivation in POME, especially to control contamination. Moreover, the location of Malaysia on the equator makes microalgae cultivation potentially productive. Other aspects that should be considered include the concentration of POME used as media, isolation/selection of microalgae strains, reactor/system selection and optimisation of growth operating conditions for microalgae biomass to be extracted for lipids as an alternative biofuel resource.

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