Maghrebian Journal of Pure and Applied Science

ISSN : 2458-715X

http://revues.imist.ma/?journal=mjpas&page=index

https://doi.org/10.48383/IMIST.PRSM/mjpas-v6i2.22927

Microalgae for future biodiesel production: Algaculture, Environnement impact

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Received 21 Novembre 2020, Revised 31 January 2021, Accepted 28 February 2021

Abstract Currently, the continued use of petroleum based fuels is considered unsustainable due to resource depletion and the accumulation of greenhouse gases in the environment, in addition to land and water degradation. Therefore, biofuels from renewable sources can be an alternative to reduce the consumption of fossil fuels and contribute to maintaining a healthy global environment and economic profitability. Unfortunately, biodiesel produced from food stocks generally consumed by humans and animals can be a source of increased food market prices due to the increased use of arable land for growing biomass for the production of first and second generation biofuels. The production of biofuels from microalgae, as a third generation of biodiesel production, has some distinctive advantages, such as their rapid growth rate, greenhouse gas binding capacity and high lipid production capacity. This mini-study examines the current status of algae-based biofuels as a renewable energy source and their impact on the environment.

Keywords: Biodiesel; microalgae; Renewable; energy; photobioreactors

1.Introduction

At the present time, a large portion of the world energy demand is met by petroleum (36%), coal (27%) and gas (23%) [1]. This means that more than 80% of global energy consumption comes from fossil fuels, mainly because of their availability and convenient use. However, it is expected that the world fossil fuel production will be less available, more expensive and of increasing environmental concern in the coming century [1, 2]. Consequently, this motivated research and application of new technologies and exploration of renewable and sustainable energy resources. The most promising alternative energy source is biomass, which can be converted into biofuels [3]. The term biofuel refers to any liquid, gas, or solid fuel mainly produced from biomass resources such as Biodiesel. Recently, there has been increasing interest in the use of algae as a feedstock for biofuel production due to their renewable nature

and the fact that they overcome the disadvantages of first and second generation biofuels [4]. Many microalgal species can be induced to accumulate substantial quantities of lipids, often greater than 60% of their dry biomass [2]. Indeed, their energy production is 15 to 300 times higher than traditional crops on an area basis. In addition, the production of third generation biofuels from microalgae do not requires irrigation, pesticides and can be grown on non-arable land and saline water [4]. Moreover, microalgae can be applied to wastewater treatment and industrial CO_2 capture from coal-fired power plants or other processes.
This mini review examines the Algaculture of microalgae in different types of photobioreactors (PBRs), the production of biodiesel and they environmental impact.

2. Algaculture of microalgae species

2.1. *Caracterstique of microalgae*

Microalgae are a heterogeneous group of photosynthetic microorganisms which gathers unicellular prokaryote (cyanobacteria) and eukaryote. These organisms can grow in various environments, under a wide range of pH, temperatures and nutrient availability conditions in freshwater or marine aquatic habitats. Their diversity is estimated at more than 50 000 species of which only 60 % have been studied [5]. They are classified according to several parameters such as morphology, cell structure pigmentation and life cycle.

Table 1. Oil contents of microalgae.

Name of microalgae	Oil content (% microalgae dry weight)	Reference
Chlorella Sp	63.78	[8]
Crypthecodinium cohnii	20	[2]
Nannochbloris Sp	20 – 35	[1]-[8].
Nannochloropsis salina	67	[8]
Schizochytrium sp	50 – 77	[9],[10]
Nitzschia sp	45 – 47	[11],[10]
Tetraselmis suecica	15 – 23	[10]
Phaeodactylum tricornutum	20 – 30	[11]
Chlorella vulgaris	28.07	[12]

Amongst primary feeds stocks, microalgae are one of the most promising alternative sources of biofuel [3] . They require a smaller area to grow where they need just CO_2, light and water to synthesize proteins, phospholipid and lipids, that can be converted to oil biodiesel with transesterification process [6]. In addition, microalgae have several advantages such as high photosynthetic efficiency. Indeed, they have the ability to produce over 10 to 100 time of oil in comparison to oil crops culturing in the same surface and [7] higher biomass production rich on lipids that can be up to 80% of their dry weight [3, 4] (Table 1).

2.2. *Microalgae cultivation style*

Microalgae can have an autotrophic or heterotrophic metabolism. In autotrophic culture, microalgae use inorganic carbon (mainly CO_2) and light as a source of carbon and energy respectively, while heterotrophic microalgae use only organic carbon as a source of both carbon and energy. For large-scale cultivation systems, autotrophic culture is usually considered as the dominant mode for biodiesel production. Therefore, for this mode of cultivation photosynthetic autotrophic species are mostly used. The microalgae culture can be carried out in two ways depending on whether the culture device is open (Open pond and Raceway) or closed in a transparent tanks (Photobioreactors).

2.3. *Open system (Raceway ponds)*

Raceway ponds are the most conventional systems reserved to culturing microalgae. This system is typically composed of a closed loop and oval recirculation channels (generally 0.3 m deep). The paddlewheel allow mixing by circulations that is necessary for the stabilization of algal growth and productivity. Nutrients are added to ensure an optimal growth. They can be obtained from using wastewater treatment plants or provided through runoff water from nearby land areas [2]. Even if these kinds of system are the most economical in terms of installation cost, it has a low biomass productivity compared with photobioreactors. Indeed, open ponds present many limitations such as their sensitivity to contamination (either by local species or by predators), a significant loss of water by evaporation and a temperature fluctuation which can significantly affect microalgal productivity[8].

2.3. Closed system (tubular PBR)

In contrast, tubular PBR are constructed from transparent material, to capture most of the sunlight. Compared to open system the photobioreactors can be provided up to five-time higher productivity.so, they are the most used to product biomass rich on lipids. Also, PBRs offer the best culturing conditions control the parameter such as (temperature, PH, nutrient, CO_2). The principal challenge of the closed system in biomass production in high cost of material and maintenance. To improve algal culturing, the combination of two system closed and open is suggested [4].

3. Biodiesel from Algal oil

The main current research on oil extraction focuses on microalgae to produce biofuel from algal oil. Biodiesel produced from microalgae appears to be the only renewable biofuel that can completely replace petroleum-derived transportation fuels without harming the food supply and other plant products. The cultivation of microalgae can produce 30-50% oil [2]. The oil from microalgae strains has a high viscosity, as does all vegetable oil. Transesterification of the oil to fatty acid methyl esters (FAME) is the most promising solution to the viscosity problem. Transesterification is a simple reaction that takes place with or without a catalyst using primary or secondary monohydric aliphatic alcohols as follows [13] (table 2).

$$\text{Triglycerides + Monohydric alcohol} \longrightarrow \text{Glycerin + Monoalkyl esters (Biodiesel).}$$

Table 2. Lipid contents of microalgae grown in marine and fresh water

Type of grown	Microalgae strains	(% dry wt)	Reference
Fresh water	*1.Botryococcus sp*	25 – 75	[7]
	2.Chlorella emersoni	25 – 63	[7]
	3.Chlorella vulgaris	19.2	[10], [11]
	4. Chlorella sp	10 – 48	[7], [11]
	5. Chlorella protothecoides	15 – 58	[7]
	6. Scenedesmus	21.1	[11]
	7.Chaetoceros muelleri	33.6	[13]
Marine water	*1.Chlorococcum sp*	79.5	[12]
	2.Nannochloris sp	29.6	[11]
	3.Nannochloropsis oculata	23 – 30	[7]
	4. Chaetoceros calcitrans CS 178	39.8	[11]
	5.Neochloris oleoabundans	29 – 65	[7]
	6.Pavlova salina	31	[7], [10]
	7.Dunaliella tertiolecta	18-71	[7], [13]

Many studies have screened and identified microalgal species for Improve the quality biodiesel production [18]. Evaluate biodiesel oil of tree microalgal species Spirulina, Chlorella and pond water algae by using hexane as a solvent. The maximum yield of pond water algae biodiesel and Spirulina algae biodiesel obtained using hexane as solvent was 74.60% and 79.50% respectively. In contrast, chloroform given less. the main advantage of biodiesel microalgae, its ready availability, renewability, higher combustion efficiency, and lower sulfur and aromatic content adopting biodiesel has a number of advantages, it does not contribute to atmospheric CO2 emissions due to microalgae photosynthetic (emit O2), the emission of NOx is lower than diesel , with other varieties of algae biodiesel . Density satisfies the European standards (Spirulina 860 kg/m3 and pond water algae 870 kg/m3) [10-14,18]. Microalgae have a much faster growth rate than terrestrial cultures. The unit oil yield of algae is estimated to be between 18,927 and 75,708 L/acre/year, which is 7 to 31 times higher than that of the next best crop ,

palm oil, at 2,404L/acre/year [10]. The major disadvantages of biodiesel are its higher viscosity, less energy content, higher cloud point and pour point, higher nitrogen oxide (NOx) emissions.

4. Environmental Impact of biodiesel based microalgae.

The increase in the price of fuel imposes high costs on families and utilities. Oil, the world's main source of fossil energy, is associated with significant environmental problems, including greenhouse gas emissions. Many research is providing an interesting solution for alternative energy sources to petroleum: the production of biodiesel from micro-algae [2, 6, 19].The production of biodiesel has many environmental and ecological benefits compared to diesel. Firstly, less of water necessary to growth the microalgae, in addition, they using for the wastewater treatment. Secondly, the production of biocarburant based of microorganism photosynthetic, decrease the amounts of CO_2 in atmosphere, due to photosynthesis of CO_2 by the microalgae. Finally, land use by the first and second generation of biofuel increase the cost of food supply. As a result, microalgae reduce the use of arable land through their cultivation in photobioreactors.

4.1. Wastewater treatment

Many studies demonstrate that the production of biodiesel by microalgae can be associated with wastewater treatment. This production of biodiesel can be more environmentally friendly. Microalgae have many properties for wastewater treatment, for example elimination of pollutants (NO^{3-}, le PO_4^{3-} le tributylétain (TBT), 17β-estradiol (E2), phenols, 2,4,6-trinitrotoluene),according to the different types of wastewater(municipal wastewater, piggery wastewater, industrial wastewater, agricultural wastewater) [20], ambient climate, and a high growth rate. On the one side, the cultivation of microalgae with wastewater can reduce the rate of overexploitation of water bodies. On the other hand, they can minimize the impacts of wastewater discharges. Therefore, the use of microalgae to produce biodiesel in combination with efficient and low-cost wastewater treatment systems offers a promising direction for water and energy problems and environmental protection [6].

4.2. Climate protection: the reduction of greenhouse gases

The development of rapid industrialization and the burning of fossil fuels have caused an increase in CO_2levels in the atmosphere. Increasing CO_2 content is an important factor in climate change (GHG emissions). This is why a lot of research shows an alternative to reducing CO_2 in the atmosphere. Use of photosynthetic organisms that convert CO_2 from the atmosphere or industrial emissions, to O_2 and biomass that can be converted to biodiesel production. Microalgae can produce 1.0 kg of algal biomass by consuming about 2.0 kg of CO_2 [4], not only is CO_2 gas reducing, but also nitrogen oxides (NOx), carbon monoxide (CO), and sulfur oxides (SOx) [3], show that biodiesel-based microalgae can reduce gas emissions (Sulphur dioxide) by up to 100% compared to diesel. In addition, [16] studied fresh microalgae Chlorella sp grown under different CO_2conditions (8%, 4%), the results showed that microalgae grown under CO_2 aeration 8% increased biomass by 23% compared to CO_2 aeration (4%).thus, the production of an environmentally friendly biodiesel with reduced gas emissions.

4.3. Land reuse

Compared to microalgae culture, microalgal biodiesel production systems have an ecological impact of much less than the first or second generation, especially since these lands do not necessarily have to be adapted to agricultural crops. The characteristic of culturing algae are a solid ground and a large area of marginal land. Such as, saline soils, arid or semi-arid lands or deserts. as a result reduces competition with food crops [21] . Microalgae are already reported to produce 7 to 31 times more oil than the next best crop. Palm oil, for the production of biodiesel from a unit yield of algae oil per unit area of 20,000 and 80,000L/acre/year [10]. The production of microalgae for biofuels could provide a concrete solution to the food-fuel conflict.

5. Conclusion

Currently, a new technology is emerging that is capable of solving the main environmental problems. The emission of CO_2, but also the degradation of soil and water through biodiesel based on oil plants, as well as the need for an inexhaustible source of energy may be problems of the past thanks to this fuel made from micro-algae, which is a perfect substitute for fossil oil.

The use of an industrial process that mixes microalgae, $CO_2$and sunlight, called photobioreactors, is at the origin of this new ecological fuel.one of the first reactors in which this accelerated process of oil formation is taking place have been in operation for several years, as well as the first attempts to introduce this fuel on the world market. We are witnessing the genesis of future energy. The development of research and engineering will guarantee a high yield from future biodiesel fields around the world. So concluding that bio petroleum produced from microalgae will be the energy and environmental solution to ensure the development of an over-polluted world.

Acknowledgments

We would like to thank my Professor Dr. Nadia El Kadmiri, and all the staff of the Sciences and Technology Department, Polydisciplinary Faculty of Taroudant, IBN ZOHR University, and Taroudant, Morocco.

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