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RESEARCH INNOVATION IN ALGAL BIOTECHNOLOGY: TOWARD THE ESTABLISHMENT OF A BIOFUEL

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ABSTRACT:

Since you're looking for a renewable fuel source for your vehicle, look no further than biofuels. Biofuels' long-term viability will hinge on the creation of sustainable technologies that are now not financially feasible. The optimal mix of technological innovation in systems and processes, together with economic feasibility in the actual execution and integrated scale-up for commercial production and sale, is required for the successful development of the algae-based biofuels and coproducts business.In response to rising oil prices and a heightened concern for ensuring energy security, biofuels research has received considerable attention. If we're going to make it to sustainability, we need to develop and explore renewable energy sources. Bio-diesel made from microalgae is often cited as a source that doesn't harm the environment. Determining whether or not algal biofuel can be used requires first quantifying the potential for the creation of algae biofuel on a major scale. A deterministic mathematical model was developed to forecast the technological potential of micro-algae biofuels in India. The model's goal is to locate locations with optimal sunshine and temperature for cultivating algal biomass. The model incorporates real-world constraints for things like light distribution, land usage, transmission, photon utilization, photosynthetic efficiency, and oil content based on data from public sources. At the click of a button, the program determines the optimal oil output, biomass production, and growth rates for each given oil % and solar exposure. Based on the existing solar radiation intensity in India, this preliminary resource evaluation predicts an annual algal biomass output of 159–345 metric tonnes per hectare and a lipids yield of 57,000–16,000 liters per hectare. The high numbers come from the abundant solar radiation in India.

Algae-based biofuels are discussed in this article along with the many predictions for its future use. Both the benefits and drawbacks of these biofuels are discussed. Global forces that encourage algal development are explained, with a spotlight on Egypt. In this article, we get an overview of algae biorefineries and how they work. It also outlines the five most effective methods for helping algae biodiesel companies cut expenses and speed up the market introduction of their product. The SWOT analysis for micro-algae reveals the internal and external possibilities and threats, as well as the strengths and weaknesses of the algae itself. There is an explanation of possible methods to improve algae-based fuels. We briefly examine the role of genetic engineering and other process advancements in the implementation of these new methods. The idea of using algae for wastewater treatment is proposed as a way to boost the profitability of algal biofuels.

***Keywords**: Research Innovation**,** Algal Biotechnology, Algal based Biofuel and Microalgae,*

INTRODUCTION

The availability of resources, especially in the food and energy industries, has been severely impacted by global climate change. Crops grown for food and feed must also be utilized for other purposes, such as chemicals, materials, and even biofuels if the European Union's intended bio-based economy is to work. The need for bio-based goods with numerous applications has increased as a result of the paucity of accessible fossil fuels. As a result, the question of whether or not food and non-food product production capacities will be adequate continues to be a matter of heated discussion (Draaisma*et al.*, 2013). With the world's population expected to hit nine billion in 2050, we need to discover innovative and long-lasting answers to the pressing challenges we'll face in the not-too-distant future.

Therefore, in order to tackle these difficulties head-on, marine biotechnology is being used to explore alternative production techniques (Submariner project, 2011). One of the most promising and powerful feedstocks for a long-term supply of food and energy goods is microalgae (Milledge, 2011; Wijffels and Barbosa, 2010; Williams and Laurens, 2010). Microalgae and cyanobacteria provide a viable alternative because of their potential to contribute to a wide range of scientific sectors; they also have the potential to benefit from cutting-edge scientific and biotechnological advances; and they may be used as a sustainable resource (Fortes Siqueira *et al.*, 2018; Stephens *et al.*, 2013).

What are microalgae?

Microalgae are single-celled, aquatic, photoautotrophic microorganisms that convert sunlight, carbon dioxide, and nutrients into biomass on their own (Sigamani*et al*, 2016). Research into microalgae includes both eukaryotic microalgae and prokaryotic oxygenic Cyanobacteria. The reason for this is that the fundamental and important components of their manufacturing are identical, as are the goods created and their uses across many disciplines (Garrido-Cardenas *et. al*, 2018).

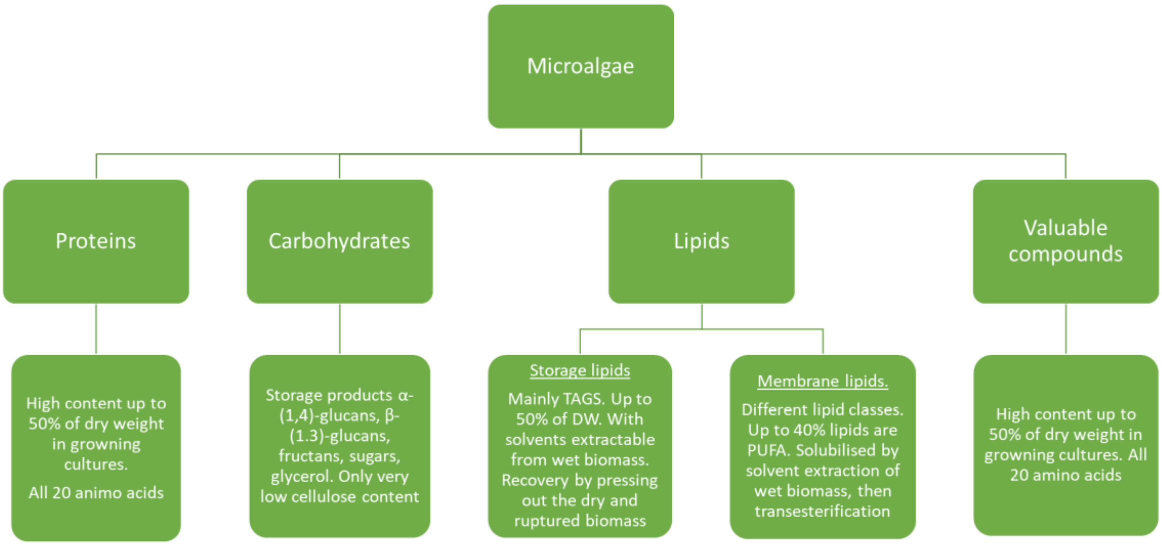
There are more than 50,000 different species of microalgae, and they may be found in both aquatic and terrestrial ecosystems. However, only around 30,000 of these species have been the subject of scientific investigation and analysis (Richmond, 2004), and only about 100 are employed in commercial applications (Su*et al.*, 2017). While microalgae are typically categorized based on color, life cycle, and cellular structure, modern next-generation sequencing methods have allowed for the discovery of previously unknown species (Ebenezer *et al.*, 2012; Brennan andOwende, 2010).

According to their physiology, which relies on the accumulation of high added-value chemicals (Guedes *et al.*, 2011), microalgae are able to adapt in a range of habitats, even in the presence of unfavorable circumstances, as seen in Fig. 1. Environmental elements like as temperature, light, pH range, CO_2, nitrogen, phosphorus, sulfur, and other nutrient supplies all play a role in the wide chemical composition range and the differentiation that occurs even amongst strains (Becker, 2004). As a result, the composition may be altered by changing the algal components and the growing circumstances, as well as switching up the product and its properties (Forján*et al.*, 2015).

External sources (such as circular and raceway ponds) are widely utilized for microalgae culture in both natural and artificial glasses of water, whereas closed systems (such as tubular, vertical columns, and flat-panel photobioreactors) have been created to address the shortcomings of the former (Rodolfi*et al.*, 2009; Carvalho *et al.*, 2006). Harvesting is the next step after cultivation and involves separating the biomass from the remaining liquid (culture medium). Since the cells of some microalgal species are so tiny (between 2 and 40 m) and the **operation might be costly, harvesting is done in a variety of ways (Lee *et al.*, 2014).**

Figure 1 Main components of typical microalgae. Modified from: Schmid-Straiger, 2009.

It is the unique adaptability of microalgae and cyanobacteria, which allows them to provide energy for growth



and preservation, that characterizes them and makes them suitable as a sustainable renewable source in a circular economy strategic environment (Herador, 2016). Microalgae and cyanobacteria, in particular, can adapt to and thrive in extreme environments including high temperatures, low temperatures, lack of oxygen, high salinity, strong light, high osmotic pressure, and high levels of ultraviolet radiation (Christaki*et al.*, 2012). Other characteristics include a short life cycle, rapid growth, high productivity, little sensitivity to seasonal changes, low production costs, and an abundance of raw resources (Christaki*et al.*, 2012). They have a distinct advantage over common plants since they don't require arable land or clean water for growth.Their adaptability means that the same method of culture may be used for a variety of purposes, including food and energy production, cosmetics, medicines, and wastewater treatment (Wang *et al.*, 2015). So, the wide range of useful applications they might potentially provide across various production technologies attests to their immense biotechnological potential (Fortes Siqueira *et al.*, 2018). Microalgae are increasingly being employed in commercial and industrial applications, and a depiction of the most common species is shown in Fig. 2.

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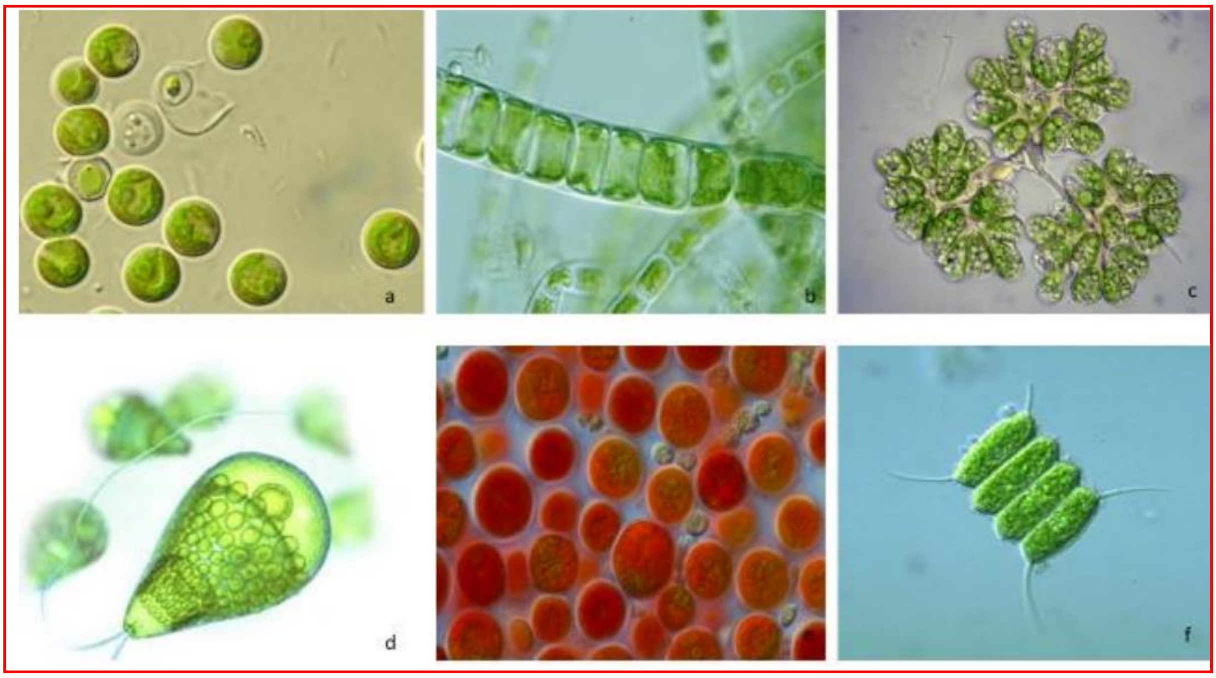

Figure 2 Representation of some of the most commercial microalgae species: a. *Chlorela vulgaris* b. *Arthrospira platensis* c. *Botryococcusbraunii* d. *Dunaliella salina* e. *Haematococcuspluvialis* f. *Scenedesmus quadricauda*

Algae-based biofuel's creditability

Compared to other types of biofuels, algae-based biofuels present several advantages. These advantages comprise

1. The capacity to produce oil throughout the entire year; hence, the oil productivity of microalgae is higher when compared to the productivity of the most productive crops.

2. Since algae thrive in brackish water and on land that is not suitable for agriculture, their presence does not have an impact on the availability of food or on other uses of the land.

3. They are able to connect the generation of CO_2-free fuel with the sequestration of CO_2.

4. The biofuels that algae make are safe to use and can be broken down quickly.

5. Have the ability to finish a whole growing cycle in only a few days, which gives them a high potential for rapid growth. Diatom algae have the potential to yield around 46 tonnes of oil per hectare and per year. Oil content can range from 20–50% of the total weight of dry biomass in a few different species.

6. With regard to the quality of the air, the production of biomass from microalgae may sequester carbon dioxide (1 kilogram of algal biomass can sequester about 1.83 kilograms of CO_2); this CO_2 is frequently accessible at low or no cost. On the other hand, the algae sector could be able to generate additional revenue by fixing the CO_2 emissions that result from the operation of other types of businesses. Although there are certain species that are able to utilize the flue gas as a source of nutrients, there are very few species that are able to survive at high concentrations of NO_2 and SO_2 that are present in these gases.

7. Since the nutrients necessary for the culture of microalgae, primarily nitrogen and phosphorus, may be derived from liquid effluent wastewater (sewer), not only is there the option of supplying its growth

environment but there is also the possibility of treating waste effluent. This might be studied by microalgae farms as a potential source of revenue in a way that would allow them to provide treatment of public wastewater while also obtaining the nutrients that the algae require.

8. The cultivation of algae does not necessitate the application of any herbicides or pesticides.

9. After the oil has been extracted from algae, the remaining biomass and proteins can be fermented to make ethanol or methane, or they can be utilized as animal feed, pharmaceuticals, or fertilizers. Algae can also be used to produce useful co-products, such as these.

10. Since the biochemical content of algal biomass may be changed depending on the growing circumstances, it is possible to considerably increase the amount of oil that is produced.

11. Capability of carrying out photobiological processes that result in the creation of biohydrogen.

BIOFUELS

Brennan and Owende (2010) discuss the conditions that must be met before a biofuel resource has the potential to become a source that is both economically and technologically sustainable.

1. To be productive, by the selection of the most efficient strains, with high lipid levels and high photosynthetic activity. These requirements are as follows:
2. To cost less than fossil fuels (in terms of production and harvest), or to be similarly competitive.
3. To require less or similar use of land.
4. To facilitate improvement of the quality of the atmosphere (CO_2 absorption).
5. To consume minimum amounts of water.
6. To be competitive (for autotrophic microalgae).

Growing microalgae and cyanobacteria have the potential to fulfill these needs, making them an important bioenergy source with several ecological benefits (Wang *et al.,* 2008). Microalgae are capable of producing polysaccharides and triacylglycerides, which increases their attractiveness as a biofuel contender. The production of bioethanol and biodiesel requires these two molecules, among others (Carlsson *et al.,* 2007). Several types of biofuels may be made from microalgal biomass by technical processes such as thermochemical and biochemical conversion, chemical reaction, and direct burning, as shown in Fig. 7. Biomass type and amount, energy form (biogas, bio-oil, biodiesel, and bioethanol), cost considerations, activity requirements, and intended product are all important considerations when settling on a particular kind (McKendry, 2002).

Claims against algae-based biofuels

While it has the potential to be a source of biofuels, the development of microalgae-based biofuel technology has been hampered by a number of obstacles, which have prevented it from being economically viable.These are some of them:

1. The choice of species needs to strike a balance between the requirements for the production of biofuel and the extraction of valuable by-products.

2. Must obtain increased photosynthetic efficiency by continuously developing photobioreactors in order to meet this requirement.

3. It is necessary to create methods for cultivating a single species, lowering the amount of water lost to evaporation, and increasing the amount of carbon dioxide that is utilized.

4. Since there are not many "farms" that are used for commercial cultivation, there is a dearth of information on cultivation on a wide scale.

5. The difficulty of introducing flue gas at high concentrations owing to the presence of hazardous chemicals such as NO_2 and SO_2 in the flue gas.

6. Selecting algae strains for cultivation that are dependent on the availability of fresh water may render large-scale operations unfeasible and contribute to an already dire shortage of freshwater.

7. Although cultivation issues for both open and closed systems have been considered and explored to a certain degree, such as reactor construction materials, mixing, optimal cultivation scale, heating/cooling, evaporation, O_2 build-up, and CO_2 administration, more definitive answers await detailed and expansive scale-up evaluations.

8. To reduce the amount of money spent on daily operations, commercial farms frequently reuse the growing medium after harvesting their algae. Reusing growth media, on the other hand, has been linked to lower algal production, which may be the result of increased contamination by algae pathogens or the build-up of inhibitory secondary metabolites.

9. One of the challenges in growing algae in a culture is that the algae themselves cast a shadow on one another, resulting in varying degrees of light saturation within the cultures. This has an effect on the rate at which the algae are growing. In addition, wild strains of algae can infiltrate and take over algal culture strains, which leads to a decrease in the amount of oil produced by the algae.

10. The harvesting of the algae is still another significant challenge that must be overcome when cultivating algae in ponds or tanks. The process of harvesting algae from tanks and extracting the oil from the algae is one that is both challenging and labor- and resource-intensive.

11. The cultivation of microorganisms for an extended period of time in cultures that are nearing saturation results in the production of cell debris that has a tendency to adhere to and dirty the walls of the vessel. Scrubbing is necessary to remove such pollution; but, after a few years of use, the scrubbing destroys the surface, which in turn affects the optical qualities of even the highest-grade glass. Scrubbing causes surface degradation after a few years of usage. Soot particles from the flue are yet another type of pollutant that might be present in the case of Green Fuel.

Sustainability Evaluation of the Biofuels Sector

The production of biofuels is the most considerable non-food use of microalgae and cyanobacteria. Microalgal biofuels have been found to be uneconomical and unable to compete with traditional fossil fuels without significant public or private investment. Considering the depletion of crude oil supplies and the rising price per barrel, recent studies have concentrated on developing microalgal biofuels into a financially feasible option (Torrey, 2008). Examination of the (Aquafuels, 2018) provides evidence that microalgal fuels may be both ecologically friendly and commercially feasible.

• Energy and carbon balance,

• Environmental impacts and

• Cost of production.

It is vital that the energy levels and carbon footprint are desirable for feedstock production to be practical. Methods of life cycle assessment (LCA) evaluate and quantify production inputs and outputs to arrive at such estimates. The absence of widespread industrial production of microalgal biofuels is the biggest problem with the idea. Because of this, the only information we have comes from the commercial or laboratory manufacture of other high-value items like dietary supplements and pigments. There is also a lack of quality LCA input data, which manifests itself in incoherent system boundaries and functional units, and inconsistent methodologies, which prevent the formation of any valid assumptions; finally, the accuracy and transparency of the underlying scientific assumptions are open to serious doubt (Slade and Bauen, 2013). However, life cycle assessment (LCA) studies show that significant energy levels are required in basic production systems that only include the cultivation, harvest, and extraction processes, suggesting that microalgal production could be more efficient in the development of products other than energy. Finally, the product can have the same CO_2 emissions as regular biodiesel if the energy and nutrients needed have a high CO_2 footprint (Slade and Bauen, 2013; Gendy and El-Temtamy, 2013).

Several metrics may be used to assess the effects on the environment. To begin, a reliable and affordable water supply is essential for the long-term viability of biofuels production. There is the possibility that saltwater or brackish water might be used in place of freshwater. This fourth possibility calls for further processing to eliminate chemicals that hinder microalgal development and drive up manufacturing costs (Darzins*et al.*, 2010). While recycling water can reduce water usage and hence nutrient depletion, it also carries the danger of infection because of the presence of bacteria, viruses, and fungus in addition to metabolites and chemicals from prior operations. Because of this, water extraction is required for waste management. Energy usage and crop positioning decisions are both heavily influenced by how far away the water supply is (Lundquist *et al.,* 2010).

It has already been shown that nitrogen and phosphorus are necessary nutrients for growing microalgae. Considering that the dry biomass already contains about 7% nitrogen and 1% phosphorus, it's clear that fertilisers will need to be used. According to Wijffels and Barbosa (2010), if the EU switched to algal biofuels for transportation, the region would need almost 25 million tonnes of nitrogen and 4 million tonnes of phosphorus annually. These figures are twice as much as Europe's current annual output of fertilisers (K. van Egmondet al., 2002). However, if wastewater treatment were integrated into biofuels production on a smaller scale, recovered nutrients from wastewater would be able to restrict the flow. Nutrient recycling is already an integral part of the design and operation of many current manufacturing systems (Lundquist et al., 2010)

Plants need carbon dioxide (CO2) as a vital nutrient during growth. Carbon has a profound effect on the energy balance of the system, which is impacted by the fertilizationof carbon dioxide. The carbon dioxide (CO2) might be added either by the direct entry of flue gases to the system or through separation from the flue gas, the latter of which would need additional energy. If the species can tolerate the presence of pollutants in the flue gases, then it is preferable to utilize them directly (Slade and Bauen, 2013). Electricity is the main traditional fossil fuel used in microalgal biofuel production, with natural gas being used in some cases to dry the biomass. While there are several environmental ways to minimize it, such as reusing waste heat from power plants and optimizing manufacturing processes to consume less energy, temperature regulation may raise this demand (Aciénet al., 2012). Last but not least, the manufacturing cost may quantify the time and money invested in each stage of production and how much they add up to as a whole, giving crucial context for future research and product development. However, like life cycle assessments (LCA), they seem to have shortcomings, the most significant of which are a lack of data and a heavy dependency on characteristics and assumptions that apply only to laboratory-scale cultivations. Furthermore, recent analyses of microalgal output, estimates, carbon dioxide collection, and system design reveal aspirational goals beyond those achieved thus far (Slade and Bauen, 2013). The economic viability of microalgal biomass production is also affected by the capacity to gather co-products.

CONCLUSION

When it comes to cultivating microalgae on a global scale, open ponds are the reactor of choice. This is in contrast to closed photobioreactors, which are more expensive to build, use more energy, and require more work to keep clean. Cultures cultivated in open ponds can be shielded from rain, temperature extremes, and excessive light by placing them within a greenhouse. Axenic cultures may be obtained by using microalgae that can thrive in harsh environments such as an alkaline medium and high salinity. The harvested microalgal biomass has several applications, including in the formulation of edibles, pharmaceuticals, pigments, polymers, fuels, and fertilizers.

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