ENVIRONMENT FRIENDLY RENEWABLE ALGAE BIOFUEL PRODUCTION AND ITS FUTURE PROSPECTS

Abstract

Biomass has gained popularity in recent years due to its capacity to generate renewable electricity, green energy, biofuels, and thermal energy. Algae, which are a sort of living biomass, are the most frequent type of biomass. They absorb carbon dioxide as they grow and expel it when used for energy. Because of the carbon cycle, many people believe biomass to be a carbon-neutral source of energy. As a result, algae are the ideal contender for biodiesel production since it can minimize greenhouse gas (CO_2) emissions while providing more fuel than other bio-oil sources that require less fresh water and fertile land. Lowering greenhouse gas emissions means less environmental effect from climate change and global warming. Adequate biomass resources and a well-functioning biomass market that can ensure stable, sustainable, and long-term biomass supplies are critical prerequisites for achieving such goals. Various countries have extensive experience with developing biomass markets and connecting available resources with market demand.

Keywords: Biomass, Algae, Carbon di oxide, Greenhouse gas

Authors

Natarajan Shanthi
Assistant Professor
PG and Research Department of Botany
Pachaiyappas College
Chennai, Tamil Nadu, India.

Kotteswari Murugesan
Assistant Professor
PG and Research Department of Botany
Pachaiyappas College
Chennai, Tamil Nadu, India.

Pillathil Jegan Pillathil Senthil Mani
Research Scholar
PG and Research Department of Botany
Pachaiyappa's College
Chennai, Tamil Nadu, India.

Selvakumar Murugan
Research Scholar
PG and Research Department of Botany
Pachaiyappa's College
Chennai, Tamil Nadu, India.

Pasupathy Allasamy
Research Scholar
PG and Research Department of Botany
Pachaiyappa's College
Chennai, Tamil Nadu, India.

Subbiah Murugesan
Associate Professor
PG and Research Department of Botany
Pachaiyappas College
Chennai, Tamil Nadu, India

I. INTRODUCTION

Algae are biofuel resources that can be farmed on nonarable land utilizing saltwater or brackish water. One big advantage of using algae for biofuels is that it does not need the use of cropland for food production. Algae are organisms that develop in watery environments and generate biomass by utilizing light and carbon dioxide (CO_2). Algae are classified into two types: macroalgae and microalgae. Macroalgae are enormous, multicellular algae that occur in ponds. These bigger algae can grow in a variety of ways. Seaweed refers to the largest multicellular algae; one example is the gigantic kelp plant, which can grow to be more than 100 feet long (Li et al., 2008). Microalgae are very small in sizes usually measured in micrometers, which normally grow in water bodies or ponds. Microalgae have more lipids than macroalgae and develop faster in nature (Lee et al., 2014). There are over 50,000 microalgal species, but only about 30,000 have been selected for studies (Surendhiran and Vijay, 2012; Richmond and Qiang, 2013; Rajkumar et al., 2014). The short harvesting cycle of algae is its main advantage, which is superior to other conventional crops with harvesting cycles of once or twice a year (Chisti, 2007; Schenk et al., 2008). Furthermore, some algae may be harvested on a daily basis, algae biofuel contains no sulphur, is non-toxic, and highly bio-degradable, algal oil can be utilized as livestock feed, and leftovers can be converted into ethanol, reducing carbon emissions (Demirbas and Demirbas, 2011). Therefore, the main focus has been carried out on algal biomass for its application in biofuel area (Behera et al., 2014).

The oil productivity (mass of oil generated per unit volume of microalgal broth per day) is determined by the algal growth rate and the species' biomass.

II. ALGAL BIOMASS

Algal biomass has been intensively explored in the last decade and is now regarded as a third-generation biomass feedstock with various advantages, including less cultivation and higher yield (Khoo et al., 2019). Algal lipids are an excellent feedstock for bioenergy products such as jet fuel, biodiesel, and petrol (Khoo et al., 2019). Algal biomass comprises microalgae, macroalgae, and cyanobacteria (Voloshin et al., 2016). In the past, freshwater microalgae have been used to feed both people and animals. These organisms may quickly take up nutrients from the liquid phase and thrive there. Numerous studies have demonstrated the high ability of freshwater microalgae in biomass for bio-based energy production, including *Chlorella vulgaris* (Al-Lwayzy et al. 2014), *Chlorella pyrenoidosa* (Yang et al. 2015), *Muriellopsis* sp. and *Scenedesmus subpicatus* (Gómez-Serrano et al. 2015), *Ankistrodesmus falcatus* (George et al. *Coelastrella* sp. (Narayanan et al. 2018), *Asterarcys quadricellulare* (Sangapillai and Marimuthu, 2019), *Scenedesmus obliquus* (Liuet al. 2013 and *Tribonema* sp. (Wang et al. 2014). Freshwater macroalgae have the ability to produce liquid and solid biofuels that can be burned directly or in conjunction with more traditional energy sources (Tumuluru et al. 2012; Grayburn et al. 2013). Furthermore, harvesting biomass as thick floating mats is much simpler and less expensive than dewatering similar biomass of suspended microalgae (Hillebrand 1983; Grayburn et al. 2013). Several frequent freshwater macroalgal taxa have been identified, including *Oedogonium, Rhizoclonium, Ulothrix*, and *Microspora* (KebedeWesthead et al. 2003; Pizarro et al. 2006; Adey et al. 2011). The oil productivity (mass of oil generated per unit volume of algal broth per day) is determined by the algal growth rate and the species' biomass.

III. CULTIVATION

Algae can be cultivated in open or closed systems, and open systems, such as lakes or ponds, can be utilized to scale up production more quickly because they are less technically sophisticated than closed systems. The cultivation system should be built so that sun radiation efficiently reaches all algae cells (Ho et al., 2011). The location of open systems is a crucial parameter to consider, bearing in mind the availability of sunshine and the requirements of the algae to be cultivated. The oval channel or racing track channel can be found in raceway ponds. They are typically constructed of concrete.

Raceway ponds provide constant carbon dioxide and fertilizer input for algal culture recirculation. They have a paddle wheel to give gentle mixing in order to prevent sedimentation. An aerator can be utilized to boost air flow rate and hence CO_2 utilization (Brennan and Owende, 2010). Dragone et al. (2010) found that the cascading system outperformed the single-channel raceway pond in terms of retention time. One of the successful raceway pond cultivation is by Sapphire Energy’s Columbus Algal Biomass Farm located at Columbus, United States, which has successfully produced 520 metric tonnes of dried microalgae biomass during 2 years of its operation without any technical issue (White and Ryan, 2015). Despite their large production capacity, open ponds have poorer productivity than closed systems because to water temperature, vapour losses, CO_2 diffusion to the atmosphere, and the possibility of contamination.

Photo bioreactors (PBRs) are designed to provide for increased light accessibility for optimal algae development. Furthermore, PBRs enable for optimal mixing, allowing the light to reach an ideal value for cell development and better gas exchange (Kunjapur and Eldridge, 2010). PBRs can be created in the form of tanks, bags, or towers. Plates or tubular PBRs might be made of plastic or glass. Bubble columns and airlift PBRs are also viable options since they create a high concentration of algal biomass production (Ugwu et al., 2008). Photobioreactors, which are closed systems, provide a regulated and controlled cultivation environment with a lower chance of contamination. Due to improved mixing capabilities, the effectiveness of CO_2 fixation in a photobioreactor exceeds that of an open system.

1. **Harvesting of Microalgae:** Filtration, centrifugation, flocculation, and flotation are just a few of the harvesting techniques that have been utilized to gather biomass (Singh and Patidar, 2018). In some cases, a combination of two or more approaches is used to boost harvesting effectiveness.

   A semi permeable membrane is used in the filtration process, allowing the liquid medium to pass through while holding onto the microalgae so that they may be collected (Al Hattab et al., 2015). This technique can extract a high concentration of cells from the medium, and because the filter membrane's pore sizes change, it can adapt to the needs of various microalgae and handle the more delicate species that are vulnerable to shearing damage. Stretch cotton-based filter membrane with a 66–93% harvesting efficiency was successfully developed by Bejor et al. (2013).

   According to each component's density and particle size, centrifugation operation separates microalgae cells from the culture media (Soomro et al., 2016). Although the effectiveness of cell harvesting with this method is great, the procedure is time- and energy-consuming (Rawat et al., 2013).

By adding a flocculating chemical to decrease the surface charge of the cells, free floating unicellular microalgae cells combine to create a bigger particle known as a floc (Muylaert et al., 2017). Iron and aluminum salts, for example, have been widely employed in industry as low-cost and readily available chemical flocculants (Bracharz et al., 2018). According to Pugazhendhi et al. (2019), the majority of the bioflocculants employed are biopolymers such acrylic acid and chitosan that are either produced naturally or chemically. When compared to their chemical counterparts, bio-flocculants are far safer, more affordable, and environmentally friendly. According to Zhu and Hiltunen (2018), flotation makes use of tiny bubbles that adhere to microalgae cells to encourage floating of the cells on the surface of the culture solution for simple harvesting.

2. **Extraction Methods:** Algal oil is extracted using a variety of techniques, including mechanical extraction and chemical extraction (Barnwal, and Sharma, 2005). The simplest and most widely used method is the oil press. Up to 75% of the oil from the pressing algae can be extracted using this method. Up to 95% of the oil is extracted from algae using the hexane solvent method, which is essentially a two-step procedure that also involves pressing the algae (Santos et al., 2009). The press first presses the oil out. The remaining algae are then combined with hexane, washed, and filtered to ensure that no chemicals are left in the oil. Hexane is the preferred chemical for solvent extraction since it is less expensive and risky than other solvents like benzene and di-ethyl ether (Kumar et al., 2017)

3. **Refinery:** A biorefinery is a type of refinery that transforms biomass into energy and other useful byproducts (for example, chemicals). Biomass conversion is a field that overlaps with hydrogen production and biogas production. It is similar to coal gasification in that the initial resource is converted to a hydrogen-containing gas at high temperatures without burning. In addition to energy and fuel, biomass can be utilized to produce carbon-based chemicals known as bioproducts. These products include glycerin, sugars and sugar alcohols, furfurals, cellulose fibre and derivatives, carbonaceous materials, resins, bioplastics, and so on (Godula et al., 2010; Ramesh et al.2015).

IV. GLOBAL ENERGY DEMAND

Global energy consumption is steadily increasing, forcing the cost of petroleum-based fuels to rise and motivating research into fresh techniques and sustainable biofuel production technologies. Annual consumption is expected to reach around 778 Etta Joule by 2035, according to global energy demand predictions (Suresh Kumar Krishnan et al 2021). In 2017, transport accounted for about 30% of worldwide final energy demand and roughly 25% of global energy-related CO_2 emissions. Global transport emissions increased by 2% per year from 2000 to 2017, reaching 8 Gt CO_2 (IEA, 2019). Road transport, mostly for passenger travel, accounted for three-quarters of overall transport emissions and was the mode with the highest absolute rise (+ 1.7 $GtCO_2$. Transport is the least diverse energy end-use sector, consuming almost two-thirds of worldwide oil final energy demand – with oil products accounting for more than 90% of total final energy demand (IEA, 2017).

The World Alternative Policy Scenario presented in the World Energy Outlook 2006 (IEA, 2006) depicts how the global energy market could evolve if countries around the world adopted current policies and measures for reducing carbon dioxide emissions and improving energy supply security. The share of renewable in global energy consumption remains virtually unchanged in the scenario, while traditional biomass declines. Hydropower production will increase, but its percentage will remain stable, while other renewable (including geothermal, solar, and wind) will grow the fastest, but from such a low base that they will remain the smallest component of renewable energy in 2030 (FP-154-E-final).

1. **Environment Friendly reduce GHG:** The amount of CO_2 released when the fuel is burned is equal to the amount of CO_2 required for the algae to develop and produce the fuel. Thus, the net CO_2 emission is zero, the same as it would have been had the algae never been cultivated. A renewable fuel source that doesn't harm the environment might be available in the form of algae biofuel. It can be grown in places where other types of agriculture are ineffective. The ecosystem is essentially unaffected by algae biofuel (Spring power and Gas, 2009). We don't need to be concerned about the ecosystem being negatively impacted significantly or permanently in the event of a spill. According to the Environmental Protection Agency, fatty acid methyl transesterification, the only method of producing algae-based biodiesel that has been studied thus far, can cut greenhouse gas emissions by more than 60% when compared to petroleum diesel (Biofuels: The Promise of Algae). Kerosene made from microalgae biomass must achieve a reduction of GHG emissions of at least 65% in comparison to the reference values, if produced in installations starting operation from 1 January 2021, in order for it to meet the GHG emissions minimum saving criteria, according to Recast of the Renewable Energy Directive II (Marie Holzleitner et al., 2020).

2. **Fuel in Future:** The usage of algae offers a number of benefits over competing biofuel systems. According to IEA predictions, biofuels might supply 27% of the world's transport fuel by 2050. Because of the growing promise for the usage of algae-based aircraft fuel demonstrates how quickly algal biomass may replace current petroleum fuels when compared to other renewable energy sources like solar and wind energy (Kumar, 2012). The idea of this unique creature being cost-effective and widely accessible as a renewable and sustainable fuel source during the next ten years can only be realized via ongoing research and development. For instance, the United States Department of Energy forecasted the potential of 99% internal combustion engines for new cars in 2040 in the International Energy Outlook 2016 (Gul, 2016). So algae-based biofuel offers a promising replacement for fossil fuels and has the potential to reduce harmful carbon emissions. However, the state of technology today prevents commercial, low-cost production. Oil will probably continue to be the main source of energy in the world even though biofuels made from algae are becoming more and more popular on a global scale (The Future of Algae Biofuel).

V. CONCLUSION

Modern biofuels, particularly those derived from algae, have the potential to replace fossil fuels while avoiding undesirable consequences such as food instability and biodiversity loss. Increased production of these fuels is projected to benefit the world economy and aid in the mitigation of climate change**.**

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