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Microalgae a Source of Bio-energy

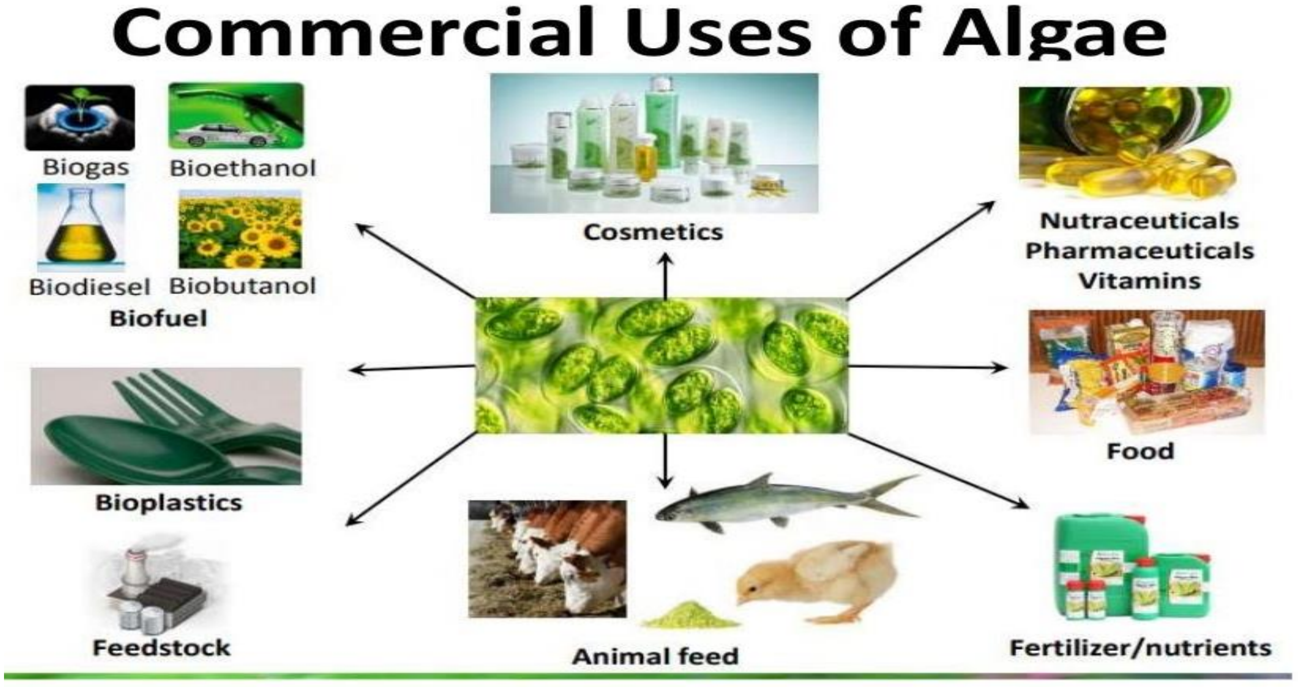
Surve V. D.[1] and Tompe T. H.[2]
[1]Associate Professor and [2]M. Sc. Student, Department of Post Harvest and Food Biotechnology, V D College of Agricultural Biotechnology, (VNMKV, Parbhani) Latur (M. S.)

SUMMARY

The major hurdles causing difficulties in mechanized transportation are the depletion of fossil fuels and the high cost of alternative plant-based substrates for producing bio-fuels. To solve these issues, bio-fuels were emerged as effective alternatives to reduce pollution caused by the emission of greenhouse gases. Among bio-fuels, bio-butanol is gaining attention as a feasible, renewable, cost-effective, alternative fuel. But the usages of conventional agricultural crops as feedstock are sensitive and controversial due to the growing concern over the availability of food worldwide. Microalgae are an excellent resource to overcome these challenges, which grows on both the sea and freshwater. Microalgae reducing their land usage with agriculture, and there is no food and fuel conflict exist. In addition, microalgae utilize inorganic carbon from the atmosphere for growth; hence they can reduce the emission levels as well as produce clean energy. Therefore, microalgae as third-generation feedstock came into practice due to their fast growth rate and higher carbohydrate content. The main focus of the present article is to discuss in detail about the major challenges faced as a feedstock to improve the production of Biofuels from microalgae such as *Chlorella sp., N. oculata, Botryococcus sp., Scenedesmus sp.,* and *Picochlorum sp.* Bioethanol production from microalgae such as *Chlorococcum sp., Spirogyra sp., C. sorokiniana, Gelidiumamansii, Sargassum sp., Gracilaria sp., Laminaria sp.,* and *Prymnesium parvum* biogas production from microalgae like *Scenedesmus, Euglena, Spirulina, and Ulva..*

INTRODUCTION

Algae are of great interest as potential feed stocks for various applications, including environmental sustainability, bio-fuel production, and the manufacture of high-value bio-products. Algal biotechnology shows that it is possible to couple the production of bio-products with the utilization of reserves contained in various waste-streams, such as those of the industrial, municipal and agro-industrial sectors. Algae can be converted directly into energy, such as biodiesel, bio-ethanol and bio-methanol and therefore can be a source of renewable energy. There is a growing interest for biodiesel production from algae because of its higher yield non-edible oil production and its fast growth that does not compete for land with food production. Microalgae are prokaryotic and eukaryotic photosynthetic microorganism that can grow rapidly and live in harsh condition due to their unicellular or simple multicellular structure e. g. prokaryotic microorganism (cynobacteria) and eukaryotic microorganism (green algae and diatoms).



In 1942 Harder and Von Witsch were first to propose that microalgae be grown as source of lipids for food or fuel. Microalgae possess a high quantity of different carbohydrates such as glycogen, starch, agar and cellulose which can easily be modified to form and table sugars for bio-ethanol production. The use of microalgae as medicine (production of bioactive and medicinal compounds), bio-fuels, bio-fertilizers, and food additives has been explored by researchers around the world. Lipid concentration in microalgae ranges from 1 to 70% of dry waste. A study suggested species of microalgae with 50-70% lipid content are favorable for biodiesel production.

Bio-energy:

Bio-energy is renewable energy derived from natural or biological sources. Bio-energy is often referred to as a renewable and sustainable energy source. It has recently become an important area of research for scientists around the world. Bio-energy is a great short- and medium-term solution to curb global warming and provide clean energy (Hariz and Takriff, 2017). The demand for bio-fuels to replace fossil fuels is high because the amount of fossil fuels currently consumed exceeds the amount of fuel produced. For example, according to base case research assumptions, the United States by 2030 would produce 991 million dry tons of biomass per year in low-yield estimates and 1147 million dry tons of biomass per year in high-yield estimates, which is much more than other nations would produce (Khoie and Yee, 2015). Statistically, this amount of biomass can be utilized to produce biofuel, which would only meet 25% of the country's annual energy needs (Khoie and Yee, 2015). During the last decade, the potential of algae as a bio-fuel feedstock has received much attention. Algal bio-fuels successfully reduce CO_2 emissions, thus protecting the environment by maintaining a balance between CO_2 production and consumption compared to fossil fuels. Biodiesel combustion releases CO_2 that is absorbed by microalgae. The combustion of bio-fuels has been shown to emit less CO_2 than fossil fuels (Merlo et al., 2021; Mondal et al., 2017). Biomass-derived bio-fuels have several advantages, including their regenerative capacity and low impact on pollution and global warming (Khan et al., 2018).

Bio-fuels production:

Algal bio-fuels offer many advantages over fossil fuels, such as

- Algal bio-fuels are readily available from common algal biomass sources,
- Algal bio-fuels contribute to the carbon dioxide cycle when burned,
- Algal bio-fuels are extremely environmentally friendly,
- Algal bio-fuels benefit the environment, the economy, and consumers,
- Algal bio-fuels are biodegradable and contribute to long-term sustainability (Ahmad et al., 2016).

They are classified into four generations depending on the feed stocks used, the feasibility of production, and the level of technological development (Alalwan et al., 2019). First-generation bio-fuels produced from conventional crops have a limited supply of feedstock because they are also the primary source of food for humans (Rodionova et al., 2017). Second-generation bio-fuels produced from agricultural waste or by-products continue to compete with land food production (Chowdhury and Loganathan,2019). Bio-fuels from microalgae are categorized as third-generation bio-fuels because they contribute significantly to first- and second-generation bio-fuels, which are derived from edible and non-edible resources, respectively.

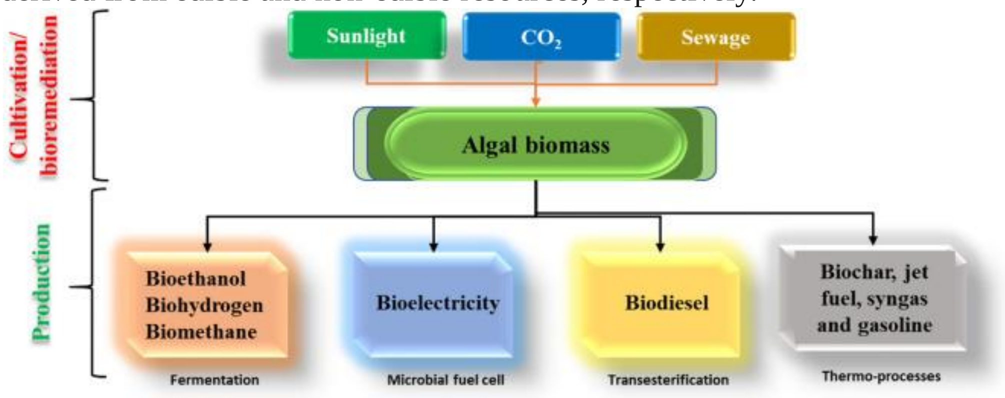


Fig.1 Bio-fuels derived from algae

Biodiesel production:

Biodiesel is a sustainable fuel produced from renewable biomass and unused lipids that can replace petroleum diesel.(Magda et al., 2021; Milano et al., 2016). The lipid content of algal biomass affects the quality and production of biodiesel and its suitability as an alternative fuel to petroleum-based diesel. Biodiesel produced from algal biomass is sulfur-free and has lower particulate matter and greenhouse gas emissions (Schuurmans et al., 2015).Biodiesel is produced from microalgae such as *Chlorella* sp., *N. oculata*, *Botryococcus* sp., *Scenedesmus* sp., and *Picochlorum* sp. *Saccharomyces cerevisiae* contains more oleic acid, which helps to improve the oxidative stability of biodiesel(Milano et al., 2016). Biodiesel is mainly obtained from microalgae via a transesterification process. Transesterification of lipids, especially triacylglycerides (TAG), in the presence of alkali or acid leads to the production of biodiesel and glycerol.The selection of microalgae strain is an important factor for biodiesel production.

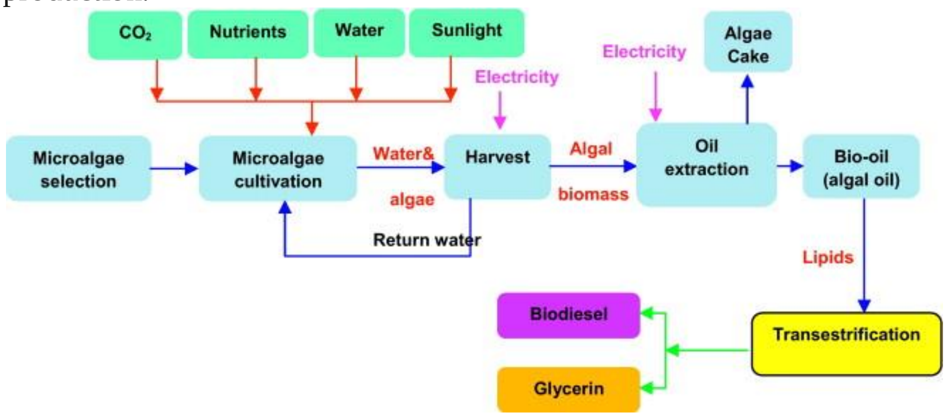


Fig.2 Bio-diesel production

Bio-ethanol production:

Bio-ethanol is produced from microalgae through several processes, including selection and cultivation of algal biomass, pretreatment, liquefaction, saccharification, anaerobic fermentation, and distillation for bio-ethanol purification(Vergara-Fernandez et al., 2008). Bio-ethanol produced from microalgae has a potential yield almost twice that of sugarcane and five times that of maize. Several algal species have been identified as significant for bioethanol production, including *Chlorococcum* sp., *Spirogyra* sp., *C. sorokiniana*, *Gelidiumamansii*, *Sargassum* sp., *Gracilaria* sp., *Laminaria* sp., and *Prymnesium parvum*(Behera et al.,2015; Constantino et al., 2021; Rajkumar et al., 2014). *C. Sorokiniana* was described as the most successful hydrolysate for bio-ethanol production with a bio-ethanol yield of 0.464 g/g reducing sugar and productivity of 0.344 g/L･h (Constantino et al., 2021).Microalgae are considered more effective feed stocks for bio-ethanol production than traditional crops, such as maize, soya beans, or sugarcane. Bio-ethanol production from microalgae biomass has several advantages, including that it does not require huge areas of arable land and relieves the environment by absorbing CO_2 from the atmosphere Figure shows a general overview of the synthesis of bio-ethanol from microalgae with different pretreatment and fermentation methods.

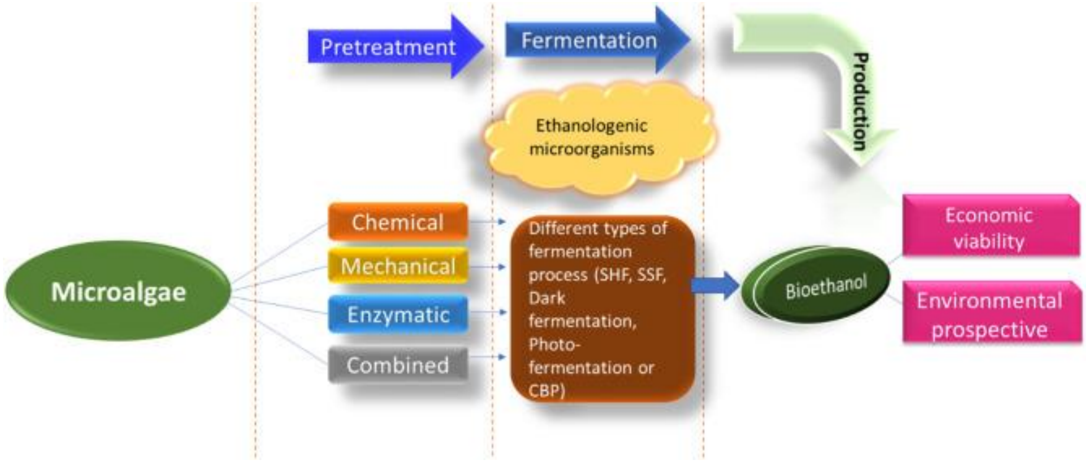


Fig.3 General Overview of the synthesis of bioethanol from microalgae with different pretreatment and fermentation methods

Biogas Production:

Microalgae can also be used to produce biogas, which can then be used to generate electricity, fuel cells, and liquid fuel. Algal biomass contains small amounts of lignin and cellulose, making it an excellent feedstock for the production of biogas by anaerobic fermentation (Harun et al., 2011).Biogas is the end product of anaerobic digestion, which contains 55-75% methane (CH_4) and 25-45% CO_2 (Chye et al., 2018). Seaweed has great potential for biogas generation. Many algae species, including *Scenedesmus*, *Euglena*, *Spirulina*, and *Ulva*, have been used for biogas production (Nagarajan et al., 2017; Tiwari and Pandey, 2012).

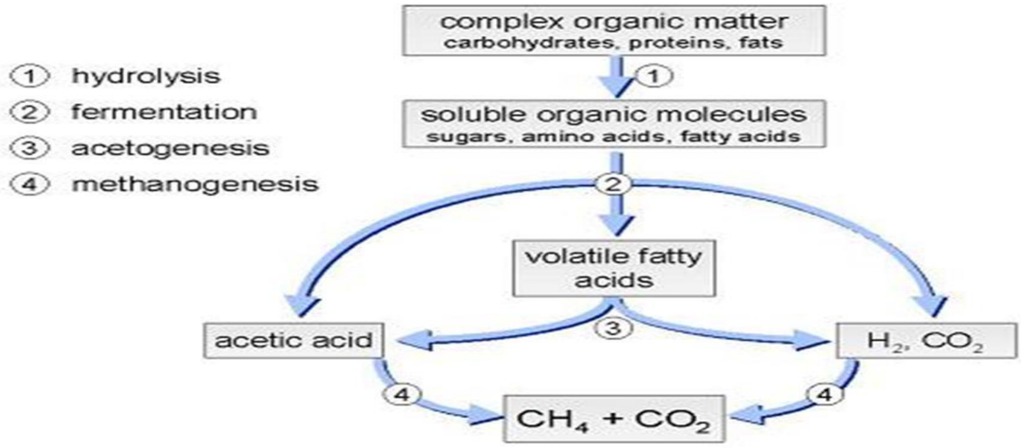


Fig. 4 Biogas production

Microalgae are an effective source of biogas because they contain higher concentrations of polysaccharides and lipids, no lignin, and lower amounts of cellulose. They are also easier to harvest, require less land for cultivation, are easily converted to biogas, and grow faster than lingo-cellulosic biomass. Furthermore, anaerobic digestion produces solid waste that is used as a soil supplement (Itskos et al., 2016; Saqib et al., 2013; Zhong et al., 2012). Biogas production involves three steps: hydrolysis, acetogenesis and methanogenesis.

Bio-hydrogen production:

The production of bio-hydrogen through biological processes is more environmentally friendly, requires less energy, and can be done under ambient conditions than thermo-chemical processes. Recently, the production of bio-hydrogen from microalgae has emerged as a potential approach for green energy production (Singh and Das,2020). Bio-hydrogen production in microalgae is classified into two types: light-dependent and light-independent-(Batyrova and Hallenbeck, 2017). In the first category, water is bio-photolyzed by microalgae and cyanobacteria, while photo-fermentation is mostly carried out by photosynthetic bacteria. In the second category, the process of dark fermentation takes place, in which organic molecules are fermented by anaerobic bacteria. Under anaerobic conditions, microalgae can produce bio-hydrogen when exposed to light and water. Bio-hydrogen is considered an efficient energy source because it does not emit greenhouse gases and produces water as a byproduct (Hallenbeck et al., 2016).Compared to other fuels, bio-hydrogen has the highest gravimetric energy density and conversion efficiency with values of 142MJ/kg, making it the most efficient fuel. Dark fermentation is a low-cost, environmentally friendly technique that also produces by-products such as lactic, butyric, and acetic acid, which can be easily commercialized. This process does not require light source and aeration, which can reduce the additional cost. Therefore, the integrated algae-bacteria system provides an improved sustainable technique to increase the efficiency of bio-hydrogen production through dark fermentation while reducing the overall cost.

Future aspects of bio-fuels:

- More research and development.
- Further private and government investment.
- Clearer regulatory and statutory guideline for algae businesses.

- Algae represent a novel bio-fuel source that has the potential to replace fossil fuels in the future.
- Advances in green technology based on microalgae can benefit the environment while providing other value-added products, such as bio-fertilizers and animal feed.

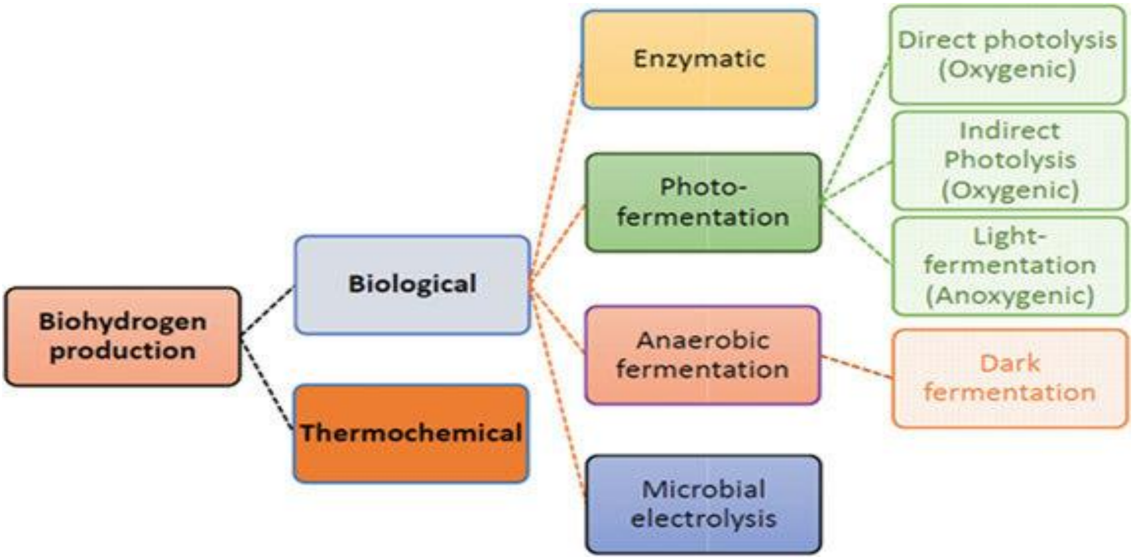


Fig.5 Bio-hydrogen production

CONCLUSIONS

This article discusses various aspects of microalgae, including their use in integrated bio-energy production and the production of high-value bio-products. Aspects such as potential bio-fuels produced from micro-algal species such as *Chlorella* sp., *N. oculata*, *Botryococcus* sp., *Scenedesmus* sp., and *Picochlorum* sp. *Chlorococcum* sp., *Spirogyra* sp., *C. sorokiniana*, *Gelidiumamansii*, *Sargassum* sp., *Gracilaria* sp., *Laminaria* sp., *Prymnesium parvum* and the use of micro-algal biomass as an energy source are also discussed.Recent technological advances have improved the economic viability of third-generation bio-fuel production while reducing overall process costs. Techno-economic assessment could also be used to design a low-cost microalgae bio-refinery that manages wastewater treatment in a circular economy.

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