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THE THIRD-GENERATION BIOFUEL PRODUCTION FROM ALGAE

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A biofuel is any hydrocarbon fuel made from organic matter (living or once-living material) in a short period of time (days, weeks, or even months). From 2010 to 2040, demand for fossil fuels is expected to increase by 40% (Bhore, 2019). As a result, need of alternative energy sources have been investigatedin order to meet our energy demands. Renewable sources of energy include solar, wind, and biomass based biofuels. Biomass has been used to generate electricity from a biological precursor. Over the previous few decades, biofuels and bioproducts have been producedto meet the demand for fossil fuels. There are different types of biofuels, such as bioethanol, biodiesel, biogas, etc. Bioethanol, often known as pure alcohol or ethyl alcohol, is the most prevalent alternative biofuel utilized in cars today;it produces fromsugars from sugarcane or corn through fermentation.Biodiesel is gaining popularity, as it closely resembles standard petroleum-based fuel produce from recycled cooking grease, animal fat, and vegetable oils used to create this product. Biobutanol is the least known of thethree biofuels, and it has the greatest promise due to Isobutanol derived from algae or bacteria, known as biobutanol.

Algae

Algae are one of the oldest biological forms. They are primitive plants (thallophytes). They lackroots, stems, and leaves, do not have a sterile layer of cells around reproductive cells, and have chlorophyll as their principal photosynthetic pigment. Algae structures are essential for energy conversion, with no development beyond cells, and their simple development allows them to adapt to current environmental conditions and thrive in the long run.

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Generation of Biofuels

Biofuels, in virtue of their positive carbon balance compared to fossil fuels, provide a huge potential for industrialized countries' sustainability and economic progress because they may be generated from locally accessible renewable materials.

First-Generation

Agrofuel is the first biofuel generation to employ specific cultivated plants as feedstocks, such as sugarcane, sugar beet, maize, palm, soybean, and sweet sorghum. Agrofuel is made by fermenting plant sugars or starches with yeast to make bio-ethanol, and extracting plant oils to make biodiesel. These processes severely harm both the food and water industries;this is the main drawback of 1st generation biofuels that create food insecurity.

Second-Generation

Non-food plants such as Jatropha, grass, switchgrass, silver grass, and non-edible components of current crops were used in the second generation of biofuels. Cultivating these second-generation biofuels requires vast land, water, and fertilizer to grow the biofuel-producing plants.

Third-Generation

Algal biofuel evolved as the third generation of biofuels with no competition to reduce land and water use andreduce excessive use of toxic pesticides. According to Lim *et al*. (2012), microalgal sources are a viable option for biofuel production and can meet worldwide demand for sustainable fuelsproduction (Saad *et al*., 2019).

Microalgae as a Source of Biofuel

As a third-generation feedstock, microalgae have enormous biofuel potential due to their rapid growth, high biomass yield, and high lipid and carbohydrate content. Algae create valuable biofuels such as biodiesel, biogas, bioethanol, and biomethane. Algal carbohydrates are used to make bioethanol, and algal oils are utilized to make biodiesel. After biofuel production, the leftover biomass can be utilized to make nutraceuticals, protein supplements, medicines, biocontrol agents, fertilizers, and animal feed. Microalgae were described as oleaginous because they can accumulate a significant amount of lipids. The algal lipid

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concentration is controlled by the habitat and environmentalparameters and ranges between 5%to 70%. Other than triacylglycerol (TAG), hydrocarbons, wax esters, sterols, and plenty derivatives, the membrane bilayer makes up the majority of algal lipids (Yu *et al*., 2011). When compared to land-based crops, microalgae have a high growth rate in a short period of time. Algal biomass yields per unit area are much higher than terrestrial biomass yields. Microalgae can thrive in a wide range of conditions. They can be grown on land or in water (both saltwater and freshwater).

Algal Biomass Production

Algae grow far quicker than food crops and can produce hundreds of times more oil per unit area than crops like rapeseed, palms, soybeans, and jatropha. The harvesting cycle for algae is 1–10 days, and that allows for multiple harvests in a short period of time. Microalgae cultivation can be done in open or covered ponds and in closed photobioreactors such as tubular, bag, and flat plate designs. Close systems are far more expensive than ponds, and they pose significant design and operational issues (overheating, fouling, gas exchange limitations, etc.). Above all, they can't be scaled up for individual growth units larger than a thousand square feet (100 m^2), often not even that (Benemann, 2009). This would imply thousands of such units, with expensive capital and considerably higher running expenses, for biofuels production, requiring hundreds of acres.

(Source - Benemann,2013)

Figure 1. Microalgae commercially cultivated and of interest in biofuels/feeds production

Open ponds, particularly shallow, mixed, raceway ponds, are far less expensive to build and run, maybe scaled up to several acres for a single growth pond (though the maximum size is currently unknown). Andis the method of choice for commercial microalgae production around the world. Almost all commercial microalgae biomass production is now done in open ponds, even for high-value nutritional items that sell for more than a hundred dollars per kilogram, when permitted costs for biofuels are less than a dollar per kilogram. Almost no such information is available on the design, operation, yields, and other critical features of commercial algae production systems.

Potential Fuels from Algae

Biofuel produced using algal biomass and oil to biodiesel, bioethanol, and syngas by transesterification fermentation and thermochemical proses, respectively -

- Crude algal oil for direct combustion or conversion into other fuels such as diesel, biodiesel, jet fuel, and gasoline
- Biogas created through anaerobic digestion of biomass
- Biohydrogen
- Bioethanol is produced through the fermentation of sugars derived from algal carbs

All these given production details are discussed below

Biomass

In general, algal biomass could be burned directly in a boiler to generate steam and electricity. Biomass can be burned alone or in combination with coal in existing power facilities. Although some major (>100MW) commercial facilities for producing power from lignocellulosic biomass (mainly wood pellets) are in operation or being developed in many countries, algal biomass is not included in any of them.Biomass to fuels via thermochemical processing. Heat is used in thermochemical processes to convert biomass into various compounds that could be used as fuel. As mentioned in the preceding section, one of these processes is combustion, which involvescomplete combustion with sufficient oxygen to release energy. Gasification, pyrolysis, and hydrothermal liquefaction are the other major thermochemical processes (Chisti, 2019).

1. **Pyrolysis-** Pyrolysis processes are performed under the absence of oxygen; the thermal decomposition of dry biomass yields solid fuel (char), liquid fuel(condense oil), and gaseous fuel products. The pyrolysis of algal biomass is often performed at elevated temperatures ranging from 300 to 700 °C. The produced vapors must be condensed by Cooling to extract the oils, leaving behind a solid residue (char)

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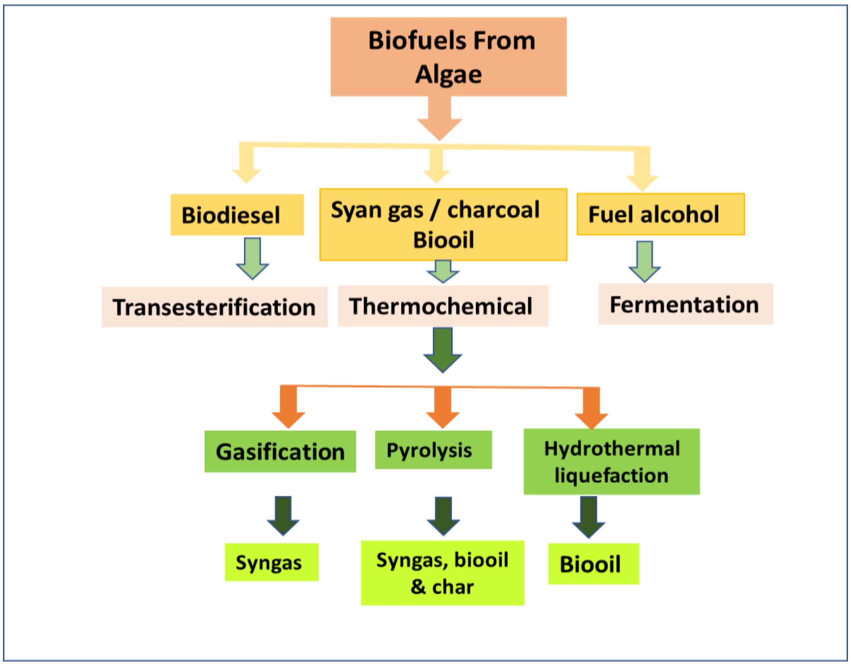

(Adeniyi *et al*., 2018).

Flow chart- 1 conversion method of different types of biofuels from algae

2. **Gasification-** At 700-1,000 °C, partial oxidation with controlled air, oxygen, or steam produces syngas (a combination of gases primarily composed of H2, CO, CO2, and CH4).

3. **Hydrothermal liquefaction-** Hydrothermal liquefaction is an alternative method that does not involve drying feedstock or using organic solvents. At elevated temperatures range between 300°C to 400°C and pressures between 40 to 200 bar, substantial dewatering operations are avoided. The product distributions typically vary from 10 to 73 percent biocrude, 8 to 20 percent gas, and 0.2 to 0.5 percent char. The biocrude produced has a similar energy value to fossil petroleum (Brand *et al*., 2014).

Fermentation

Fermentation is a biological conversion step that involves microorganisms hydrolyzing cell walls into fermentable sugars. The anaerobic breakdown of sugars into biogas, bioethanol, or biohydrogen is referred to as fermentation. After the oil extraction, a large amount of solid material known as biomass remains. This remaining biomass can be utilized to make bioethanol, another algae-based fuel. This can be performed by fermenting with yeast, which produces carbon dioxide, which can then be recycled back into the algae's growth process (Clarens *et al*., 2010).

Biodiesel by Transesterification of Algal Oil

The transesterification process involves the reaction between triglyceride molecules of oil and alcohol in the presence of an acid catalyst, which results in the formation of glycerol and mono-alkyl fatty acid esters. Because biodiesel is normally transesterified with methanol, fatty acid methyl esters (FAME) and glycerol are generated as byproducts. The transesterification process reduces the viscosity of FAME in comparison to the parent oil, but the fatty acid makeup remains the same. Methanol, ethanol, propanol, butanol, and amyl alcohol are commonly used alcohols; however, methanol is widely employed in the transesterification of microalgae oils due to its low cost and physical and chemical properties.

Sl. No	Aspects	Issues
1.	Environmental	➢ Water resource abuse ➢ Waterway damage ➢ Soil degradation, overexpansion of land usage, loss in land service expectancy, and soil erosion ➢ Animal habitat disruption ➢ Eutrophication, algae blooms, fish kills, and biological invasion
2.	Economic	➢ Expensive setup phase ➢ Requires significant maintenance investments
3.	Social	➢ Water contamination may have an impact on nearby wildlife, farm animals, and people. ➢ Concerns concerning the safety of genetically engineered algae ➢ Disease transmission
4.	Cultural	➢ It takes time to encourage people to accept unconventional microalgae use.

Table 1. The critical challenges of large-scale algae production for biofuel production

(Source Saad *et al*., 2019)

Conclusion

While the algae sector is well-developed for food, feed, and nutraceutical purposes, as well as high-value goods, algae for biofuel is still in its early stages. For algal biofuel manufacturing to be economically viable, the sector still requires a lot of research and development. The expensive infrastructure, operating, and maintenance expenses appear to be the most significant obstacles. To make algae biofuel production more appealing, need to incorporate new and efficient processes are required.

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