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SCENARIOS FOR THE SCOPE OF PLANT AND ALGAE IN BIOFUEL PRODUCTION

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ABSTRACT

Biofuel is basically a technique through which fossil fuels are being replaced by natural resources. Biofuels are of two types primary biofuels and secondary biofuels. Primary biofuels are the one that can be obtained from fuelwoods, plants and animal waste while secondary biofuels are directly created from plants and microbes and are divided into three sub-categories 1st generation biofuels, 2nd generation biofuels and 3rd generation biofuels. Green algae are basically eukaryotic, photosynthetic, watery plants that belongs to unicellular organism group. They contain a green pigment known as chlorophyll but lack stems, roots and vascular tissues. On the other hand, biomass is the sustainable organic material required for the generation of electricity and energy hence green algae biomass is the combination of both algae and biomass so they are one of the greatest sources of energy and it can provide enough amount of energy which means it can substitute the fossil fuel hence green algae biomass could be a feasible alternative to fossil fuels. But in spite of that, this innovation must overpower some of the obstacles before it can be competitively and widely deployed in the fuel market. These challenges involve strain recognition and advancement in terms of both oil efficiency and crop preservation as well as nutrient, resource allocation and the manufacturing of co-products to upgrade the financial matters of the complete framework. Biofuel is the only sustainable source which can substitute the fossil fuel directly for the present and the future energy restriction as it is an environment- friendly and viable energy. As a result, algae are one of the most suitable for the production of biofuel because of their quick development, high photosynthetic effectiveness and high biofuel productivity.

KEYWORDS: Strain recognition, advancement, photosynthetic, energy, environment.

INTRODUCTION

Biofuels are most sustainable and eco-friendly source of energy. Biodiesel does not contain Sulphur or any aromatic compounds hence why combustion of these biofuels results in low emission of carbon-monoxide, hydrocarbons and particulates. (Karmakar et al., 2010) Biofuels can be classified into two main categories such as **primary biofuels** and **secondary biofuels.** Primary biofuels are natural and can be produced from firewood, plants, animal waste and crop residue. On the other hand, secondary biofuels are directly generated from microorganisms and plants and they have classification of three subclasses as well **1st generation biofuels, 2nd generation biofuels and 3rd generation biofuels**. (Voloshin et al., 2016).

Figure 1: Algal fuel.

Biodiesel has gained attention because it is non-polluting and is playing an important part in lessening pollution.

(Hood, 2016) The increasing demand of petroleum is making people search for an alternative and biofuels are the best alternate. (Ananthi etal., 2021) The only reason for searching an alternative is tremendously increase in urbanization. Biofuel can be produced by several ways but for production of biodiesel ***microalgae*** is considered as most promising feedstock. About 40,000 microalgal species have been identified and many of these species can accumulate about 20-50% lipids of their total biomass. Among various sources microalgal as third generation biodiesel feedstock has attracted attention because it has rapid growth rate and high lipid level with a plus point of nontoxicity of biodiesel. (Joshi & Thipse, 2019).

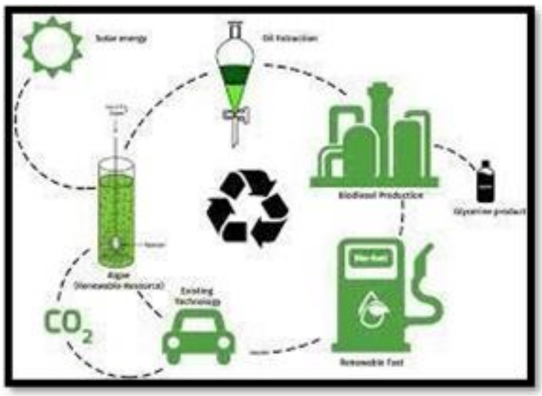

Figure 2: CO2 sequestered algal biomass.

Beside algae, plants are also a major source of biofuels if we look into ethanol production and butanol long chain hydrocarbons from starch, cellulose and hemicellulose. Major benefit is the fixation of carbon which is being produced while burning of biofuel. From past few decades' ethanol is being produced from corn-starch and sugar cane. In 2014 approximately 14 billion gallons of ethanol was produced in USA from corn-starch. (Hood, 2016) Biodiesel can be produced from various oils and virgin vegetables oil. About 100 years ago vegetables oil was used in diesel engine forthe first time but this led to various problems like incomplete combustion, high smokeproduction and sticking of oil rings. (Karmakar et al., 2010).

To overcome this problem transesterification was done to produce biodiesel. Different vegetables oil is being used for the production of biodiesel having different fatty acid composition. These vegetables oil includes soybean, rapeseed, palm are the most studied ones. Less common or less conventional oil seeds are also being used for the production of biofuels such as tobacco and rubber seeds. (Karmakar et al., 2010) Tobacco seed product a by-product tobacco leaf production has been proved to be a suitable source for diesel in raw. (Veljković et al., 2006).

As a matter of fact, biofuels are the future of fuel on this planet earth it will aim two goals in one shot by saving us from more pollution and by getting rid of carbon fuel which is more dangerous and lethal. Plants and microorganisms are future saviour of human kind on this planet and will take care of our energy production source and savingour planet from climate change, pollution and UV index etc.

GENERATIONS OF BIOFUELS

The use of biomass instead of fossil fuels for the production of fuel has been adopted all over the world recently. Researchers have found different sources such has woody biomass, agricultural biomass, aquatic biomass, animal biomass and human biomass can be used for this purpose. Solid, liquid and gaseous biofuels can be produced by different methods like, fermentation, esterification, anaerobic digestion, extraction, densification, etc. (Vassilev & Vassileva, 2016).

On the basis of source biofuels can be divided into three generations, first, second and third generation. The first generation is based on plants which are edible tohumans, for example, corn, wheat and sugarcane. The second generation includes all the varieties of plants that cannot be consumed by humans such as plant residues, wood, grasses, etc. The third generation compromises micro and macro algae. (Nanda et al., 2018).

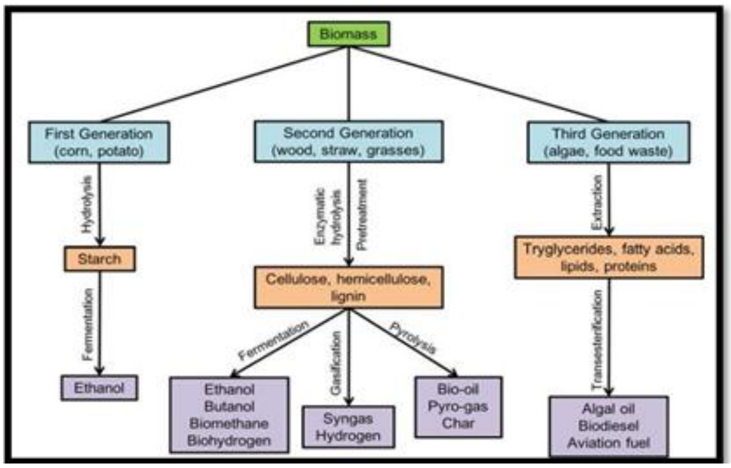

Figure 3: Schematic overview of the basic steps in the production of first, second, and third generation biofuels.

First Generation Biofuels

As the world population continues to grow, the demand of energy increases as well. Crop productivity, cultivation area and biofuel yield are the main factors for biofuel production. First generation feedstock is said to be a reliable source of energy which can reduces the usage of fossil fuels. 10% of energy demand is being met by 2% of agriculture land. First generation biofuels are biodegradable and environmentally and socially friendly. (Mat Aron et al., 2020).

- **Drawbacks of First-Generation Biofuels**

Due to increase in population, nutrition needs are not fulfilled and that 2% agriculture land that is producing feedstock for fuel can feed up to half of current world population. This has led to increase in market price of edible feedstock as well. (Mat Aron et al., 2020).

Second Generation Biofuels

Second generation biofuels are better for consumption as they are produced bynon-edible part of plants and there is no competition of food. The land requirement, water supply and use of fertilizers is not important for this purpose. (Mat Aron et al., 2020). Instead of using certain parts of plants like in first generation, whole plant can be used for production of biofuels. (Ruan et al., 2019). The waste biomass can be usedto generate electricity and heat by directly burning and also as raw material for wastewater treatments. (Alalwan et al., 2019).

- **Drawbacks of Second-Generation Biofuels**

Along being convenient it is also an expensive method and use of agriculture and forest residue compromises quality of soil and makes it difficult for new crops to grow on it. Before using second generation biofuels, they require complex process to make them usable. (Ruan et al., 2019).

Third Generation Biofuels

The discovery of using micro and macro algae for biofuels was led after limitations of first- and second-generation biofuels. Algae has high lipid productivity that is why they are widely considered for production of biofuels. Micro algae require low cultivating cost and are easily grown on moist surfaces whereas cultivating days for macro algae is only 5 to 6 days. (Mat Aron et al., 2020). Another benefit of algal biofuel is that it requires no land for cultivation and has no toxic impact on environment. The energy produced from algae is higher than as from conventional crops. (Ruan et al., 2019).

- **Drawbacks of Third Generation of Biofuels**

Although using algae for the production of biofuels is a promising way to generate large amount of energy, the processing cost of drying algae and then using it for lipid extraction is way much higher. (Mat Aron et al., 2020). The technologies required for these complex processes are still under development so it is not commercially feasible. (Ruan et al., 2019).

ALGAL BIOMASS AND ITS PRODUCTION

Algae and Biomass

Alge is eukaryotic, photosynthetic, non-flowering, watery plant/organism belonging to a broad group that includes seaweeds and a variety of single-celled organisms. Chlorophyll is found in algae; however, they lack genuine stems, leaves, roots, and vascular tissue.

Figure 4: Algae.

Whereas, biomass is a renewable organic material that is utilized for the production of energy such as heat and electricity. It can also be used for transportation and different environmental treatments for maintaining sustainability in the world.

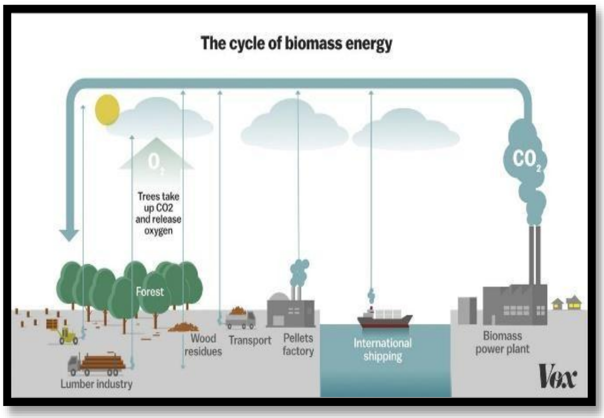

Figure 5: Biomass and energy.

Algal Biomass

Algal biomass is an amalgam of two terms which are algae and biomass. They both arecombined to produce a great energy source which is used to produce good quality of biofuels and aids in many waste-water treatments such as swine-wastewater. (Chen et al., 2020) Most commonly used algal biomasses are micro-algal biomass.

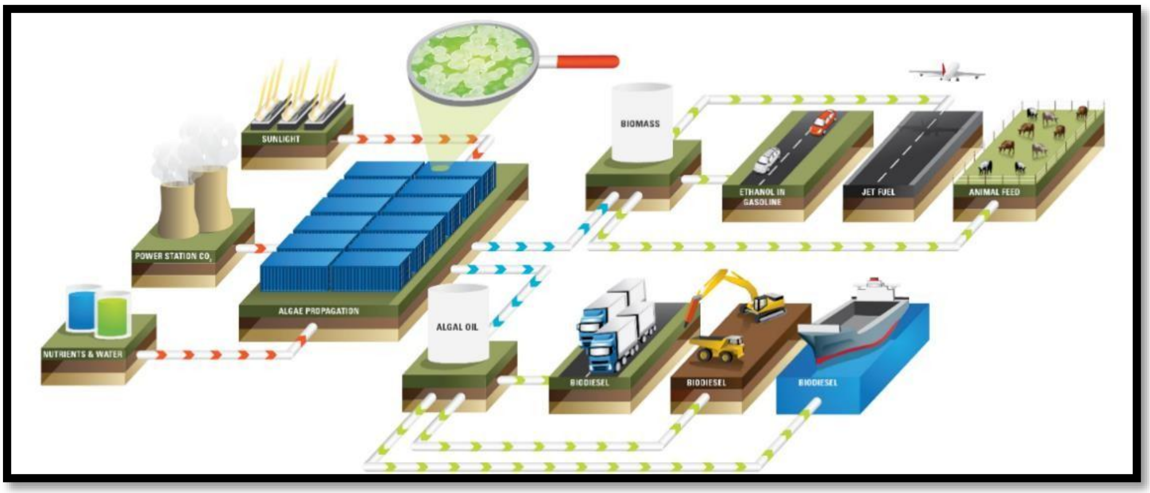

Figure 7: Algal Biomass and Bio-fuels.

Production of algal biomass

Algal biomass requires many nutrients for its growth as well as many environmental factors also contributes in its production. These are mainly nitrogen, organic carbon, sunlight and water, respectively. Production of algal biomass takes place by two main methods which are the production of algal biomass in photo-bioreactors (PBR) and open ponds. (Antoni et al., 2007).

Production of algal biomass by using solar energy is also in process. Micro-algal biomass is an extraordinary energy source as it beneficially stores sunlight-based energy which can then be changed over to other practical biofuels. This stored sunlight plays a key role in the production of algal biomasses. Without sunlight the growth is not possible as algae is photosynthetic and photosynthesis requires sunlight. The use ofsolar trackers aids them to conquer photo-inhibition, accordingly balancing out photosynthesis to boost the production of biomass in the development of green growth (algae). (Leite et al., 2013).

Role of *C. vulgaris* microalgae is also seen in greater production of biomass. *C. vulgaris* microalgae is observed all the while recuperating supplements from sludge centrate and producing biomass in a membrane photo-bioreactor (MPR). Microalgae development and supplement evacuation were assessed at two unique supplement stacking rates (sludge centrate). The outcomes show that *C. vulgaris* microalgae couldflourish in sludge centrate. Supplement stacking incongruously affects biomass development and has a striking effect on supplement expulsion productivity. Sludge centrate is difficult environment for growth of living organisms but this microalga cangrow well giving a good production of biomass. It is prescribed to work the MPR framework in lower hydraulic retention time (HRT) to further develop the membrane obstruction and energy utilization. (Chen et al., 2020).

C. sorokiniana AK-1 algae is also experimentally proven for greater production of biomass in swine wastewater. According to the experimental statistics, *C. sorokiniana* AK-1 showed the best resistance toward swine wastewater and got the most elevated biomass focus, growth (5.45 g/L) and protein efficiency (0.27 g/L/d) when becoming stronger in swine wastewater. (Chen et al., 2020).

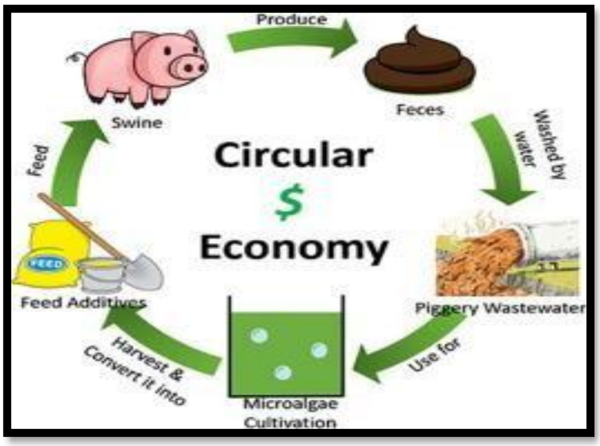

Figure 8: Algal biomass production in swine wastewater.

Algal biomass production and ensuing change to biofuels have acquired a lot of significance lately because of its quicker reaping, CO2 simple production and utilization, a lesser necessity for land, and enormous lipid content usage. The production of algal biomass is highly appreciated. Both open ponds and closed photo-bioreactors (PBR) production level are widely used but it is valued that the "open ponds" are more reasonable economically contrasted with PBRs used now-a-days for better algal biomass production. (Leite et al., 2013).

CONVERSIONS

When the cultivation and production of biomass is done, then the conversion of biomass into biofuel comes. (Voloshin et al., 2016). There are several processes available for theconversions mainly depend upon the kind and amount of biofuel production, which type of energy we want, environmental values, end products and its cost. (Porpatham et al.,2012)

Classification

1. Thermochemical conversions
2. Biochemical conversions
3. Direct combustion
4. Chemical conversions

1. Thermochemical Conversion

For the production of compounds having low molecular mass and oxygen content, we applythe treatment of high pressure and temperature. (Voloshin et al., 2016).

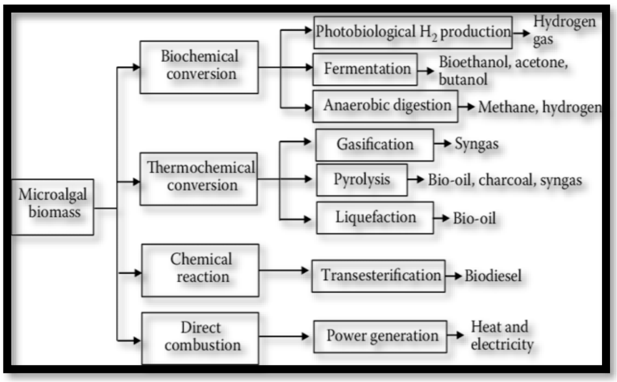

Figure 9: Classifications of conversions.

Sub Classification

It is sub divided into further classifications:

1. Pyrolysis
2. Gasification
3. Direct liquefaction

a. Pyrolysis

The conversion of biomass into charcoal, liquid (crude or oil) in the absence of air under the pressure of 750k is known as pyrolysis. This conversion has an ability of 70% for pyrolysis processes. It can be favorable for the production of different compounds with 95.5% ability from fuel to feed conversions. (Demirbaş, 2001).

b. Gasification

The conversion of biomass into gas in the presence of 800-900°C, by partial oxidation is known as gasification. (Porpatham et al., 2012). It is useful for the production of syngas. It is the combination of hydrogen and carbon monoxide. Amount of syngas changes according to the presence of water. (Voloshin et al., 2016).

c. Liquefaction

Degrading of biomass into small parts that are not stable in the existence of appropriate catalyst, which will combine later for the production of biofuels is known as liquefaction. As compared to pyrolysis high pressure i.e., ranges from 5-20 atm and low temperature is used. This happens in the availability of water and appropriate catalyst.

1. Biochemical Process

Processes that occur in living organisms working with the help of chemical reactions are known as biochemical processes. (Voloshin et al., 2016)

Sub Classification

Biochemical process can be divided into two types;

1. Fermentation
2. Anaerobic digestion

a. Fermentation

The conversion of sugars and starch into ethanol is known as fermentation. Enzymes help to convert the starch into sugar, and then yeasts help to convert the sugar into ethanol. (Porpatham et al., 2012). The last selling price of alcohol generally 55-80% in the market depends upon the cost of raw materials used in the fermentation process. Biomass made from sugar is generally expensive than starch depending biomass because it does not require any additional processing, while starch based do so.(Demirbaş, 2001).

b. Anaerobic Digestion

Degradation of biomass into the combination of methane and carbon dioxide in the nonappearance of oxygen and presence of some action of bacteria is known as anaerobic digestion. (Demirbaş, 2001). It also produces energy with minimal heat content i.e., 20- 40%. (Porpatham et al., 2012).

3. Direct Combustion

The conversion of heat into electricity is known as direct combustion.(Voloshin et al., 2016). In the presence of high temperature that ranges from 800-1000 warm gases are also produced. (Porpatham et al., 2012).

4. Chemical Conversion

Providing some reactions in the availability of catalysts to get some products is known as chemical conversion. The process use for chemical conversion is known as **transesterification**. By transesterification, biodiesel will produce by using triglycerides present in the biomass. (Voloshin et al., 2016).

PRODUCTION OF BIOFUELS FROM PLANTS

Biofuel is both a renewable and environmentally friendly fuel. The products typically used to make biofuels are ones not safe for human consumption such as, corn stalks, grasses and wood chips. The material used to make biofuels from plants is also called plant "biomass". (Carroll & Somerville, 2009).

This plant biomass is harvested and processed and broken down to convert the plant cells into renewable fuels or chemicals. (Luterbacher & Luterbacher, 2015).

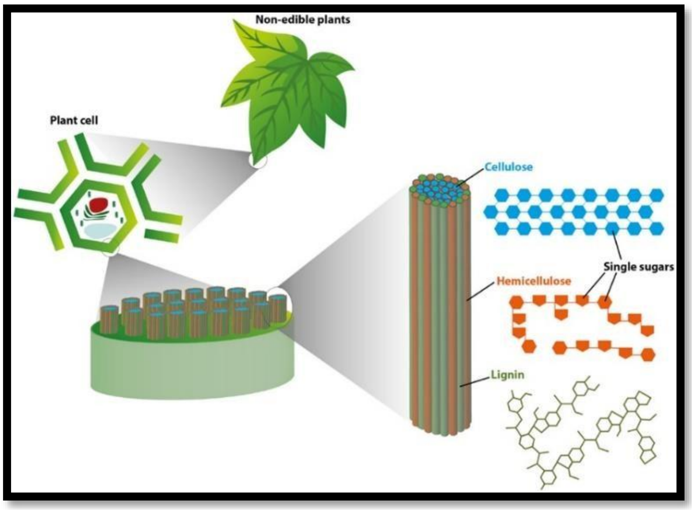

Figure 10: This figure illustrates the basic structure of plant tissues, starting at the level of the leaf (Top: "non-edible plants") and zooming in to the cellular level (Left: "plant cell").

The plant cell wall is composed of three complex molecules called cellulose, hemicellulose, and lignin. Cellulose and hemicellulose are packed with simple sugar building blocks, that are bound together in a compact structure with the help of lignin. (Hood, 2016) To access the sugar within, these complex molecules need to be broken down, only then it is converted to biofuel. They can be broken down by either using a harsh chemical or a solvent. The solvent γ -valerolactone (GVL) is a cheap and renewable solvent as it is made of a biomass itself. It can extract up to 70% of the sugar trapped within the biomass. The product is then purified to make biofuels. (Voloshin etal., 2016).

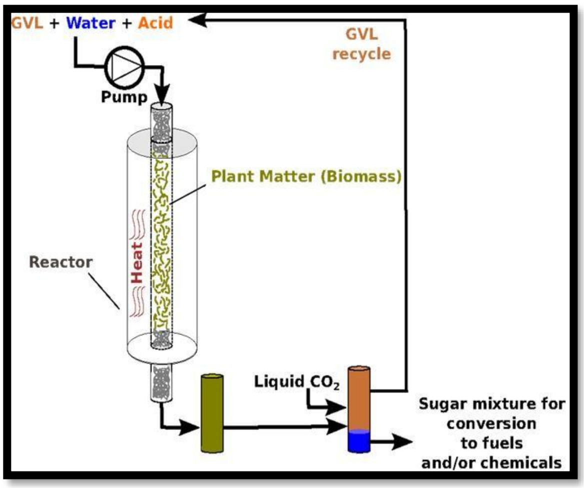

Figure 11: Illustration of sugar production from plants, using GVLas a solvent.

Plant-based biofuels are the most plentiful source of renewable fuels, offering the manufacture of ethanol and butanol (as gasoline additives) and long-chain hydrocarbons (for diesel additives or as jet fuels) from starch, cellulose, hemicellulose, and oils. Plants get their energy from sun which will be a constant source for the next million years. Unlike fossil petroleum and natural gas, the carbon produced from the combustion of biofuels is continuously cycled rather than being released from ancient fixed carbon sources. (Voloshin et al., 2016).

THE ENVIRONMENTAL IMPACTS OF ALGAE AND PLANTS BIOFUELS

Cultivation of algae have various impacts on the environment behind the usage of energy in this process.(Slade & Bauen, 2013) These can be positive or negative impactsbecause of the several natural, technical, social and economic barriers. The IRP (International Resource Panel) uplift this problem regarding biofuels in their report namely "Towards sustainable production & use of resources: Assessing biofuels" (Priyaet al., 2021).

Positive Impacts

Biofuels are cost efficient that gives elevated amount of power and performance. (Priyaet al., 2021).

CO2 Emission

Biofuels are environmentally friendly because of the reason that burning of biofuels that release CO2 in the environment are consumed by the plants for growing, as we need oxygen for breathing. This makes the low emission of CO2 in the environment than the burning of fossil fuels. (Luterbacher & Luterbacher, 2015) (Priya et al., 2021).

Oxygen Content

Oxygen content makes the greatest difference in biofuels & fossil fuels. Biofuels has greater content of oxygen i.e., 10 to 45 % while biofuels have zero. Having oxygen in compound makes it more combustion competent & gives appropriate antiknock value. (Demirbas, 2009).

Usage of Land

The main important benefit of algae production is the usage of minor part of the significant land. And this will also reduce the competition of food among the species. Authorities of geology limit the part of land for open-air pond system because it requires very small part of land. Places near the equator are preferred from theprevention of solar radiation on the cultivation of algae biofuels. (Bošnjaković & Sinaga, 2020). Because near the equator minimum isolation is 3000 km per hour. Hawaii, Israel & south California are the best places for the production of algae biofuels. (Slade & Bauen, 2013).

Negative Impacts

To make biofuels less toxic and easy to use, we need large amount of energy. Allocation& dispersion of fuels is very tough and makes it more expensive. (Priya et al., 2021).

Water Resources

To reduce the amount of evaporation, we should use the fresh water but it is not easy. So here the ideas of usage of seawater & brackish water taken from reservoir. (Slade & Bauen, 2013) But here comes the problem of toxic compounds present in the brackish water, so we have to give the pretreatment to the water to reduce the levels of inhibiting compounds. But it increases the power & energy costs of biofuels. And recycle water also has the large amounts of bacteria, fungi & viruses. The greater distance from the water source is also a critical factor. Digging of 100m takes 6% more energy sources than the natural source. (Slade & Bauen, 2013).

Use of Nutrients & Fertilizers

We also need the extra number of nutrients & fertilizers for the production of algae. The requirement not only depends upon the species but also on the increase amount of accumulation of carbohydrates & lipids. Dry algae consist of 7% N & 1% P and we need large amounts of fertilizers for the production of fuels from algae. According to the research, we need 250 lac tones of N & 40 lac tones of P per annum for the substituting of current fossil fuels with algal biomass. (Slade & Bauen, 2013). And for the production of 1000 kg of N fertilizer, we need 37 to 40 kJ energy of natural gas. (Bošnjaković & Sinaga, 2020).

EXAMPLES RELEVANT TO INDUSTRY

In the recent years, the production of algae has increased tremendously. Algae are a diverse group and thus using them in the industry would provide us with massive amounts of raw material. Moreover, it is to be noted that the **heterotrophic** variety of micro-algae is more flexible for cultivation than the autotrophic one because of the following two reasons:

- They can grow in the dark condition as well
- They are capable of accumulating higher lipids

Algae are able to deliver highest lipid content among the available biofuel varieties. Their **triglyceride** content is approximately 45-220 times higher than other terrestrial varieties of biomass. (Vassilev & Vassileva, 2016).

Following table illustrates the use of different algal products in industry:

Table 1: Commercial applications of algae.

Product	Use
Agar	Food ingredient, hydrocolloids, fruit preserves, clarifying brewing agent, paper industry and other pharmaceutical and biological/microbiological uses
Alginate	Food additive, textile printing, pharmaceutical, medical, paper, cosmetic and fertilizer industries
Antioxidants	Preservatives in food, pharmaceutical, cosmetic and chemical industries
Astaxanthin	Food supplement as antioxidant and food dye additive
Beta-carotene	Supplement for vitamin C and precursor for vitamin A, food additive as antioxidant and colouring agent
Bioenergy and biofuels	Aviation gas, biobutanol, biodiesel, bioethanol, biogas, biohydrogen, biomethane, biooil, biosyngas, gasoline, jet fuel, solid fuel
Biorefinery products	Various biofuels and chemicals
Biochar	Combustion, agricultural and sorbent uses
Biosorbents	Ion exchange materials that bind strongly heavy metal ions
Carragen or carrageenan	Gels, food additive, pet food, toothpaste
Carotenoids	See beta-carotene
Catalysts	Catalytic properties due to alkali and alkaline earth species
Chemicals	Medicinal and industrial uses
Conditioners	Chemical, cosmetic and farming industries
Cosmetic products	'Skin foods' as thickening agents, water-binding agents and antioxidants
Digester residue	Compost and/or vermicompost
Extraction of hydrocolloids or gums	Phytocolloids such as agar, carrageenan and alginate. Food industry
Extraction of lipids, carbohydrates, starch and cellulose	Gasoline, biodiesel, jet fuel, renewable hydrocarbons, alcohols, biogas
Extraction of minerals and trace elements	Food supplements, metallurgy, glass production
Extraction of proteins	Animal/fish feeds, fertilizers, industrial enzymes, bioplastics, surfactants
Feed	Animal food
Fertilizers	N-, P- and K-rich fertilizers
Food and drink	Nori, aonori, kombu, wakame, jam, cheese, wine, tea, soup, noodles, pasta, beverages, powders, tablets, capsules, others
Fruit and vegetable preservatives	Food industry
Glass production	Glass industry
Paper pulp supplements	Paper industry
Pharmaceutical applications	Pharmaceutical industry
Phytosterol	Food supplements
Pigments	Natural colourants in paper and textile industries
Textile production	Textile industry
Therapeutic materials	Pharmaceutical industry

Algal and plant biomass are being used on industrial scale mainly for energy productionin the following ways:

1- Liquid biofuel productions

Biodiesel and bio-alcohols are supposed to be the best alternative of other fuels. For theproduction of bioethanol (bio-alcohol), algae can be used as it is a good source of biohydrogen. Moreover, starch from corn, bagasse and sucrose from wheat can also beused for this purpose.

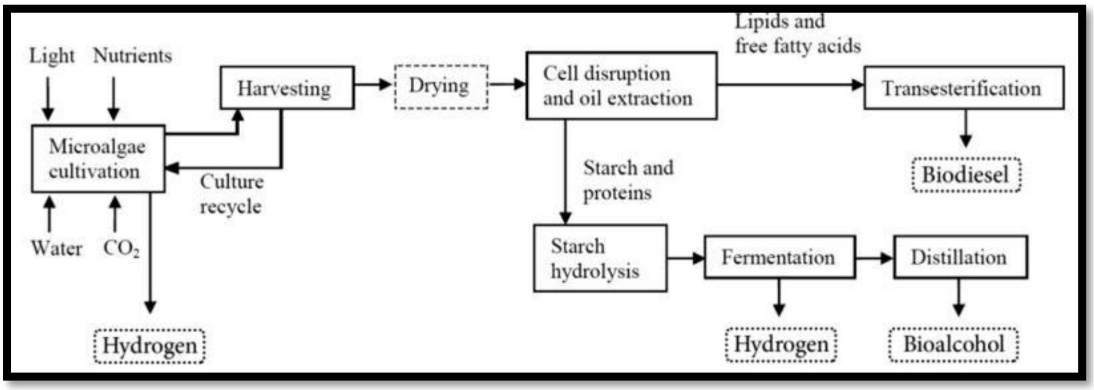

Figure 12: Series of steps where algal biomass is used for the production of biodiesel, bio-alcohol and hydrogen.

As biomass is enriched in triglycerides, it can be used for the production of biodiesel. Through **transesterification**, triglycerides are converted to glycerin and **FAME** where FAME is the major component of biodiesel. (Hood, 2016)

$$\text{Triglyceride} + 3CH_3OH \longrightarrow C_3H_8O_3(\text{Glycerine}) + 3\text{FAME}$$

2- Photobiological hydrogen production

These days, hydrogen demand has accelerated in the world and meeting these demandsis the primary goal of energy industry. About **96%** of the hydrogen demands are met by using fossil fuels. An environment friendly way for the production of molecular hydrogen is the use of micro-algae. In 1990's, it was discovered that **ChlamydomonasReinhardtian** can be made to produce hydrogen in the sulfur deprived medium. Thus, biofuels can be used for hydrogen production under specific conditions.(Voloshin et al., 2016) The goal can be achieved in following ways:

1. **Direct bio-photolysis;** using algae for splitting water to hydrogen and oxygen
2. **Indirect bio-photolysis;** photo-fermentation through microbes
3. **Dark fermentation**; hydrogen is produced from the starch produced by the algae that have been grown for the accumulation of starch through bacterial fermentation (Voloshin et al., 2016)

CONCLUSION

Up until now, much work has been done in order to improve the effectiveness and efficiency of the biofuel production processes from the algal and plant biomass and still much more work is needed. Being the most environmentally sustainable energy source, algal and plant biomass use for energy production can help to generate low cost and ecologically friendly energy with large amounts of raw material available. As different varieties of biomass differ in their respective chemical compositions, each process for the biofuel generation should be restricted to smaller biorefineries rather than the bigger ones to address the economic concerns. Although the disadvantages of using algal and plant biomass for biofuel production prevail yet the major environmental and socio-economic benefits compensate these barriers and make thema sustainable energy source.

Third-generation biofuels are not competitive in the energy market at this time. It is inthe development phase. Algae biomass has not yet become a common feedstock for motor fuel production, despite the abundance of intensive bioreactors.

The fact that a lot of miscellaneous work is being done in this area shows that thealgal energy is now flourishing in all directions which includes

- Increasing growth rates
- Improving harvesting methods
- Genetic engineering of crops
- Optimization, and thermal methods for biofuel production.

This is due to the urgency of the energy issue; the environmental risks associated withthe use of fossil fuels and the disadvantages of first and second-generation biofuels. Butmore work on improving algae farming and processing mechanisms need to be done to ensure the commercialization of microalgae biofuels. However, we can expect that in the future biofuels can meet the energy demand. It will be an ecological and inexpensivesolution to energy problems. (Vassilev & Vassileva, 2016).

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