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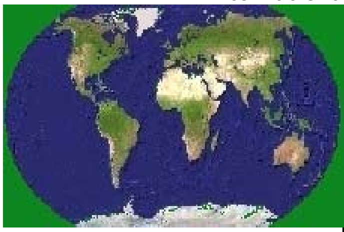

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Microalgal biorefineries: The choice for clean fuel production

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Abstract
The uncertainty in the price of petroleum crude and the fact of depleting resources forces to the search of new and renewable energy. Biodiesel are assumed to be promising alternative to traditional petroleum fuels, biodiesel or Fatty acid methyl esters (FAME) can be produced from vegetable oils. Large scale production of biodiesel increased in the past decade, but the usage of conventional vegetable oils for the production of biodiesel ends in food vs fuel crisis. The approach of biodiesel production from microalgal oil acts as a suitable alternative to these situations, which again leads to the waste disposal problems. These production facilities leaves enormous amounts of byproducts which are a threat to the environment which results in problem over the disposal of these effluents shoots up the cost of biodiesel, on the other hand usage of conventional vegetable oils for the production of biodiesel ends in food vs fuel crisis. Integrated biorefinery systems can be a suitable alternative to overcome the pitfalls, in simple a biorefinery can be termed as zero waste technology. Several researches are under progress to study the efficiency of various types of biorefinery approach. This paper discusses about the various options available in the area of microalgal biorefineries for the effective utilization of biomass feedstock thereby reducing the wastes generated.

Keywords: Biodiesel, Bio-refinery, Environment, Biomass, Byproducts.

1. Introduction

The price of petroleum crude in world market is fluctuating and trading around $110 per barrel, which is imposing a strong impact on developing nations and slow down the industrial output which leads to a huge economic decline. On the other hand the demand for the petroleum oil is rising significantly. More than 95% of the crude oil requirement is consumed by transportation sector. Alternative fuels derived from biomass feed stocks promises a suitable alternative to the conventional energy resources. Fermentative production of alcohols and conversion of certain vegetable oils and oils from other sources to biodiesel yields special interest because their potential to use as a substitute for conventional fuel without any major modification in the system, also it was proved that these oils release low emission when compared to the conventional fuels.

2. Microalgal biodiesel

Microalgae are unicellular microorganisms found in water sources either in fresh water or marine. Algae can act as a suitable alternate to the use of food crops such as corn and soybean for fuel (Chisti, 2007, Hu *et al*., 2008). Microalgae have high potentials in biodiesel production compared to other oil crops. First, the cultivation of microalgae does not need much land as compared to that of terraneous plants (Guan Hua Huang *et al*., 2010, Chisti Y. 2007). Even though algae can substitute such crops it requires plenty of water for their growth, their water demand is as high as 11 -13 million L ha-1 year-1 for cultivation in open ponds (Senthil Chinnasamy *et al*., 2010). They can be cultivated in waste water sources from which they utilize nitrogen, phosphorus and other inorganic compounds for their growth. Microalgae are photosynthetic organisms, they can utilize the CO_2 generated from industries and other sources for their optimal growth, thereby paves way for carbon mitigation (Shakeel A. Khan *et al*, 2010).

They tend to produce various metabolic products (Wijffels *et al*., 2010) which can be utilized for the production of value added products. It was reported that most of the microalgal species were rich in lipids and proteins (Carioca *et al*., 2009), more particularly they have the ability to synthesize triacylglycerols (TAGs). TAGs are considered to be the potential feedstock for the production of biodiesel. (Shakeel A. Khan *et al*, 2010). They can able to produce and accumulate large quanitity of lipids which vary from 20-50% on dry weight basis. Various species of microalgae have various capacities of lipid production

Table 1: Oil content of microalgae (Chisti, 2007).

Microalga Oil content	(% dry wt)
Botryococcus braunii	25–75
Chlorella sp.	28–32
Crypthecodinium cohnii	20
Cylindrotheca sp.	16–37
Dunaliella primolecta	23
Isochrysis sp	25–33
Monallanthussalina	>20
Nannochloris sp.	20–35
Nannochloropsis sp.	31–68
Neochloris oleoabundans	35–54
Nitzschia sp.	45–47
Phaeodactylum tricornutum	20–30
Schizochytrium sp	50–77
Tetraselmis suecica	15–23
B. braunii	25–75

It was reported that the marine species *Nannochloropsis* can able to produce more oil when compared to other species studied, Radolfi *et al.* reported the result of his study with 30 different microalgal strains in which Nannochloropsis sp. F&M-M26 produced 61 mg/L/day of lipid.

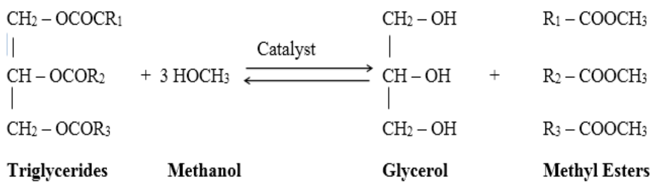
Table 2: Efficiency of various microalgal species (Table adapted from Radolfi *et al.*)

Microalgae	Biomass productivity (g/L/day)	Lipidcontent (%biomass)	Lipid productivity (mg/L/day)
Marinestrains			
Porphyridium cruentum	0.37	9.5	34.8
TetraselmissuecicaF&M-M33	0.32	8.5	27.0
Tetraselmissp.F&M-M34	0.30	14.7	43.4
TetraselmissuecicaF&M-M35	0.28	12.9	36.4
PhaeodactylumtricornutumF&M-M40	0.24	18.7	44.8
Nannochloropsissp.F&M-M26	0.21	29.6	61.0
Nannochloropsissp.F&M-M27	0.20	24.4	48.2
Nannochloropsis sp.F&M-M24	0.18	30.9	54.8
Nannochloropsissp.F&M-M29	0.17	21.6	37.6
Ellipsoidionsp.F&M-M31	0.17	27.4	47.3
Nannochloropsissp.F&M-M28	0.17	35.7	60.9
NannochloropsisCS246	0.17	29.2	49.7
Isochrysissp.(T-ISO)CS177	0.17	22.4	37.7
PavlovasalinaCS49	0.16	30.9	49.4
PavlovalutheriCS182	0.14	35.5	50.2
Isochrysissp.F&M-M37	0.14	27.4	37.8
Skeletonemasp.CS252	0.09	31.8	27.3
ThalassiosirapseudonanaCS173	0.08	20.6	17.4
SkeletonemacostatumCS181	0.08	21.1	17.4
ChaetocerosmuelleriF&M-M43	0.07	33.6	21.8
ChaetoceroscalcitransCS178	0.04	39.8	17.6
Fresh Water			
Chlorococcumsp.UMACC112	0.28	19.3	53.7
Scenedesmussp.DM	0.26	21.1	53.9
ChlorellasorokinianaIAM-212	0.23	19.3	44.7
Chlorellasp.F&M-M48	0.23	18.7	42.1
Scenedesmussp.F&M-M19	0.21	19.6	40.8
ChlorellavulgarisF&M-M49	0.20	18.4	36.9
Scenedesmus quadricauda	0.19	18.4	35.1
MonodussubterraneusUTEX151	0.19	16.1	30.4
ChlorellavulgarisCCAP211/11b	0.17	19.2	32.6

3. Microalgal biorefineries

Even though there is huge advancement in the technology for the maximum production, problems such as waste generation and their disposal problems shoots up the whole production cost. More particularly the waste or byproducts are generated in large quantity during the refining process of the produced biofuel. Much more research activities are under progress for the effective utilization of these waste or byproduct. The concept of microalgal biorefinery systems can be a suitable alternative to mitigate this crisis.

The biorefinery is similar in concept to the petroleum refinery, except that it is based on conversion of biomass feedstocks rather than crude oil. Biorefineries in theory would use multiple forms of biomass to produce a flexible mix of products, including fuels, power, heat, chemicals and materials. In a biorefinery, biomass would be converted into high-value chemical products and fuels (both gas and liquid). By-products and residues, as well as some portion of the fuels produced, would be used to fuel on-site power generation or cogeneration facilities. A biorefinery is a facility that integrates biomass conversion processes and equipment to produce fuels, chemicals, feed, materials and energy from biomass. The objective of a biorefinery is to optimize the use of resources and minimize wastes, thereby maximizing benefits and profitability. Inspite of using vegetable oils, microalgal oil was studied to be a better alternative for the production of biodiesel. It is mainly obtained by the transesterification of microalgal oils in the presence of a catalyst by a primary alcohol (usually methanol) leading to a fatty acid methyl ester (FAME) and byproducts with major amount of glycerol.



It was estimated that at approximately 10 wt% of glycerol is generated as waste in biodiesel and oleochemical industry (Da Silva *et al*, Dasari *et al*.,). These glycerol can be used as substrate for the biological production of various products like 1,3-propanediol, 1,2-propanediol,dihydroxyacetones, hydrogen, polyglycerols, succinic acid, and polyesters which can aid for the reduction of total production cost of biodiesel (Naresh Pachauri *et al*., 2006). Biomass is converted to liquid fuel using glycerol that can be blended with gasoline as an alternative fuel (Demirbas, 2000). Mixed culture fermentation of glycerol synthesizes short and medium chain polyhydroxyalkanoate blends (Koller *et al*., 2005). Tokuma Fukuoka *et al*., synthesized a novel branched type PLA containing glyceric acid which is a breakthrough in utilization of waste glycerol for the production of value added bioproducts.

4. Conclusion

Microalgal biorefineries are in general found to be promising technology for the production of biodiesel, which can be an integrated facility to produce various bioproducts as listed above. They have several advantages which includes, these biorefineries can provide higher surface area for microalgal oil production, like other technologies it does not need more cultivable area thereby can manage food vs fuel crisis, it can be a source to mitigate CO_2 and other toxic gases. Even though microalgal biorefineries have several advantages; there are some pitfalls as in the current situation the technology is in initial stage and need improvements in the process development.

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