Article

Algae a promising alternative for biofuel

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Abstract

Research on renewable and environmentally friendly fuel is growing rapidly and many scientists and governments are interested to grow it fast due to limitation of conventional fuel sources and their harmful effects on the environment. Biofuels are not only the best and reliably available fuels attained from renewable sources which are environment friendly. Besdies biofuels are abundantly available in all the locations easily accessible and highly sustainable. In the present review, the authors present a brief highlight of challenges that necessitates to be covered in order to make both, micro as well as macro algae a viable option to produce renewable biofuels. It is interesting to note that algae are varied, pervasive, and productive and also having less impact with plants as a food for human and animals. Further research is required to a high quantity of product innovation because most dedicated algae are faced uneconomically high costs.

Keywords biofuel; CO_2; lipid; macroalgae; microalgae; renewable energy.

1 Introduction

The significant reduction in the amount of reserves and the subsequent increase in challenges to extract fuel from accelerating variables of oilfields have successfully led to the discovery of many promising alternatives of fossil fuels. Although in the last century, worldwide efforts were attempted to manufacture an efficient energy from nuclear power but enormous investments were rather poured into manufacture of water power. However, recent goals have being imposed on the manufacture of energy primarily from solar and wind power. Nevertheless, in the present era, bioenergy or better said energy from the biomass which have its roots planted since ancient energy sources has made a grand comeback essentially in less developed nations of globe. The bioenergy in combination with other renewable energy sources namely solar, wind and hydraulic might be useful to make an immense diversification in portfolio of energy production with a point of view to minimize the cost of dependency on fossil fuels. It is to be noted that with increasing exhaustions in the petroleum reserves and environmental impacts which are imposing very frightful scene of exhaust gases primarily fossil based fuels, research on renewable and environment friendly fuels have been confronted with much recognition in the recent years. Undoubtedly, today with oil at its highest peak the alternative renewable energy sources are availing more and more importance. However, according to the Energy Information Administration (EIA, 2009), the recent estimates of global reserves of petroleum and natural gas that are recoverable are respectively 1.3 trillion barrels and 6,186 trillion cubic feet. Day round global consumption of oil and gas is 85.4 million barrels and 261 billion cubic feet respectively (Statistics Oil Gas, 2008).

With the present era's energy consumption levels, it is inevitable that oil and gas will be completely exhausted in next 40 to 60 years. Over the past century, estimated levels of heat-trapping gases mainly from greenhouses have substantially elevated due to burning of fossil fuels namely oil and coal with integration of deforestation. The term `biofuel' pertains to the solid, liquid as well as gaseous fuels that are invariably produced from biorenewable or renewable feedstocks that are combustible. Comparatively, liquid biofuels will attain a higher importance since they are bound to replace the petroleum fuels. Highest variation in biofuels and petroleum feedstocks is essentially the oxygen content. Biofuels are not only the best and reliably available fuels attained from renewable sources but they are absolutely pollution free, abundantly available in locals, easily accessible and highly sustainable. Figure 1 depicts the global biodiesel production from 1993 to 2008.

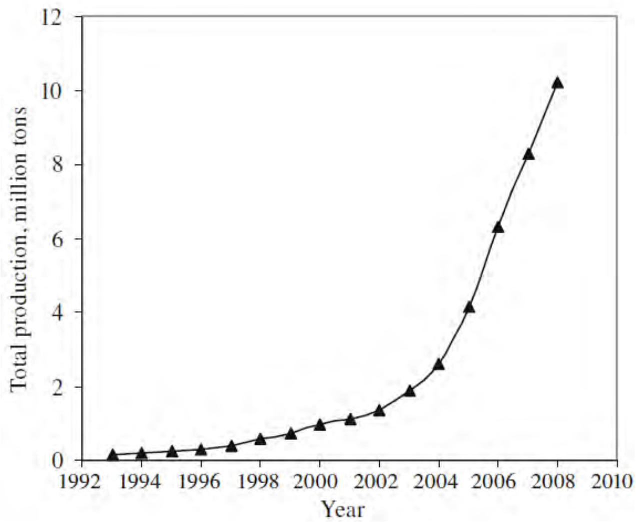

Fig. 1 Global production of bio-diesel (Demirbas, 2008).

In the present review, we are presenting a brief highlight of challenges that necessitates to be covered in order to make both micro and macro algae a viable option to produce renewable biofuels. Optimizing these points will provide the extensive benefits that are availed via developing these technologies not only to produce biofuels but also other high valued commodities namely animal feeds, human foods, high quality fertilizers, chemicals, waste treatment and greenhouse gas abatement.

1.1 Algae vis-à-vis CO_2

During the last few decades, since price of conventional fuel or oil is on verge of considerable rise, CO_2 emission has no doubt become a growing environmental concern. Prior to Industrial era, carbon dioxide concentration in atmosphere was 280 ppm for innumerable years and it has been elevating since then, rising to an optimal level of 267 ppm in 1999 (Geider et al., 2001). Thus, inevitably the average temperature of earth's surface is rising at a threatening rate. Concern over climate change is one of the essential challenges that we are facing and it is imperative that necessary steps have been taken to reduce the gas emissions from greenhouses. Fatal consequences of environment related to the gases emitted from greenhouse has led to an instant and serious need to manufacture alternative fuels that are renewable as well as environment friendly. One of the key elements in environmental concern is induction of global warming from accumulation of CO_2

that is emitted from green houses (Herzog and Drake, 1996). Almost half of the CO_2 that is getting aggregated is being emitted from green house gases (Hughes and Benemann, 1997) and around 20 billion tonnes of fossil CO_2 are emitted from burning of fossil fuels and 2 to 8 billion tonnes from biosphere via human mediated oxidation (Vitousek, 1994). Rising CO_2 in the atmosphere is attributing to more and more research to not only finds methods to reduce but also eventually eliminate CO_2 emissions that are anthropogenic based (Turkenburg, 1997).

Fortunately, the favourable climate and economic conditions have induced several tropical countries to avail innumerable and extensive low cost options essentially for the indirect biological CO_2 mitigation, via viable projects of forestry, agriculture and biofuel (Benemann, 1997). Few species of microalgae namely Chlorella, Spirulina and Dunaliella have been invariably exploited commercially. It is highly estimated that commercial profit that is attained from mass production of biomass could possibly offset the total operational costs incurred for CO_2 sequestration. Extensive studies have been carried out for utilizing Chlorella sp. in CO_2 sequestration. For an instance, Hanagata et al., (1992) has revealed that Chlorella sp. can be successfully propagated under environment of 20% CO_2. This species has been explored as a health food (Becker, 1994). After successfully assessing the CO_2 tolerance of Dunaliella sp. it is now being widely utilized for the production of β-carotene on a large scale (Graham and Wilcox, 2000). Nevertheless, the integrated many technical problems have still to be resolved.

Nevertheless, for removal of carbon dioxide, this does not seem to be a truly feasible option primarily for reduced propagation of higher plants, requirement of fresh water and the exorbitant cost of land to grow such plants. Algae on the other hand are not only the most optimum organisms for CO_2 bioremediation but are also proved to be the most feasible option for the recycling or sequestration of CO_2 since they can simply fix carbon by photosynthesis because they are incorporated with incredible area productivity in relation to other photosynthetic organisms like trees (Benemann, 1997; Richmond, 1999). However, microalgae cultures also avail many characteristics that make them an arguable option for higher productivities as compared to higher plants (Benemann, 1997).

1.2 Algae and future sustainability of food

The state-of-the-art technologies that could be integrated are essentially those which minimize effect of biofuel production on food supplies worldwide and at the same time promote future sustainability of agriculture produce. These essentially compromise of (i) optimum selection of crop, (ii) propagation of determined potent crops on minor lands and (iii) possible manufacture of oil from algae, essentially those which do not require fresh water or farmland (Johnston and Holloway, 2007). Algae is being widely accepted as an alternative for the huge production of novel oil, but the difficulties of increased cost, invective contamination of species with increased H_2O consumption have to be greatly solved (Nagle and Lemke, 1990; Aresta et al., 2005). Seaweeds and microalgae have an established history of cultivation primarily as a viable source for commercial products (McHugh, 2003; Pulz and Gross, 2004). Since 1970's, they have also been an interesting subject for intensive findings in relation to their viability as fuel source (Chynoweth, 2002).

With the rising costs of power, these photosynthetic organisms have again being looked upon as an interesting option for high source of biofuels mainly the liquid transportation fuels. The rise in fossil fuel costs and mitigation goals pertaining to greenhouse gas, has invariably led to development of renewable energy sources, primarily liquid biofuels for transportation (Huesemann, 2006). It is estimated that this amazing organism can lead to an incredible expansion effectively in the transportation biofuel production without competing for tillable land that could inevitably have an adverse effect on the supply of food and feed.

When compared to the higher plants, algae have exhibited two main benefits for the production of biofuels. Prime benefit is their potent and high propagation in the water, thus leading to water avoidance and limitations to nutrients, in addition to their incredibility for continuous growth with maximum production. Moreover, algae are integrated with few parts like stems and roots that are considered to be non-productive. The next benefit is that cultivation of algae does not need tillable land and can be easily carried out in shallow ponds or hardpan soils utilizing saline or brackish water, or for seaweeds, in coastal or in open ocean settings in theoretical grounds. However, significant barriers pertained to biological and technical grounds have to be solved prior to fuels from micro as well as macro algal feed stocks will competitively face other biofuels or renewable energy sources.

Vasudevan and Briggs in 2008 reviewed not only state of the art but also challenges in production of biodiesel from algae. Compared to traditional crops of oleaginous, the essential benefits integrated with production of oil from microalgae are (i) it can be grown on land that is non arable like deserts, swamps or oceans with nil effect on production of food; (ii) it has potential for higher yield of oil as compared to oil crops. Chisti in 2008 claimed that biodiesel from microalgae seems to be the only renewable biodiesel that has high potential to meet the demand of globe for transport oil. It is even found to be better than bioethanol since energy content of biodiesel is 1.6 times more than bioethanol. However, process to manufacture biodiesel is not viable economically (Chisti, 2007). Production of biomass is a key parameter for economic evaluation of biodiesel generation from algae. However, it is possible to acquire improvements via genetic as well as metabolic engineering in addition to utilization of photobioreactors (Vasudevan and Biggs, 2008; Chisti, 2007).

1.3 Production of algae

Algae can invariably grow under all severe conditions; irrespective of whether it is pH, temperature or salinity extremes. Algae are simple micro organisms which are either aquatic or microscopic. These are photosynthetic micro organisms which are unicellular. They can live in freshwater or saline environments and can covert sunlight, water or even the carbon dioxide to biomass of algae. The biomass of algae are composed of three essential components namely carbohydrates, proteins and natural oils.

The cost effective production of fuel will basically need that we make use of algal biomass more efficiently. In order to attain it we have to utilize the three options of fuel production mentioned earlier in many combinations. Most simple option will be production of methane gas since the dual processes involved namely biological and thermal are not very sensitive to the biomass form. Gasification is considered as technology of brute force because it involves breakdown of any form or organic carbon into methane.

By contrast, production of ethanol is regarded as most effective conversion of carbohydrate fraction. The production of biodiesel is exclusively applied to natural oil fraction. Few combinations of all three components can be used as an animal feed and process design models that are developed under program are regarded as trio combination of animal feed production, biodiesel production and biological gasification.

For biofuels production via microalgae, only the open, paddle wheel mixed, raceway pond design, has necessary combination of not only potentially high productivity but also low cost as utilized by major commercial microalgae producers. Usually, these ponds are constructed either from plastic or concrete lined and vary from 0.2 to 0.5 ha in size. Moreover, CO_2 is supplied via diffusers.

The main challenge integrated for biodiesel generation from algae is its economics. Utilization of photobioreactors to obtain a high content of oil is increasing the cost of production considerably. Benemann and Oswald in 1994 depicted that the prominent cost estimate from 1996 for production of algal biodiesel utilizing open ponds whilst assuming 40% oil content with 30 g/m^{2}d biomass production utilizing flue gas CO_2 puts the cost. Other promising challenge for production of biodiesel from alga is need to dump CO_2 rich air into system. Considering availability of flue gas from power plants of fossil fuels it becomes a necessity to strive for shifting away from reliance on fossil fuels thus building a novel energy system that is dependent on flue emission from fossil power plants does not sound logical. A system of algae that receives its CO_2 from sources of biomass that is either from direct combustion or some form of digestion or fermentation is feasible but similar biomass sources can even be utilized for direct production of ethanol or fuels that are produced thermodynamically. The net yield of fuel from an algal biodiesel system that is fed with CO_2 from combustion of waste biomass and at same time assuming carbon in portion of algae that is not turned into fuel would be reintroduced into system again as CO_2. This is similar to directly converting biomass into ethanol via hydrolysis and fermentation or into alkane fuels via gasification and Fischer Tropsch synthesis, but surprisingly with increased cost.

1.4 Renewable energy

Much recent interest is focussed upon research based on production of energy from renewable sources like hydrocarbon production by biomass pyrolysis (Weissman and Goebel, 1987; Sheen et al., 1998). Most renewable sources that are utilized in biomass pyrolysis are being obtained via higher plants rather than microalgae although the later are considered as major prime producers in oceans (Geider et al., 2001). The depletion of fossil fuel such as coal and oil will eventually lead to over-emission of CO, renewable biomass does not lead to increase in atmospheric concentration of CO and such materials are regarded today as essential future energy resources (Sheen et al., 1998). Algae lead to production of high amount of lipids which constitute as a potential application in renewable fuel. Thus, it is clearly needed for microalgae to be regarded seriously as potential source of renewable fuels.

Today, we can find an incredible increase in the global interest towards production of biofuels from biomass. There are however many reasons integrated:

- Global warming which is associated with high level of gases emitted from green houses
- The onset of peak oil in economy worldwide
- Concerns of national energy security and
- Opportunities perceived for regional development which are more sustainable.

The lipid content can reach up to 44.3% of cell dry weight via heterotrophic cultivation. Recently, Liu et al. in 2008, studied effect of iron on growth as well as lipid accumulation in *Chlorella vulgaris* and found that increase in chelated Fe^{3+} results to stimulation of oil production in microalgae. The oil content was 56.6% biomass by dry weight which is comparable with oil crops ranging from 50 to 60%. However, this low net photosynthetic efficiency of terrestrial crops has led to higher focus on microalgae as a potential energy crop (Vasudevan and Briggs, 2008) but this approach is facing significant challenges of its own. It is observed that high oil algae strains grow slower as compared to low oil strains (Lewin, 1985), thus a system for growing algae for oil production is required to prevent takeover from a low oil species that is undesirable. This means either enclosing the system which attributes to a `photobioreactor' which is a transparent enclosure for growing algae in a fancy aquarium or making environment intolerable to strains other than desirable ones that is by genetically engineering a species to become resistant to some poison. Although it is inevitable that the latter approach is not ecologically desirable but former approach has led to introduction of cost challenges as photobioreactors are significantly more expensive to build and manage as compared to open ponds. Another challenge is that algae will generate highest oil concentrations when stressed particularly due to restriction of nutrient. This nutrient deficiency will also reduce their growth rate more than enough to offset increase in oil concentration where total oil production per land area is reduced (Sheehan, 1998). In true sense, the goals of high reproduction rate as well as high oil content are naturally and mutually exclusive.

Few algae species are capable to produce lipids which can be released and converted effectively to renewable diesel. For instance, the high lipid content and $CaCO_3$ producing capability of microalgae (coccolithophorids) is potential advantage of cultivating such algae on large scale for liquid fuels. It is determined that sooner or later conventional fuel resources will terminate and then there will be quite a prosperous future for production of biofuel especially by utilization of high lipid content microalgae.

The renewable diesel that is algae-based is an interesting prospect as a potential biofuel production in areas that are not suitable for farming. Furthermore, estimates of potential oil production from algae could be as high as 160 tons/ha which is comparatively 30 times more than palm oil (Table 1).

Table 1 The potential oil producing capability of variable plants as compared to microalgae (after Benemann, 2008).

Oil yields	liters/ha-yr	barrels/ha-yr
Soybeans	400	2.5
Sunflower	800	5
Canola	1,600	10
Jathropha	2,000	12
Palm Oil	6,000	36
Microalgae	60,000-240,000	360 -1500

Innumerable researchers have examined molecular biology and genetics of algae and have identified essential pathways integrated in lipids production.

The five steps involved in production of biodiesel from algae are shown in Fig. 2.

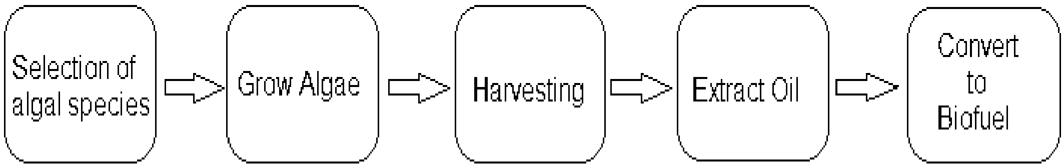

Fig. 2 Steps of biodiesel production from algae.

Stephan et al., (2001) has reported that over past four decades, a considerable amount of research has evaluated potential of microalgae to be used for production of usable biomass and at same time to sequester rich flue gases of CO_2 from power plants. Following oil crisis of 1970s, the US Department of Energy explored microalgae as a rich source of energy. They carried out microalgae wastewater treatment and harvested algal biomass to be converted into methane gas via an anaerobic digestion (Benemann et al., 1977).

In 1993, Ginzburg explored the high possibility of utilizing algae *Dunaliella salina* for oil production via biomass pyrolysis. It comparatively can produce oil 20% cheaper as compared to fossil oil. His calculation was based upon cells growing which could not be achieved in any type of outdoor cultivation system. Similarly, Wu et al., in 1999, could achieve high production of methane by high temperature pyrolysis of *E. huxleyi*. Unfortunately all these reports as well as researches were conducted on small scale. One of the most essential factors that limit growth as well as improvement of microalgal biotechnology is its least prospect as an alternative design for production system of microalgae that would be able to satisfy the requirement of microalgae production for fuels (Sheen et al., 1998). This is primarily true for closed photobioreactors which are unable to compete with open system due to their high cost of construction and operation. The costs of simplest closed photobioreactor will be much above what is affordable for fuel production process (Richmond, 2000).

1.5 Biofuel products from microalgae

Microalgae are capable of generating widest range of biofuels comprising of ethanol, methane, hydrogen and oil. This algal biomass can be very simply harvested with 80 to 95% moisture content. In addition, it could be dried and combusted to produce electricity (Kadam, 2002). However, this option is considered to be least attractive. The option that is more promising is recovering biofuels from wet algal biomass directly after harvest. The most direct approach is extraction of vegetable oils from biomass which can be either converted readily to biodiesel via transesterification or converted into diesel like popularly called `green diesel' by hydrocracking. One microalga capable of producing hydrocarbon is *Botrycoccus braunii* which can be refined further like petroleum. Other microalgae are capable of accumulating hydrocarbon which can be later converted by yeast or other bacterial fermentation into ethanol, butanol or any other liquid fuel. Finally, entire biomass, with minute regard to its composition can be converted by well-known methanogenic process of anaerobic digestion into biogas.

2 Methane

Anaerobic digestion is microbial conversion of organic matter not only into biogas but also mixture of methane, CO_2, water vapour and minute amounts (usually less than 1%) hydrogen sulphide and sometimes hydrogen (Gunaseelan, 1997). The reported yield of methane were found to be typically around 0.3 $1g^{-1}$ of biomass of volatile solids which is about half of theoretical maximum primarily based upon biochemical composition of biomass. The low yield is due to several reasons which comprises of recalcitrance of few species of algae to biodegradation and inhibition of microbiological conversion process by ammonia released from biomass. Thermochemical as well as mechanical pretreatments can solubilize biomass by breaking down cell walls which are resistant to biodegradation. This further resulted in significant increase in methane production rates (ca. 30%) for sewage ponds harvested microalgal biomass (Chen and Oswald, 1998). In case of Spirulina maxima biomass, since it doest not possess a strong cell wall the limiting factor of low yields is correspondent to ammonia inhibition (Samson and LeDuy, 1983). This problem can be circumvented by addition of carbon rich waste to biomass of microalgae thus doubling yield of methane and reducing ammonia levels via nitrogen sequestration into additional biomass of bacteria (Yen and Brune, 2007). Another alternative is developing cultures of bacteria that are more resistant to ammonia inhibition.

3 Ethanol

Ethanol can be produced from microalgae via two alternative processes. More straightforward of these two conversions is however yeast fermentation of products integrated with carbohydrate storage like starch in green algae, glycogen in cyanobacteria or even glycerol accumulated by Dunaliella at high salinities. This type of fermentation which is yeast mediated fermentation of microalgal biomass is demonstrated by many scientists with physical pre-treatment of algal biomass in order to make their intracellular carbohydrates available to enzymatic saccharification into simpler sugars (Matsumoto et al., 2003; Shirai et al., 1998).

4 Hydrogen

Since early 1970s, production of photobiological hydrogen is assessed to be a potential source of clean fuel (Prince and Kheshgi, 2005). Biological hydrogen can even be produced via plants by biophotolysis of water utilizing microalgae (green algae and cyanobacteria), in addition to fermentation of organic compounds and photodecomposition of organic compounds through photosynthetic bacteria. It is quite desirable to utilize a continuous process incorporating nonsterile substrate with a readily available mixed microflora for production of hydrogen by biomass fermentation (Hussy et al., 2005). However, a successful biological conversion of biomass to hydrogen will truly depend upon processing of raw materials to generate feedstock that can be fermented via microorganisms.

There exist three principal processes through which hydrogen can be produced via microalgae: (i) dark-fermentations, (ii) light-driven fermentations or photo-fermentations and (iii) biophotolysis, the splitting of water into oxygen and hydrogen (Nath and Das, 2004; Benemann and Pedroni, 2007).

Dark fermentation includes anaerobic conversion of reduced substrate from algae namely starch, glycogen, or glycerol into hydrogen, solvents and mixed acids. This process is carried out either via anaerobic bacteria or by microalgal cell itself via process of selffermentation (Miura et al., 1981&1982; Ohta et al., 1987). However, these dark anaerobic fermentations of hydrogen will be limited to produce low yields due to constraints of thermodynamic, with only 25% of energy in starch being converted into hydrogen (Hallenbeck and Benemann, 2002).

Organic acids produced via dark fermentations can be converted into hydrogen via nitrogen-fixing photosynthetic bacteria in process known as `photofermentation' (Benemann, 1977). Although dark fermentation of microalgal biomass to generate organic acids accompanied by photofermentation for production of hydrogen has been demonstrated successfully by many groups but overall yields of hydrogen and efficiencies of light energy conversions were quite low for economical viability (Kawaguchi et al., 2001).

Hydrogen production by microalgae via direct or indirect biophotolysis is inevitable. The concept is utilization of microalgae for catalytic conversion of solar energy and water into hydrogen fuel with oxygen as by-product. Latest research is concentrating on direct biophotolysis where water is split into hydrogen and oxygen without carbon fixation as an intermediate (Hallenbeck and Benemann, 2002). This reaction is however limited by strong inhibition of hydrogenase enzyme by oxygen. Even if oxygen inhibition is overcome still direct biophotolysis will suffer from practical issues of generating hydrogen-oxygen mixtures that are explosive and the need for exorbitant photobioreactors to incorporate reactions. In indirect biophotolysis, the production of hydrogen and oxygen takes place at different times or in variable stages, with intermediate fixation and release of subsequent recycled CO_2 (Hallenbeck and Benemann, 2002). In initial stage, the oxygen evolution via photosynthesis and fixation of carbon into storage carbohydrates such as starch or glycogen will take place which are used as light driven or dark fermentative process for production of hydrogen in the second stage. This type of biophotolysis is a theoretical concept and remains to be experimentally demonstrated.

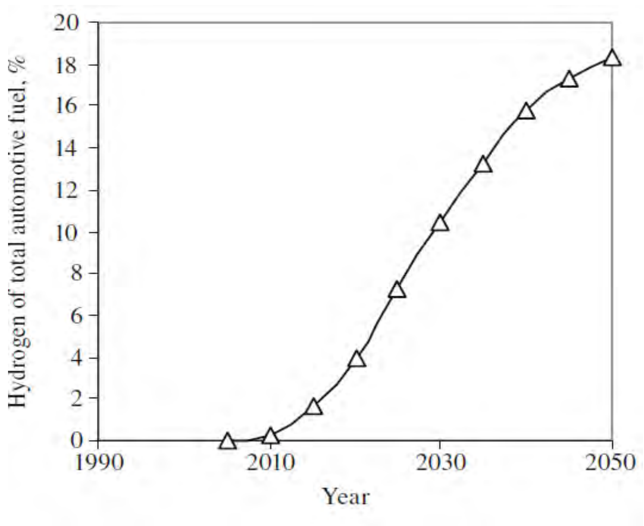

Fig. 3 overview of hydrogen in comprehensive automotive fuel (after Demirbas, 2008).

The technology of biohydrogen plays an important role in future since it can make use of source of energy that is renewable. Fig. 3 demonstrates futuristic view of the share of hydrogen in comprehensive automotive fuel consumption worldwide.

5 Oil

Sheehan et al., 1988 depicted that there are several microalgae especially green algae as well as diatoms that can accumulate considerable amounts of neutral lipids basically as triacylglycerols (TAGs; vegetable oils). These lipids can further be extracted from biomass and converted successfully into either biodiesel or green diesel which is considered as an efficient alternative for transportation fuels that are petroleum based. These products capable of storing high energy are optimally present to the extent of 30% dry weight of cells. The biosynthesis of lipid is usually triggered under conditions when metabolic energy supply via photosynthetic is normal but cellular growth is limited either due to nutrient deficiency (Roessler, 1990).

6 Macroalgae

Seaweeds are attracting incredible attention as a potential energy source in relation to microalgae since they neither possesses extractable oils nor high carbohydrate content thus making them a viable option to be utilized as feedstock not only for production of ethanol or butanol but also other fermentations. However, cost of methane production via seaweed biomass is equivalent to methane production via conversion of terrestrial feedstocks namely sorghum or poplar thus converting them into a competitive prime raw material for biofuel production (Chynoweth et al., 2001; Chynoweth, 2002).

7 Biofuel Production via Macroalgae

US Marine Biomass Program studied the production of methane via seaweed (Chynoweth, 2002) and have also demonstrated its pilot scale recently at Japan. Seaweed can also be a good resource for production of ethanol (Horn et al., 2000). *Laminaria hyperborea* extracts can be fermented to ethanol via conversion of by products of alginate production namely mannitol and laminaran. The best yield of ethanol was however by utilization of 0.43 g g^{-1} raw material seaweed as substrate in batch culture, using bacterium *Zymobacter palmae* and yeast *Pichia angophorae* although its optimization is require for enabling an industrial implementation (Horn et al., 2000).

The instance which is truly notable is system of offshore ring by German scientists in order to produce *Laminaria saccharina* for food (Buck and Buchholz, 2004). Although stated aim was for development in food industry, but this technology could be transferred as a viable option for production of biofuel feedstock from seaweed. The most cost competitive option amongst seaweeds is undoubtedly genus Laminaria which can be successfully converted to methane in relation to terrestrial biomass as well as municipal solid waste (Chynoweth et al., 2001).

8 Conclusion

Though the capability of microalgae and seaweeds to be utilized as feedstock for conversion to biofuels is gaining accelerating importance but it has yet to be realized. The challenges' pertaining to scientific as well as technological fields has to be assessed prior to considering these sources as an economically viable alternative to produce renewable energy. McHugh reported in 2003, that though seaweeds can be considered as significant resource for economy but commercial production of microalgae remains to be a minor activity. Both types of algae biomass are not capable of being produced on large scale in spite of availability of diverse land and coastal as well as oceanic resources. Several economic projections have revealed that the potential of cultivating algae as an efficient energy feedstock is comparatively favourable as compared to other plant resources as biofuel (Chynoweth et al., 2001; Sheehan et al., 1998). However, there exists a major doubt in all aspects of design as well as operation of these systems for biomass production and to a lesser degree for processes involved in conversion of biomass to biofuels. Whether it is off-shore production of seaweed or on-shore production of microalgae, the present technology is capable of producing high-value products the cost of which could range from lowest of 10 to highest of 100 fold than that basically needed for production of biofuels. Neither open-ocean farming nor on-shore ponds for production of algae utilizing power plant flue gases are demonstrated at pilot scale. It is highly a challenging option to utilize algae as an alternative renewable energy for cultivating them at a scale that could eventually cause a remarkable impact on the energy economy of globe. Not only coastlines are considered today as a limited resource but also the competing needs of society is limiting extent of utilization of near-shore environments for the production of seaweed on large scale. Although production of biofuels from algae is not likely to be a major resource for energy but at same time no other single biofuel approach could offer a solution to our rising problems of energy resources. However, they together could be able to substitute the current demand of fossil fuels though their future utilization could be not sufficient for the supplies that are declining and subsequent environmental costs which are rising.

The essential characterizing indicator of the following system is that it is primarily not dependent on organic substrates since these algae can highly utilize sunlight as a sole source of energy and water as sole source of electrons. Therefore, H_2 generation which takes place via system based on green algae will truly resemble the optimal alternative to the scenario for production of an energy carrier which not only utilizes sunlight and water but also is significantly clean (Kruse et al., 2005). For instance, it is worthwhile to consider the model organism Escherichia coli which are thoroughly studied in addition to purple bacteria and cyanobacteria with extraordinary significance to H_2 produced by unicellular green algae. However, it is to be noted that with microalgal or biofuel production system via seaweed, the net energy as well as greenhouse gas balance problems are quite unpredictable since at present there is no large scale or even pilot scale operating system existing. The current analyses are totally based upon the conceptual engineering designs which are needed to be validated. The essential energy input to biomass production of microalgae will cover pumping of CO_2 to and its effective transfer to culture of algae. There are even other inclusions like mixing of cultures, harvesting of biomass, energy for biomass processing, biofuel production plant, water supply in addition to introduction of nitrogen and other fertilizers and chemicals.

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