Algae for Lipid as Renewable Energy Source in Coal Mining Area: A Critical Review

Deepanjali Singh and Kumar Nikhil

***Abstract*— Rapidly depleting stocks of fossil fuels including coal and increased emission of green house gases in the atmosphere has necessitated the exploration of cost effective sustainable renewable energy sources, thus shifting our focus to Algae. Due to its high photosynthesis efficiency and great ability to fix carbon dioxide, the algal lipid provides a promising solution to meet the energy demand and supply in the oil industry. Vast areas of abandoned coal mine can be best utilized for the algae cultivation. The conditions prevalent in the coal mine areas which support the algal growth include sunlight, carbon dioxide and vast stretch of waste water which get accumulated due to rain or otherwise in opencast abandoned pits. Apart from the economic utilization of the barren land, cultivation of algae is also environmentally useful due to the CO_2 sequestration.**

***Index Terms*— Algae, microalgae, lipid, biodiesel, coal mining pits, open cast areas, fossil fuel.**

I. INTRODUCTION

The vast difference between the demand and supply of fossil fuels such as coal, petroleum and the natural gas and the increasing concern about their harmful effects of the environment has resulted in turning the focus towards the sustainable renewable energy. Microalgae biomass is one such sustainable energy source which can be easily harnessed in barren lands and waste water [1] .Apart from other uses, the lipid extracted from this algal biomass can be used as a feedstock for biodiesel production [2].

Abandoned coal mines/ open cast pits possess ideal conditions for the growth of algae. These coal mines are vast barren land having unlimited sunlight and carbon dioxide, which are the ultimate requirement for algal growth. Cultivating algae in these areas may put these barren lands, in the form of open pit not backfilled, into use as well as reduce the level of green house gases by carbon dioxide fixation.

II. ALGAE AS ENERGY SOURCE

Microalgae in general describe the small prokaryotic (cyanobacteria) and eukaryotic organisms found in marine, fresh and waste water systems. They have simple cellular structure and large surface-to-volume body ratio which gives them the possibilities of large uptake of nutrients. They are fast growing and efficient converters of solar energy capable of producing many times the biomass per unit area compared to terrestrial plants. Microalgae are remarkable and efficient biological factories of converting zero energy in the form of CO_2 into a high-density liquid to be used as bio-diesel and heavy biomass. [3], [4], [5], [6], [7], [8].

They attract energy researchers due to their fast growth rate, great photosynthetic activity, superior biomass production and lack of arable land requirements for biofuels [9].

III. ALGAL LIPID

Algal cells have the potential to rapidly accumulate lipids such as triglycerides, that contain fatty acids important for high value fatty acids and/or biodiesel production [10]. Some algae species have high oil/lipid content (upto 60% by weight) and can produce upto 15,000 gallons of oils per acre per year (due to their fast growth cycle) under optimum conditions.

Algae are the only biofeedstock that can theoretically replace all of our petro-fuel consumption of today and tomorrow. Owing to the fact that oil feeds are much lower for other feedstocks when compared to those from algae, it will be very difficult for the first generation biodiesel feedstock such as soy or palm to produce enough oil to replace even a small fraction of petro-oil needs without displacing large percentage of arable lands towards crops for fuel production [11].

Table 1: Comparison of potential oil yields of algae and other oil seeds [12]:

CROP	OIL YIELD gallon/acre
Corn	18
Cotton	35
Soyabean	48
Mustard seed	61
Sunflower	102
Rapeseed/Canola	127
Jatropha	202
Oil palm	635
Algae:	

Manuscript received May 15, 2014.

Deepanjali Singh, Post Graduate (Renewable Energy) student of TERI University, New Delhi, India & Summer Project-Trainee (April 2014 – June 2014) at EMG, CSIR-CIMFR, Dhanbad, Jharkhand, India. Contact # +91-9199770623.

Dr. Kumar Nikhil, Principal Scientist, EMG, CSIR-CIMFR, Dhanbad, Jharkhand, India. Contact # +91-9835568089.

a. 10g/m²/day at 15% Triglycerides	1,200
b. 50g/m²/day at 50% Triglycerides	10,000

IV. METHODOLOGIES OF LIPID EXTRACTION

Though microalgae cells have the potential to rapidly accumulate lipids, lipid extraction methods from them are not well established. Although there are different techniques available, there is currently no standard method for the lipid extraction due to the bias derived from these extraction methods. These methods include the Bligh-Dyer (Chloroform+methanol) method;two other chemical extractions using different solvents and sonication; direct saponification (ether+KOH) and supercritical CO_2 extraction [10].

Table 2: Comparison of lipid content extracted from different lipid extraction method [10]:

	Chl:Met	Dic:Met	Pro: Hex	Eth: KOH	Sc CO_2
Lipid content % dry wt.	11.66 ± 1.16	15.05 ± 0.46	13.35 ± 10.15	9.40 ± 1.64	10.88 ± 0.46

Chl:Met – Chloroform and methanol method
Dic:Met – Dichloromethane and methanol method
Pro:Hex – Propane-2-ol and Cyclohexane method
Eth:KOH – Ether and Potassium Hydroxide method
$ScCO_2$ - Supercritical CO_2extraction method

The above comparison omits the Soxhlet extraction method as it is extremely time consuming, which could cause thermo-degradation of ω-3 fatty acids. Li *et al* (2014) suggested the supercritical CO_2 extraction technique to be the most effective extraction of microalgae lipids [10]. However, the lipid profile of microalgae is highly dependent on microalgae cultivation techniques, biomass processing, cell disruption and strain selection in addition to solvent polarity and extraction processing [19], [20].

V. USES OF LIPID

The lipid or the oily part of algal biomass is the feedstock for the production of biodiesel. These can be extracted and converted into biodiesel through the process similar to that of any other vegetable oil, or converted in a refinery into ‘drop-in’ replacements for petroleum based fuels. Alternatively or following lipid extraction, the carbohydrate content of algae can be fermented into bioethanol or biobutanol.

Apart from biodiesel production, the polyunsaturated fatty acid oils derived from microalgae are added to infant formulas and nutritional supplements and pigments are important as natural dyes [13].

VI. ECONOMICS OF LIPID EXTRACTION

For being commercially successful, biofuel production from algae is still needed to minimize the level of uncertainty and insecurity which has crept due to techno-economic constraints [17]. Cultivating algae in coal mines might increase the production cost because coal mine system is very much similar to the open pond system. Furthermore, the accumulation of coal dust and ash over algae crop may add to the capital cost as the algae need to be purified before undergoing the lipid extraction process. Oil production from algae is expensive due to its high energy requirements and capital cost [18]. Algae growth depends significantly on the temperature as the biological activity ceases after the optimum temperature is reached. In the coal mining areas, abundant algal growth can be observed during the post-monsoon period whereas minimal growth is observed in the summer or pre-monsoon season. All these factors significantly affect the lipid productivity from the algal biomass.

VII. CONSTRAINTS

Extracting lipid is one of the most key and limited processes for biofuels production based on microalgae at a large scale. The conventional method of lipid extraction generally involve dewatering before extracting lipids since residual water in wet microalgal biomass hinder mass transfer of lipids from the cell and then lead to s decrease in efficiency of lipid extraction. Lardon *et al* [14] and Patil *et al* [15] reported that the consumption energy of the drying accounted for the majority of the total process energy (approx. 84.9%). In addition the organic solvents used in conventional methods are regarded as highly-toxic, being environment unfriendly. These shortcomings obstruct the application of conventional method for the industrial lipid extraction, despite high extraction efficiency. Thus, a novel approach needs to be developed for the lipid extraction at the industrial scale, which ought to be an effective eco-friendly process [16].

VIII. CONCLUSION

Algae play a very significant role in the bio-economy and enjoy a very significant position in the ecological pyramid. It can be efficiently cultivated in places which are unsuitable for other activities like coal mining area. Utilization of abandoned coal mines for microalgae cultivation is not only economically viable for organization but it reduces the air pollution significantly, by sequestering carbon dioxide and transforming green house gases into green energy, which would in turn help to the bridge the gap between energy supply and energy demand. This activity would also increase the employment opportunities in the area. Apart from the algal lipid, there are other algal products which are significantly beneficial such as proteins, colorants, biofertilizers, and bioplastics. This would definitely prove to one step closer to the use of green and sustainable energy, though a lot work and research is yet to be done in this field.

ACKNOWLEDGEMENT

The author is highly grateful to Director, CSIR-CIMFR, Dhanbad for providing the facility to complete this article and permission to publish it.

REFERENCES

[1] Ghayal M.S. and Pandya M.T. "Microalgae biomass: a renewable source of energy". *Energy Procedia* 32(2013) 242-250.

[2] Sharif Hossain A.B.M, Salleh Aishah, Boyce, Amru Nasrulhaq, Chowdhary Partha, Naqiuddin Mohd. "Biodiesel fuel production from algae as renewable energy." *American Journal of Biochemistry & Biotechnology*. 2008, Vol 4 Issue 3, p250-254.

[3] Sawayama S, Inoue S, Dote Y.D. Yokoyama S.Y. *Energy Convers Mgmt* 1995;36:729-731.

[4] Kurano N, Ikemoto H, Miyashita H, Hasegawa T, Hata H, Miyachi S. *J Mar Biotech* 1995;3:108-110.

[5] Kurano N, Ikemoto H, Miyashita H, Hasegawa T, Hata H, Miyachi S. *Energy Consers Mgmt* 1995;36:689-692.

[6] Chang,Ed-Haun, Yang, Shang-shyng, *Bot Bull Acad Sin* 2003;44:53-52.

[7] Yue L, Chen W. *Energy Conservation and Mgmt*. 2005;46(11-12):1868-1876.

[8] Moris MG, Costa JAV. *Jour Bact* 2007;129(3);439-445.

[9] Pan P, Hu C, Yang W, Li Y, Dan L, Zhu L, Tong D, Qing R, and Fany. (2010) " Renewable nergy resources and technologies applicable to Ireland." *Renewable Sustainable Energy Rev* vol 13 pp1975-1984.

[10] Li *et al.* "A Comparative study: the impact of different lipid extraction methods on current microalgae lipid research." *Microbial Cell Factories* 2014,13:14.

[11] http://www.oilgae.com/

[12] Pienkos PT. *Potential for biofuels from algae*. NREL/PR-510-42414. National Renewable Energy Laboratory (NREL), Golden CO; 2007.

[13] Spolaore P, Joannis-Cassan C, Duran. E, Isambert A. "Commercial applications of Microalgae." *Journal of Bioscience and Bioengineering*, 101:pp 87-96, 2006.

[14] Lardon L, Helias A, Sialve B, Steyer J.P., Bernard O. "Life-cycle assessment of biodiesel production from microalgae." *Sci Technol*. 2009, 17, 6475-6481.

[15] Patil P.D., Gude V.G., Mannarswamy A, Cooke P, Nirmalakhandan N, Lammers P, Deng S.G. "Comparison of direct transesterification of algal biomass under supercritical methanol and microwave irradiation conditions." *Fuel* 2012, 97, 822-831.

[16] Yang F, Xiang W, Sun X, Wu H, Li T, Long L."A novel lipid extraction method from wet microalga *Picochlorum* sp. at room temperature." *Marine drugs* 2014, 12, 1258-1270; doi:10.3390/md12031258.

[17] Dazin A.l., Pienkos P, Edye L. 2010. "Current status and potential for algal biofuels production"; A report to IEA *Bioenergy task* pp39.

[18] Barbara M.J., Hoogakker J and Wijffels RH 2003. "Optimization of cultivation parameters in photobioreactors for microalgae cultivation using the A-stat technique biomolecular engineering." Vol20 (4-6), pp115-123.

[19] Schenk PM, Thomas-Hall S, Stephens E, Marx U, Mussgnug J, Posten C, Kruse O and Hankamer B. "Secong generation biofuels: High efficiency microalgae for biodiesel production." *Bioenergy Res* 2008, 1:20-43.

[20] Li Y, Moore RB, Qin JG, Scott A and Ball AS. "Yields, hydrocarbon contents and energy content of liquids extractable from green algae *Botryococcus braunii*." *Biomass Bioenerg* 2013, 52:103-112.