ejpmr, 2016,3(10), 235-238.

SJIF Impact Factor 3.628

EUROPEAN JOURNAL OF PHARMACEUTICAL AND MEDICAL RESEARCH

www.ejpmr.com

Research Article

ISSN 3294-3211

EJPMR

RENEWABLE ENERGY RESOURCE MANAGEMENT –PRODUCTION OF OIL FROM *ALGAE*

***Y. Neeraja[1], Ammani[2], Lumbini Devi and Alekhya**

[1]Deaprtment of Microbiology, Ch.S.D.St. Theresa's Autonomous College, Eluru.
[2]Department of Microbiology, Acharya Nagarjuna University, Guntur.

***Correspondence for Author: Y. Neeraja**

Deaprtment of Microbiology, Ch.S.D.St. Theresa's Autonomous College, Eluru.

Article Received on 07/08/2016 **Article Revised on 27/08/2016** **Article Accepted on 17/09/2016**

ABSTRACT

The use of fossil fuels as energy is now widely accepted as unsustainable due to depleting resources and also due to the accumulation of greenhouse gases in the environment. Renewable and carbon neutral biofuels are necessary for environmental and economic sustainability. Microalgae appear to be the only source of renewable energy that is capable of meeting the global demand for transport fuels. Like plants, microalgae use sunlight to produce oils but they do so more efficiently than crop plants. The aim of the present study is to evaluate the feasibility of the water bodies of Eluru city to produce algal oil, which can be used as renewable energy. Algal cultures from Thammileru Stream, Kolleru Lake and Composite culture were evaluated for the oil production. The cultures were maintained in an open pond system with regular observation of growth conditions and periodic harvestation. Oils were extracted using solvent extraction method by Soxhlet apparatus. The extracted lipids were quantitatively analyzed by gravimetric method and qualitatively by Specific gravity, Density, Acid value and Iodine Value to assess their use as renewable energy. Higher oil production was observed from the composite culture which is a mixture of Thammileru Stream and Kolleru Lake. The qualitative analysis of extracted lipids proved that micro algal oil is a source of renewable energy.

KEYWORDS: Thammileru Stream, Kolleru Thammileru Stream and Kolleru Lake.

INTRODUCTION

The use of fossil fuels as energy is now widely accepted as unsustainable due to depleting resources and also due to the accumulation of greenhouse gases in the environment. Renewable and carbon neutral biofuel are necessary for environmental and economic sustainability.[1] Renewable energy demand is constantly increasing as the reservoir of fossil fuel are depleting. Unfortunately Renewable energy produced from oil crop, waste cooking oil and animal fats are not able to replace fossil fuel. The viability of the first generation biofuels production is however questionable because of the conflict with food supply.[2]

Production of biofuel using microalgae biomass appears to be a viable alternative. The oil productivity of many microalgae exceeds the best producing oil crops.[3] Microalgae are photosynthetic microorganisms which convert sunlight, water and CO_2 to sugars, from which macromolecules, such as lipids and triacylglycerols (TAGs) can be obtained. These TAGs are the promising and sustainable feedstock for biofuel production. Micro algal bio refinery approach can be used to reduce the cost of making micro algal biofuel. Micro algal-based carbon sequestration technologies cover the cost of carbon capture and sequestration.[4]

There are many other options for carbon sequestration as demonstrated by the work currently underway in ‘clean coal’ technology. Here the approaches associated with ‘carbon capture and storage’ (CCS) can be applied not to fossil fuels but to biofuels thereby again making them carbon negative. The various geosequestration options being investigated include disposal of carbon dioxide (CO_2) down mineshafts, down oil wells and in various kinds of geological formations.[5] The irony is that coal technology can never be clean, in the sense of being carbon negative. In fact, it can never even achieve carbon neutrality, since this is a theoretical optimum, which could never be achieved in practice, given that fossil fuels would need to be input at various steps of the value chain. These approaches to carbon sequestration both bio sequestration and geosequestration when applied to biofuels have the potential to draw more carbon from the atmosphere than is emitted through their use as fuel.

In green algae, the light-harvesting complex bound to chlorophyll and carotenoids capture light energy as photons. This energy is used by photosystem II in the catalytic oxidation of water, forming protons, electrons, and molecular O_2.[6]

Algae for Biofuel

While a number of bio-feed stocks are currently being experimented for biofuel production, algae have emerged as one of the most promising sources for biofuel production. Though research into algae as a source for biofuel is not new, the current oil crisis and fast depleting fossil oil reserves have made it more imperative for organizations and countries to invest more time and efforts into research on suitable renewable feedstock such as algae. Algae are the fastest growing plants in the world and can be grown year round, unlike seasonal crops. These farming do not require agricultural land or clean water, so it does not compete with food crops for these resources. While it is difficult to compare one energy crop to another, per hectare of farming of algae is around 10 to 100 times more productive than corn, soy, palm or Jatropha, Unlike other energy crops, the entire biomass produced from algae can be used in end products. Algae also act as a sink for carbon dioxide where about 2.2 tonnes of carbon dioxide is utilized as the carbon source by the algae. Lastly the algae can be used to produce renewable biofuels needed to reduce dependence on non-renewable fuel sources such as coal, oil and natural gas.[7] Species listed are currently being studied for their suitability as a mass-oil producing crop, across various locations worldwide. Neochloris oleoabundans[8] – it is a microalga belonging to the class Chlorophyceae; Scenedesmus dimorphus[9] - it is a unicellular alga in the class Chlorophyceae; Phaeodactylum tricornutum[10] – it is a diatom etc. The other favored algae are Bacilliarophy (diatom algae). However, the diatom algae need silicon in the water to grow, whereas green algae require nitrogen to grow. Under nutrient deficiency the algae produced more oils per weight of algae; however the algae growths also were significantly less. Algae are the most promising renewable source for the production of biofuels. Algae can be used for the production of biodiesel, bioethanol[11], hydrogen and methane.

Strategies influencing algae growth

There are some physical and chemical strategies which influence the algae growth.

Physical conditions

Some physical conditions which influence the algae growth are Temperature, Light intensity, pH.

Chemical conditions

Some chemical factors also influence the algae growth are Nitrogen source, Carbon dioxide, Minor nutrients[12] and vitamins.

Experimental Methodology

Algal samples collected from different waste water bodies were repeatedly washed with distilled water. The cultures were grown in separate tubs with synthetic feed as a source of nutrient medium for their initial growth. The tubs were frequently exposed to sunlight for shorter intervals to undergo photosynthetic process for the production of organic matter by utilizing the atmospheric carbon dioxide. Later the cultures were grown in domestic waste water as the nutrient medium naturally and exposed to sunlight daily in the open atmosphere, and simultaneous p^H monitoring was done. The grown algae were harvested periodically. The harvested algae was air dried, powdered and kept for solvent extraction by using Soxhlet apparatus[13] and the extracted solvent was rotovapoured and Derivatized. The oil obtained was analyzed quantitatively by gravimetric method and qualitatively by determining Specific gravity, Density, Acid value and Iodine value.

ANALYTICAL PROCEDURES

pH, Oxidation-reduction potential (ORP), Chemical Oxygen Demand (COD), Volatile Fatty Acids (VFA), Determination of Iodine value of Micro algal Oil(ASTM D 1959-97), Determination of Acid value of Micro algal oil (ASTM D – 664), Determination of Specific gravity and Density for Micro algal oil.

RESULTS AND DISCUSSION

Algal oil

Cultivation of algae was performed in the lab as an open pond system under natural conditions. During cultivation different parameters were analyzed such as pH, nutrient concentration, trend of organic substrate and organic acids (VFA). The effective algal biomass production was observed when the cultures were operated between pH 7.5 to 8.9. Lipid content was also found to influence by the type of lakes or the characteristics of the lake.

Oil efficiencies of the cultures selected in the present study

Based on the amount of oil extracted, the algal culture from the composite culture of the different lakes was found to contain higher oil content (3.807%) compared to the cultures collected from other lakes of the city. The algal oil from the Thammerelu (1.132%) was also found to be good compared to Kolleru Lake (1.291%).

pH profiles of the three mixed cultures

During the cultivation of algae in an open pond system.[14] Regular monitoring of pH was performed. Initially the cultures were grown in domestic waste with pH 7.5. The optimum pH required for the growth of algae is 7.5 to 8.7. During the experimental run fluctuations were observed at the initial phases later the cultures were adapted to the optimum conditions in almost all the cases.

When pH was observed for Thammerulu, Kolleru Lake and Composite cultures a good correlation was noticed in pH values along with the oil efficiency. Optimum pH conditions showed good result both in biomass growth and lipid accumulation. The percentage of oil recovery was found to be maximum in composite culture followed by Thammerulu culture due to the controlled and optimized pH acquired by the buffering action of the system during the experimental run. The cultures from

Kolleru Lake reported lower percentages of oil comparatively showing uncontrolled pH conditions.

pH profile during morning and afternoon observation of mixed culture for all the cycles

The pH readings in the morning and afternoon were also observed for the three cycles which made a significant change that the pH readings in the morning hours was low compared to the afternoon. The daily (afternoons) pH of the culture increased rapidly from 6.6 to a maximum value of 8.5 after the introduction of the micro algal culture. This is due to the initial uptake of CO_2 by the micro algal cells during the day. The daily pH value of the culture decreased slightly and stabilised at 8.7. Early mornings and afternoons pH profiles were observed during the cultivation of microalgae in outdoor culture tub. After the sixth day resulting from the buffering capacity of the water and the complete adaptation of the micro algal cells to the culture environment. During the night, the pH value of the culture decreases massively as the micro algal cells do not photosynthesise but actually undergo respiration to release more CO_2 which decreases the culture suspension with pH 8.1-8.3. This phenomenon is confirmed by early mornings and afternoons quantifications of dissolved CO_2 levels during the cultivation process.

ORP values of three mixed cultures observed during the operation of first cycle

In the period of algal cultivation of 8 days cycle in the open pond, the oxidation reduction potentials of the algal cultures were observed daily. The algal cultures were grown in the waste water with an initial ORP of -45.3mv. The oxidation and reduction potentials of the Composite culture and Kolleru Lake culture gradually decreased from -45.3 to a least of -120mv. During the study of Thammerulu culture the decrease in ORP has been noticed from -50mv to -142.7mv.

COD profiles for the three mixed cultures during first cycle operation

COD analysis performed to the algae cultures reveals that the algae also have the capability to purify the water. The culture was grown in the waste water for the production of oil. COD analysis was performed from the first day of the cycle to the end, which resulted in the decrease in COD concentrations. The cultures of Kolleru Lake and Thammerulu showed maximum COD removal efficiency compared to the composite culture.

VFA profiles for the three cultures during first cycle operation

Volatile fatty acids [VFA] analysis was done for the culture tubs which showed the gradual decrease in the VFA concentration. VFA for the composite culture at the beginning of the cycle was found to be 1799.45mg/l which later reduced to 828.37mg/l at the end of the cycle. Similarly for Thammerulu VFA concentration was 1191.17mg/l at the beginning and 465.58mg/l at the end of the cycle. The waste water from the algae culture tub of Godavari River was found to be 1433.03mg/lit at the beginning which reduced to 468mg/lit at the end of the cycle.

OIL SAMPLE	ACID VALUE (ASTM D-664)	IODINE VALUE (ASTM D 1959-97)	SPECIFIC GRAVITY	DENSITY
STANDARD VALUES	<0.5 mg KOH/gm of acid	<25(Efficient biodiesel)	0.86-0.90	$0.88 gm/cm^3$
Kolleru Lake	0.55 mg KOH/gm	21.63 gm/100 gm of oil	0.92	$0.94 gm/ cm^3$
Thammerulu	0.27 mg KOH/gm	17.18 gm/100gm of oil	0.99	$0.88 gm/ cm^3$
Composite Culture	0.55 mg KOH/gm	19.09 gm/100 gm of oil	0.96	$0.90 gm/cm^3$

The values obtained from micro algal oil were compared with standard biodiesel values. The specific gravity of micro algal oil was 0.92 for MG culture, 0.99 for TH culture and 0.96 for composite culture which were close to the standard values of 0.86 – 0.90. The density of micro algal oil was 0.94 gm/cm^3 for MG culture, 0.90 gm/cm^3 for composite culture which were close to the standard value and 0.88 gm/cm^3 for TH culture that lies within the normal range. The acid value should be less than 0.5 mg KOH/gm of acid. The acid values for micro algal oil were 0.55 mg KOH/gm of acid for MG and composite cultures which were slightly higher than standard value. The acid value for TH culture was 0.27 mg KOH/gm of acid that lies within the normal range. The iodine value should be less than 25 gm I/100 gm of oil for its use as efficient biofuel. The iodine values were 21.63, 17.18, 19.09 gm I/100 gm of oil for Kolleru Lake, Thammerulu and composite cultures. The values mentioned show the possibility of using micro algal oil as a source of renewable energy.

SUMMARY AND CONCLUSION

On the progress of our work towards the target of producing renewable energy from algae cultures of Thammerulu, Kolleru Lake and Composite culture, the results were found to be positive. The collected cultures were cultivated under natural growth conditions. Algae were grown in the laboratory using domestic waste water as the source of nutrients. The grown algae were collected, dried under sunlight and powdered. The powdered algae were subjected to Soxhlet extraction process. Oil obtained was weighed by gravimetric method. Oil was later Derivatized and analyzed qualitatively by Specific gravity, Density, Acid value and Iodine Value. The oil percentage was higher in composite culture (3.807%) followed by Kolleru Lake culture (1.291%) and Thammerulu (1.132%). The results obtained from qualitative analysis of micro algal oil were compared with standard biodiesel values. The values obtained were within the range of standard biodiesel values. From these results, we conclude that micro algal oil is a source of renewable energy production, chemical feedstock production and pharmaceutical ingredients.[15,16]

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