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Kinetic Study of Algae Biomass Grown in Natural Medium Using Spectroscopic Analysis

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Abstract

Algae are simple autotrophic organisms that produce complex organic compounds from simple inorganic molecules such as carbon dioxide using energy from light or inorganic chemical reactions. These complex organics include a substantial amount of triacylglycerol which can be readily converted into biodiesel by the well known Transesterification process. In addition, the

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residual algal biomass which results after the extraction of the triacylglycerol can also be utilized to produce ethanol, value-added chemicals, and animal feed..This research work was carried out with a focus on utilizing the natural resources of *Sultanate of Oman* to produce bio-products of commercial and societal importance. Algae biomass from seawater were separated and cultivated in laboratory. One of the challenging aspects of the research work is the zeroing in on the type of biomass used for extraction that survives in the desalination reject stream available aplenty from the desalination plants in Oman. After initial growth period, biomass were separated and grown in small photo bioreactors with sufficient lighting arrangement. Subsequently this was used for the growth study to find out its feasibility for large scale cultivation. The important factor in the analysis of the biomass is to relate the growth in terms of measurable parameters. Spectroscopic method of analysis was used in determining the biomass growth. This spectroscopic analysis has been substantiated by dry weight measurements. The proposed spectroscopic analysis has been found to be simple and successful in determining the algae growth. This methodology can well be extended to determine the algae biomass in large scale commercial applications especially for algae grown in wastewater and effluent medium. This study will discuss a rate limiting step of the growth of Polysiphonia, Ectocarpus, Diatoms, Meuisnopedia and Cyanobacteria under its optimum growth conditions identified in the lab and the use of the kinetic data for large-scale cultivation system design and operation.

1 Introduction

Algae biomass is proved to be an effective raw material for many useful products such as fuel oil, fertilizers, protein and other substances. The advantage is that it does not compete with conventional crops and agricultural crops. The growth of algae can well be achieved in any wastewater and reject streams. This medium should contain nutrients and other compounds require for the growth of algae. The identification of the suitable medium is an important role. This is crucial as the world is facing water shortage and crisis due to the global climatic change.

The growth of algae is done in a suitable photobioreactor. Kinetic study of the algae biomass is an important parameter for determining its suitability for commercial or large scale mass production for the extraction of oil and other useful compounds. The growth kinetics of the algae was studied by the use of spectroscopic analysis. This growth study was conducted without the addition of required nutrients to test its ability to grow in an unaided environment as well as take up the nutrient available in the growth medium. The focus of the research is to determine the capability of the algae to uptake the nutrients available in growth medium such as domestic, industrial wastewater and desalination reject stream that are available aplenty in Oman.

2. Literature Survey

Algae are marine and freshwater plants that have higher photosynthetic efficiencies than terrestrial plants and are more efficient capturing carbon. The use of algae to capture carbon dioxide as a method for greenhouse gas mitigation has been discussed by Mike Packer (2009). Algae biomass in aquatic environment has been influenced by the abnormal appearance of unpleasant water-bloom or eutrophication problems. It is the cause for odors and being obstacle to water purification systems. So physical and chemical were employed to remove algae from water and transform it to become algae sludge and disposed as municipal waste. However, algae and other biomass have become focal points as alternative energy resources, since they are renewable by fixation of CO_2 through photosynthesis from the atmosphere. Yang et al (2004) applied a thermochemical liquefaction process to convert the biomass of algae into oil in the presence of water at high temperature (about 300–340 °C) and high pressure (about 20 MPa), with or without an alkali catalyst. The energy balance and CO_2 mitigating effect of a liquid fuel production process from microalgae using thermochemical liquefaction were studied by Sawayama et al 1999. Microalgae have been grown in mass culture mainly for food production and waste treatment (Govindarajan et al 2009). Initial efforts at mass culture of microalgae were only directed towards food production. However, the most promising early results of mass algae culture was to use microalgae for wastewater treatment in oxidation ponds. The same concept can be utilized for the treatment of wastewater and desalination reject stream to achieve near zero discharge treatment plants. The prominent feature of this methodology is to utilize the existing brine evaporation ponds for the cultivation of the algae.

3. Experiments

Algae biomass was obtained from Al Athiba seawater and transferred to a bath containing seawater collected near the algae collection. Table 1 shows the analysis of the natural medium used for the growth of the algae.

Table 1 Analysis of Natural Medium for Microalgae

Color	Hazen Units	5 - 10
Odor		None
pH		8.19
Electrical Conductivity	mS/cm^{-1}	54.9
Total Dissolved Solids	mg/L	36648
Total Hardness	ppm as $CaCO_3$	6500
Calcium Hardness	ppm as $CaCO_3$	1200
Magnesium Hardness	ppm as $CaCO_3$	1285.5
Total Alkalinity(Alk)	ppm as $CaCO_3$	112
Bicarbonate Alk	ppm as $CaCO_3$	112
Carbonate Alk	ppm as $CaCO_3$	0
Hydroxide Alk	ppm as $CaCO_3$	0
Turbidity	NTU	1.06
	CATIONS	
Calcium as Ca^{2+}	ppm	50.12

Magnesium as Mg^{2+}	ppm	1197
Sodium as Na^{+}	ppm	11160
Potassium as K^{+}	ppm	460
	ANIONS	
Chloride	ppm	2566.614
Sulphate	ppm	2448.507
Nitrate	ppm	Not detected
Fluoride	ppm	1.946
Bromide	ppm	41.667
Silicates as SiO_2	ppm	0.610

μScm^{-1} – microsiemens per centimeter

ppm – parts per million

mg/L – milligrams per litre

NTU –Nephelometric Turbidity Units

FRC – Free Residual Chlorin

Few of the cultures were found to decay when tried to grow in the laboratory due to the probable contamination by larva of fish and other marine organisms. Then active biomass were removed and grown in a small photobioreactors as shown in Fig. 1. It was conducted in the series of small scale photo bioreactors with the adequate supply of indoor lighting in the laboratory.

Fig. 1 Algae Biomass in Laboratory Scale Photobioreactor

Spectroscopy examination was selected and validated with dry mass measurements in the research. After substantial growth period, a portion of the algae biomass was separated and analyzed for the various parameters such as percentage transmission, concentration, optical density. Then the biomass was filtered and dried to find out its weight. The same methodology was adopted for rest of the algae biomass for various growth periods.

4. Results and Discussion

The biomass assay was carried out to determine the nature of species found in the culture. It was found to contain the species of *Polysiphonia*, *Ectocarpus, Diatoms, Meuisnopedia and Cyanobacteria*. The growth of the biomass was continuously monitored by conducting analysis using spectrophotometer. This includes % transmission; concentration and optical density are determined and used as growth parameters. Simultaneously weight of biomass was recorded. Table 2 shows the spectroscopic analysis of the biomass and dry weight measurements.

Table 2 Spectroscopic Analysis of Algae Biomass for Kinetic Study and Dry Weight Measurements

Days	% Transmission	Concentration	Optical Density	Dry Weight Measurements (gram in 50 ml of medium)
0	96	12	0.0	0.8
4	95.6	20	0.019	1.7
8	85.7	67	0.070	2.5
12	82	80	0.08	2.7
16	74	128	0.127	3.6
20	61.4	219	0.218	4.23
24	55	243	0.242	4.8

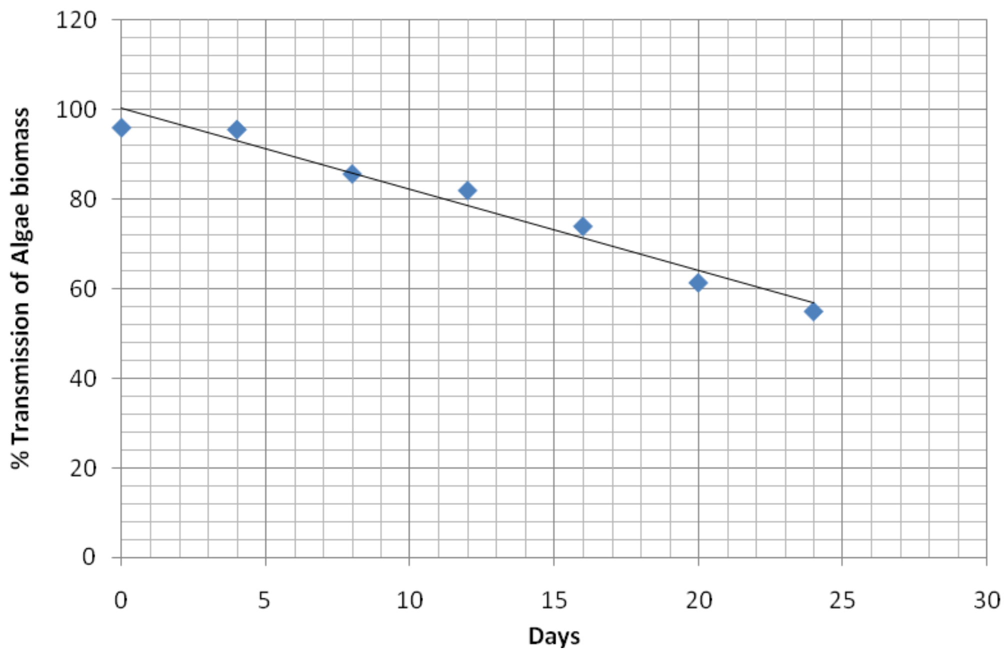

Fig. 2 Percentage Transmission Vs Days – Spectroscopic Analysis of Biomass

The digital spectrophotometer is used for spectrophotometer analysis of a solution of any concentration. The output is available on the digital display in the forms of optical density (Absorbance), percentage transmission (%T) and concentration (C). The instrument operates at wavelength of 340 nm to 960nm. Fig. 2 shows the percentage transmission as function of growth period and Fig. 3 shows the optical density of algae biomass as function of growth period obtained from the Spectroscopic Analysis of Biomass for Kinetic Study. Fig. 4, variation in algae density as a function of time exhibits a linear growth kinetics

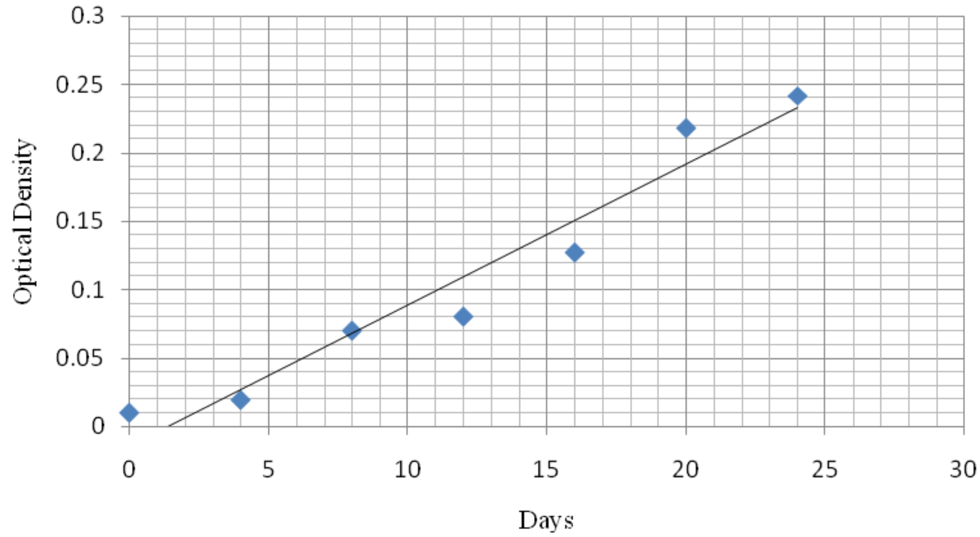

Fig. 3 Optical Density of Biomass Vs Days – Spectroscopic Analysis of Biomass

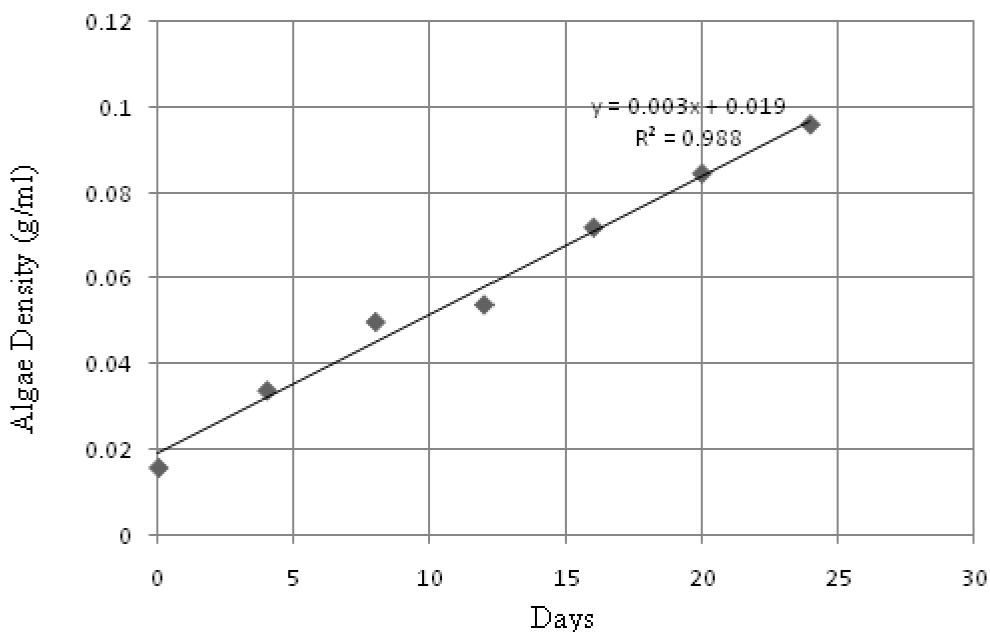

Fig. 4 Algae Biomass Density as a function of Growth Period

5. Conclusions

From this research work on kinetic study of algae biomass in natural medium, the following conclusions were drawn:

(i) Segregation of biomass from natural resources suffers from huge contamination that lead to the growth of the biomass is only to be attempted in a small culturing flask with sufficient light source.

(ii) Generation of biofuel / bioproducts is feasible by using algae biomass even without the addition of nutrients.

(iii) Identifying the algae biomass capable of taking up the nutrients from the medium during the starvation period is itself is a challenging task in the work.

The advantages of using Spectroscopic analysis for kinetic study are:

(i) Accurate as it can detect degraded chlorophyll and other pigments

(ii) Cost effective

(iii) Growth parameters can be related by a calibration chart

(iv) Results obtained are comparable with dry mass measurements.

The research has been found to be successful in its approach of achieving the growth without the addition of nutrients. This was done with an objective of cultivating the algae biomass in extreme conditions. Then the same algae biomass can be grown in process industry effluents and domestic wastewater as its medium. This attempt of accomplish growing the algae biomass in an unaided environment can be seen as definitely warranty a detailed further study.

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6. References

Ahmed Alsaeed.2009 Extraction of Fuel from Microbial Biomass Grown in Process Industry Effluents, Technical Project Level

4, B.Sc(POM) Caledonian College of Engineering, Oman,.

Bakheet Hassan Fadhi 2009 Kinetics Study of Bioenergy from Microalgae, Technical Project Level 4, B.Sc(POM) Caledonian College of Engineering, Oman, 2009.

Govindarajan et al, 2009 Treatment of Desalination Reject Stream & Conversion of energy using Microalgae, Research proposal submitted to Middle East Desalination Research Centre (MEDRC), Oman.

Mike Packer.2009 Algal capture of carbon dioxide; biomass generation as a tool for greenhouse gas mitigation with reference to New Zealand energy strategy and policy, Energy Policy, Volume 37, Issue 9, pp 3428-3437.

S. Sawayama, T. Minowa and S-Y. Yokoyama. 1999 Possibility of renewable energy production and CO_2 mitigation by thermochemical liquefaction of microalgae, Biomass and Bioenergy, Vol. 17, 1, pp 33-39.

Sheehan, J., Dunahay, J., Benemann, J. and Roessler, P. 1998 A Look Back at the U.S. Department of Energy’s Aquatic Species Program: Biodiesel from Algae, NREL/TP-580-24190, National Renewable Energy Laboratory, Colorado.

Y. F. Yang, C. P. Feng, Y. Inamori and T. Maekawa. 2004 Analysis of energy conversion characteristics in liquefaction of algae, Resources, Conservation and Recycling, Vol. 43, 1, pp 21-33.