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Production of Bio Fuels from Eichhornia Crassipes Algae

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Abstract: *In a bid to promote renewable energy and control of dam pollution, algae, a plant notorious for growing in waste water dams was used to produce algae oil. Algae plantswere collected from the dam and algae oil was extracted using the Soxhlet procedure. Hexane was used as the solvent. A conversion rate of 14% was obtained for an extraction time of 6 hrs. This algae oil will then be trans-esterified to produce a bio fuel. The bio fuel can be used as an alternative to petrochemical fuel and is sulfur free. Moreover, it is proven to be the cleanest fuel for combustion systems.*

Keywords: *Algae Oil, Bio Fuels, Renewable Energy, Soxhlet Extraction*

1. INTRODUCTION

The production of biodiesel using algae biomass has received much attention throughout the world. This is due to depletion of fossil fuels and also due to the accumulation of greenhouse gases in the environment. The use of renewable and carbon neutral biodiesel from algae is necessary for a sustainable environment. Much attention is being directed to finding alternative energy resources for many countries. According to Korbitz (1999) the energy crisis in the world has led many countries to take a series of steps to resolve this problem [1]. The increasing need of fuel in Zimbabwe in transport industry and agricultural sector has necessitated the search for other fuels as an alternative to diesel. Therefore, alternative biodiesel is the only option to fulfill the requirements in future.

1.1 Eichhornia Crassipes Algae

Eichhornia crassipes algae is a cosmopolitan, perennial, mat-forming aquatic species, which can tolerate a wide range of habitat conditions (temperature, illumination, pH, salinity, winds, current and drought. It is primarily a fresh water plant but can survive up to 13 days in sea water. Optimal growth conditions are a pH of 7.0, a phosphorus concentration of 20ppm and adequate nitrogen. The largest infestations are thus found in waters enriched by sewage and industrial effluent or by run-off from fertilized agricultural land. The algae is morphologically very plastic with rapid vegetative propagation, features that make it well adapted for long distance dispersal and successful colonization of diverse habitats.

Fig1. *Eichhornia crassipes* algae

2. BRIEF LITERATURE

Currently, bio-ethanol from corn starch, sugar cane or sugar beet, and biodiesel from oil crops such as palm and oilseed rape, is the most widely available forms of biofuel. However,

sustainability of these biofuels is an issue since production of a significant proportion of fuel result in competition for arable land with food crops[2]; [3]. The use of algae overcome this concern since algae has higher productivities than land plants, with some species having doubling times of a few hours, some species can accumulate very large amounts of triacylglycerides (TAGs), the major feedstock for biodiesel production and high quality agricultural land is not required to grow the biomass.The use of algae for biofuels production can also serve other purposes. Some possibilities include the removal of CO_2 from industrial flue gases by algae bio-fixation [4] , reduction of green house gas emissions of a company while producing biodiesel, wastewater treatment by removal of NH_4^+, NO_3^+ , PO_4^+ ions, making algae to grow using these water contaminants as nutrients or ponds [4] . After algae oil extraction the resulting algae biomass can be processed into ethanol, methane, livestock feed, used as organic fertilizer due to its high N:P ratio, or simply burned for energy cogeneration [4]. The ability of algae to grow under harsher conditions with reduced nutrient requirements means it can be grown in areas unsuitable for agricultural purposes independently of the seasonal weather changes, thus not competing for arable land use, and can use wastewaters as the culture medium, not requiring the use of freshwater.

There are three well-known methods to extracting the oil from microalgae namely: (1) Expeller/press method, (2) Solvent extraction using chemicals method and (3) Supercritical fluid extraction method [5]. The most popular extraction method is the Soxhlet extraction using hexane as a solvent and an extraction time of 4 hours[6]. Other solvents, such as petroleum ether, methanol or a hexane–ethanol mixture, can be used. There are many factors to be considered and optimized in production and extraction of algae oil from algae. These include energy and material inputs such as nutrients, and energy for mixing during growth, and appropriate treatment of waste products and varying some factors on the extraction process itself.The objectives of this study were therefore to find optimum operating conditions for the extraction of algae oil using Soxhlet extraction method. The ratio of algae to the amount of hexane used was varied from that in literature and extraction time was ranged from four to six hours. Other solvents such as methanol and ethanol will be examined in the future.

3. MATERIALS AND METHODS

3.1 Materials

Algae plants were obtained from Lake Chivero where they are rapidly multiplying daily because of waste water. Thealgae were dried and then crushed using a multifunction blender (Home luck P505). It was ensured an average moisture content of 14.36% and was achieved @180ºC for 5 minutes. A moisture analyzer model MS-70 (A and D Company Ltd) was used for moisture analysis. 4g of the crushed algae was then used in the algae oil extraction. The mass of the dried algae was measured using an electronic precision balance model BNI-E510.

n-hexane with 99.5% purity was used as the extracting solvent. The hexane was obtained from Associated Chemicals Enterprises (ACE) Pvt Ltd.

3.2 Extraction method

The Soxhlet Extraction method/Hexane solvent oil extraction

The Soxhlet Extraction method/Hexane solvent oil extraction was used with minor modification. The extraction time range employed was 4 to 6 hours. This procedure can also be applied at industrial level.

The Soxhlet Apparatusmodel used had a vertical condenser and it was obtained from LabConco. Solvent Extraction is a process which involves extracting oil from oil-bearing materials by treating it with a low boiler solvent as opposed to extracting the oils by mechanical pressing methods (such as expellers, hydraulic presses, etc.) The solvent extraction method recovers almost all the oils and leaves behind only 0.5% to 0.7% residual oil in the raw material unlike in the case of mechanical pressing whereby the residual oil left in the oil cake may be anywhere from 6% to 14%[7]. The solvent extraction method can be applied directly to any low oil content raw materials. It can also be used to extract pre-pressed oil cakes obtained from high oil content materials. Since high percentage of oilis recovered, solvent extraction has become the most popular method of extraction of oils and fats[7].

In a nutshell, the extraction process consists of treating the raw material with hexaneor and recovering the oil by distillation of the resulting solution of oil in hexane called miscella. Evaporation and condensation from the distillation of miscella recovers the hexane absorbed in the material. The hexane thus recovered is reused for extraction. The low boiling point of hexane (69°C), [7] and the high solubility of oils and fats in it are the properties exploited in the solvent extraction process.

3.3 Procedure

4g dry sample of ground algae were putinto a filter paperbag. The filter paper bag was then thread-tied on the open end and placed in an extraction chamber. The extraction chamber was suspended above a round bottomed flask containing the specific hexane solvent directly below a condenser. The flask was heated and the hexane evaporated at its boiling point which is 69^{o}C. The hexane then moved into the condenser where it was converted into a liquid that trickles into the extraction chamber containing the algae sample. The extraction chamber was designed so that when the solvent surrounding the sample exceeds a certain level, it overflows and trickles back down into the boiling flask.

At the end of the extraction process, the filter paper containing algae sample was removed. The hexane solvent was evaporated and condensed to be recovered in another funnel for reuse in subsequent extractions. The mass of the remaining lipid was measured and the percentage of lipid in the initial sample was calculated. The experiments were carried out at different extraction times and different amount of hexane where employed. An experimental design was used to study the effects of these parameters on the amount of algae oil produced.

The % of algae oil extracted was calculated as indicated below:

$$\%\ Algaeoilextracted = \frac{Amountofalgaeoilobtained\ (g)}{Amountofgroundalgaeused\ (g)} * 100\%$$

3.4 Experimental Design

A 2^2 full factorial design wasused[8]. This was done so as to investigate the effect of extraction time in hours and amount of hexane used in mls on the amount of algae oil extracted. The extraction time investigated was between 4hrs and 6hrs, whereas the amount of hexane used was varied between 200mls and 300mls. In total 4 experiments were carried out according to the design as illustrated in Table 1.

Table 1:$2^{2.}$ *Experimental design used to investigate effect of extraction time and amount of hexane used*

Experiment	Conditions
1	4hrs; 200mls
2	4hrs;300mls
3	6hrs;200mls
4	6hrs;300mls

4. RESULTS AND DISCUSSION

The results obtained from the experiments are shown in Table 2 and Figure 1.

Table 2. *Algae oil extracted (%) at varying extraction times and amounts of hexane*

Extraction time (hrs)	Amount of hexane used (mls)	Amount of hexane recovered (mls)	Algae oil obtained (g)	% Algae oil extracted
4	200	150	0.93	23.25
4	300	250	0.59	14.75
6	200	100	1.46	36.50
6	300	200	0.77	19.25

Increase in extraction timealso increased the percentage of algae oil extracted irrespective of the amount of solvent used (see Figure 1). The percentage of algae oil extracted increased by 57% when the extraction time was increased from 4hrs to 6hrs whilst a constant 200mls of hexane was being used (see Table 2). Also, the percentage of algae oil extracted increased by 30.5% when the extraction time was increased from 4hrs to 6hrs whilst a constant 300mls of hexane was being used (see Table 2). This behavior is probably because all the algae oil were extracted due to the

longer times employed, even the microscopic algae oil. Also probably all the interstitial water in the algae cell walls was taken out during the extraction process [7] . The same result of increased algae oil extraction rate with increased extraction time was observed by Ahmad *et al.*, (2010) when they investigated the effect of extraction time on extraction of Herba Leonuri using the Soxhlet Procedure.

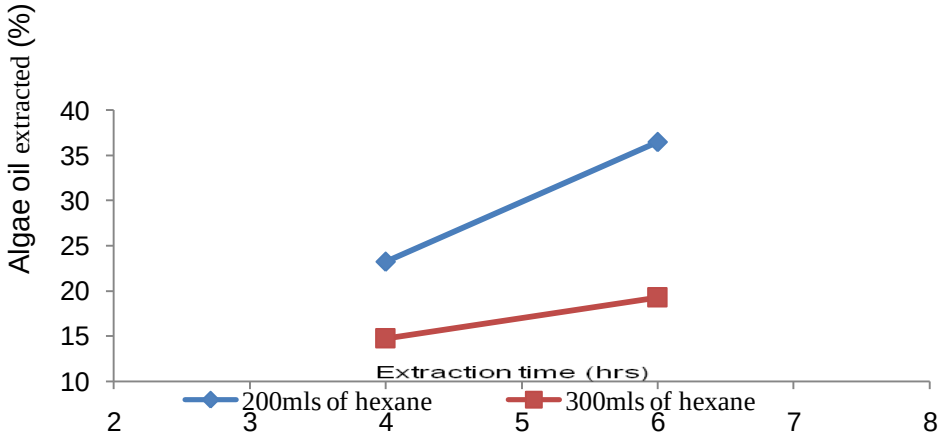

Figure 1. *Effect of extraction time and amount of hexane used on algae oil extraction*

On the other hand, increase in the amount of hexane used decreased the percentage of algae oil extracted (see Figure 1). The percentage of algae oil extracted decreased by 36.6% when the amount of hexane used was increased from 200mls to 300mls at a constant extraction time of 4hrs (see Table 2). Also, the percentage of algae oil extracted decreased by 47.3% when the amount of hexane used was increased from 200mls to 300mls at a constant extraction time of 6hrs (see Table 2). Ahmad *et al.*, (2010) also reported a lack of consistence in using hexane as a solvent in the Soxhlet procedure when they investigated the mass yield obtained from hexane and methanol during extraction of Herba Leonuri. They observed a dip in the mass yield with hexane but no conclusive result on this behavior was given.

5. CONCLUSIONS

The highest yield of algae oil (36.5%) was found at an extraction time of 6hrs with 200mls of hexane being used. This indicates that highest yields of algae are obtained with increased extraction time and lower algae-hexane ratios.So, for production of 1000 liters of algae oil at an extraction time of 6 hours, about 2.75 tones of dry algae will be used. 140L of hexane will be employed as solvent of which 50% of it will be recovered in the process.

There is on-going work on the behavior of oil extracted with increased amounts of hexane used. In our future work, the algae oil extracted will be analyzed to determine the actual composition. Furthermore, the extracted algae oil will be trans-esterified to obtain the bio fuel.

6. DELIMITATIONS

The algae oil results shown were done at micro-scale. Thus, the results projected may not be true reflections of a macro plant.

7. FUTURE WORK

Comparative analysis of algae oil extracted from other internationally available algae species will be done. The researcher wishesto engage the Harare City Council, Fale Treatment plant to use their wastewater for algae farming. In addition to this, an industrial plant for processing of the bio fuels from algae at macro level will be developed and lastly commission the industrial plant.

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