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Production of Biodiesel Using Algae

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ABSTRACT: Bioenergy is one of the most important components to reduce greenhouse gas emissions and substitute of fossil fuels. The need of energy is increasing continuously, because of increases in industrialization and population. Biodiesels are a renewable energy source, made from organic matter or wastes, that can play a valuable role in reducing carbon dioxide emissions. Biodiesels are one of the largest sources of renewable energy in use today. Biomass is one of the good sources of energy. Currently biodiesel is becoming popular as an environmentally friendly fuel. It has been used in the automotive industry. Biodiesel is much better lubricant than petrol, diesel and extends engine life. An attempt was made to produce biodiesel using algae. Algae are the major global primary producer which is beneficial. Carbon dioxide fixation rate of algae is much higher than the terrestrial plants. Flash point of Spirogyra biodiesel and Oedogonium biodiesel comes 1550°C and 1480°C respectively. Fire point of Spirogyra biodiesel and Oedogonium biodiesel comes 1590°C and 1530°C respectively. Macroalgae to biofuels is currently a much less researched topic than the microalgae to biofuels route, but interest in this topic is accelerating. Thus, the study has demonstrated systematic approach to production of biodiesel.

KEYWORDS: Algae, Biodiesel, Biofuel.

I. INTRODUCTION

1. General

Biofuels are a wide range of fuels which are derived from biomass. The term covers solid biomass, liquid fuels and various biogases. Biofuels are gaining increased public and scientific attention, driven by factors such as oil price hikes and the need for increased energy security. Biodiesel fuel can be prepared from waste cooking oil, such as palm, soybean, canola, sunflower, coconut, corn oil, fish oil, chicken fat and algae which would partly decrease the dependency on petroleum-based fuel. Biodiesel can be used as a fuel for vehicles in its pure form, but it is usually used as a diesel additive to reduce levels of particulates, carbon monoxide, and hydrocarbons from diesel-powered vehicles. Biodiesel is produced from oils or fats using trans-esterification and is the most common biofuel in Europe. Biofuels provides 1.8% of the world's transport fuel. Investment into biofuels production capacity exceeded worldwide and is growing.

2. Background

The craving for new, sustainable energy sources has turned a garden pond nuisance, green algae, into one of the most promising renewable fuel feedstocks. The sudden popularity of algae is due to reports of very high oil yields and dramatic greenhouse gas (GHG) savings, all devoid of any negative effect on farming. But an in-depth analysis of algae reveals that their potential is not limitless and that further research is needed in order to maximize the benefits drawn from and minimize the environmental impacts caused by algae.

3. Biofuel history

The idea of using Algae as a source of food, feed and energy goes back more than half a century. Production of methane gas from algae was proposed in the early 1950s and received a big impetus during the energy crisis of the 1970s, when projects were initiated to produce gaseous fuels (hydrogen and methane). The ASP researchers worked primarily on growing algae in open ponds, making significant contributions to our understanding of growing algae for fuel. Thousands of different species were isolated and tested, the impacts of different nutrient and CO₂ concentration were documented, the engineering challenges of mass-producing algae addressed and a solid foundation of algae-fuel research built. But in 1995, faced with financial constraints and cheap oil, the DOE made the decision to terminate the program.

4. Motivation

The world’s energy needs currently are strongly dependent on fossil fuels like petroleum, coal, natural gas. The energy crisis is becoming the most grown-up global problem for human civilization and its development. Since the energy demand of more than 80% is fulfilled by fossil fuels. The current fluctuating global oil prices and limited fossil fuel resources have induced an interest of researchers and consultancies worldwide to find prominent renewable energy solutions for transportation fuel and other energy needs. Bio-energy has great potential to fulfill the energy needs as a renewable energy for human society. Biodiesel, biogas, bioethanol, biohydrogen are the main forms of biofuels. Biodiesel renders a promising alternative to petroleum fuels because it can be easily blended with them without much modification in the design of diesel engine. Biodiesel comprises monoalkyl esters derived from either animal fats or vegetable oils such as soybean oil, corn oil, rapeseed oil, canola oil, palm oil, castor oil, etc. Biodiesel or methyl ester is the renewable, biodegradable and non-toxic fuel and therefore it is a clean source of energy which has the potential to replace fossilfuels.

1.2 Economic benefits of macroalgae

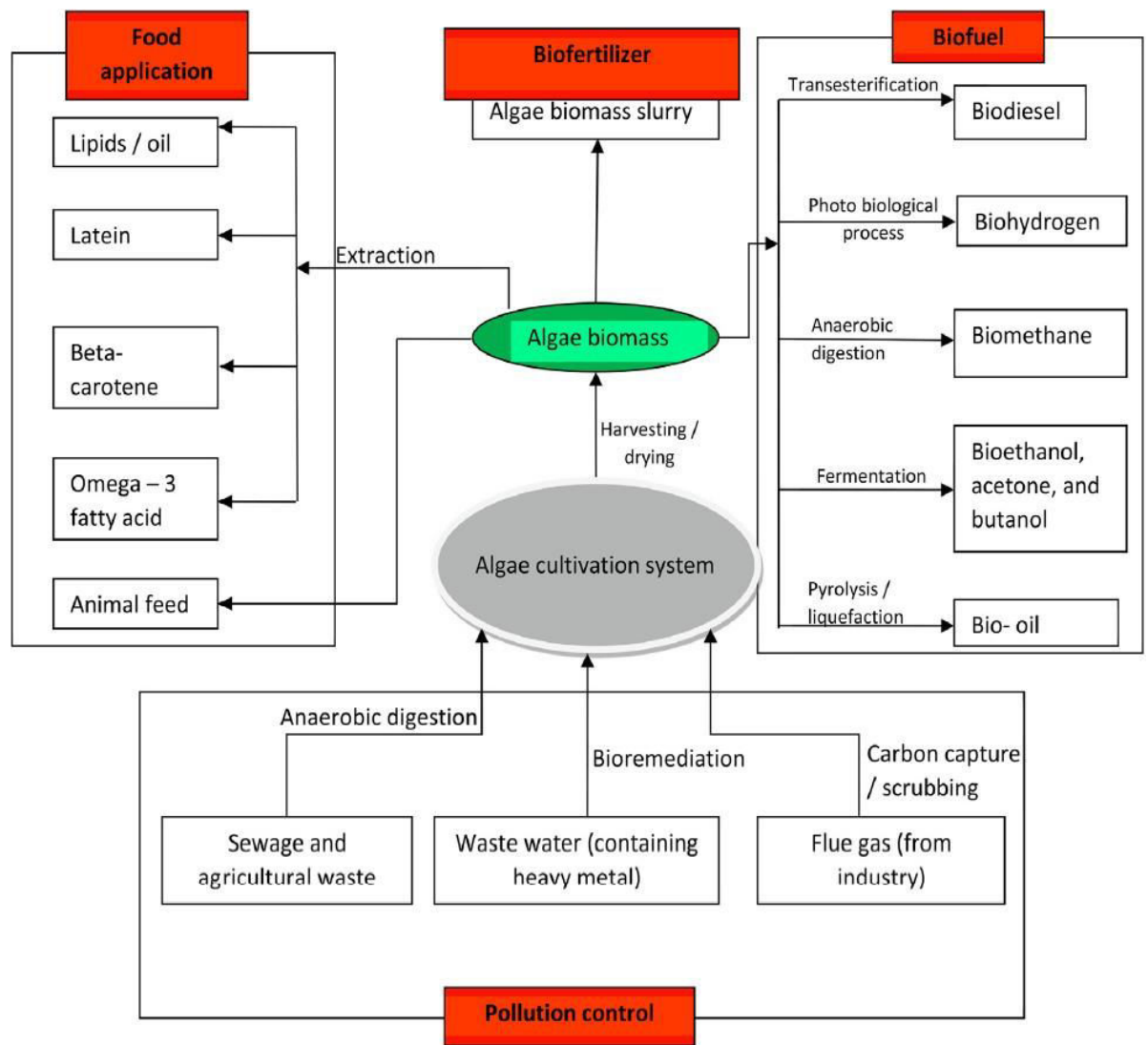


Figure 1.1: Schematic diagram of economic benefits of macroalgae

Applications of macroalgae to engineering solutions are in abundance. One of such areas includes waste water treatment. Application of algae to waste water treatment via bioremediation techniques is an efficient process of pollution control which removes nitrogen, phosphorus and heavy metals such as cadmium, zinc, nickel, and lead. By combining algae and waste water treatment, low effluent nitrogen and phosphorous concentrations can be achieved. Nutrients from wastewater treatment sludge can be recycled to produce biomass and oil that can be harvested to make useful products. This process is environmentally friendly and does not lead to secondary pollution. It is also applied in sewage treatment, eutrophication prevention, biofertilizers production and greenhouse gas emission abatement by CO₂ scrubbing.

1.2 Aim:

The aim of the project is to produce biodiesel using algae.

1.3 Objectives:

2. To break down achievability and manageability of algae as another biomass feedstock.
3. To examine the transformation of algae biomass to bioenergy.
4. To examine the characteristics of biofuel.

II. METHODOLOGY

2.1 Methodology :

- **Sample Collection :** The algae *Oedogonium* and *Spirogyra* were collected from the prawn farm of aquaculture sites at **Shindewadi village in Pune district of Maharashtra, India** and from **Institute of environment education and research, SP Biological Lab, Pune**. The algal species were identified using standard methods under high-resolution microscopes. The microscopic image of *Oedogonium* and *Spirogyra* is shown in figure.



Figure 2.1 : Microscopic image of *Oedogonium* and *Spirogyra*

The algae collected from this site were washed and squeezed to drain all water. Then, the algae were cut into small pieces and dried in shade for 48 hours followed by heating in an oven at 400°C until the moisture was removed and weight was observed for constant value. The dried pieces of algae were ground with a blender as much as possible to turn it into powder form. Lipid content was determined by gravimetric quantification method. The flow diagram of biodiesel production from algae is shown in figure.

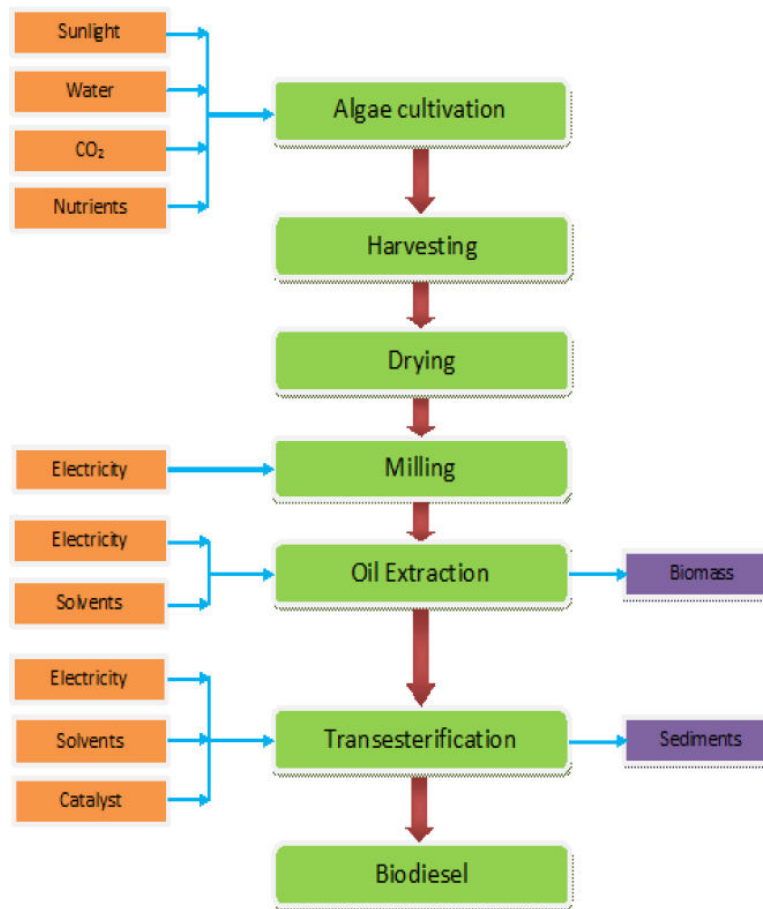


Figure 2.2 : The flow diagram of biodiesel production process from algae

• **Extraction of Oil:**

Solvent extraction was carried out to extract the oil from the algae. The solvent used was recycled to reduce the processing cost. Two methods were followed for extraction of oil as discussed below.

1. Chloroform methanol method-

A dried algal species of known weight (200 g dry weight) was taken and mixed with chloroform methanol (2000 ml) extraction solvent mixture for 20 minutes with the help of agitator. Mixture of chloroform methanol (1000 ml) was added after 10 minutes. Hexane ether method-A dried algal species of known weight (500 g dry weight) was taken and mixed with hexane ether (5000 ml) extraction solvent mixture and kept for 24 hrs, followed by filtration of the solution. mixture and kept for 24 hrs, followed by filtration of the solution



Figure 2.3 : Lipid extraction with hexane using reflux

III. RESULTS AND DISCUSSION

3.1 Results:

3.1.1 Drying of Algae :

The dry weight of algae *Oedogonium* was 2000 g after drying operation from fresh weight (wet wt.) of 6250 gm and the dry weight of algae *Spirogyra* was 2070 gm from fresh weight (wet wt.) of 7390 gm after drying as shown in table 1.

Table 3.1: Measurement of conversion of fresh weight to dry weight of algal biomass with % conversion

Algae Species	Fresh wt./wet wt.	Dry Wt.	% conversion
<i>Oedogonium</i>	6250 (g)	2000(g)	32(%)
<i>Spirogyra</i>	7390 (g)	2072(g)	28.03(%)

Dry weight percentage of biomass was greater in *Oedogonium* than in *Spirogyra* species.

3.1.2 Lipid Percentage:

The lipid percentage value in algal species was evaluated as 16.20% in *Oedogonium* and 14.25% in *Spirogyra* on a dry weight basis.

3.1.2 Algal Oil Yield:

The algal oil extracted from algal species *Oedogonium* and *Spirogyra* was measured and compared for both chloroform methanol and hexane ether solvent extraction method as shown in table 2 and table 3 below.



Table 3.2: Measurement of oil extracted from Oedogonium and spirogyra species using chloroform methanol method

Algae Species (1000 g dry wt.)	Extracted algal oil	Biomass
Oedogonium	167.7 g	465.5 g
Spirogyra	154.3 g	472.4 g

Table 3.3: Measurement of oil extracted from Oedogonium and spirogyra species using hexane ether method

Algae Species (1000 g dry wt.)	Extracted algal oil	Biomass
Oedogonium	162.2 g	479.4 g
Spirogyra	147.9 g	485.0 g

167.7 g of algal oil and 465.5 g of biomass were produced from 1000 g (dry wt.) of Oedogonium species and 154.3 g of algal oil and 472.4 g of biomass was produced from 1000 g (dry wt.) of spirogyra species by chloroform methanol method. While a 1000 g (dry wt.) of Oedogonium produced 162.2 g of algal oil and 479.4 g of biomass. A 1000 g of spirogyra produced 147.9 g of algal oil and 485 g of biomass by hexane ether method. Extracted oil was found greater in Oedogonium than spirogyra. The biomass after oil extraction was higher in spirogyra than Oedogonium algae.

3.1.1 Free Fatty Acid (FFA):

The FFA percentage value in algal species was found to be 2.016% in Oedogonium and 2.604% in spirogyra on a dry weight basis.

3.1.2 Effect of Catalyst Concentration on Algal Methyl Ester:

The effect of catalyst concentration (potassium hydroxide and sodium methoxide) on yield of methyl ester was studied for Oedogonium and spirogyra algal oil. Biodiesel yield was low at lesser catalyst loading due to incomplete reaction and then increased as the catalyst loading was increased. The maximum methyl ester yield was found at 0.7 wt% of potassium hydroxide and sodium methoxide as a catalyst.

3.1.3 Effect of Temperature on Algal Methyl Ester :

The effect of operating temperature was observed at 500°C, 550°C, 600°C, 650°C, 700°C, 750°C by keeping other parameters constant such as time 1 hour, catalyst KOH (0.7 wt%) and oil to methanol ratio (1:10) as shown in figure.

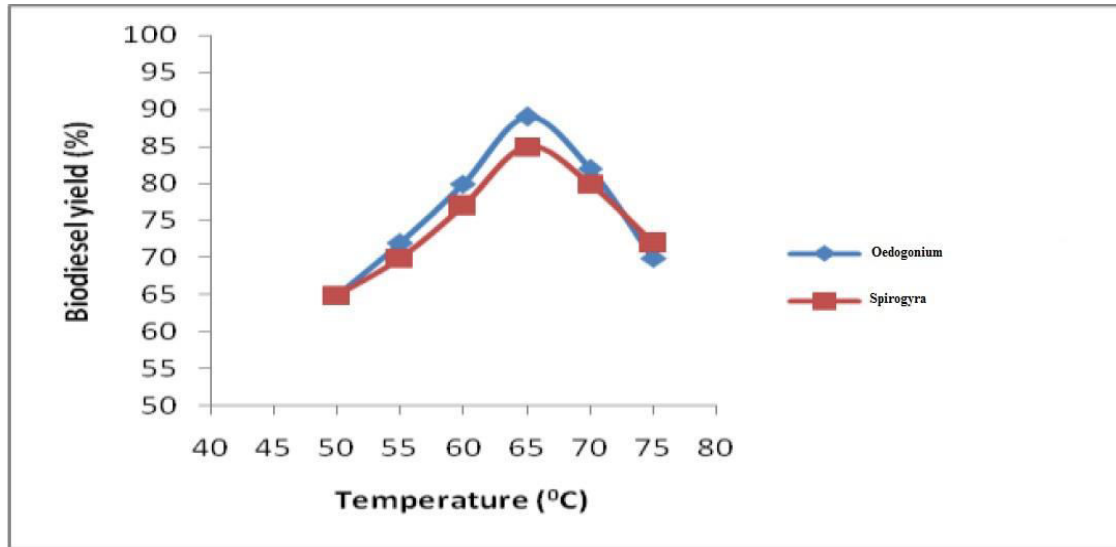


Figure 3.1 : Effect of temperature on biodiesel yield for constant time 1 hour, catalyst KOH

The same procedure was followed for catalyst NaOCH₃ and it was found that yield of methyl ester was higher at 65°C which is the boiling point of methanol for both algal oils as shown in figure.

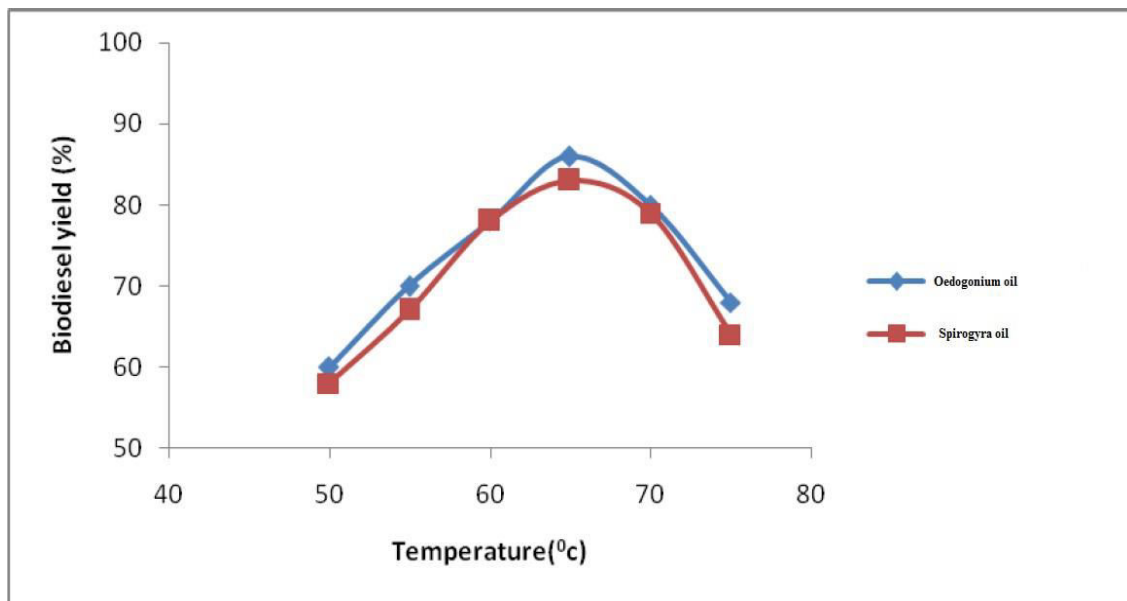


Figure 3.2 : Effect of temperature on biodiesel yield for constant time 1hr, catalyst NaOCH₃



3.1.1 Effect of Time on Algal Methyl Ester:

The effect of reaction time on yield of biodiesel was observed for 60 min, 90 min, and 120 min as shown. The other parameters were kept constant such as temperature 650°C, catalyst KOH/NaOCH₃ (0.7 wt %) and oil to methanol ratio (1:10). The temperature 650°C was selected as biodiesel yield was highest at 650°C.

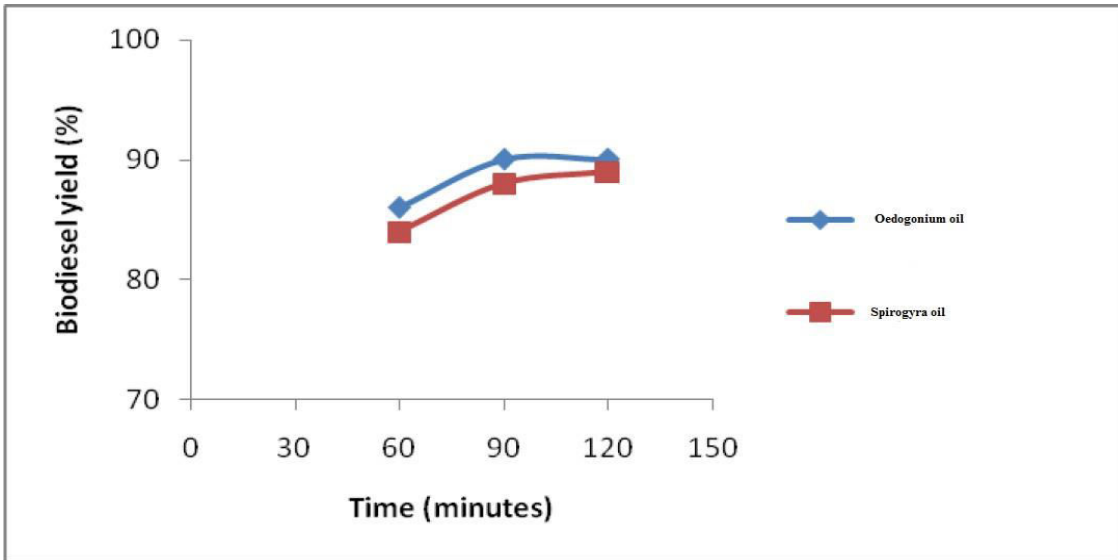


Figure 3.3: Effect of reaction time on biodiesel yield for constant temp. 650°C, catalyst KOH

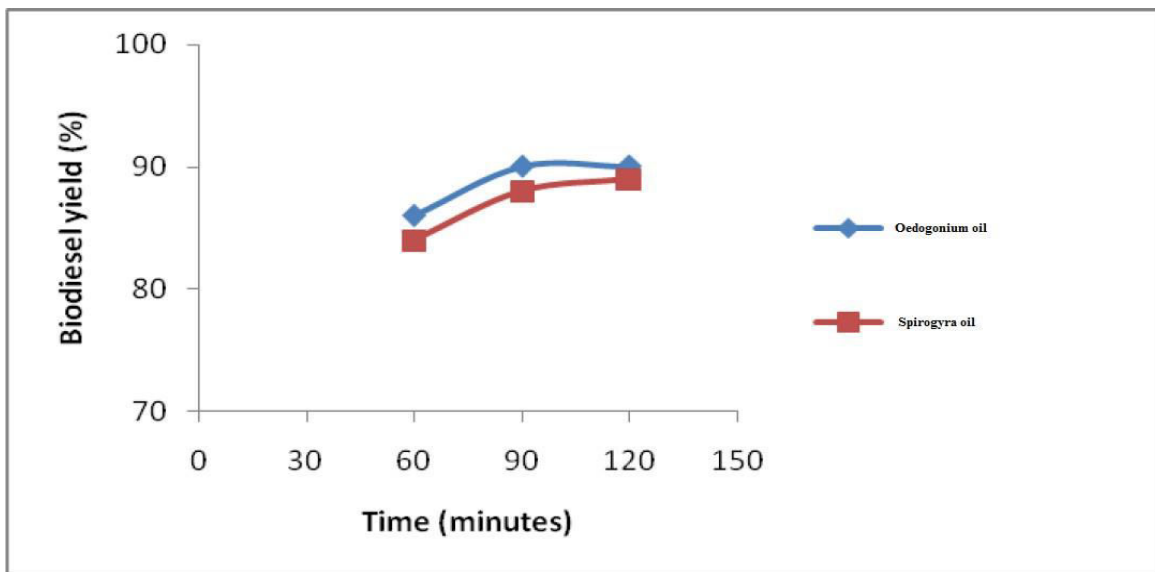


Figure 3.4 : Effect of reaction time on biodiesel yield for constant temp. 650°C, catalyst NaOCH₃

It was found that methyl ester yield was optimum at 90 minutes reaction time for both algal oils. Oedogonium methyl ester yield was greater than spirogyra methyl ester. The time required to complete the transesterification process was 90 minutes beyond which, it gave minimal increment which was not feasible. The transesterification reaction at temperature 650°C and reaction time of 90 minutes using catalyst KOH gave maximum yield percentage of biodiesel for both Oedogonium oil (94%) and spirogyra oil (91%).



3.2 Analysis:

The properties of produced algal biodiesel were analysed as shown in table 3.4.

Table 3.4: Properties of produced biodiesel

Properties	Spirogyra biodiesel	Oedogonium biodiesel
Cloud point	30°C	30°C
Pour point	-70°C	-90°C
Flash point	1550°C	1480°C
Fire point	1590°C	1530°C
Kinematic viscosity at 400°C	3.5 mm ² /s	3.0 mm ² /s
Acid Value	0.472 mgKOH/g	0.434 mgKOH/g
Relative density	868.2 kg/m ³	864.3 kg/m ³
pH	7	7

The composition of the fatty acid methyl ester of produced biodiesel was analysed using gas chromatography method shown in table.

3.2.1 Properties of biodiesel:

The properties of the biodiesel give an indication of whether it would be suitable or not. So, the main properties of biodiesels such as the acid number, viscosity, density, flash point, fire point, cloud point, pour point were studied using standard methods. Three replications were done for all the tests, and their means were calculated.

● **Acid number :**

The titration method was used to estimate the acid number of the biodiesel. 0.1–0.5 mL of biodiesel was taken in a conical flask. A 50 mL of solvent mixture (95% ethanol and diethyl ether in 1:1 ratio) was added to it and mixed thoroughly. This solvent–oil mixture was titrated with 0.1 M KOH using 1% phenolphthalein indicator. The formula for calculating acid number is as follows:

$$\text{Acid number of biodiesel (mg KOH/g)} = \frac{56.1 \times \text{Normality of the KOH solution} \times \text{Volume of KOH used}}{\text{Weight of the sample taken}}$$

● **Kinematic viscosity :**

The biodiesel was poured into the heat chamber of a Redwood viscometer and heated up to 400°C. The stopper of the viscometer was displaced to let the heated biodiesel drain out of it and be collected in a measuring cylinder placed underneath. As 50 mL of the biodiesel was collected in the measuring cylinder, the stopper was placed again to stop the flow of the biodiesel.

● **Relative density (D) :**

The pycnometer was kept inside a refrigerator after filling them up with algal biodiesel. They were taken out of the refrigerator when the temperature of the biodiesel reached 15°C. The mass and volume of the biodiesel were measured, and the density of the biodiesel was calculated. The formula for measuring the density is as follows:

$$D(\text{kg/m}^3) = \frac{\text{Mass of the pycnometer containing the biodiesel} - \text{Mass of the empty pycnometer}}{\text{Volume of the biodiesel}}$$

- **Flash and fire point:**

The biodiesel was kept inside the flash and fire point apparatus, and a cotton thread was placed in it. The biodiesel was heated with a gas stove. Another ignited cotton thread was dragged on the surface of the former thread. The temperature at which the spark came out of first thread was noted as the flash point of the biodiesel, and the temperature at which the thread started burning was noted as the fire point of the biodiesel.

- **Cloud and pour point:**

The cloud and pour point apparatus were filled up with it. The glass vessel of this apparatus, filled up with biodiesel, were placed in their slots of the apparatus. The temperature at which the paraffin in the biodiesel started solidifying and cloudiness appeared in the biodiesel was noted as the cloud point. The temperature at which the biodiesel becomes semi-solid was noted as the pour point of the algal biodiesel.

Results :

- Flash point of Spirogyra biodiesel and Oedogonium biodiesel comes 1550°C and 1480°C respectively.
- Fire point of Spirogyra biodiesel and Oedogonium biodiesel comes 1590°C and 1530°C respectively.

IV. CONCLUSION

In the attempt of biodiesel production, two algae species were selected i.e. Oedogonium and Spirogyra. Among two methods of extraction of algal oil, solvent extraction chloroform methanol method was found better than hexane ether method. The optimum conditions for biodiesel production were observed at temperature 650°C, reaction time 90 minutes and catalyst KOH through transesterification reaction for both algal species. From the experimental work and analysis, algal biodiesel can be a superlative option over other biodiesel and a good alternative to the conventional fuels both economically and environmentally. Depletion of crude petroleum may result in huge scarcity of this fuel future. The market price of petro-diesel is also increasing for the same reason. So, biodiesel from unused algae might be one solution to the problem as the raw material, for this fuel has no commercial value. All the properties of this biodiesel were found to be within the limits of ASTM standards.

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