The Use of Microalgae Biodiesel in Diesel Engine :

Production, Extraction and Engine Performance

Assoc. Professor Dr. T. F. Yusaf

Saddam H Al-lwayzy

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Outline

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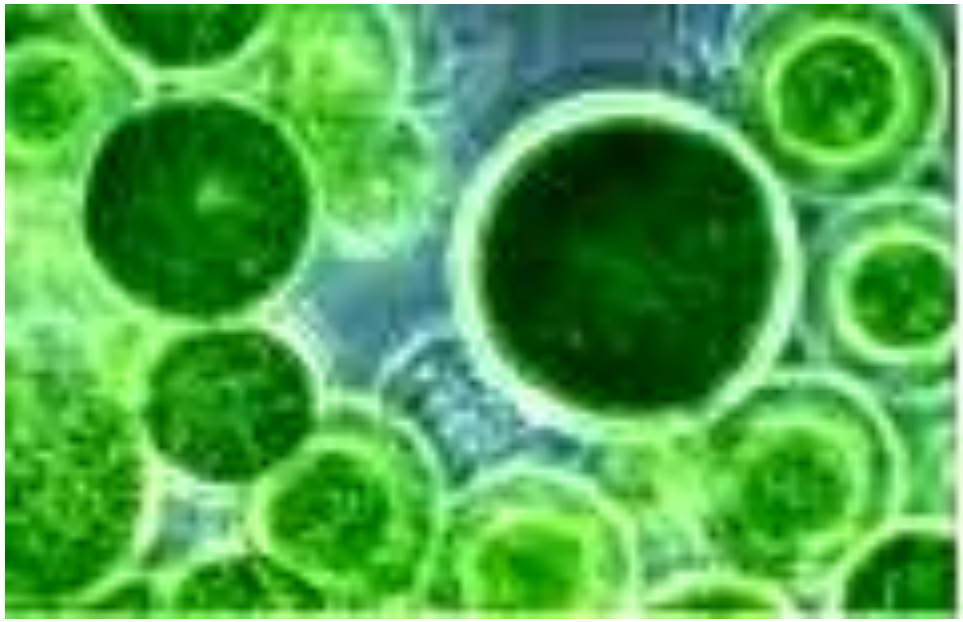
2. Literature review
3. The aim and objectives
4. Methodology
5. Ultrasound application in microalgae fuel production

Introduction

- Alternative fuel has recently become more attractive due to the fossil fuel; depleting, high cost and high emission.
- Microalgae biodiesel is renewable, produce less emissions, and its productivity is many times higher than crops biodiesel
- Many studies have been done on microalgae biodiesel production and its properties, however the performance and the emissions of this fuel in diesel engine has not been reported.

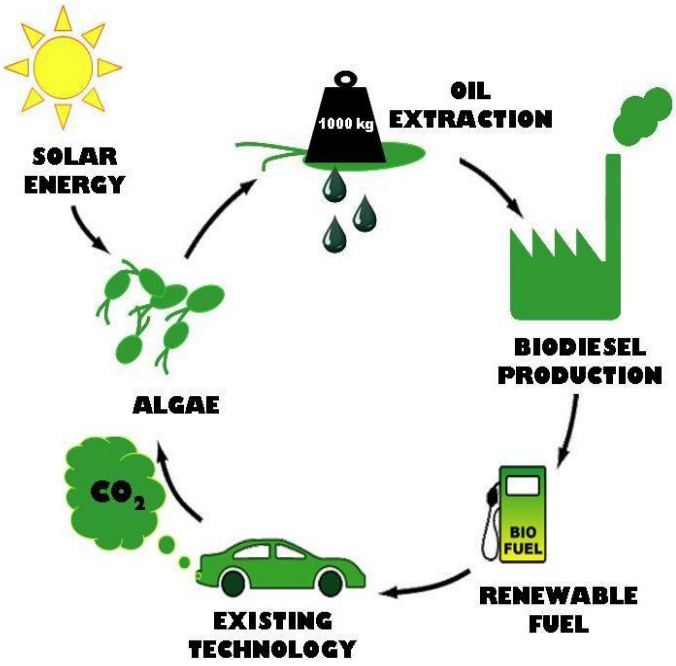
Literature Review (What is microalgae?)

Mata et al. (2010) defined microalgae as photosynthetic microorganisms that can grow rapidly and live in harsh conditions due to its unicellular or simple structure.



Literature Review (Why microalgae?)

1. It is renewable ,environmentally friendly and it can contribute in reducing the CO_2 level at the atmosphere because microalgae consume CO_2 and converts it to oil (Hossain et al., 2008).



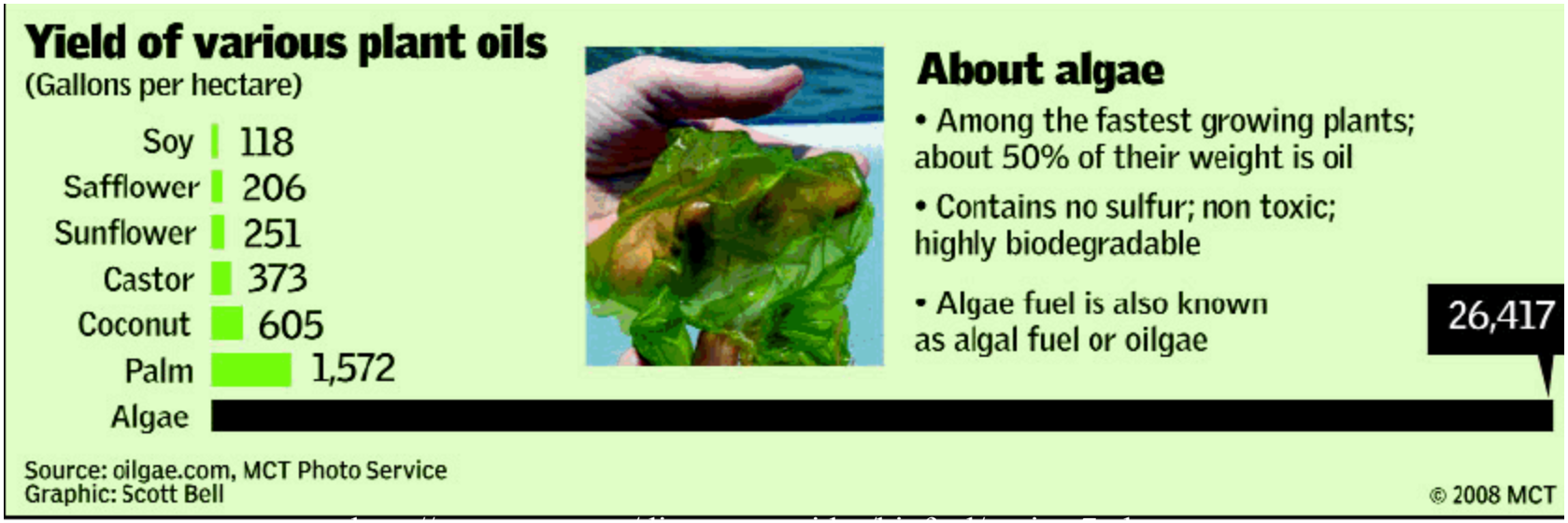
Literature Review (Why microalgae?)

2. Microalgae is non-edible and can grow in different conditions such as fresh water, marine water and/or grow in the lands which are not suitable for agriculture, therefore that will not affect the human food (Widjaja et al., 2009), (Mata et al., 2010).

Literature Review (Why microalgae?)

3. Microalgae biodiesel production per unit of area is many times higher than crops biodiesel. The productivity of diatom algae are about 46000 Kg of oil/hectare/year (Demirbas, 2007).

4. Some microalgae oil content about 80% of dry weight (Amin, 2009).



5. Microalgae biofuel is non-toxic, contains no sulphur and highly bio-degradable. After extracting oil the left material can be used as soil fertilizer or to produce ethanol (Demirbas & Fatih Demirbas, 2010)

Literature Review (Growing microalgae)

Microalgae can be grown in many different ways (Shen et al., 2009

- Growing microalgae
  - Small scale
  - Large scale
- That can be
  - Open system
  - Close system

Open system

Closed system

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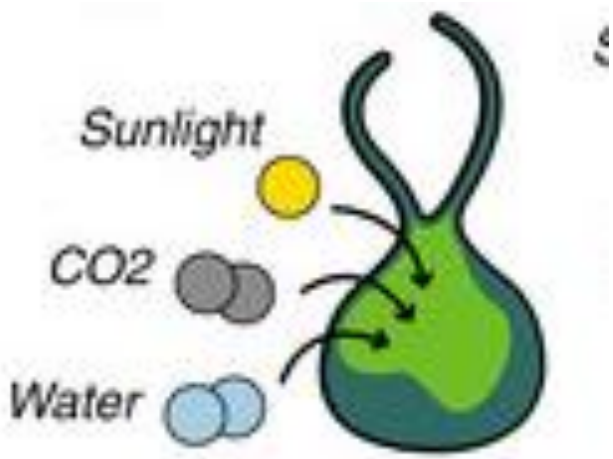
Literature Review (Growing microalgae)

- Growing microalgae require;
- Light, Water, CO2 and Nutrients



Literature Review

(Harvesting microalgae and oil extracting)

The extraction of microalgae oil from the biomass can be in physical or chemical methods. Oil press is used as physical extraction, while chemical extraction is used to make the extraction more effective (Anderson & Sorek, 2009).

Literature Review

(diesel engine performance and emissions fuelled by biodiesel)

Basha et al. (2009) conclude from the review of biodiesel that;

- The characteristics of biodiesel combustion are comparable to diesel.
- Biodiesel blends with diesel showed significant improvement in engine performance.
- Biodiesel blends produced higher NO_x emission as well as unburnt hydrocarbon UHC.

The Aim

The overall aim of USQ project is to

1. produce a new alternative, renewable and environmentally friendly fuel from microalgae
2. use this fuel in diesel engine specially for agricultural applications.
3. This work also aims to achieve comparable engine performance and reduce the exhaust gas emissions concentration with the aid of mathematical simulation.

Objectives

- The objectives of USQ project are to;

1. Grow fresh water microalgae *Chlorella vulgaris* to produce microalgae biodiesel and enhance the lipid content.
2. The physical and chemical properties of microalgae biodiesel from *Chlorella protothecoides* and *Chlorella vulgaris* will be analysed and compared with the ASTM standard and with diesel.
3. Evaluate the performance and the exhaust gas emissions components of a single cylinder diesel engine using microalgae biodiesel from *Chlorella protothecoides* in different blend ratios. The results will be compared with conventional diesel under different operating conditions with the aid of MATLAB simulation.
4. Evaluate tractor performance and emissions using the new fuel.

Methodology (growing microalgae)

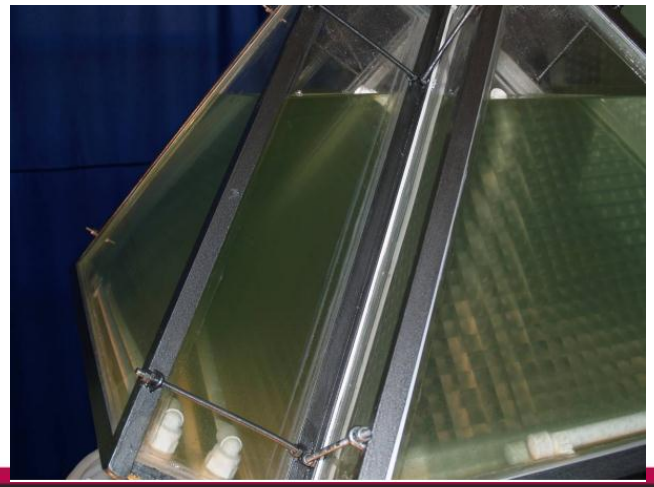
The growing of microalgae is divided into two scale.

- **1. Small scale:** The culture of (*Chlorella vulgaris*) was obtained from the Commonwealth Scientific and Industrial Research Organization (CSIRO), Australia.

In this stage microalgae was grown, harvested, oil extracted and converted to biodiesel, the physical properties were calculated from their Fatty Acid Methyl Ester.

Methodology (growing microalgae)

2. **Large scale**: USQ microalgae team are moving to a large scale production using 4000L Photobioreactor. The reactor was designed to produce about one L of microalgae oil per day.

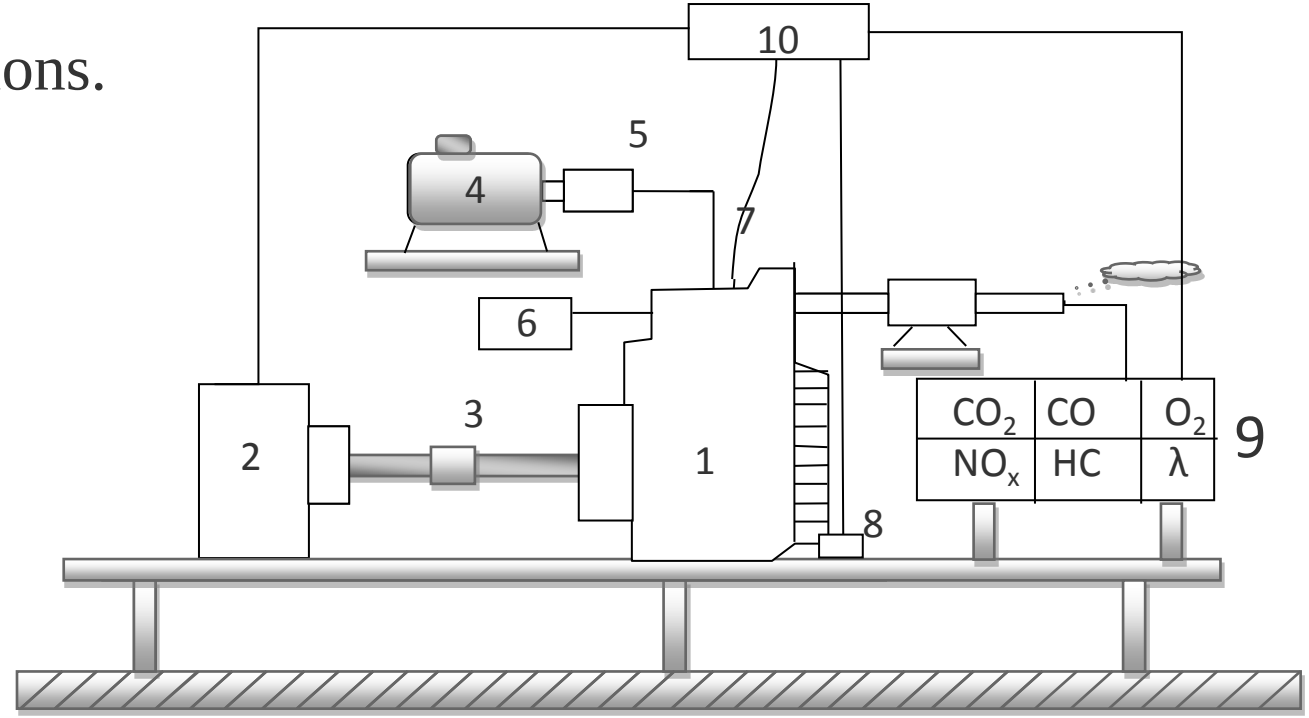


Methodology (MATLAB simulation)

- MATLAB routine is developing with
  - Modifying the routine to be used for diesel engine.
  - Modifying the routine to use different blend ratios of microalgae biodiesel and diesel.
  - The new engine configuration (engine data).

Methodology (engine test)

- A single-cylinder four-stroke air cooled direct injection diesel engine used in the test. To evaluate the engine performance and emissions.

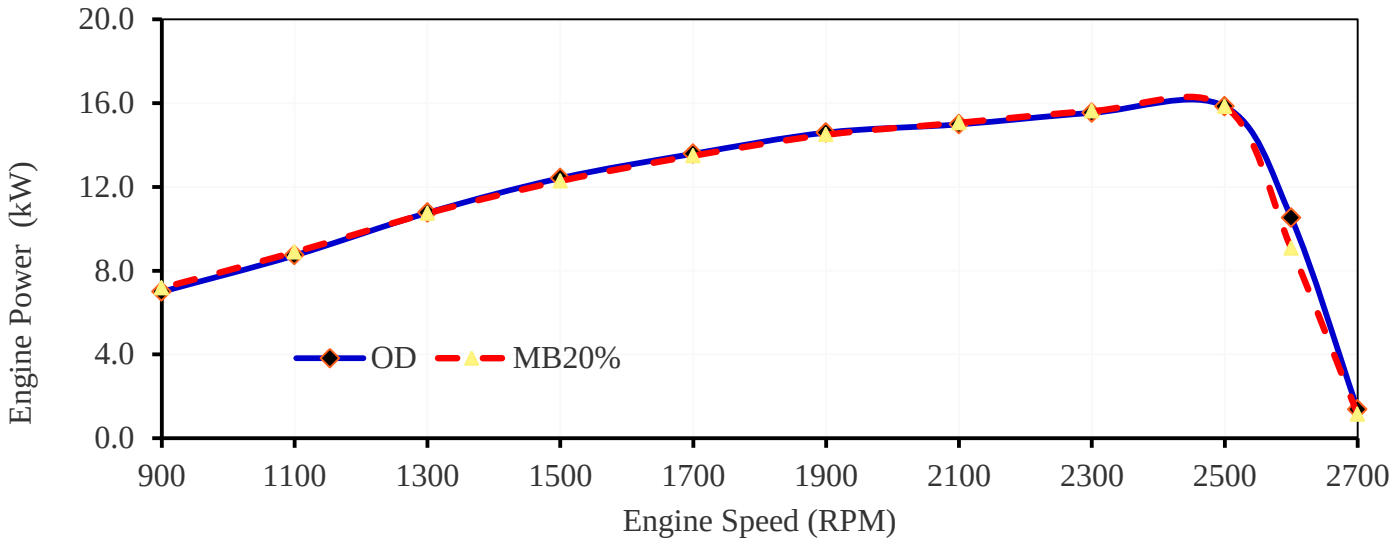


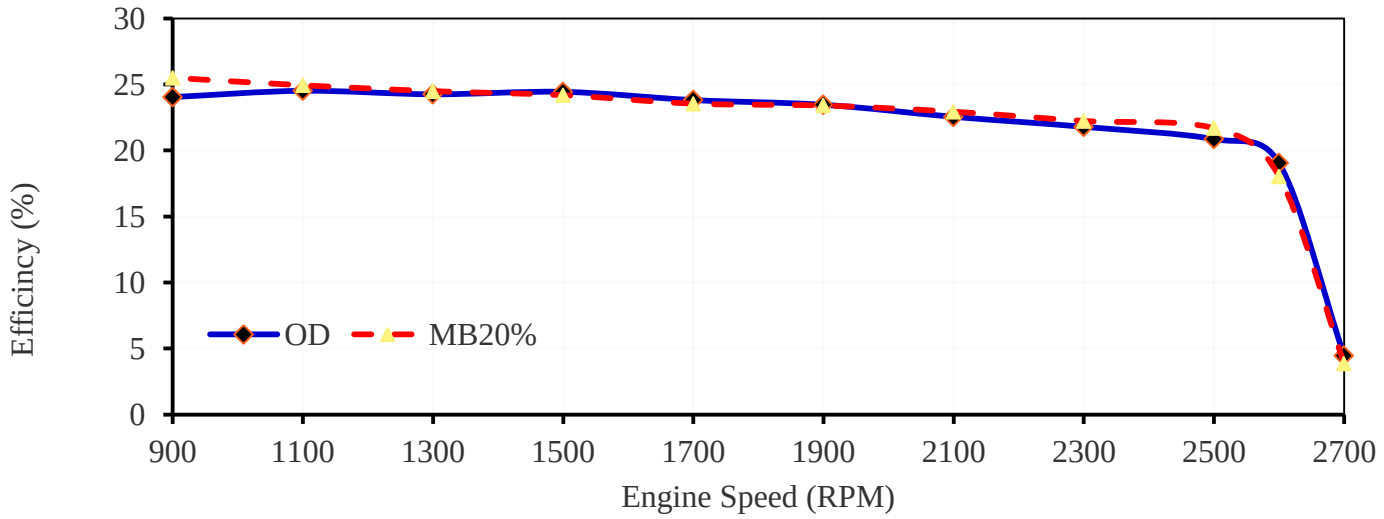
Schematic diagram of experimental setup consist of 1- Engine, 2- Dynamometer, 3-Drive shaft, 4-Fuel tank, 5-Fuel rate meter, 6- Inlet air flow meter, 7-Pressure sensor, 8- Crank angle encoder, 9- Gas analyser, 10- Data acquisition.

Methodology (tractor test)

- A PTO test has been conducted using John Deer tractor to evaluate the engine performance and emissions using microalgae biodiesel (MB-B20) in comparison with conventional diesel

Methodology (tractor test)





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Ultrasound application

For extracting oil from microalgae biomass, the ultrasound has been used to enhance the extraction efficiency. Cravotto et al. (2008) reported that Ultrasound reduce the extraction time of microalgae and enhance the oil yield.

Ultrasound application

The ultrasound was reported as a method to enhance converting oil to biodiesel , the bubble collapsed caused by using ultrasound enhance the mixing of the mixture of oil and methanol. The cavitation may cause a localized increase in temperature which enhance the transesterification reaction (Santos et al., 2009)

Ultrasound application

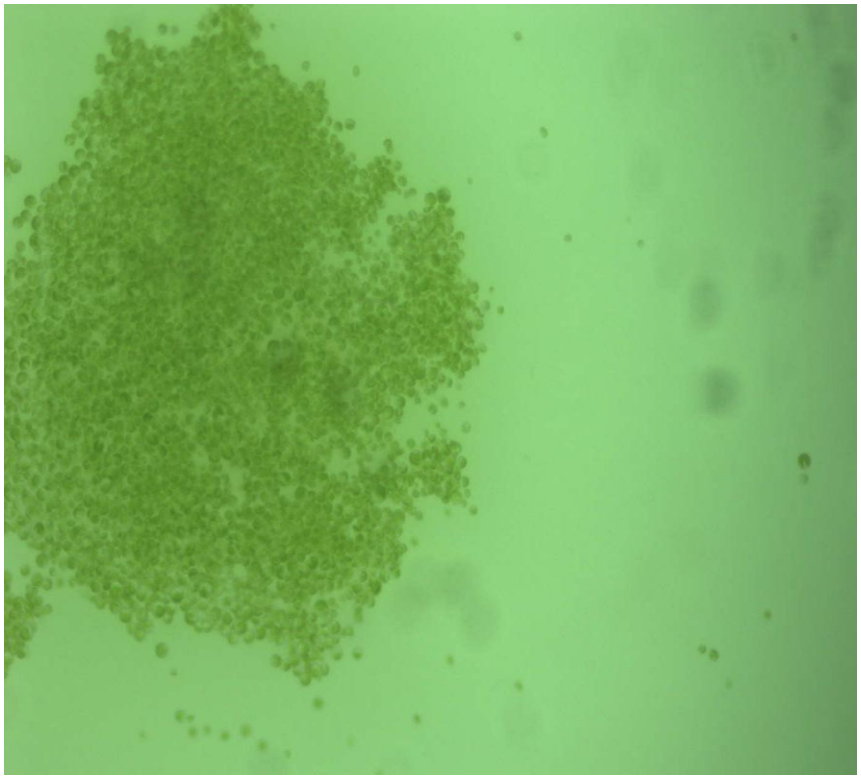
Xu et al., (2006) reported that the preparing micro-emulsion of water- diesel can be enhanced using Ultrasonic cavitation and mechanical effect

Ultrasound application

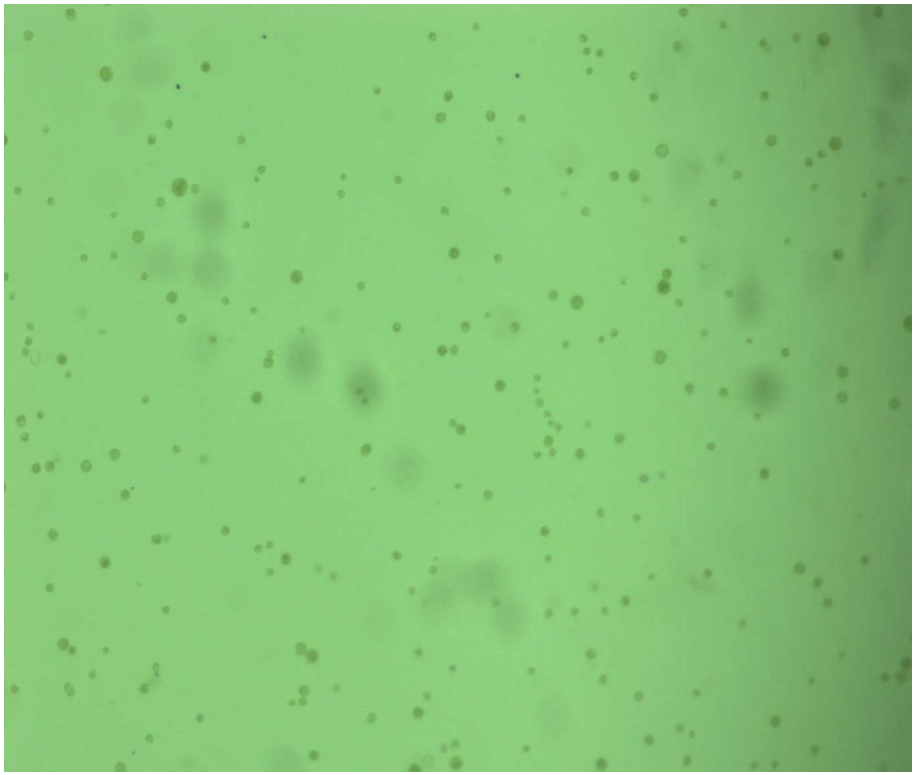
Ultrasound was found effectively break microalgae colonies to individual cells and increase the time of sedimentation.

Ultrasound application

Before Ultrasound



After Ultrasound



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Ultrasound application

That will help in making emulsion fuel diesel-water-microalgae term of:

1. Homogenising the emulsion,
2. Preventing injection problems (clogging, cracking,....),
3. Reducing the emulsion viscosity.

Reference

Santos, FFP, Rodrigues, S & Fernandes, FAN 2009, 'Optimization of the production of biodiesel from soybean oil by ultrasound assisted methanolysis', *Fuel Processing Technology*, vol. 90, no. 2, pp. 312-6.

Cravotto, G, Boffa, L, Mantegna, S, Perego, P, Avogadro, M & Cintas, P 2008, 'Improved extraction of vegetable oils under high-intensity ultrasound and/or microwaves', *Ultrasonics Sonochemistry*, vol. 15, no. 5, pp. 898-902.

Xu, N, She, J, Han, P & Lu, X 2006, 'Effect of ultrasound and emulsifier on preparation of diesel-water micro-emulsion', *Chemical Industry and Engineering Progress*, vol. 25, no. 11, p. 1349.
Mata, TM, Martins, AA & Caetano, NS 2010, 'Microalgae for biodiesel production and other applications: A review', *Renewable & Sustainable Energy Reviews*, vol. 14, no. 1, pp. 217-32.

Hossain, Salleh A, Nasrulhaq A, Chowdhury P & Naqiudden M 2008, 'Biodiesel fuel production from algae as renewable energy', *American Journal of Biochemistry and Biotechnology*, pp. 250-45.

Widjaja, A, Chien, C-C & Ju, Y-H 2009, 'Study of increasing lipid production from fresh water microalgae Chlorella vulgaris', *Journal of the Taiwan Institute of Chemical Engineers*, vol. 40, no. 1, pp. 13-20.

Basha, SA, Gopal, KR & Jebaraj, S 2009, 'A review on biodiesel production, combustion, emissions and performance', *Renewable and Sustainable Energy Reviews*, vol. 13, no. 6-7, pp. 1628-34.

Demirbas, A 2007, 'Importance of biodiesel as transportation fuel', *Energy Policy*, vol. 35, no. 9, pp. 4661-70.

Thank you

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