Optimizing Parameters of n-Hexane Solvent Extraction Method for Efficient Algal Oil Production

Dr. Rahul Krishnaji Bawane[1], Nilima Baliram Gadge[2], Dinesh Krishnaji Bawane[3], Aakash Shrianant Bhujbal[4], Varad Pramod Kale[5]

[1, 4, 5] Mechanical Engineering, Pimpri Chinchwad College of Engineering and Research, Pune - 412101, India.
[2] Mechanical Engineering, Nutan College of Engineering and Research, Pune - 410507, India.
[3] Automobile Engineering, Government Polytechnic, Nagpur - 440001, India.

Abstract: The rise of industrialization and excessive use of natural resources for energy, such as fossil fuels, the globe is experiencing an energy crisis and environmental problems this century. Fossil fuel combustion releases greenhouse gases into the atmosphere, exacerbating global warming. Worldwide research efforts are concentrated on fuels with lower emissions of NO_x and CO_2 that are renewable. These fuels are essential to the green economy and sustainability. The process of turning algae into biodiesel is a viable alternative fuel that is readily available, ecologically friendly, and technically sound. This study examined a variety of oil extraction process parameters from algal biomass. As a solvent, n-Hexane was used to extract oil from macroalgae. Investigations and analysis were done on the effects of the n-Hexane to oil ratio, algal biomass size, and contact duration on the extracted oil percentage yield. After a maximum of contact time, a larger solvent to algal biomass ratio, and a lower algal biomass size, the most oil could be recovered from algae.

Keywords: Biodiesel, Algal, Solvent Extraction, Alternate energy

1. INTRODUCTION

These days, the development of alternative renewable, biodegradable, and sustainable biofuels is being driven primarily by the effects of global warming, the depletion of fossil fuel supplies, and rising petroleum costs [1]. Algal-derived biofuels are thought to have the potential to displace traditional fossil fuels [2]. In many industrialized and emerging nations around the world, it is also the fuel substitute that is developing the quickest [3]. In addition, it reduces the amount of sulfur dioxide, unburned hydrocarbons, and particulate matter released during combustion [4]. The most potential substitute for the depletion and pollution produced by fossil fuels is the use of macroalgae in the manufacture of biodiesel. A number of algae-species have oil content more than 50%, which may be readily harvested and processed using present methods to provide transportation fuel [5]. With their quick growth rate, ability to be cultivated on non-arable land, ability to be grown in wastewater, ability to be collected every day, and non-seasonal production, microalgae provide several advantages over other feedstocks for biodiesel. Its trash used for various things, including feeding animals [6].

There are several ways to use algae to produce electricity. Transesterification is one of the most effective methods for turning algae oil into biodiesel. The capacity to effectively and efficiently extract oil from the biomass cells is one of the primary barriers to fully using lipid-producing microalgae. There are several techniques for obtaining the algal oil, such as chemical and mechanical extraction [7]. Chemicals and the solvent extraction technique are an effective way to extract algae oil [8]. The solvent extraction process is preferred over the mechanical pressing method because it extracts 100% of the oil, leaving the algal biomass with just 0.5–0.7% remaining [9].

Although hexane is a less costly and risky solvent than other solvents, it is the chemical of choice for solvent extraction [6]. However, benzene and di-ethyl ether are also useful. Spring water, brackish water, and ponds are rich sources of green algae. Several centimeters in length and with a diameter of around 0.1mm, it resembles cellular hair in structure. It also contains unbranched cylindrical fibers. For the purpose of producing biodiesel or bioethanol, algaegenerate proteins, carbohydrates, and lipids [10].

2. MATERIALS AND METHODS

The project aims to extract oil from macroalgae species taken from an open pond by chemical means, employing n-Hexane as a solvent. Researchers looked examined how the percentage yield of oil extracted was affected by the n-Hexane to oil ratio, the mesh size of the algal biomass, and the contact duration. This section discusses the compounds used in the investigation as well as the analytical process.

Hexane, methanol, and NaOH were analytical-grade compounds. Without doing any more purification, the compounds were utilized. The algae sample that was collected and to remove the water, the samples were left out in the sun light for two days. To get various mesh sizes of algal biomass, the dried samples were pulverized using a pestle and grinder, and the fine powder was then run through various micron sieves. In order to remove any remaining water, the ground algae were dried for 30 minutes at 80°C in an incubator. After that, the powdered algae were kept in several jars for the extraction within a closed container.

The obtained algae samples were dried to a 100% powder. To extract oil, hexane was combined with dried crushed algae in a 250 ml separator funnel. The mixture was then allowed to settle and allow the two levels in the funnel to separate for a whole day. The pre-weighted 50 ml beaker was filled with the organic phase that contained the algal oil. By filtering out the algae biomass, the algal oil was isolated, and an electronic weight balance was used to weigh it. Hexane was liberated from the extracted oil by evaporating it in a water bath. For the various solvent extraction method parameters, each extraction was carried out in triplicate.

$$Extracted\ oil\ efficiency = \frac{Mass\ of\ oil\ extracted}{Mass\ of\ dried\ algae}$$

3. RESULTS AND DISCUSSION

The solvent extraction technique was used to study various parameters of oil extraction from open pond algae. The goal of the study was to identify the parameter that increased oil output and enhanced extraction efficiency.

- **Varying the ratio of n-Hexane to Algae -**

Researchers have conducted experiments with varying solvent volumes and a constant quantity of dried algae. Finally, Table 1 presents the derived findings. The extracted oil efficiency was seen to increase with an increase in the amount of solvent.

Table 1. Oil Extraction Under Varying Mass of Solvent

Sample No.	Algae Biomass (gm)	n-Hexane (ml)	Algae to n-Hexane Ratio	Oil Extracted (gm)	Oil Yield (%)
1	100	100	1	2.65	2.65
2	100	135	1.35	3.05	3.05
3	100	165	1.65	5.25	5.25

The mass of the dried algae has been varied while maintaining a constant solvent volume in the experiments. The derived outcomes are then listed in Table 2. It was found that when the solvent to algae ratio increased, there is raised the oil yield.

Table 2. Oil Extraction Under Varying Mass of Algae Biomass

Sample No.	Algae Biomass (gm)	n-Hexane (ml)	Algae to n-Hexane Ratio	Oil Extracted (gm)	Oil Yield (%)
1	65	100	1.54	2.25	1.81
2	50	100	2.00	2.65	5.30
3	35	100	2.85	2.87	8.20

Figure 1. illustrates the impact of the solvent to algae ratio on the extracted oil yield percentage. The % yield of oil was found to rise in proportion to the n-Hexane to algae ratio. It may be inferred that a larger ratio of solvent to algae biomass would result in a better extraction efficiency because the higher yield at a solvent to algae ratio is explained by the additional solvent available to extract oil from the algal biomass [10, 11].

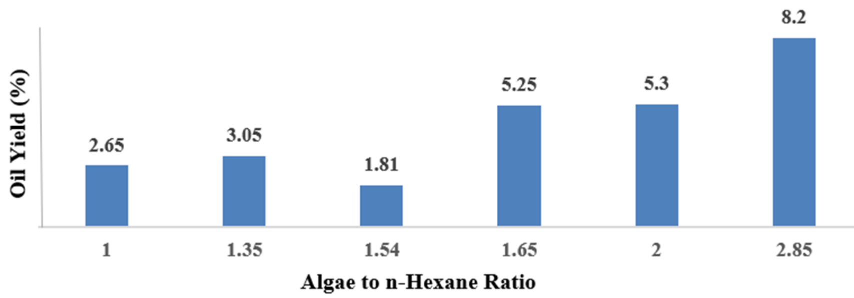

Figure 1. Oil Yield against variation of algae to n-Hexane ratio

While maintaining a consistent mass of algae and solvent volume, experiments have been carried out with varying sizes of algae. The ratio of algae to solvent (1:1.65) was maintained. Following that, Table 3 presents the derived outcomes.

Table 3. Oil Extraction Under Varying Size of Algae Biomass

Sample No.	Algae Biomass (gm)	n-Hexane (ml)	Algae Biomass Size (mm)	Oil Extracted (gm)	Oil Yield (%)
1	100	165	0.85	5.15	5.15
2	100	165	0.60	6.75	6.75
3	100	165	0.30	7.65	7.65

The oil extraction efficiency was found to rise from 5.15% to 7.65% when the biomass size was reduced from 0.85mm to 0.30mm. The increased surface area of interaction between the solvent and algal biomass result in improving oil extraction efficiency. Compared to larger algal biomass particles, smaller particles interact with the solvent more readily, increasing oil yield [10, 12].

The solvent to algal ratio and the size of the algae have remained consistent throughout the experiments, despite the variations in contact time. The derived outcomes are then summarized in Table 4.

Table 4. Oil Extraction Under Varying Contact Time of Solvent-Algae Biomass

Sample No.	Algae Biomass (gm)	n-Hexane (ml)	Reaction Time (hour)	Oil Extracted (gm)	Oil Yield (%)
1	100	165	10	3.45	3.45
2	100	165	15	4.73	4.73
3	100	165	25	5.35	5.35

There was a range of 10 to 25 hours of interaction time. The extracted oil efficiency was found to increase with contact duration. Maximum yield at maximum contact duration may result from improved solvent-algal biomass interaction, which promotes homogeneous mixing and increases the solvent's solubility in the oil [10, 13]. Thus, by extending the contact period, oil is collected from every part of the algae species.

4. CONCLUSION

In this work, oil was recovered using a solvent extraction method from algae by examined several solvent extraction procedure parameters. It was shown that the highest oil extraction from algal biomass was achieved with a 2.85:1 n-Hexane to algal biomass ratio, a maximum contact period 25 hours, and smaller algal biomass sizes of 0.30mm. The yield of extracted oil increases by 3.09 times when the ratio of solvent to algae biomass is increased from 1:1 to 2.85:1.

REFERENCES

[1] Abbaszaadeh A, Ghobadian B, Omidkhah MR, Najafi G. Current biodiesel production technologies: A comparative review. Energy Conversion and Management, 2012; 63: 138-148.

[2] Blinová L, Bartosová A, Gerulová K. Cultivation of microalgae (Chlorella vulgaris) for biodiesel production. Research Papers Faculty of Materials Science and Technology Slovak University of Technology, 2015; 23(36): 87-95.

[3] Ho SH, Huang SW, Chen CY, Hasunuma T, Kondo A, Chang JS. Bioethanol production using carbohydraterich microalgae biomass as feedstock. Bioresource Technology, 2013; 135: 191-198.

[4] Langholtz MH, Coleman AM, Eaton LM, Wigmosta MS, Hellwinckel CM, Brandt CC. Potential land competition between open-pond microalgae production and terrestrial dedicated feedstock supply systems in the US. Renewable Energy, 2016; 93: 201- 214.

[5] Mata TM, Martins AA, Caetano NS. Microalgae for biodiesel production and other applications: a review. Renewable and Sustainable Energy Reviews, 2010; 14(1): 217-232.

[6] Jeevan Kumar, Prashant & Garlapati, Vijay Kumar & Dash, Archana & Scholz, Peter & Banerjee, Rintu. (2017). Sustainable Green Solvents and Techniques for Lipid Extraction from Microalgae: A Review. Algal Research. 21. 138-147. 10.1016/j.algal.2016.11.014.

[7] Veillette M, Chamoumi M, Nikiema J, Faucheux N, Heitz M. Production of biodiesel from microalgae. Advances in Chemical Engineering, 2012; 10: 245-260.

[8] Kumar RP, Gnansounou E, Raman JK, Baskar G, editors. Refining biomass residues for sustainable energy and bioproducts: technology, advances, life cycle assessment, and economics. Academic Press; 2019.

[9] Kumar M, Khosla K, Thakur IS. Optimization of process parameters for the production of biodiesel from carbon dioxide sequestering bacterium. JEES, 2017; 3: 43-50.

[10] Xu H, Miao X, Wu Q. High quality biodiesel production from a microalga Chlorella protothecoides by heterotrophic growth in fermenters. Journal of Biotechnology, 2006; 126(4): 499-507.

[11] Topare, Niraj & Raut-Jadhav, Sunita & Renge, Vilas & Khedkar, Satish & Chauhan, Y. P. & Bhagat, Sanjay. (2011). Extraction of oil from algae by solvent extraction and oil expeller method. International Journal of Chemical Sciences (Impact Factor-0.063). 9. 1746-1750.

[12] Demirbas A. Production of biodiesel from algae oils. Energy Sources, Part A: Recovery, Utilization, and Environmental Effects, 2008; 31(2): 163-168.

[13] Silitonga AS, Masjuki HH, Mahlia TM, Ong HC, Chong WT, Boosroh MH. Overview properties of biodiesel diesel blends from edible and non-edible feedstock. Renewable and Sustainable Energy Reviews, 2013; 22: 346-360.