



Optimization of oil extraction process from blended sludge and algae for biodiesel production

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Article history

Received 06.07.2021
Accepted 04.08.2021
Available online 06.09.2021

Keywords

Extraction optimization
Factor parameters
Microalgae
Sewage sludge
Biodiesel
Response surface

Abstract

Sewage sludge is one of the most polluting wastes that affect the environment, which contains organic and inorganic pollutants released into the surroundings. Using non-renewable energy for the engine also releases large amounts of pollutants results from combustion products was other issues to the environment. The decline of non-renewable energy sources, such as natural gas, fossil fuel, and petroleum made the world increase the production of alternative fuels like waste-derived fuels. Recently, biodiesel production developed from edible oil to cover the depilation of non-renewable energy supply. But it has also become a significant challenge for food security. Therefore, finding other potential opportunities for lipid extraction is crucial. Algae and sludge conversion presented by recent studies seem to be a promising method. The paper presents the extraction and optimization of lipids from blended sludge and algae for biodiesel production. The procedure of the study was a characterization of algal and sludge wastes, the extraction of the lipid component by Soxhlet extraction, and the parameters optimization for maximum oil yield obtain. Temperature, extraction time, and solvents were the basic factor affect oil extraction yield. In the optimization 80 temperature, 6hrs time and hexane solvent results in 61% oil extraction yield which maximum point. Algae and wastewater sludge high potential of lipid and can be substitute edible oil supplies for biodiesel production.

DOI: 10.30657/pea.2021.27.27

JEL: L23, M11

1. Introduction

Sewage sludge is a residual material left over from urban wastewater treatment. Generally, urban sewage sludges originated from toilets, baths, showers, kitchens, sinks and, etc. The Sewage sludge is a complex heterogeneous mixture of micro-organisms, non-digested organics such as paper, plant residues, oils, and fecal materials, and moisture (Cieřlik et al., 2018). In many countries, the use of wastewater sludge for fertilizer and renewable energy sources is prevalent (Iglesias et al., 2018). Nowadays, sewage sludge becomes the source of energy generation in advanced technology. It is also helpful in solving several problems of energy supply limitation and the healthy advancement of the environment (Arain et al., 2018). Algae are micro-organisms that grow in the aquatic environment by using sunlight biomass as nutrients and carbon dioxide (CO₂) for respiration to develop their structural cell. Multicellular algae mostly grow & survive in every oxidation pond around warm and humid areas. Figure 1 shows the micro-algae survival areas of the oxidation ponds in Jimma University,

Jimma Technology Institute. Micro-algae most grows and survive at the end process of the maturation pond. Because of algae's age and unfavorable conditions, algae die at the end of the maturation pond (Li et al., 2018). The dead algae settle down and become sludge, which contains a high concentration of lipid (Tan et al., 2018). Oil content in micro-algae can exceed 70% dry weight of biomass (Milano et al., 2016).

Recently, the interest in sustainable energy production from renewable energy sources is continuously increasing. The composition of lipids in algal much depends on genetic and phenotypic factors, including environmental and cultural conditions (Sharma et al., 2018). Under unfavorable ecological or stress conditions, many micro-algae change their lipid biosynthetic pathways to form and accumulate neutral lipids (20 to 50 percent dry cell weight). They store neutral lipids in the form of Triacyl glyceride (TAG), which helps them to survive in this adverse condition (Shuba and Kifle, 2018).

The growth and developments of green algae on the surface of oxidation ponds shown in Fig. 1. The matured algae located at the maturation pond shown in Fig. 1(B) black green color.

While Fig. 1(A) yellow-green color shown developing algae in the facultative pond.

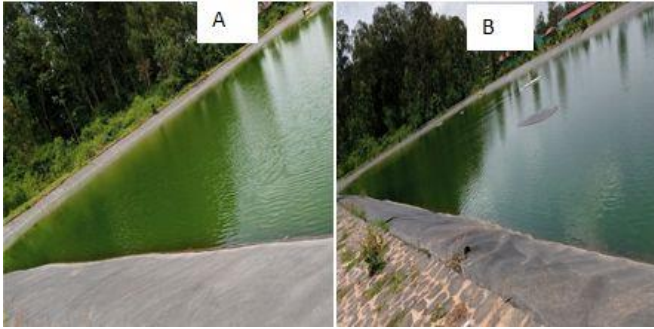


Fig. 1. Photograph of microalgae in oxidation pond area

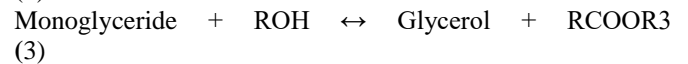
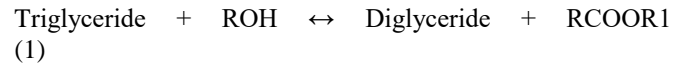
Vegetable oils - nowadays, over 95% of the world's production (Kirubakaran and Selvan, 2018). However, the competitive potential of biodiesel is limited by the high price of the common lipid feedstocks (Rulli et al., 2016), which constitutes between 70-85% of the overall biodiesel production cost, strongly influencing the final price of this biofuel. In addition, the excessive cultivation of edible oil seeds for biodiesel raises the concerns of food shortage, which competes with fuel production (Pachapur et al., 2020). Therefore a low-cost and non-edible feedstock is required to reduce the production cost and facilitate competitiveness with petroleum diesel.

Wastewater treatment, sludge disposal, and algae are the most available in large quantities and non-edible feedstock, which uses as raw materials for biodiesel production profitable (Rehan et al., 2018).

The waste sewage sludge recovery for lipid extraction is an advanced technology for sustainable energy generation when converting to biodiesel in a green environment. Lipids are defined by the property of low solubility in water and high solubility in non-polar solvents, such as hexane, chloroform, methanol, ethanol, and diethyl ether. Lipids are usually classified into two groups: compounds with polar heads and a long non-polar tail and fused-ring compounds. The first group contains triglycerides, fatty acids, and phospholipids, while the second group includes cholesterol as one of the essential fused-ring compounds (Wang et al., 2016).

The most important step needed for lipid extraction and biodiesel production is the Soxhlet extraction process. The Soxhlet extraction process is an essential technique used to extract organic material from a solid and may be used for biodiesel production. By refluxing the solvent, the solid is washed repeatedly, and extracted material drops and is collected in a flask. Transesterification is the process of converting one ester into another ester. It is a method in which oils/fats are chemically converted into their corresponding fatty ester. The exchanging of fatty ester conversion organic group R1 of an ester with the organic group R2 of alcohol in the presence of an acid or a base as a catalyst (Akoh, 2017). The mechanism that synthesis of esters by acid-catalyzed transesterification is similar to esterification, except for lack of water formation. Triglycerides are converted to diglyceride, followed by monoglyceride, and results in glycerol. For each step, a molecule of

a methyl ester of fatty acid produced in the chemical equation below (Vargas et al., 2018). Triglyceride reacts with alcohol to give ethyl ester of fatty acid and glycerol incomplete reaction. Triglycerides to Diglyceride to Monoglyceride to Glycerol (biodiesel) in the steps of transesterification reaction had shown in reactions 1, 2, 3 below.



Where R represents the carbonyl group and R1, R2 and R3 were represent alkyl groups in ethyl esters of fatty acid produced.

Energy has become a crucial factor for humanity. Nowadays, modern society consumes large amounts of energy to maintain a high standard of living and ensure economic growth and development. Currently, 87% of all the energy consumed in the world comes from fossil fuels (Lizunkov, 2018). Globally, fossil fuels are declining as the demand for energy increases. Therefore, it is essential to replace energy sources with renewable sources. The most important thing is not only to produce energy from renewable sources but to generate optimal yield is also another task. In this study, the edible oil used to produce biodiesel would be replaced by the oil extracted from the blended sludge with algae. The extraction of oil from blended sludge and algae has attracted the attention of researchers because the source of oil to produce biodiesel is blended sludge with algae, which is a waste product. It is interesting to use waste as an energy source. The use of edible oil as an energy source disrupts food security.

This research investigates the utilization of wastewater sludge blended with micro-algae as a source of lipid feedstock to produce biodiesel.

The main objective of this study is to optimize the process of lipid extraction from blended sludge and algae for biodiesel production, and the process optimization for extraction carried out by using RSM. The factor effects of lipid extraction optimization were temperature, time of extraction, and solvents of extraction. The specific tasks of this study are to classify and characterize the blend of sewage sludge waste and microalgae, extract the lipid components using the Soxhlet extraction process, parameter optimization, and data analysis process using RSM.

2. Materials and Methods

The authors performed the study, using both experimental and numerical data analysis methods. The main experimental steps used in this research are collecting and characterizing raw materials, extracting oil at different parameters, and repeating the test to obtain more accurate results. In numerical analysis, the RSM is used for the optimization process. The model deals with the process and a set of optimal parameters for oil extraction.

3. Experimental

3.1. Chemical and Equipment Requirements

Apparatus and chemicals are required during the experimental run: Hexane (purity >97%), Sulphuric acid (purity >99.999%), Methyl heptadecanoate (purity >99.0%), Sodium chloride, Sodium hydrogen carbonate.

Concerning apparatus: Soxhlet for extraction apparatus, pH meter, sludge collector, furnace, liquid chromatography, heating mantle - explosion-proof, with temperature control, boiling flask 125 ml or appropriate size, analytical balance - capable of weighing, vacuum pump, or another vacuum source, paper extraction thimble for Soxhlet apparatus, glass wool or small glass beads to fill a thimble. the dry blended sludge and algae in the same proportion were required as feedstocks.

3.2. Sampling and characterization procedure

The Samples and data collecting was taken from Jimma Technology Institute oxidation ponds (in maturation pond). Triple data of sludge sample was taken from the downstream of ends of maturation ponds and triple data of algae was also collected from the surface of facultative and maturation ponds.

The sample was collected by plastic bag and taken into Jimma technology institute experimental laboratory as shown in Fig. 2B.

10L sludge sample containing 90% of the moisture and, 10L algae sample containing 95% of the moisture, were collected from the oxidation ponds. After collections of samples, the sludge and algae samples were dried in the sun for the 3 days. The moisture content was reduced to about 20 percent for both sludge and algae. Fig. 2(A) shows the structure of the oxidation pond used for sampling, Fig. 2(B) shows a sample of data taken from the oxidation pond, Fig. 2(C) sludge drying in sun, and Fig. 2(D) microalgae drying in sun. The proximate analysis was used for characterizing a blended sample of sewage sludge and algae. Soxhlet apparatus was also used to extract lipid components, followed by analyzing the quality of the extracted lipid. The RSM was used for the modeling and optimization process of extraction.

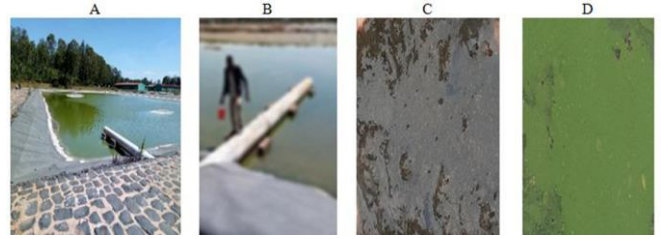


Fig. 2. The data sampling and dreing process in sun light.

Proximate analysis was carried out by determining total solid, fixed solid, volatile matter, moisture content, and ash content. The extraction of the lipid components from blended sewage sludge and algae using the Soxhlet extraction apparatus was the next process step.

3.3. Lipid Extraction Procedures

An equal proportion of dried sludge and algae measured in g were blended. The empty thimble and, an empty round bottom flask was weighed. Then add the dried blended sample (20g) into the thimble, it was weighed again, and the reading was recorded. Then, 200ml of hexane, ethanol, and methanol were added into a 250ml round bottom flask respectively. The heating process was maintained to allow 70, 75, and 80 for each round of the extraction. The extraction time 4, 5, and 6 hrs for each of the extraction terms. The solvent was removed from the flask by a rotary evaporator after the lipid had been extracted. Then, the lipids were stored in desiccators and weighed the next run. The yield of extracted material was determined by gravimetry and expressed in gram extractable lipids per gram dry sludge. The step was repeated by changing the extraction time, solvent and temperature.

Figure 3 clearly shows that the three sections of the overall lipid extraction and biodiesel production process. The first section is an extraction in which the lipid components were extracted using solvent extraction. The second section is the evaporation or separation in which the solvents were separated from solute lipid. The last section is the transesterification reaction in which glycerol (lipid) was converted into an ester.

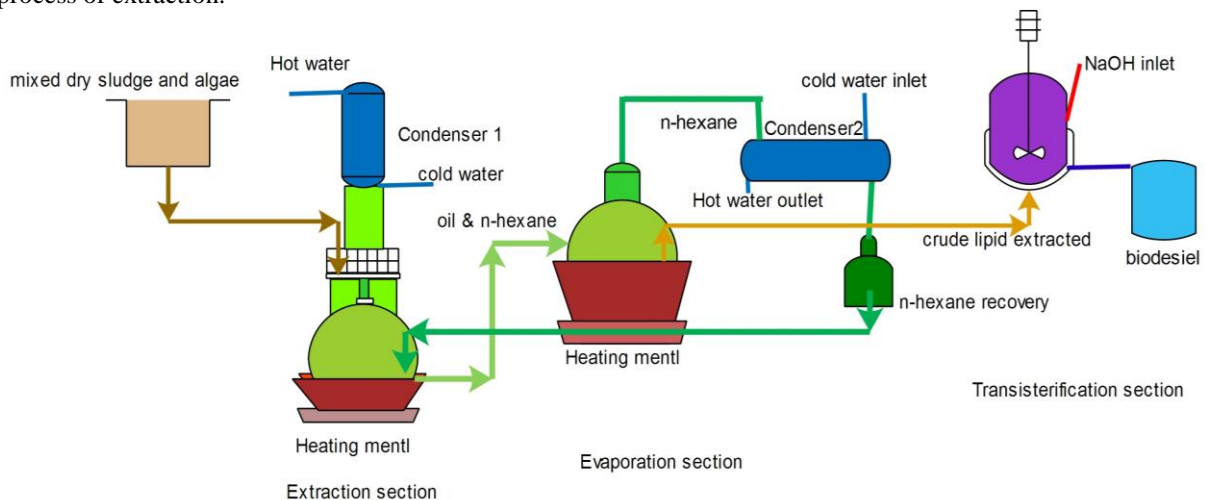


Fig. 3. The procedure of overall oil extraction and biodiesel production flow diagram

4. Results and discussion

This section presents the physical characterization of the raw material proximate analysis, the experimental and numerical analysis, and data optimization using RSM. In the experimental study, 27 tests were recorded and, the effects of parameters such as the temperature of extraction, solvents for extraction, and time of extraction on the oil yield are discussed. For the numerical analysis Response Surface Method (RSM) was used to obtain the optimal result. Extraction and biodiesel production process. The first section is an extraction in which the lipid components are extracted using solvent extraction. The second section is the evaporation or separation in which the solvents were separated from solute lipid. The last section is the transesterification reaction in which glycerol (lipid) was converted into an ester.

4.1. Physical Characterization of Raw Materials

Wastewater sludge and dry algae were characterized by proximate analysis and differentiated in moisture content, ash content, fixed carbon, and volatile matter.

The proximate analysis was performed according to the American Society for Testing and Materials (ASTM) standard method. The moisture content, volatile matter, and ash contents of the sample were determined according to ASTM D 3173 (Standard, 2011a), ASTM D 3175 (Standard, 2011b), and ASTM D 3174 (Duan et al., 2019) respectively. Fixed carbon was determined by subtracting the sum of the determined moisture content, volatile matter, and ash content from 100 (% mass) (Álvarez-Álvarez et al., 2018). Equations 1 to 4 presented below were used to determine these different contents.

Moisture content: moisture content was determined by using an oven dryer. First, the sample was weighted, and the second time after drying at 108°C for 1.5 hours. The percentage of dried moisture content is calculated according to Equation 1:

$$MC(\%) = \frac{m_i - m_f}{m_i} 100\% \quad (1)$$

where: *MC* is moisture content, *m_i* is the initial dried weight of the sample (in this case 20 grams), and *m_f* is the final dried weight of the sample.

Volatile Matter (VM):

According to ASTM D-3175 standard test methods, Volatiles matter is the percentage of volatiles, excluding water vapor, released by heating the sample under controlled conditions. The measured weight loss of the sample determines the amount of volatile matter released under the test conditions. During the test, a muffle furnace was used for determining the volatile matter. The first dried sample was weighted. The weighted sample was heated in the furnace for 7 minutes at 900 ± 10°C. Equation (2) is used to determine the percentage of volatile content.

$$VM(\%) = \frac{W_1 - W_2}{W_1} 100\% \quad (2)$$

Where: *VM* is volatile matter content in percent, *W₁* is the dry weight of the sample in (g) before heated, and *W₂* is the weight of the sample in (g) after heated in a muffle furnace for 7 minutes.

Ash content (A):

According to the standard test method ASTM D-3174, ash content is the residue that remains after the sample has been heated at the final temperature. In this study, the dry sample was weighted after the sample heated at 815 ± 10°C for 45 min. Equation (3) is used to determine the percentage of ash content for the sample after removing moisture content and volatile matter.

$$A(\%) = \frac{g_1 - g_2}{g_1} 100\% \quad (3)$$

where: *A* is ash content in percent, *g₁* initial dry weight in (g) before heating, and *g₂* is the weight in (g) of the sample removed during the heating process at 815 ± 10°C.

Fixed carbon (FC):

Fixed carbon is the material that remains after the determination of moisture content, volatile matter, and ash content. It is the difference between the summation of these three values and 100. Equation (4) shows how fixed carbon is determined from the original weight samples.

$$FC(\%) = 100 - (\%MC + \%VM + \%A) \quad (4)$$

The results obtained from Equations (1-4) are presented in Table 1. According to the proximal analysis, the volatile matter in the sludge is lower than in dry algae, as shown in Figure 4, which means that the lipid content of dry algae is higher, which is the source lipids. Volatile matter is the highest component of sludge and algae. The component of a highly volatile matter in the sample indicates high oil content. Ash content was the highest component in addition to a volatile, as shown in Table 1.

Table 1. Summary of raw material characterization

Measurement	Sludge	Algae
MC (w/w %)	10	11
VM (w/w %)	47	56
A (w/w %)	37	30
FC (w/w %)	6	3

Fig. 4 shows the characterization of algae and sludge. The volatile matter of algae was greater than the volatile matter of sludge and shows that the higher oil content indicates in algae than that of in sludge. For the containing the higher ash and fixed carbon content results lower oil contents.

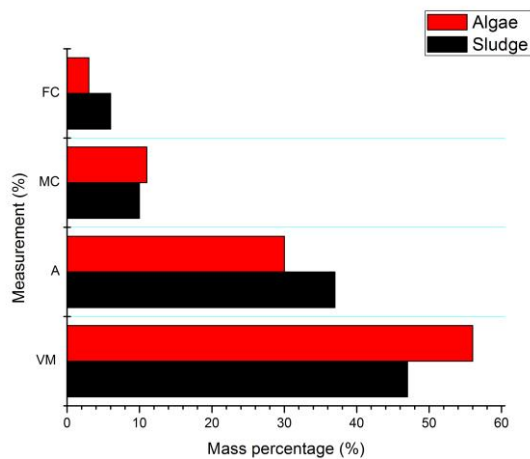


Fig. 4. Characterization of sludge and algae by proximate analysis

4.2. The Oil Extraction Results

The lipid content was calculated as the total crude lipid yield for each experimental set. The extracted sample was described in mass percentage based on Equation (5). The equation is mathematically formulated for oil yield through an application of the Soxhlet process unit.

$$\text{Oil Extraction yield (\%)} = \frac{w_2 - w_1}{M_2 - M_1} * 100 \quad (5)$$

Where M_1 represents the mass in (g) of the thimble, M_2 is the total mass in (g) of thimble and sample in (g), W_1 is the mass in (g) of the round bottom flask, and W_2 is the total mass of the round bottom and lipid after extraction in (g). In Table 2, there are presented results of the oil extraction with process parameters of time, solvents, and temperature this helps to determine the solution output of the yields of the highest oil during the different experimental run. Figure 5 indicates the lipid extraction result obtained by the Soxhlet extraction process.



Fig. 5. Experimental Soxhlet oil extraction at laboratory

The test result shows that different parameters change the product (oil yield). The test at the 15th run gave the maximum oil yield among all tests run. Hence, the 15th test was performed at the temperature of 80°C, the retention time of 6hrs, and with hexane solvent. The oil yield obtained at this was 61%, which was the maximum value, among other test results.

In this study, 61% of the oil was obtained from the blended sample of sludge and algae. Recent research shows that the maximum oil extraction from green microalgae is 18.3 percent oil yields at a temperature of 61.31°C and an extraction time of 2.54 hours (Yusuff, 2019). When compared with this study, the oil yield obtained in this study was tripled than that of previous research studied. This significant difference was due to the temperature and time factors.

The temperature vs. oil yield, time vs. oil yield, and solvents vs. oil yield were shown in Figures 6. From the results, it is clearly shown that the oil yield increases up to a certain amount as the temperature from 70 to 80, time increases from 4 to 6 hrs, and solvents changes from methanol to ethanol than to hexane

4.3. Fitting Model Development from Experimental Result, Using RSM

In this section, a numerical study was performed by the Design-Expert software. A mathematical equation has also been developed to determine the optimal yield. The yield calculated in Table 2 has resulted from the experimental equation 5, the numerical study and data analysis using RSM reduce the costs and time required for experimental investigation. It also provides information about the effect of the factors and gives the optimal result.

There were no more oil extraction yield changes with temperature changes from 70 to 80, which shows that the temperature changes no significant effects on oil extraction yield ranges 60 to 61% in the given interval of temperature at extraction time of 6hrs and with hexane solvent Fig.6(A). The time factor was a moderately significant factor that affects the oil extraction yields that increases from 54 to 61% in the time range from 4 to 6hrs at 80°C with hexane solvent has shown Fig. 6(B).

In this experiment, the solvent factor was the major significant factor that affects oil extraction yield. Methanol ethanol and hexane solvent were analyzed and hexane was the highest efficiency for extraction that may result from high polar solvents compared to methanol and ethanol. At 80°C temperature and 6 hrs extraction time; methanol can yield 43%, ethanol can yield 47% while hexane can yield 61% of oil extraction shown in Fig. 6(C).

In the Fig. 6(A) shows the yield changes with temperature changes and there were no significant changes of yields with the temperature changes from 70 to 80. This shows that there were no discrepancies in the boiling points among the solvents of methanol, ethanol, and hexane.

Table 1. Design Summary of product recovery in each experimental run

Run	Factor 1 A: temp (°C)	Factor 2 B: time (Hour)	Factor 3 C: solvents	W1(g)	W2(g)	M1(g)	M2(g)	Yields of oil extraction
1	80	5	Ethanol	200	220	60	60.45	44
2	80	5	Hexane	200	210	60	60.17	57
3	75	4	Ethanol	200	215	60	60.39	38
4	70	6	Ethanol	200	225	60	60.47	53
5	70	5	Methanol	200	230	60	60.77	39
6	80	4	Methanol	200	222	60	60.6	36
7	80	4	Ethanol	200	221	60	60.55	38
8	75	6	Methanol	200	218	60	60.44	41
9	70	6	Methanol	200	219	60	60.46	41
10	75	6	Ethanol	200	216	60	60.35	46
11	70	4	Ethanol	200	217	60	60.45	38
12	75	5	Methanol	200	220	60	60.51	39
13	70	4	Methanol	200	223	60	60.66	35
14	70	4	Hexane	200	225	60	60.45	55
15	80	6	Hexane	200	224	60	60.39	61
16	75	4	Hexane	200	226	60	60.47	55
17	80	6	Methanol	200	226	60	60.60	43
18	75	6	Hexane	200	221	60	60.35	60
19	75	5	Hexane	200	222	60	60.38	58
20	70	5	Ethanol	200	219	60	60.45	42
21	80	5	Methanol	200	220	60	60.50	40
22	80	4	Hexane	200	218	60	60.35	52
23	75	4	Methanol	200	220	60	60.57	35
24	70	5	Hexane	200	216	60	60.28	57
25	70	6	Hexane	200	219	60	60.32	60
26	75	5	Ethanol	200	218	60	60.43	42
27	80	6	Ethanol	200	217	60	60.37	46

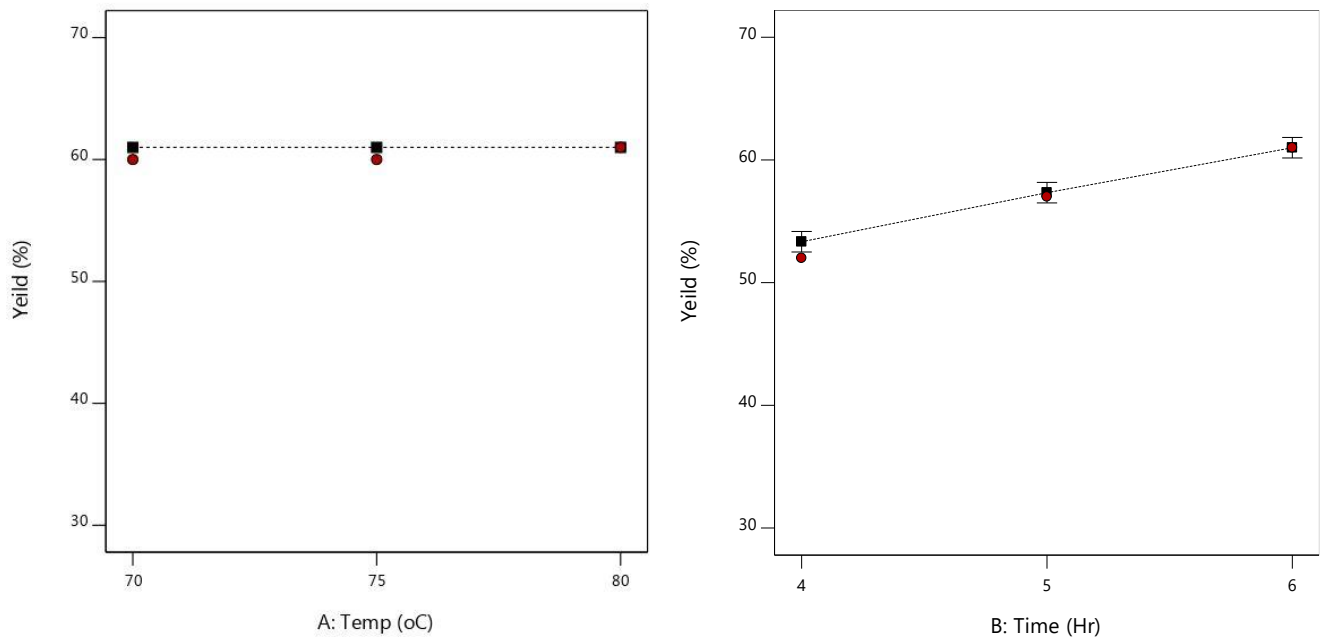


Fig. 6A, 6B. Individual factors with given interval of measure parameters (A, B are temperature (°C), time (hrs) and solvent respectively)

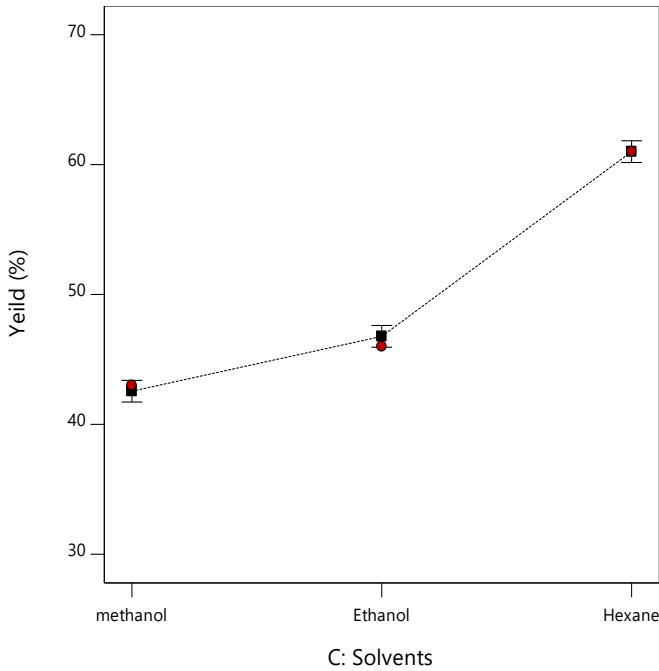


Fig. 6C. Individual factors with given interval of measure parameters (C are temperature (°C), time (hrs) and solvent respectively)

The model summary of RSM was shown in Table 3.

As the extraction time increases from 4 to 6hrs the extraction yields increase from 55 to 61% at 80 temperature constant and there were no changes of extraction yields after 6hrs. Fig. 6(B). By setting constants temperature at 80 and the time at 6hrs maximum extraction yield was obtained by hexane solvent Fig. 6(C).

Table 2. Summary of statical model optimization results

Factors	Units	Values								
Time	hrs	4	4	4	5	5	5	6	6	6
Solvent		C1	C2	C3	C1	C2	C3	C1	C2	C3
Yields	%	35	39	53	39	43	57	43	47	61

Where A, B, and C are temperature, time, and solvents respectively. The optimization model summary generated by the changing variables using RSM shown in Table 3 and also the significant factors were time and solvents within the ranges of temperature.

From the summary of statical model optimization, yield was depends on variables of time and solvents rather than temperature, C1, C2 and C3 represents methanol, ethanol and hexane respectively. Tabale 3. While the temperature changes results no significant changes in yields in the giventemperature ranges.

Fit Statistics

Std. Dev. = 1.71 (R² = 0.9679)

Mean = 46.33 Adjusted R² = 0.9621

C.V. % = 3.69 Predicted R² = 0.9517

Adeq Precision = 35.452

The Predicted R² of 0.9517 is in reasonable agreement with the Adjusted R² of 0.9621; i.e. the difference is less than 0.2.

The static data analysis was almost accurate according to model simulation optimization and the data point approached the exact line shown in Fig. 7.

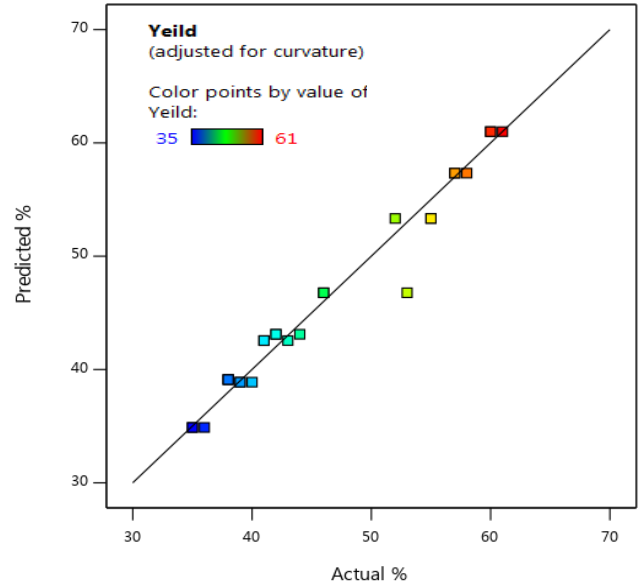


Fig. 7. Statically data precise and validation of oil yields in percent

The data points were approximate nearest to or on the striate line that the model shows almost accurate and the color changes from dark blue to dark red on data points shows from minimum to maximum oil yield model design Fig. 7. Variable Interactions

The variable interaction shows that the interaction of one variable on the other may affect the output yields. The time and temperature factors interaction on the extraction results in little or no significant effects on the yields shown in Fig. 8(A) the graph lines Horizontal Streets, the meaning was no yield change with temperature change in the different extraction time. The lines B1, B2, and B3 represent extraction time 4, 5, and 6hrs respectively. The time and solvent interaction were shows the positive response on the extraction yield. At the extraction, time increases from 4 to 6 hrs, and solvent changes from methanol to hexane the extraction yield increases. Fig. 8(B). The lines C1, C2, and C3 represent methanol, ethanol, and hexane solvents respectively.

Graphically the optimization allocated in Fig. 9 indicates by red dots on the line factor parameter and blue color dot for maximum yield of extraction. For the temperature taken three intervals 1, 2 and 3 represent 70, 75, and 80°C respectively, for the time factor 1, 2 and 3 represent 4,5 and 6 hrs respectively, And for the solvent factor 1, 2 and 3 represents methanol, ethanol, and hexane respectively shown Fig. 9.

The desirability shows that the accuracy of model states and out of 24 counts that three variable with two replicates the solution shown 1 solution.

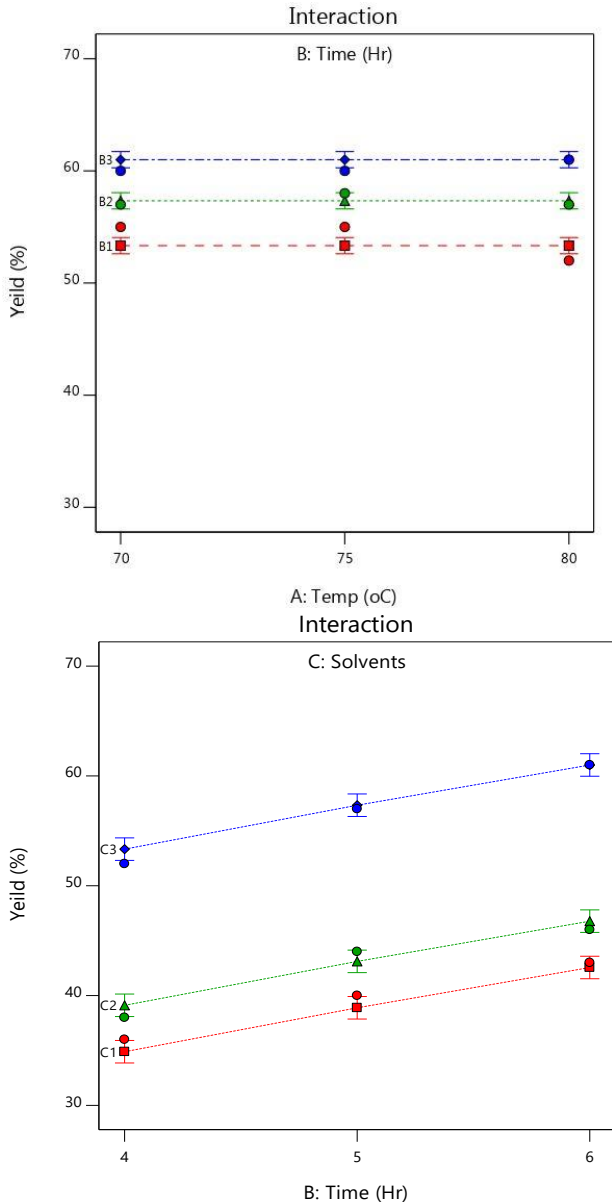


Fig. 8. variable interactions effects on the extraction yields

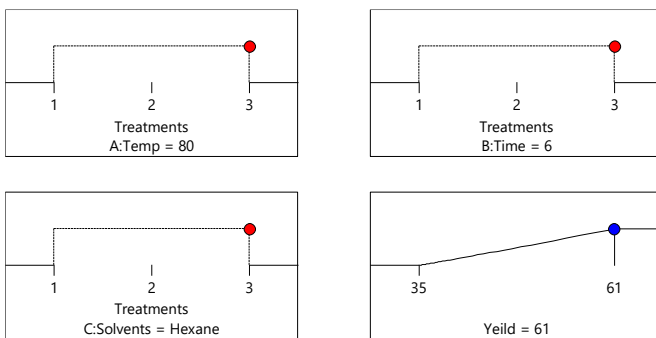


Fig. 9. Variable optimization for product maximization

The analysis of the replacement for the nonrenewable energy and edible oil that is used for biodiesel needs further investigation after transesterification reactions than convert the extracted oil to biodiesel or ester.

5. Conclusions

This paper presents the optimization of the lipid oil extraction process from the blended sludge and algae. This lipid oil, which is extracted from sludge and algae, is used for biodiesel production. In developed countries, edible oil is used for both biodiesel production and food supply. This co-function of oil affects food security and increases the cost of raw materials, resulting in a loss of product profitability. In developing countries, there are fewer opportunities to use edible oil to produce biodiesel due to their economy. But there has also been an increase in the number of consumers of a fuel engine with an unbalanced economy. Therefore, lipid-rich wastes such as algae and sludge are the solution to such a problem by extracting oil compositions (lipids) for biodiesel production. In this study, lipid (non-edible oil) was extracted from the blended sludge and algae for this purpose. This is the best alternative for sustainable energy production and solves the problem of energy demands.

Optimization of lipid oil extractions is influenced by significant parameters such as temperature and extraction time. In the laboratory experiments, the tests were run 27 times by changing the time and temperature. About 61% of oil yield was extracted from blended sludge and algae at a temperature of 80°C, using hexane solvent and an extraction time of 6 hours. It is the optimal result obtained from this study.

Some researchers investigated biodiesel production. However, the oil yield obtained from their study is very low. If the oil is produced at different temperatures, different solvents and at different times, the oil yield is lower than this optimal point. In this study, the process parameters optimization like time, temperature and solvents were performed to get the optimal oil yield. Depending on the numerical and experimental results, the mathematical model was also proposed for the extraction of the lipid. This model is very helpful in minimizing the cost and time wastes on the experiment. Therefore, this study has a lot of advantages in sustainability, if it is taken at an industrial scale. The calorific value of sludge from PSTP was found to be 2.1 MJ/kg. This is too low for it to be considered for power generation through combustion since other low-quality fuels like lignite coal (14.7-19.3 MJ/kg, ASTM D388-99) and sugar bagasse (18.61MJ/kg, have comparatively higher energy values compared to this. The HHV value however does fall in the accepted range of HHV for Wet Sewage Sludge, 1000-3000 KJ/kg.

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从混合污泥和藻类中优化用于生物柴油生产的油提取工艺

關鍵詞

提取优化
因子参数
微藻
污水污泥
生物柴油
响应面

摘要

污水污泥是影响环境的污染最严重的废物之一，其中含有释放到周围环境中的有机和无机污染物。将不可再生能源用于发动机也会释放大量来自燃烧产物的污染物，这对环境来说是另一个问题。不可再生能源（如天然气、化石燃料和石油）的减少使世界增加了替代燃料（如废物衍生燃料）的产量。近来，生物柴油生产从食用油发展到覆盖不可再生能源供应的脱毛。但这也成为粮食安全的重大挑战。因此，寻找其他潜在的脂质提取机会至关重要。最近的研究提出的藻类和污泥转化似乎是一种很有前途的方法。本文介绍了从混合污泥和藻类中提取和优化用于生物柴油生产的脂质。该研究的过程是对藻类和污泥废物进行表征，通过索氏提取法提取脂质成分，以及获得最大油产量的参数优化。温度、提取时间和溶剂是影响油脂提取率的基本因素。在优化的 80 度温度、6 小时时间和己烷溶剂中，最高点为 61% 的油提取率。藻类和废水污泥含有高潜力的脂质，可替代食用油供应用于生物柴油生产。
