

Evaluating the Physicochemical Properties and Characterization of *Argemone Mexicana* Biodiesel Blends with Diesel Fuel.

*Pappu Kumar¹, Om Prakash¹

¹Department of Mechanical Engineering, NIT Patna, India

*Corresponding Author: pkumar88417@gmail.com

Received 2 May 2024; Revised 15 June 2024; Accepted 3 October 2024

Abstract : With high energy demand and the adverse effects of fossil fuel pollution, countries are considering alternate energy sources for a healthy life. To meet this requirement, researchers are considering another alternative fuel, such as biofuel. The driving force behind adopting biofuel is a reduced risk of pollution and a lesser impact on global warming. Biofuel is one of the most important alternative fuels that can replace fossil fuels. This research investigated the potential use of non-edible blends of *Argemone Mexicana* seeds in diesel to extract biodiesel suitable for engines. In this work, seeds were collected from crops harvested from the selected land area. The crude oil has been extracted from the conventional oil expeller, and the yield was 31% (by wt%). A two-step transesterification process was used to extract biodiesel using different combinations of molar ratio and catalyst combination. The maximum yield observed was 88% at a molar ratio of 8:1 at a temperature of 70°C and 0.4% catalyst concentration. The different *Argemone Mexicana* methyl ester blends were prepared by homogenizer. Later, the chemical and thermophysical properties were evaluated with an ASTM standard for different biodiesel blends at 15°C, 30°C and 45°C, respectively. The analysis of the work revealed that the *Argemone Mexicana* methyl ester proved to be a potential alternative fuel.

Keywords: Biodiesel, *Argemone Mexicana* seed, Production, Cost-effectiveness

1. Introduction

The desire for sustainable development and a pollution-free environment has intensified the global demand for renewable fuels [1]. The rising need for clean, sustainable alternative energy sources that generate non-fossil fuels to meet emissions targets is driving the growth of renewable fuels. Under ideal operating conditions, all alternative liquid biofuels can reduce and regulate CO, NO_x, and soot emissions [2]. First-generation technology has been the first significant transition stage away from traditional fossil fuels. Subsequently, the focus has shifted to the next generation of biofuels produced from non-food biomass, such as forestry and crop residues and sawdust, crops grown specifically for energy production (such as jatropha, rapeseed, and miscanthus), the lignocellulosic fraction of municipal and industrial solid waste, and biomass derived from algae [3]. The rising trend in coal and crude oil imports emphasizes the need for alternate energy sources. Biodiesel is a promising solution due to its renewable nature and environmental benefits. It is biodegradable, non-toxic, and offers high lubricity, reducing engine wear [4]. Biodiesel also significantly lowers carbon monoxide emissions, particulate matter, and unburned hydrocarbons, making it a greener alternative to traditional diesel. It can be produced from edible and non-edible feedstocks, especially non-edible oils like Jatropha, which can grow in arid lands. Biodiesel can reduce dependency on fossil fuel imports, lower fuel prices, and create environmental job opportunities. As a result, biodiesel is increasingly being considered a viable part-replacement for petroleum diesel, contributing to reduced exhaust pollutants and promoting sustainable energy practices [5]. In recent times, biodiesel has been a promising factor for use as engine fuel. Therefore, many researchers have started working on the potential use as an engine fuel. As a result, the research on the viable use of biofuel has increased for the

10.48047/jocaaa.2024.33.07.58

potential replacement of fossil fuels. Chozhavendhan et al. highlighted the potential of biodiesel as a renewable, biodegradable, and non-toxic fuel. It discussed various production parameters, feedstocks, and catalysts, emphasizing the need for cost-effective and efficient processes to commercialize biodiesel as a sustainable alternative to fossil fuels [6]. Sun et al. 2020 revealed the effect of exhaust gas recirculation on biodiesel blend ignition and combustion properties and investigated their emission and performance characteristics [7]. Saravanan et al. investigated the thermal performance and emission characteristics of the biodiesel blends of Rapeseed and Mahua. The results show the similar characteristics of diesel and its viable use in engine fuel [8]. Yaşar and Fevzi discussed the different generations of feedstock for their biodiesel properties. The author showed that algae-oil-based biodiesel has a higher ester content cetane number and excellent cold flow properties [9]. Yesilyurt et al. explored the thermal performance and emission characteristics of the quaternary vegetable oil blends, safflower-biodiesel, alcohol, and diesel fuel. The authors suggested these biofuels have viable alternatives to pure biodiesel or vegetable oil [10]. Singh et al. investigated the effect of n-butanol on the eucalyptus biodiesel blends and its transesterification and characterisation of the fuel properties [11]. Hoseini et al. explored Portulaca seed oil as a novel feedstock type biodiesel and its transesterification optimisation and investigated the thermophysical properties within ASTM compliance [12]. Chhabra et al. reviewed the extraction technique of non-edible neem containing 30-40% oil content. The author showed that its vast spread all over India and its long-life cycle proved to be the potential option for biodiesel at a very low price [13]. Gupta et al. examined the potential use of the non-edible plant Mahua (*Madhuca Indica*) as a biofuel production and the diverse application of its seed cake and biogas. The detoxification method also improves the usability of seed cake for animal feed and mushroom cultivation [14]. Lu et al. investigated the production of non-edible oil of *Jatropha Curcas L.* Oil and its suitability for the engine oil. Because higher free fatty acids contain pre-esterification using sulphuric acid as a catalyst, followed by transesterification with methanol and KOH. The yield of biodiesel was found to be 98% [15]. Singh et al. investigated the *Argemone Mexicana*-type biodiesel thermal performance and emission characteristics in the multi-cylinder CI engine. The author showed an improvement in the brake thermal efficiency reduction in HC and CO emissions and improvement in NO_x emission [16]. With the rising population in the world and the scarcity of food and fertile land, the production of biodiesel from edible oil has become a big problem. So, a need of focus should be on producing biodiesel from non-edible oils such as *Neem*, *Mahua*, *Jatropha*, *Kopak*, *Sal*, etc. The biodiesel production from non-edible oil on wasteland significantly impacts India's economy. This approach can alleviate the high fuel demand burden by utilising wasteland for non-edible oil production. Utilizing non-edible oils for biodiesel reduces dependency on imported crude oil, potentially saving substantial foreign exchange. Therefore, much attention is required for the production of biodiesel from non-edible oil. A populous country like India has a huge demand for edible oil, so producing biodiesel from non-edible oil is important. The advantage of this type of oil is that it grows on waste or unfertile land that can be used as an important asset for biodiesel [17]. *Argemone Mexicana* is a non-edible plant belonging to the prickly poppy family. It is commonly found in the wasteland, roadside, or river banks. In India, it is commonly known as *Satyanashi* or *Shialkanta*. After conducting several literature reviews, less attention is paid to the production of the *Argemone Mexicana* plants, extraction techniques, characterisation and cost-effectiveness. Also, there is a need for extensive investigation of the physio-chemical properties for the potential use of transportation fuel.

In this investigation, we aim to cultivate *Argemone Mexicana* seedlings in a confined area in India. After minor irrigation, we collected the seeds and proceeded with the extraction of crude oil. The transesterification process was used to extract *Argemone Mexicana* methyl

10.48047/jocaaa.2024.33.07.58

ester (AMME). Further, the thermo-physical properties of its blend with diesel were investigated, and the results were compared with the ASTM standard.

2. Material and Method

2.1 Materials

The seed of the Argemone plant was procured, and the plant was cultivated in Bihar at in December. After weekly irrigation for about two months, the plant reached about one meter in height. The plant was yellow, and it had thorn leaves. The bulk of the plant seed was purchased from the local market. The seeds were dried in direct sunlight for three to four days to remove moisture content.

2.2 Oil Extraction Process

The conventional oil extraction process was used to extract crude oil from Argemone Mexicana. The raw material of plain seed was 30 kg, and the yield by weight of the seed was observed as 32 %. The total weight of the seed oil was 9.5 kg. The following formula was used to calculate the oil content percentage. Figures 1a, 1b show the *Mexicana* seed and Plants



Figure 1a: A. Mexicana Seeds



Figure 1b: A. Mexicana Plants

$$\begin{aligned} \text{Oil content}(\%) &= \left(\frac{\text{Total wight of the oil content}}{\text{Total wight of the raw material seed}} \right) \times 100 \dots\dots\dots (1) \\ &= \left(\frac{9.5}{30} \right) \times 100 \end{aligned}$$

The oil content in terms of percentage is found to be 31%.

The *argemone* seed oil contains 30-40% oil, which is primarily composed of palmitic acid (5-15%), oleic acid (15-40%), stearic acid (3-10%), palmitoleic acid (1-2%) and linoleic acid (40-60%). These results agree with those of Martínez-Delgado et al. [18]. The higher the oil's FFA content, the more significantly it may impact the biodiesel yield, complicate purification and separation, and reduce reaction efficiency. These FFA will react with alcohol and catalyst during transesterification, forming the soap solution and minimising biodiesel yield.

2.3 Biodiesel Extraction Process

The oil expelled from the oil expeller contains more than 3% FFA; hence, firstly, an esterification process is required. For esterification, 110 mL of Argemone crude oil was

10.48047/jocaaa.2024.33.07.58

mixed with 28 mL of methanol and H_2SO_4 and heated on a hot plate magnetic stirrer at $60^\circ C$ for up to one hour. The oil was held in a separate funnel for 5 hours. Then, phase separation occurs. The lower layer is a fatty acid, whereas the top layer is an ester. The ester amount measured was 100 mL. For the transesterification process, the same esterified volume of oil was placed on a heated magnetic stirrer, 26ml of ethanol was added, and 0.5 grams of Na metal was used as a catalyst. The mixture was stirred for up to 1 hour at 60° for biodiesel separation. After the reaction, the mixture was allowed to settle. The lower layer was glycerol, which had been removed by separating the funnel, while the top layer was transesterified *Argemone* ester (TAE). Finally, the TAE was washed two to three times to eliminate contaminants and excess water, yielding pure biodiesel.

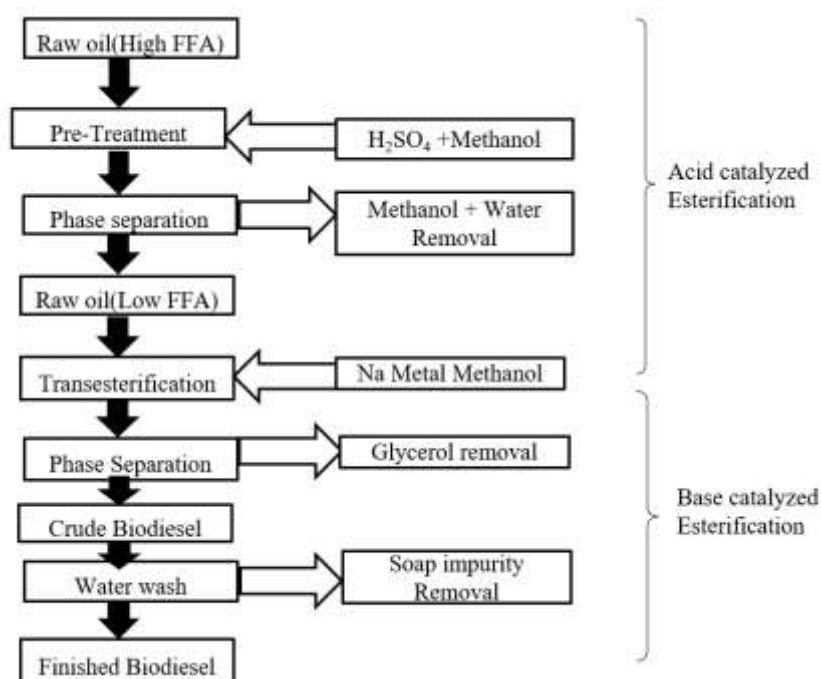


Figure 2: Flow diagram from harvesting to extraction of biodiesel.

2.4 Esterification/Transesterification Process

After extracting the Raw argemone, the initial phase esterification process was used, which involves methanol with different molar ratios and H_2SO_4 as a catalyst. After the FFA is removed, the low-content FFA is allowed to occur in the transesterification process, in which Na metal is used as a catalyst in the hot magnetic strainer [16]. The detailed flow diagram is shown in Figure 2.

Table 1: Series of experiments for the transesterification process

Sample No.	Different variations of parameter			Results Biodiesel Yields (%)
	Molar Ratio	Heating Time(min)	Concentration of Catalyst (% of Raw oil)	
1 st	4:1	60	0.4	82
2 nd	4:1	70	0.4	83
3 rd	4:1	60	0.5	84

4 th	6:1	60	0.5	83
5 th	6:1	60	0.4	82
6 th	6:1	70	0.4	88
7 th	6:1	60	0.5	87
8 th	8:1	70	0.4	88
9 th	8:1	60	0.5	86
10 th	8:1	70	0.5	86

2.5 Process parameter/calibration undertaken during the experiment

The equipment was calibrated before the experiment started to ensure the accuracy and consistency of the results.

2.5.1 Calibration of the equipment [19]

- Calibration of the temperature sensor: Temperature control is critical for the transesterification process to maintain a precise reaction time.
- Calibration of the volumetric equipment such as flask, burette, and pipettes to ensure accurate measurements.
- Calibration of the balance to ensure the accurate weighing of the reactance and catalysts.

2.5.2 Acid-catalyzed esterification pretreatment [20]

- Typically used as a sulphuric acid as a catalyst and involves mixing the argemone raw oil with methanol. The results convert into fatty acid methyl esters (FAME) and water.
- Setting of temperature sensor
- Use a magnetic bead (stir bar) to stir the solution continuously with a particular molar ratio.

2.5.3 Transesterification Process [21]

- Setting the temperature sensor before the experiment
- Selection of molar ratio and addition of base catalyst as Na Metal by wt% of oil.
- Continuous stirring of mixture and time of reaction.

2.5.4 Separation by water washing

- Separation of two layers in a separating funnel after the transesterification Process during the overnight settling.
- The lower level of the glycerol was removed, and the upper level of the methyl-ester obtained from *Argemone-Mexicana* was removed by hot-water washing method and stored in the separating funnel as shown in figure 3(a) and 3(b)[22].
- The average yield of the biodiesel during the experiment is found to be approx. 85%.

2.5.5 Determination of physicochemical properties.

$$\text{Biodiesel yield}(\%) = \left(\frac{\text{total weight of the obtained raw oil}}{\text{total weight of crude biodiesel(after glycerol removal)}} \right) \times 100 \dots (2)$$



Figure 3a: Magnetic stirrer with hot plate

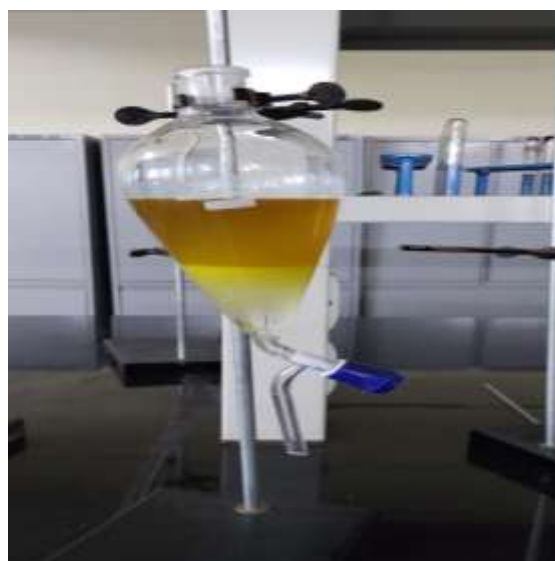


Figure 3b: Extraction of biodiesel

3. Results and Discussion

3.1 Transesterification reaction

The FFA content of argemone oil is more than 3%, which may result in corrosion and poor oil atomisation. Hence, a two-step process is required for the production of biodiesel. After the esterification for the successful removal of FFA, ten samples with different combinations of the parameters were chosen for the transesterification process, as shown in Table 1. Acid-catalysed H_2SO_4 , methanol as alcohol and raw argemone oil were used in the reaction. In the first sample, the molar ratio for ethanol to oil is 6:1 with a temperature of 60°C and 0.4% catalyst concentration. The yield is found to be 82%. In the second sample, with the same molar ratio and catalyst concentration at a temperature of 70°C , the yield is found to be 83%. In the third and fourth samples, at a temperature of 60°C and 0.5% catalyst concentration with a molar ratio of 4:1 and 6:1, the yield is 84% and 83%, respectively. Similarly, a total of ten experiments has been performed with different parameters. The maximum yield is 88% at a molar ratio of 8:1 at a temperature of 70°C with a catalyst concentration of 0.4%.

3.2 Characterisation of the Biofuel

Characterising the thermophysical properties is essential for assessing fuel quality and use in CI engines. The present research has determined physical and chemical properties like density, kinematic viscosity, and calorific value for the different blends. To ensure the accuracy of the data, each experiment was performed three times, and the average values were reported.

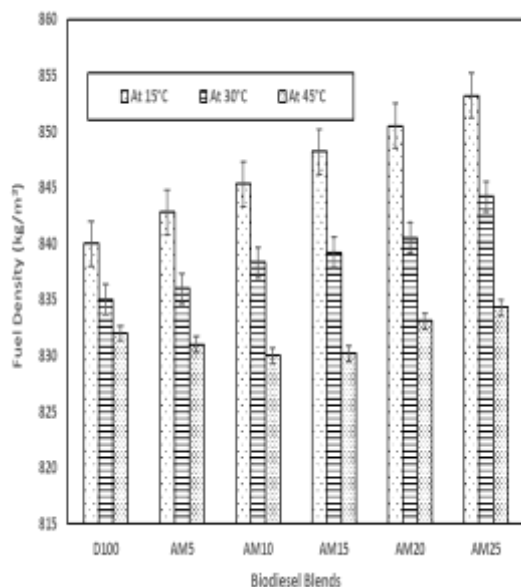


Figure 4: Variation of fuel density for different blends

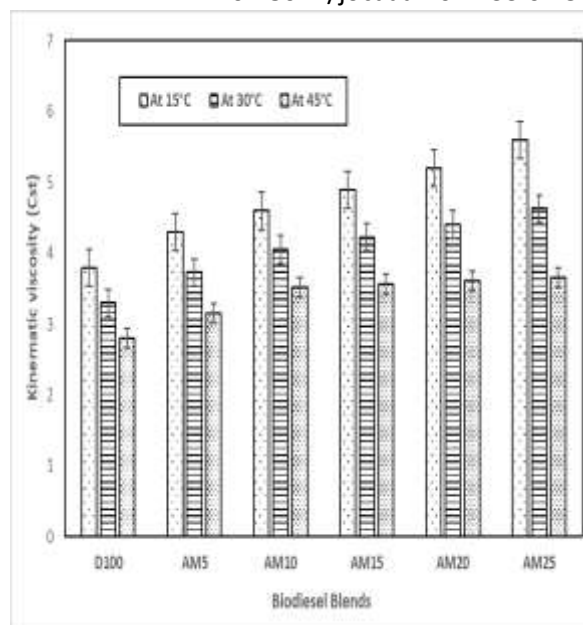


Figure 5: Variation of kinematic viscosity for different blends

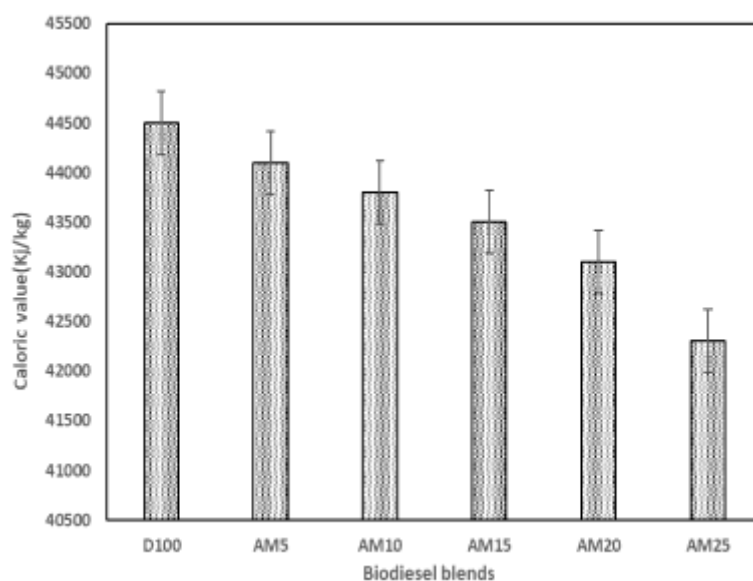


Figure 6: Calorific value for different blends

Figures 4, 5, and 6 demonstrate the different properties of AM oil used in this study and measured by instruments like bomb calorimeter and rheometer. Each instrument was calibrated before the experiments. As we know, viscosity is an important parameter affecting the flow and atomization during combustion. Also, density plays an important factor in breaking into tiny droplets of fuel at the time of injection in the cylinder and affects the fuel's compressibility [21]. Figure 5 shows the effects of fuel density of the diesel and biodiesel blends (AM5, AM10, AM15, AM20, and AM25) at 15°C, 30°C, and 45°C. The increase in the kinetic energy results in the expansion of the fluid volume, and hence density will decrease. Figure 5 shows the effect of kinematic viscosity for each sample of biodiesel blends at 15°C, 30°C, and 45°C with an ASTM D445 (accuracy $\pm 0.01 \text{ mm}^2/\text{s}$). Increasing trends of kinematic viscosity have been observed for higher biodiesel blends. Also, for each sample, lesser kinematic viscosity had been observed at higher temperatures. The calorific value of

10.48047/jocaaa.2024.33.07.58

the different biodiesel samples blends with a bomb calorimeter, as shown in figure 6. The calorific value of the fuel is the amount of heat released per unit mass of the fuel burned, with the combustion products being cooled back to room temperature. First, the calorimeter was calibrated with a known calorific value of the benzoic acid, and the water equivalent was calculated. A known amount of fuel was taken and placed in the crucible. The crucible was placed in the closure ring, and a fine magnesium wire was tightened across the electrode. A cotton reel was attached with the wire touching the sample. The bomb was charged with O₂ gas of 25 ATM from an oxygen cylinder without replacing the original air content. As soon as the circuit was completed, the bomb was fired after the current was switched on. The heat released by the fuel increases the temperature of the water. After reaching the preliminary period, the temperature was recorded. The above process was repeated for each sample [23]. As per the graph shown in figure 6, the calorific value of biodiesel is usually lower than diesels due to its higher oxygen content. For each biodiesel blend, the calorific value is approximately the same but slightly less than that of pure diesel. These biodiesel blends suit the CI engine [16]

5. Conclusion

This work concluded that the non-edible waste plant could be utilised as a potential source of biodiesel as an alternative fuel. The following are the significant findings of the work.

- These plants generally grow on unfertile land that can be used as a potential source of biofuel. The cultivation of this plant may renew interest as it has low maintenance costs.
- The raw oil yield of the biodiesel was 31% by weight. Because it contains more than 3% FFA, a two-step esterification and transesterification process were used to extract biodiesel.
- After extraction of crude oil, H₂SO₄ and Na metal by wt% were used as a catalyst in the esterification and transesterification process, respectively.
- The maximum biodiesel yield was 88% with a molar ratio of 8:1 at a temperature of 70°C and 0.4% catalyst concentration.
- Its chemical properties, such as kinematic viscosity and caloric value, agree with diesel; hence, it is suitable as an alternative fuel.

Finally, it is concluded that biodiesel extracted from the argemone Mexicana plant could be a potential alternative fuel source. However, more research needs to be addressed on engine performance and emission characteristics in the future.

Acknowledgement

The I.C. Engine Laboratory Research Facility of the “Mechanical Engineering Department of The Muzaffarpur Institute of Technology Muzaffarpur, Bihar” is duly acknowledged.

Disclosure statement

The authors reported no potential conflict of interest.

Data- availability statement

The datasets generated during and analysed during the current study are available from the corresponding author upon reasonable request.

Funding Statement

10.48047/jocaaa.2024.33.07.58

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

References

- 1 Basha, Syed Ameer, K. Raja Gopal, and S. Jebaraj. "A review on biodiesel production, combustion, emissions and performance." *Renewable and sustainable energy reviews* 13, no. 6-7 (2009): 1628-1634.
- 2 Chiong, Meng Choung, Cheng Tung Chong, Jo-Han Ng, Su Shiung Lam, Manh-Vu Tran, William Woei Fong Chong, Mohammad Nazri Mohd Jaafar, and Agustin Valera-Medina. "Liquid biofuels production and emissions performance in gas turbines: A review." *Energy Conversion and Management* 173 (2018): 640-658.
- 3 Gupta, Vijai K., Ravichandra Potumarthi, Anthonia O'Donovan, Christian P. Kubicek, Gauri Dutt Sharma, and Maria G. Tuohy. "Bioenergy research: an overview on technological developments and bioresources." *Bioenergy research: advances and applications* (2014): 23-47.
- 4 Silitonga, A. S., H. H. Masjuki, T. M. I. Mahlia, H. C. Ong, W. T. Chong, and M. H. Boosroh. "Overview properties of biodiesel diesel blends from edible and non-edible feedstock." *Renewable and sustainable energy reviews* 22 (2013): 346-360.
- 5 Mekhilef, Saad, S. Siga, and Rahman Saidur. "A review on palm oil biodiesel as a source of renewable fuel." *Renewable and Sustainable Energy Reviews* 15, no. 4 (2011): 1937-1949.
- 6 Chozhavendhan, S., M. Vijay Pradhap Singh, B. Fransila, R. Praveen Kumar, and G. Karthiga Devi. "A review on influencing parameters of biodiesel production and purification processes." *Current Research in Green and Sustainable Chemistry* 1 (2020): 1-6.
- 7 Sun, Chunhua, Yu Liu, Xinqi Qiao, Dehao Ju, Qing Tang, Xiaoyuan Fang, and Feng Zhou. "Experimental study of effects of exhaust gas recirculation on combustion, performance, and emissions of DME-biodiesel fueled engine." *Energy* 197 (2020): 117233.
- 8 Saravanan, A., M. Murugan, M. Sreenivasa Reddy, and Satyajeet Parida. "Performance and emission characteristics of variable compression ratio CI engine fueled with dual biodiesel blends of Rapeseed and Mahua." *Fuel* 263 (2020): 116751.
- 9 Yaşar, Fevzi. "Comparision of fuel properties of biodiesel fuels produced from different oils to determine the most suitable feedstock type." *Fuel* 264 (2020): 116817.
- 10 Yesilyurt, Murat Kadir, Mustafa Aydin, Zeki Yilbasi, and Mevlüt Arslan. "Investigation on the structural effects of the addition of alcohols having various chain lengths into the vegetable oil-biodiesel-diesel fuel blends: An attempt for improving the performance, combustion, and exhaust emission characteristics of a compression ignition engine." *Fuel* 269 (2020): 117455.
- 11 Singh, Rickwinder, Sandeep Singh, and Mukesh Kumar. "Impact of n-butanol as an additive with eucalyptus biodiesel-diesel blends on the performance and emission parameters of the diesel engine." *Fuel* 277 (2020): 118178.
- 12 Hoseini, S. S., G. Najafi, and A. J. I. C. Sadeghi. "Chemical characterization of oil and biodiesel from Common Purslane (*Portulaca*) seed as novel weed plant feedstock." *Industrial Crops and Products* 140 (2019): 111582.
- 13 Chhabra, Mayank, B. S. Saini, and Gaurav Dwivedi. "Impact assessment of biofuel from waste neem oil." *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects* 43, no. 24 (2021): 3381-3392.
- 14 Gupta, Aditi, Rohit Chaudhary, and Satyawati Sharma. "Potential applications of mahua (*Madhuca indica*) biomass." *Waste and Biomass Valorization* 3, no. 2 (2012): 175-189.
- 15 Lu, Houfang, Yingying Liu, Hui Zhou, Ying Yang, Mingyan Chen, and Bin Liang. "Production of biodiesel from *Jatropha curcas* L. oil." *Computers & Chemical Engineering* 33, no. 5 (2009): 1091-1096.
- 16 Singh, Mandeep, and Sarbjot Singh Sandhu. "Performance, emission and combustion

10.48047/jocaaa.2024.33.07.58

- characteristics of multi-cylinder CRDI engine fueled with argemone biodiesel/diesel blends." *Fuel* 265 (2020): 117024.
- 17 Antizar-Ladislao, Blanca, and Juan L. Turrion-Gomez. "Second-generation biofuels and local bioenergy systems." *Biofuels, Bioproducts and Biorefining: Innovation for a sustainable economy* 2, no. 5 (2008): 455-469.
- 18 Martínez-Delgado, Alejandra Anahi, José de Anda, Janet María León-Morales, Juan Carlos Mateos-Díaz, Antonia Gutiérrez-Mora, and José Juvencio Castañeda-Nava. "Argemone species: Potential source of biofuel and high-value biological active compounds." *Environmental Engineering Research* 27, no. 2 (2022): 200619.
- 19 Moffat, Robert J. "Describing the uncertainties in experimental results." *Experimental thermal and fluid science* 1, no. 1 (1988): 3-17.
- 20 Chai, Ming, Qingshi Tu, Mingming Lu, and Y. Jeffrey Yang. "Esterification pretreatment of free fatty acid in biodiesel production, from laboratory to industry." *Fuel processing technology* 125 (2014): 106-113.
- 21 Anjum, Syed Shahbaz, Om Prakash, and Amit Pal. "Conversion of non-edible Argemone Mexicana seed oil into biodiesel through the transesterification process." *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects* 41, no. 19 (2019): 2356-2363.
- 22 Pisarello Milesi, Maria Laura, Maira Alejandra Maquirriain, Paula Sacripanti Olalla, Valentina Rossi, and Carlos Alberto Querini. "Biodiesel production by transesterification in two steps: Kinetic effect or shift in the equilibrium conversion?" (2018).
- 23 Singh, Dipti, and S. P. Singh. "Low-cost production of ester from non edible oil of Argemone mexicana." *Biomass and Bioenergy* 34, no. 4 (2010): 545-549.