JOURNAL OF MECHANICAL ENGINEERING, SCIENCE, AND INNOVATION

ITATS

Research Article

Performance Enhancement of Motorcycle Engines Using Lemongrass Oil-Based Fuel Additive

Journal of Mechanical Engineering, Science, and Innovation
e-ISSN: 2776-3536
2025, Vol. 5, No. 2
DOI: 10.31284/j.jmesi.2025.v5i2.7778
ejurnal.itats.ac.id/jmesi

Pangga Urip Setio Budi[1], Ade Suhara[2], Agus Supriyanto[1], Dhea Intan Patya[1], Khoirudin Khoirudin[1] and Rizki Aulia Nanda[1]

[1]Department of Mechanical Engineering, Faculty of Engineering, Universitas Buana Perjuangan Karawang, Karawang, Indonesia
[2]Department of Industrial Engineering, Faculty of Engineering, Universitas Buana Perjuangan Karawang, Karawang, Indonesia

Corresponding author:
Agus Supriyanto
Department of Mechanical Engineering, Faculty of Engineering, Universitas Buana Perjuangan Karawang, Karawang, Indonesia
Email: agus.supriyanto@ubpkarawang.ac.id

Abstract

The increasing number of motor vehicles has led to higher fuel consumption, especially among two-wheeled vehicles, contributing to elevated emissions of hydrocarbon (HC) and carbon monoxide (CO). This study investigates the potential of lemongrass oil (LO) as natural additive to reduce exhaust emissions from RON 92 fuel. The LO was extracted via maceration and characterized by its physical properties, including density (0.893 g/mL), viscosity (5.30 mPa.s), and boiling point (222 °C), consistent with pure LO standards. The additive as then blended into RON 92 fuel in 0.99%, 1.47%, and 1.96% to determine its optimal performance. Results showed that a 1.96% of LO addition yielded the highest reduction in HC, CO, and CO_2 emissions, respectively 49.73%, 49.23%, and 31.91%. Furthermore, engine performance improved, with power increasing by 0.27 HP and torque by 0.21 Nm within an engine speed range of 5200-5700 rpm. These outcomes suggest that LO enhances combustion efficiency and reduces emissions. The findings highlight the potential of LO as an environmentally friendly fuel additive and support ongoing efforts to develop sustainable alternatives to conventional fossil fuels in Indonesia.

Keywords: *Lemongrass essential oil, additive fuel, exhaust gas emission, motorcycle engine performance*

Received: May 28, 2025; Received in revised: August 5, 2025; Accepted: August 7, 2025

Handling Editor: Naili Saidatin

INTRODUCTION

Fossil fuel consumption has been greatly accelerated by the high degree of public mobility and the growing number of motor vehicles [1]. Exhaust gas emissions including carbon monoxide (CO) and hydrocarbons (HC), which are harmful to the environment and human health, are largely caused by the increasing number of vehicles, especially two-wheelers [2]. An extensively used tactic to lessen the harmful impacts of vehicle exhaust emissions is the use of gasoline additives. Changing the fuel's chemical qualities, especially its research octane number (RON), and improving its physical attributes are the main goals of adding these additives. The goal of this strategy is to enable more thorough and effective combustion, which will result in lower emissions and more environmentally friendly emissions [3]. Fuel additives can be categorized into two groups: natural additives and synthetic additives [4], [5]. Because natural additives are environmentally safe and have the ability to function on par with or even better than synthetic additions, their use has recently attracted attention.

The use of natural additives, like essential oils like lemongrass oil (LO), has been shown in numerous earlier studies to improve combustion efficiency, reduce emissions, and help maintain engine temperature stability [6]. Siswanto & Ruslan have already looked into this phenomenon. They found that a gasoline combination containing fuel additives at concentrations of 5–10% might lower HC and CO levels without impairing engine performance. According to these studies, there is a positive effect on vehicle performance, especially when more ecologically friendly exhaust gases are produced [7]. This is further supported by the results of Rusli et al., who proposed that the presence of oxygenated molecules in essential oils is responsible for the decrease in HC and CO levels after the addition of essential oil-based natural additives [8]. These substances are thought to improve combustion efficiency by raising the amount of oxygen present during combustion, which lowers emissions of exhaust gases, especially HC and CO [9]. Essential oils from lemongrass, also known as LO, are among the many essential oils that have been shown to possess high concentrations of oxygenated molecules. Research on using LO as a gasoline additive is still scarce, though.

According to the foregoing elucidation, the objective of this study is to assess the viability of LO as an additive for RON 92 fuel, with the aim of achieving more environmentally friendly exhaust emissions. To ensure that the addition of this additive does not compromise the performance of the vehicle's engine, additional tests were conducted. It is hypothesized that the results of this study will contribute to the development of sustainable, bio-based fuel additives and provide a practical solution to reduce vehicular emissions without sacrificing engine performance. So, the novelty of this study lies in the exploration of the use of lemongrass oil (LO) as a natural additive for RON 92 gasoline used in conventional motorcycles. This study simultaneously evaluates the impact of LO on engine performance and exhaust emissions, which have not been comprehensively studied before. Additionally, this approach promotes the concept of sustainable energy by utilizing locally available, environmentally friendly resources, aligning with the direction of future bio-additive development. Moreover, the utilization of essential oil-based additives is congruent with global initiatives to transition towards greener energy alternatives. The utilization of locally sourced natural resources is a key component of this approach, as it fosters the principles of a circular economy and reduces reliance on fossil fuels. Future research is encouraged to further optimize blend ratios and evaluate long-term engine compatibility.

METHODS AND ANALYSIS

Lemongrass Oil Extraction and Physical Properties Evaluation

The extraction of lemongrass oil (LO) commenced with the drying of 1000 grams of lemongrass stalks, which had been cut into small pieces approximately 20 mm in length. The drying process was conducted under direct sunlight for approximately three consecutive days. Subsequently, the dried lemongrass was ground and subjected to maceration for 24 hours. Maceration refers to the process of soaking the plant material in a solvent. In this study, 600 mL of distilled water was employed as the solvent. Distilled water was chosen due to its ability to effectively preserve essential oil compounds by minimizing their evaporation and allowing for easy separation after extraction [10]. The resulting mixture was then filtered, and the LO was separated from the solvent via distillation. Distillation is a separation technique that exploits differences in boiling points between two liquids [11]. The distillation was carried out at approximately 100 °C, causing the distilled water to vaporize while leaving behind the LO, which has a higher boiling point (approximately 212 °C) [12]. Finally, the extracted LO was filtered once more to eliminate any residual impurities, yielding a clear oil.

The extracted LO was subsequently subjected to physical property evaluation to assess its quality, with comparisons made against those of pure LO. The physical properties analyzed included density, viscosity, and boiling point.

Density is defined as a measure of the mass of essential oil per unit volume [13]. The density of LO was determined using a graduated cylinder and a balance. First, the empty graduated cylinder was weighed. Then, a specific volume of LO was added, in this study using 10 ml. After that, the graduated cylinder containing the LO was weighed again, and the difference in mass was recorded. The density of the LO was then calculated using Equation 1 below:

$$\text{Density (g/ml)} = \frac{\text{Mass of LO (gram)}}{\text{Volume of LO (ml)}} \tag{1}$$

Subsequently, the viscosity measurement was conducted using a viscometer set of the NDJ-5S type. Prior to testing, it was ensured that the device was properly assembled and positioned on a flat and stable surface, as indicated by the position of the bubble within the level indicator. The rotor used was fully submerged according to the immersion mark, and care was taken to ensure that no air bubbles were present in the LO sample. In this study, the rotational speed was set to 60 rpm. The viscometer was then operated, and the viscosity value of the LO was displayed on the digital screen. The reading was observed until it stabilized, and the measurement was repeated several times to ensure the accuracy and reliability of the data obtained. Lastly, the boiling point of the LO was determined using a boiling point apparatus. The LO sample was placed in the boiling flask, heated gradually, and the temperature was monitored with a precise thermometer. The boiling point was recorded when a steady temperature was observed during continuous vaporization.

Investigation of Exhaust Gas Emissions and Engine Performance

LO obtained from the extraction process was added to RON 92 fuel, where the LO acts as an environmentally friendly additive. To determine the optimal conditions for the addition of LO, the LO was added in varying volumes of 10 mL, 15 mL, and 20 mL, then it mentioned in the percentage concentration as 0.99%, 1.47%, and 1.96%. The initial test conducted was the exhaust gas emission. Each sample was subjected to an emission test

Table 1. Engine specification.

Specifications	Value
Engine type	4-stroke, SOHC (Single Overhead Camshaft) engine with eSP (enhanced Smart Power) technology
Number of cylinders	1 cylinder
Bore x stroke	47 x 63.1 mm
Displacement	108.2 cc
Ratio compresion	10 : 1
Maximum power	6.6 kW (9 PS / 7,500 rpm)
Maximum torque	9.3 Nm (0.95 kgf.m) / 5,500 rpm
Cooling system	Air-cooled
Strarting up	Pedal and electric dinamo starter
Clutch type	Automatic, centrifugal, dry type
Transmission type	CVT (Continuously Variable Transmission)
Injection system	PGM-FI (Programmed Fuel Injection)
Oil capacity	0.65 L

on a motor vehicle with engine specifications as shown in Table 1. The exhaust gas analysis was performed using a Gas Analyzer set following SNI 09-7118.3-2005, as stipulated in the Regulation of the Minister of Environment and Forestry Number 8 of 2023. The exhaust gases investigated focused solely on the concentrations of HC and CO. Subsequently, the LO sample that demonstrated a reduction in HC and CO emissions was further evaluated through a dyno test to assess its effect on power, torque, and air-fuel ratio (AFR).

RESULTS AND DISCUSSIONS

The physical properties of LO, such as density, viscosity, and boiling point, are of particular interest. The LO obtained exhibited a brownish yellow hue, which some have suggested is indicative of the efficacy of the LO extraction process, as evidenced by a comparison with prior studies. It is important to note that the discrepancy in the physical properties of LO from the present study and those of previous studies is less than 10% in terms of relative error rate. This index may serve as an indicator of the efficacy of extraction processes.

Furthermore, the LO obtained was utilized as an additive to RON 92 fuel. The initial evaluation entails an exhaust emission test, the objective of which is to assess the levels of HC and CO. The objective of this study was to determine the optimal amount of LO to be used as an additive. To this end, the volume of LO added was varied, with the amounts tested being 0.99%, 1.47%, and 1.96%. As demonstrated in Figure 1, the exhaust emission test results indicate that the addition of 1.96% of LO to RON 92 results in the greatest reduction in HC, CO, and CO_2 exhaust emissions, 49.73%, 49.23%, and 31.91%, respecti-

Table 2. Comparison of physical properties between LO and previously studies.

Properties	This work	Previously Work	Ref.
Density (g/mL)	0.893	0.895	[14]
Viscosity (mPa.s)	5.30	4.82	[15]
Boiling point (°C)	222	212	[16]

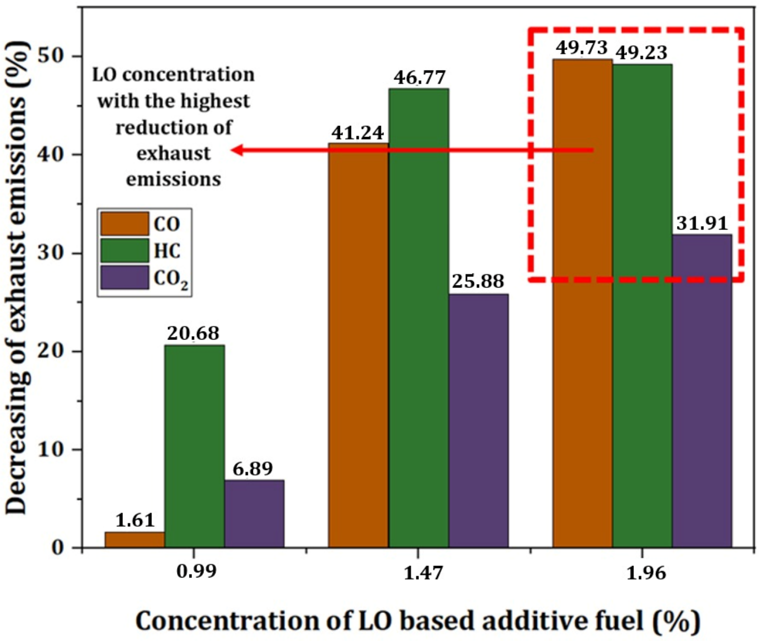


Figure 1. The decreasing of HC, CO, and CO_2 after the addition of LO.

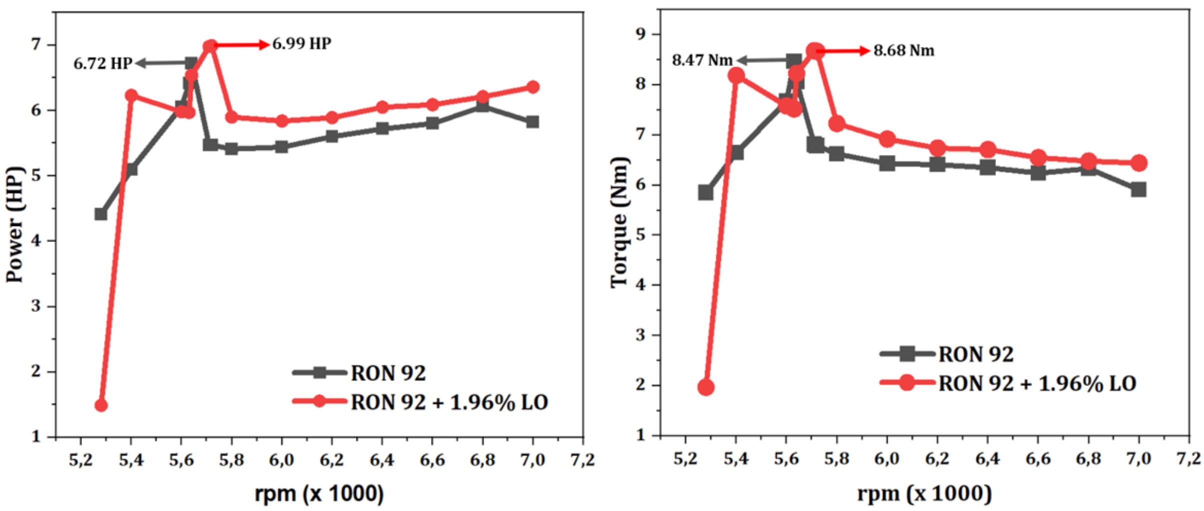
vely. LO contains main compounds such as citral, limonene, and geraniol that have been demonstrated to improve the quality of fuel combustion and reduce exhaust emissions [17], [18]. LO is notable for its natural oxygenating properties [19], which are attributable to the presence of oxygen atoms in each molecule. The presence of oxygen atoms has been demonstrated to enhance the combustion process of HC, CO, and CO_2. This outcome is particularly salient given the prevailing environmental concerns regarding the release of these substances. Furthermore, the presence of limonene and geraniol compounds in LO suggests their potential as mild solvents, which can facilitate the cleaning of the combustion chamber. A pristine combustion chamber has the potential to enhance the efficiency of the combustion process, thereby reducing the emissions of HC, CO, and CO_2. Additionally, it has been determined that the most optimal addition of LO to RON 92 fuel is 1.96%. Further experimentation is necessary to ascertain the impact of lemongrass oil on vehicle engine performance. The objective of this test is to ascertain that there has been no diminution in the functionality of the vehicle's engine. Consequently, power, torque and AFR tests were conducted to validate this hypothesis.

Then, several tests were conducted to determine the effects of adding a 1.96% of LO additive to RON 92 gasoline fuel on engine performance. The findings, based on dynamometer testing, revealed a substantial enhancement in engine power and torque when the additive was incorporated into the fuel. As demonstrated in Figure 2(a), the maximum power output of pure RON 92 fuel is 6.72 HP at 5640 rpm, while the mixture of RON 92 and 1.96% of LO results in a maximum power of 6.99 HP at 5720 rpm. This increase in power suggests that the fuel mixture with LO enhances combustion efficiency. Furthermore, a shift in peak power from 5640 rpm to 5720 rpm is observed. This shift signifies that the incorporation of LO additives enhances the combustion process, rendering it more stable and optimal at slightly higher engine speeds. The observed phenomenon may be attributable to the presence of active compounds, such as citral and geraniol, in LO. These compounds function as natural oxygenates, thereby enhancing combustion quality and extending the optimal combustion zone [20]. This shift signifies that the engine possesses the capacity to sustain elevated performance across a broader rpm range subsequent to the incorporation of the additive, which may result in enhanced fuel efficiency during operation.

The enhancement in engine performance is further evidenced by an increase in torque, as illustrated in Figure 2(b). The maximum torque exhibited an increase from 8.47 Nm at pure RON 92 to 8.68 Nm at the RON 92 and LO blend, also at the range 5600-5800 rpm. This enhanced torque performance signifies that fuel combustion is more vigorous and efficient, resulting in greater torsional force on the engine crankshaft [21]. This enhancing effect can be attributed to the presence of active compounds in LO, such as citral and geraniol, which function as natural oxygenates. These compounds enrich the fuel mixture with additional oxygen, thereby accelerating the combustion process and reducing incomplete combustion. Furthermore, the volatility of LO can facilitate the mixing of fuel with air, thereby enhancing the combustion process and reducing the accumulation of carbon deposits within the combustion chamber. This results in improved thermal efficiency and overall engine performance [22]. Consequently, the utilization of LO additives can serve as a promising bio-additive alternative, enhancing vehicle performance while contributing to the mitigation of exhaust emissions.

Then, as illustrated in Figure 3, a comparative analysis of Air-Fuel Ratio (AFR) values is presented, examining the distinction between pure RON 92 fuel and a mixture of RON 92 with 1.96% of LO additive at varying engine speeds. In general, the AFR values of both fuels decreased as the engine speed increased. However, the fuel blended with LO additive exhibited AFR values that were generally higher than those of pure RON 92 across nearly the entire rpm range. The AFR values of the RON 92 with LO blend ranged from 13.23 to 12.65, while the pure RON 92 experienced a more precipitous drop from approximately 13.16 to 12.55.

A higher AFR in fuels with LO additives indicate a "leaner" combustion (more air relative to fuel), which generally contributes to better thermal efficiency and lower carbon monoxide (CO) emissions [23]. This phenomenon can be attributed to the presence of oxygenate compounds in LO, such as citral and geraniol, which augment the oxygen content of the fuel mixture, thereby facilitating more complete combustion. Consequently, the rise in AFR values in the RON 92 and LO blend suggests that this additive not only enhances engine performance, but also contributes to the mitigation of



(a) (b)

Figure 2. Comparison of (a) power and (b) torque curves of motorcycle engines running on pure RON 92 fuel and RON 92 fuel with 1.96% LO, in relation to engine speed (rpm).

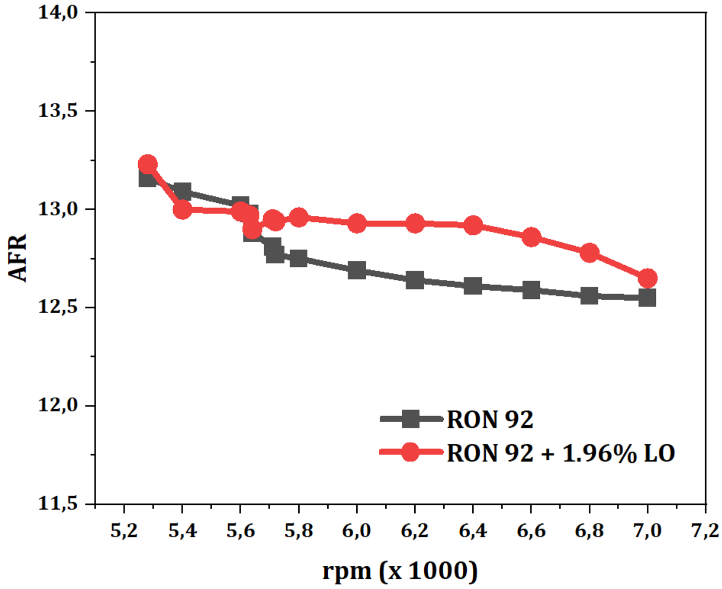


Figure 3. Comparison of AFR values for pure RON 92 fuel and RON 92 fuel with 1.96% LO added, in relation to engine speed (rpm).

exhaust emissions through the optimization of the combustion process.

Based on the findings of this study, LO has a great potential as an environmentally friendly fuel additive for the future. This oil contains oxygenated compounds such as citral and geraniol, which can increase the oxygen content in fuel mixtures, thereby improving combustion efficiency and completeness. This improved combustion not only enhances engine performance but also reduces harmful exhaust emissions such as CO and HC, which contribute to air pollution and negative health impacts on humans. Beyond these technical aspects, LO is a natural material derived from renewable resources and readily available locally, supporting reduced reliance on fossil fuels and synthetic additives that negatively impact the environment. The use of LO as an additive aligns with global trends toward green energy and a circular economy, where the sustainable use of natural resources is a key focus. With ongoing research and development, LO could become an alternative fuel additive that not only improves engine efficiency and reduces pollution but also helps drive the transition toward cleaner and more environmentally friendly energy systems in the future.

CONCLUSIONS

In summary, lemongrass oil (LO) was successfully extracted and applied as a fuel additive to RON 92. Physical property tests confirmed that the density, viscosity, and boiling point of the extracted LO were consistent with those of pure LO standards. The engine performance testing demonstrated that the addition of 1.96% of LO resulted in the greatest reduction in HC, CO, and CO_2 emissions, by 49.73%, 49.23%, and 31.91%. respectively, alongside slight increases in engine power and torque by approximately 0.27 HP and 0.21 Nm. These findings highlight the potential of LO as a natural, environmentally friendly additive that supports efforts to reduce air pollution, particularly in Indonesia. Further research is recommended to evaluate the long-term effects of LO additives on engine durability and emission performance under varied conditions. Such studies will help to better understand the practical applicability of LO as a sustainable fuel additive.

ACKNOWLEDGEMENTS

The authors would like to express their sincere gratitude to the Energy Conversion Laboratory, Universitas Buana Perjuangan Karawang, for the support and facilities provided throughout this research.

DECLARATION OF CONFLICTING INTERESTS

The authors declare that they have no potential conflicts of interest regarding the research, authorship, and/or publication of this article.

FUNDING

The author(s) received no financial support for the research, authorship, and/or publication of this article.

REFERENCES

[1] T. Jeyaseelan, P. Ekambaram, J. Subramanian *et al*., "A comprehensive review on the current trends, challenges and future propects for sustainable mobility," *Renew. Sustain. Energy Rev*., vol. 157, no. 112073, pp. 1-18, Apr: 2022.

[2] N. Szymlet, Ł. Rymaniak, and P. Lijewski, "Two-wheeled urban vehicle – a review of emissions test regulations and literature," *Energies*., vol. 17, no. 3(586), pp. 1-20, Feb: 2024.

[3] A. Racha, S. Pai, C. Samanta *et al*., "Sustainable fuel additives derived from renewable resources: promising strategies for a greener future," *ACS Omega*., vol. 10, no. 19, pp. 19256-19282, May: 2025.

[4] J. Zhang, Y. Wang, V. L. Muldoon *et al*., "Crude glycerol and glycerol as fuels and fuel additives in combustion applications," *Renew. Sustain. Energy Rev.,* vol. 159, no. 112206, pp. 1-22, May: 2022.

[5] Musyaroh, W. Wijayanti, and M. N. Sasongko, "The effect of sweet orange peel addition into premium gasoline on fuel consumption and flue gas emissions," *IOP Conf. Ser.: Mater. Sci. Eng.*, vol. 1034, no. 012038, pp. 1-9, Feb: 2021.

[6] M. A. Asokan, S. S. Prabu, S. Prathiba *et al*., "Emission and performance behaviour of blends of diesel/lemongrass oil in DI diesel engine," *Mater. Toda Proc.,* vol. 46, no. 17, pp. 8080-8085, Apr: 2021.

[7] A. Siswanto and W. Ruslan, "Pengaruh penambahan zat aditif toluena pada bahan bakar premium terhadap performa vespa sprint 150 3V," *JSA*, vol. 2, no.9, pp. 1604-1616, Sep: 2021.

[8] M. S. Rusli, H. Setiapraja, E. Agustian *et al*., "Effect of the addition of essential oils-based bio-additive on biodiesel B30 performance during durability and fiels tests," *IOP Conf.Ser.: Earth Environ. Sci.*, vol. 1354, no. 012026, pp. 1-11, Jun: 2024.

[9] G. Singh, S. Sharma, j. Singh *et al*., "Optimization of performance, combustion and emission characteristics of acetylene aspirated diesel engine with osygenated fuels: an experimental approach," *Energy Rep.*, vol. 7, no. 1, pp. 1857-1874, Nov: 2021.

[10] I. D. Sahputra, Zulfadli, L. Hanum, "Ekstraksi minyak atsiri dari daging buah pala (myristica fragrans houtt) dengan metode distilasi air-uap," *JIMPK*, vol. 8, no. 2, pp. 58-65, Dec: 2024.

[11] E. Koswara, H. Sonawan, N. N. Suryaman, "Improving freshwater yield from simple seawater distilation dispensers through condenser pipe modifications," *AEJ*, vol. 14, no. 3, pp. 191-196, Sep: 2024.

[12] S. O. Okpo and I. Edeh, "A comprehensive review on lemongrass (cymbopogon citratus) oil extraction and its applications," *EPRA Int. J. Res. Dev.,* vol. 8, no. 4, pp. 258-273, Apr: 2023.

[13] S. P. Bangar, W. S. Whiteside, F. Ozogul *et al*., “Development of starch-based films reinforced with cellulosic nanocrystals and essential oil to extend the shelf life of red grapes,” *Food Biosci.,* vol. 47, no. 101621, pp. 1-10, Jun: 2022.
[14] W. D. S. Martins, J. S. F. D. Araujo, B. F. Feitosa *et al*., “Lemongrass (cymbopogon citratus DC. Stapf) essential oil micropaticles: development, characterization, and antioxidant potential,” *Food Chem.,* vol. 355, no. 129644, pp. 1-7, Sep: 2021.
[15] T. Sufin dan E. D. Daryono, “Pengaruh suhu dan konsentrasi minyak atsiri sereh terhadap sifat fisik minyak jelantah sebagai bahan bakar pengganti biodiesel,” *JIP*, vol. 13, no. 2, pp. 141-146, Nov: 2024.
[16] T. Chaudhary, C. Varshney, A. Khan *et al*., “Pharmacological potential of lemongrass oil: a systematic review and meta analysis,” *Biochem. Cell. Arch.*, vol. 24, no. 1, pp. 587-593, Apr: 2024.
[17] K. Kolla, P. Periyasamy, M. Prabhahar *et al*., “Effect of three and five holes nozzle on thermal efficiency and emission characters of DI-CI diesel engine with lemongrass biodiesel as alternate fuel,” *Therm. Sci.,* vol. 26, no. 2, pp. 1197-1205, Feb: 2022.
[18] B. Ashaq, K. Rasool, S. Habib *et al*., “ Insights into chemistry, extraction and industrial application of lemon grass essential oil-a review of recent advances,” *Food. Chem. X.,* vol. 22, no. 101521, pp. 1-18, Jun: 2024.
[19] F. Benoudjit, I. Hamoudi, A. Aboulouz, “Extraction and characterization of essential oil and hydrolate obtained from an algerian lemongrass (cymbopogon citratus),” *Alger. J. Environ. Sci. Technol.,* vol. 8, no.1, pp. 2256-2263, Mar: 2022.
[20] N. Fitri, R. Riza, M. K. Akbari *et al*., “Identification of citronella oil fractions as efficient bio-additive for diesel engine fuel,” *Designs*, vol. 6, no. 1, pp. 1-13, Feb: 2022.
[21] K. Tsitsilonis and G. Theotokatos, “A novel method for in-cylinder pressure prediction using the engine instantaneous crankshaft torque,” *Proc. Inst. Mech. Eng. Pt. M J. Eng. Marit. Environ.,* vol. 236, no. 1, pp. 131-149, Feb: 2022.
[22] T. Jia, X. Zhang, Y. Liu *et al*., “A comprehensive review of the thermal oxidation stability of jet fuels,” *Chem. Eng. Sci.,* vol. 229, no. 116157, pp. 1-23, Jan: 2021.
[23] Z. Liang, Z. Yu, H. Liu *et al*., “Co,bustion and emission characteristics of a compression ignition engine burning a wide range of conventional hydrocarbon and alternative fuels,” *Energy.,* vol. 250, no. 123717, pp. 1-13, Jul: 2022.