Evaluation of Motorcycle Fueled with Blends of Gasoline and Pyrolytic Oil from Plastic–Palm Kernel Shell Co-Pyrolysis

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Abstract

This study explores the co-pyrolysis of plastic grocery bags and palm kernel shells (PKS) as a sustainable solution for addressing plastic waste and producing renewable energy. A stainless-steel batch reactor operating at 500ºC produced pyrolytic oil, char, and non-condensable gases, with a product yield of 48.3%, 26.7%, and 25.0%, respectively. Pyrolytic oil was characterized by higher viscosity, density, and oxygen content but a lower heating value compared to gasoline (pertalite). Various blends of pyrolytic oil (0–30%) with pertalite were tested in a 108 cc motorcycle engine. While pure pertalite offered better torque and power at low speeds, pertalite with 10% and 20% pyrolytic oil showed comparable engine performance at low to medium rotational speeds and better performance at high rotational speeds. In addition, blends with higher pyrolytic oil concentrations improved fuel efficiency, with the 30% blend achieving the best fuel economy at 33.3 km/L. The study concludes that pyrolytic oil can be a viable alternative fuel for motorcycles, particularly in carburetor systems, but requires further refinement to address particulate content and enhance compatibility with fuel injection systems.

Kata kunci: co-pyrolysis, motorcycle, palm kernel shell, plastic waste

Abstrak

Studi ini mengeksplorasi ko-pirolisis kantong plastik belanja dan cangkang inti sawit (PKS) sebagai solusi berkelanjutan untuk mengatasi limbah plastik dan menghasilkan energi terbarukan. Reaktor fized bed terbuat dari stailess steel dioperasikan pada 500ºC menghasilkan minyak pirolitik, arang, dan gas yang tidak terkondensasi, dengan hasil produk masing-masing 48,3%, 26,7%, dan 25,0%. Minyak pirolisis yang dihasilkan memiliki viskositas, densitas, dan kandungan oksigen yang tinggi dengan nilai kalor yang lebih rendah dibandingkan dengan bensin (pertalite). Variasi campuran minyak pirolisis (0–30%) dengan pertalite diuji dalam mesin sepeda motor 108 cc. Studi ini menyatakan bahwa pertalite murni menawarkan torsi dan daya yang lebih baik pada kecepatan rendah, pertalite dengan campuran 10% dan 20% minyak pirolisis menunjukkan kinerja mesin yang sebanding dengan berbahan bakar pertalit tanpa campuran pada kecepatan rotasi rendah hingga sedang. Selain itu, pertalite dengan campuran 10% dan 20% minyak pirolisis menghasilkan kinerja yang lebih baik pada kecepatan rotasi tinggi. Campuran dengan rasio minyak pirolisis yang tinggi mampu meningkatkan efisiensi bahan bakar, dimana dengan campuran 30% menghasilkan penghematan bahan bakar terbaik hingga 33,3 km/L. Studi ini menyimpulkan bahwa minyak pirolisis dapat menjadi bahan bakar alternatif yang layak untuk sepeda motor, terutama dalam sistem karburator, tetapi memerlukan penyempurnaan lebih lanjut untuk mengatasi kandungan partikulat dan meningkatkan kompatibilitas dengan sistem injeksi bahan bakar.

Kata kunci: ko-pirolisis, sepeda motor, cangkang kelapa sawit, sampah plastik

1. Introduction

The rapid depletion of fossil fuel reserves and their associated environmental impacts have drawn significant global attention. Fossil fuels, which dominate the global energy market, contribute extensively to greenhouse gas emissions, air pollution, and resource scarcity [1]. Addressing these challenges necessitates the exploration of renewable and sustainable alternatives to fossil fuels. Plastic waste and agricultural residues, such as palm kernel shells (PKS), are promising candidates for bioenergy production due to their abundance and energy potential [2]. Plastic waste, a persistent environmental pollutant, contains hydrocarbons suitable for fuel production. Since the 1950s, when plastic was first discovered, and 2015, 7.8 billion tons of plastic were produced worldwide [3]. Meawhile, daily plastic waste accounted in Indonesia is around 180 ton/day [4]. However, recycling (19.5%), incineration (25.5%), and landfills (55.0%) are currently the primary ways used to manage plastic trash. As a result, a number of ecological catastrophes brought about by prolonged improper treatment have surfaced recently, including the devastation of soil ecosystems in landfills for plastic trash [5]. Municipal solid trash mostly consists of thermoplastics, polystyrene, polypropylene, low and high density polyethylene, and polyethylene terephthalate [6]. Compared to high density polyethylene, the polymer structure of low density polyethylene exhibits a higher degree of branching and crosslinking [7]. Their pyrolysis oil composition is rather similar, though, since they both use polymeric ethylene and are mostly composed of n-alkanes, alkenes, and alkadienes. Although polypropylene pyrolysis also yields alkenes in the resulting oil, the polymer's branching structure makes the oil's composition more complicated than that of polyethylene [8].

In tropical areas, specifically in Indonesia and Malaysia, palm kernel shell, a byproduct of the palm oil industry, is readily accessible. Palm oil is a key commodity in the worldwide agricultural market, accounting for almost 40% of all vegetable oil [9,10]. Co-pyrolysis of plastic waste and PKS represents a sustainable strategy for converting these waste streams into valuable pyrolytic oil, which could serve as a renewable alternative to conventional fuels [11,12]. The dual use of these materials addresses two pressing global issues: plastic waste pollution and energy scarcity. In addition, this approach aligns with global efforts to address waste management and energy challenges simultaneously, paving the way for cleaner energy solutions.

Pyrolysis, a thermochemical decomposition process conducted in the absence of oxygen typically between 350 and 650ºC, is a widely researched method for converting biomass and plastic waste into liquid, gaseous, and solid products, and it also takes place during the beginning stages of gasification and combustion [13,14]. Pyrolysis offers flexible solutions for a variety of waste streams by handling a broad range of waste materials, such as industrial waste, plastics, municipal solid waste, and agricultural leftover. Anaerobic digestion, fermentation, and other biological decomposition methods, on the other hand, are only suitable for organic and biodegradable materials and cannot be used to decompose plastics or inert garbage [15]. Pyrolytic oil, the liquid fraction, has gained significant interest due to its potential as a renewable and alternatif fuel. Fixed-bed and fluidized-bed reactors are commonly used for pyrolysis. Fixed-bed reactors, characterized by their simplicity and cost-effectiveness, are widely applied in small-scale applications. However, they face challenges such as non-uniform heat distribution and lower product yields. In contrast, fluidized-bed reactors offer improved heat and mass transfer, leading to higher oil yields, but their operational complexity and higher costs make them less accessible for certain applications [16]. Despite its limitations, the fixed-bed reactor remains a viable option for co-pyrolysis due to its operational simplicity and feasibility for small-scale pyrolysis systems.

Extensive research has been conducted on pyrolytic oil as a vehicle fuel, demonstrating its potential to partially replace gasoline and diesel. Studies highlight its comparable calorific value and combustion properties, yet challenges such as high oxygen content, acidity, and instability persist [17]. Singh et al. [18] combined crude pyrolytic oil with diesel in various quantities without post-treatments, seeing higher carbon dioxide (CO), nitrogen dioxides (NOx), and carbon dioxide (CO_2) emissions in the blends than in regular diesel. Yaqoob et al. [19] evaluated plastic pyrolytic oil and diesel blends in a direct injection of single-cylinder, 4-stroke diesel engine. The results revealed that diesel with 5% pyrolytic oil had a maximum braking power of 1.92 kW at 2500 rpm. At 3500 rpm, the engine attained a thermal efficiency of 51.6%, which was greater than while running on full diesel fuel (47.44%). Furthermore, diesel with 15% pyrolytic oil produced the least amount of CO2 across all engine speeds. Faisal et al. examined the performance and emission characteristics of pyrolytic oil and diesel mixes in a compressed ignition engine. Before being blended with diesel fuel, the pyrolytic oil was hydrotreated at 60 bar and 360ºC in a hydrogen atmosphere using an additional $NiMo/Al_2O_3$ catalyst. This study discovered that diesel containing 15% pyrolytic oil (PO15%) has a greater braking power (BP) and brake thermal efficiency (BTE) than diesel fuel by up to 4.77% and 3.77%, respectively. Furthermore, PO15% emits less CO_2 and NOx at all running speeds than diesel fuel. However, this fuel blending emits slightly more CO and unburned hydrocarbon (UHC) than diesel at all speeds. Most investigations have focused on fuel performance and emission in stationary compressed ignition engines, with limited studies addressing the use of pyrolytic oil blends in actual vehicle applications, specifically in a spark ignition engine. This gap underscores the need for further research to evaluate the compatibility and performance of pyrolytic oil blends in motorcycles, a widely used mode of transportation, particularly in developing countries.

Given the increasing demand for sustainable transportation fuels and the pressing need to mitigate environmental pollution, the application of pyrolytic oil as a motorcycle fuel represents an urgent research priority. Motorcycles have become a popular means of transportation due to their low initial cost and versatility, particularly in highly populated metropolitan regions. Because to their small size, motorcycles can easily navigate congested streets and traffic [20]. Motorcycles account for a significant portion of the vehicle fleet in many regions, particularly in Asia, where more than 70% of motorcycles are ridden [21]. Developing a viable pyrolytic oil-gasoline blend for motorcycles could provide an accessible and sustainable alternative fuel solution, thereby reducing dependency on fossil fuels and addressing plastic and agricultural waste management challenges.

This study aims to investigate the performance of a motorcycle fueled with a gasoline-pyrolytic oil blend derived from the co-pyrolysis of plastic waste and PKS. The research focuses on evaluating engine performance and fuel efficiency to assess the feasibility of this innovative fuel blend. By addressing the research gap in pyrolytic oil application in motorcycles, this study contributes to advancing alternative and renewable energy solutions and fostering sustainable transportation systems

2. Materials and Methods

2.1 Pyrolytic Oil Production

The research used an equal mixture of LDPE plastic grocery bags and palm kernel shell as feedstock. The plastic was chopped into little pieces (about 3 cm × 3 cm) and rinsed with water to remove impurities before being sun-dried for use. The palm kernel shell was then fractured into pieces ranging from 3 to 5 mm. The physical and chemical properties of the pyrolysis feedstock can be seen in our earlier study [11].

The pyrolysis procedure was carried out in a batch reactor made of stainless steel and heated electrically. The reactor measures 200 mm in height and diameter. A water-cooled condenser measuring 2.1 meters was attached to the reactor's exit to keep the vapor temperature below 40^{o}C. A proportional integral derivative (PID) controller was used to control the 3.0 kW electric heater, which produced the required heat. Approximately 5000 g of plastic shopping bag and palm kernel shell were put into the reactor. The feedstock was heated from room temperature to 500^{o}C, which was maintained until no more pyrolytic fumes escaped the condenser. The pyrolytic oil was then weighed, as was the remaining char in the reactor. The amount of non-condensable gas (NCG) was estimated by noting the disparity. Figure 1 shows a schematic of the experimental setup.

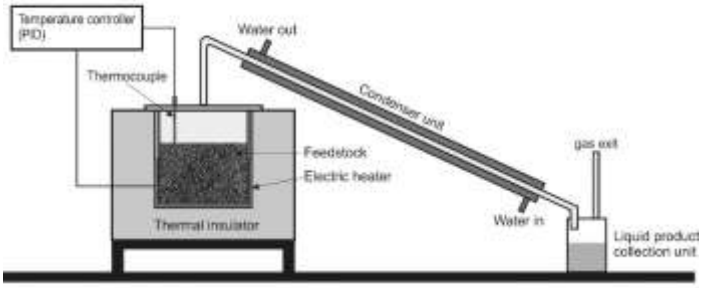

Figure 1. Experimental aparatus of fixed bed pyrolysis

The viscosity of the fluid products was evaluated using an NDJ 8 S viscometer from WANT Balance Instrument Co., Ltd., China, in a glass beaker containing 75 cc of pyrolytic oil. The rotational velocity and rotor version were modified to meet the viscosity criteria. The caloric value of the pyrolysis oil was determined with a Parr 6050 Bomb Calorimeter from Parr Instrument Company in Moline, Illinois, USA. A sample of 0.70–0.72 ml of pyrolytic oil was obtained from the top layer and burned in an oxygen-saturated calorimeter to calculate the energy. The chemical composition of the pyrolysis oil was evaluated using a GC-MS QP2010 SHIMADZU instrument. The gas chromatography column used was an Agilent HP-5MS (30 m x 0.25 mm x 0.25 m), with ultra-pure helium gas at a split ratio of 32.3:1. The compounds were identified by comparing their chromatographic peak regions and retention time data with those in the NIST library. The chemical substances discovered by the equipment were classified based on their chemical group and hydrocarbon chain lengths. Meanwhile, the acidity of the liquid product was measured using a digital callibrated pH meter.

2.2 Engine Test Procedure

The torque, power, and fuel consumption of gasoline (pertalite) and pyrolytic oil mixing were studied on an automatic transmission motorbike driven by a single cylinder four stroke spark ignition (SI) engine. The SI engine had a cylinder size of 108 cc and a compression ratio of 9.2:1. The fuels were created using the following mixing ratios: pyroltic oil 0%vol. (0% vol. PO), pyroltic oil 5%vol. (5% vol. PO), pyroltic oil 10%vol. (10% vol. PO), pyroltic oil 20%vol. (20% vol. PO), and pyroltic oil 30%vol. (30% vol. PO). The Sportdyno V3.3 dynamometer (Figure 2) was used to test the motorbike's torque and power when fed with these fuel adjustments. The engine was run at a rotational speed of 2000 to 8500 rpm.

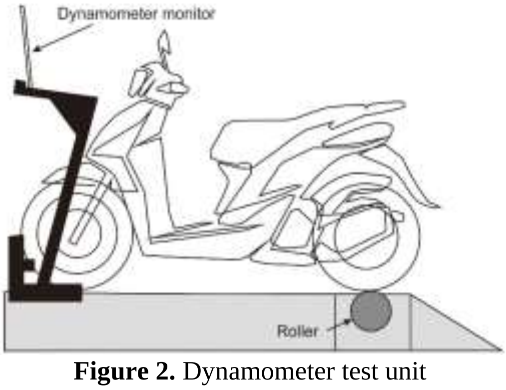

Figure 2. Dynamometer test unit

The motorcycle's fuel consumption was measured while driving 5 kilometers. The fuel injector to the carburetor was changed by connecting it to the burette, which made it easy to read the amount of fuel reduction. The motorbike traveled at an average speed of 40 km/h. The fuel usage was estimated by dividing the driving distance by the decreased gasoline volume. All tests were carried out in triplicate to guarantee reproducibility, and the results were averaged.

3. Results and Discussion

Figure 3a shows the evolution of the pyrolysis reactor temperature tested using a plastic grocery bag and palm kernel shell mixture. Initially, after the electric heater was turned on, the reactor temperature was constant at room temperature until eight minutes. It indicates that during that time the heat transfer from the electric heater to the feedstock in the reactor occurred gradually, and after eight minutes, the feedstock received the heat. At 8 to 16 minutes, the reactor temperature increased significantly due to the feedstock receiving the sensible heat until around 97°C. At the time of 16 to 32 minutes, the temperature remained constant due to the evaporation process of water content in the feedstock by receiving the latent heat. At the time of 32 to 36 minutes, the temperature raised dramatically to 196.1 oC, followed by the lower gradient of increasing temperature to 382.5°C at 48 minutes. It demonstrates that at the time 32 to 36 minutes, the feedstock absorbed the sensible heat, followed by the initial thermal decomposition of the feedstock at the time 36 minutes. After the temperature reached around 200°C, the slow-rate decomposition process occurred for 48 minutes, achieving a temperature of 382.5°C. After that time, a faster thermal decomposition rate occurred, indicated by a slow rise in temperature due to the absorbance of heat transferred from the electric heater for decomposition, which is an endothermic process. Moreover, the heat was also released by the evaporation of pyrolytic vapor, and finally, it was rejected by the water flow in the condenser system. After 100 minutes, the reactor temperature tended to constant due to the control of PID system to maintain the temperature around 500°C.

The pyrolytic oil and char products were wighted and calculated their yields, which is shown in Figure 3b. The product of pyrolysis, including pyrolytic oil, char, and non-condensable gas (NCG) were 48.3%, 26.7%, and 25.0%, respectively, where the liquid phase was the most dominat product. This product yield distributions was relevant with the experiment conducted by Hassan et al. [22] that the liquid product of plastic bottle and palm kernel shell co-pyrolysis achieved the optimal value at pyrolysis temperature of 500°C, namely 52.6%.

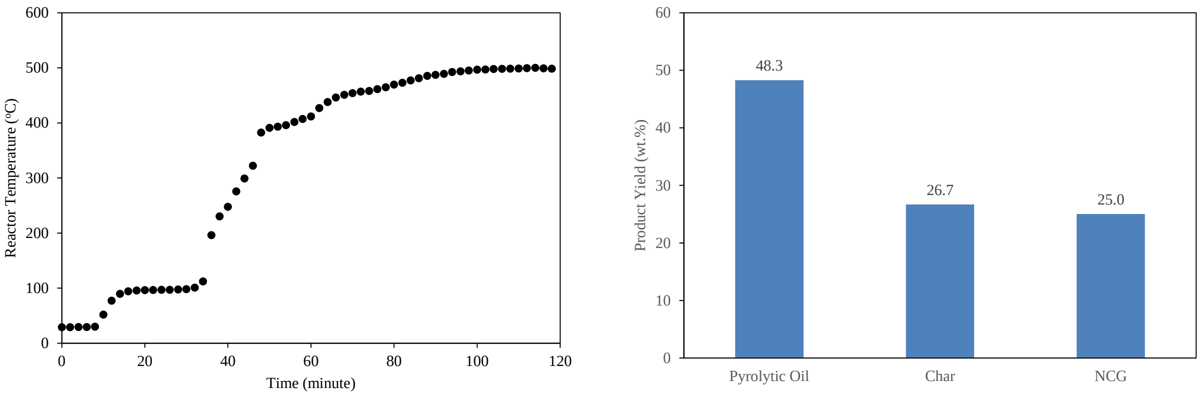

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Figure 3. (a) Reactor temperature; (b) Pyrolysis product yield

Fuel properties including density, viscosity, and heating value are contrasted in Table 21. As a conventional fuel, gasoline (pertalite) has a much higher heating value (18.0%) with a lower acidity (16.1%). The viscosity of pyrolytic oil from co-pyrolysis of plastic grocery bags and palm kernel shells, on the other hand, was more than thirty folds higher than that of pertalite. Pertalite's density, viscosity, and heating values were 742.8 kg/m^3, 0.463 mPa.s, and 44.32 MJ/kg, respectively, according to similar results published in the literature [18]. This pertalite heating value was also reflected in the observation of Sunaryo et al. [4], namely 45.63 MJ/kg. In contrast, the heating value of pyrolytic oil of co-pyrolysis plastic and palm kernel shell from reference [22] was 37.78 MJ/kg; meanwhile, the other properties, such as density, viscosity, and acidity were not measured. In summary, our results did not differ much from those of other studies.

Table 1. Fuel properties

Fuel	Density (kg/m^3)	Viscosity (mPa.s)	Heating Value (MJ/kg)	pH
Gasoline (Pertalite)	743.4	0.57	43.3	5.6
Pyrolytic Oil	908.8	19.1	35.5	4.7

The chemical compositions of pyrolytic oil and pertalite as revealed by GCMS analysis are shown in Figures 4a and b. Similar to the method used in pyrolytic oil, the chemical composition of pertalite was gathered for this study from reference [23], and the data was assessed by categorizing according to the hydrocarbon chain length and chemical composition group. Pyrolytic oil was often denser and more viscous than pertalite. The extended hydrocarbon chain

(C_{10}–C_{17}) (Figure 4) indicates that the higher density of pyrolytic oil was due to chemical components with a high molecular weight. Pertalite, on the other hand, had a lower density because it was composed of a short hydrocarbon chain that was mostly composed of C_6–C_9. The hydrocarbon chain's length also affected the viscosity of the gasoline. The viscosity of pyrolytic oil is greater than that of pertalite because the viscosity increases with the length of the hydrocarbon chain [24]. Additionally, the fuel's degree of unsaturation affected its viscosity; aromatics had the highest degree of unsaturation while alkenes had the lowest degree relative to the other hydrocarbons. As the degree of unsaturation falls, fuel viscosity rises [25]. Alkanes and alkenes with lower levels of unsaturation than aromatics and cyclics made up the majority of pyrolytic oil. Consequently, the viscosity of the pyroltic oil was higher than that of pertalite. Figure 5 illustrates how the pyrolytic oil's heating value decreased somewhat when oxygenated compounds were added. Long carbon chain alcohols with low oxygen concentration, including 1,15-Pentadecanediol, were the main oxygenated molecules found in the liquid products. Thus, even though pyrolytic oil included a considerable amount of oxygenated compounds (23.65%), its heating value was only 19.9% less than pertalite's.

The length of the hydrocarbon chain in pertalite was short. Figure 4a illustrates how it was distributed from C_7 to C_{11} with a trace quantity (0.178%) of $C_{27}H_{60}$ (tripropylene). Most of the hydrocarbons were cyclic and aromatic (15.97% and 57.2%, respectively), with the biggest proportion (74.8%) found in the group with the lowest hydrocarbon chain length (C_6–C_9). In the meanwhile, alkane and alkene hydrocarbons decreased to minor fractions, accounting for 0.2% and 1.41% of the total area, respectively. In other words, the smallest hydrocarbon chain length encompassed all cyclic hydrocarbons. While alkanes accounted for just 2.82% of the hydrocarbon chain length C_{10}–C_{13}, aromatics accounted for 22.24%. Unlike pertalite, pyrolytic oil had a little quantity (1.99%) of extremely long hydrocarbon chain length (>C_{22}) and a large proportion of long-chain hydrocarbons, up to 38.33% of C_{10}–$C_1$3 and 34.79% of C14–C17. Furthermore, at 21.46%, the short hydrocarbon chain length (C_6–C_9) was much shorter than pertalite. Alkenes, oxygenated compounds, and alkanes accounted for the majority of the C_6–C_9 hydrocarbon chain lengths in pyrolytic oil (9.93%, 4.01, and 3.91%, respectively), with octanoic acid emerging as the most abundant portion of oxygenated compounds. At 16.57%, 13.08%, and 5.65%, respectively, the hydrocarbon chain lengths of C_{10}–C_{13} in pyrolytic oil were mostly found in alkenes, alkenes, and oxygenated compounds. With small amounts of alkenes, oxygenated compounds, and alkanes (17.39%, 10.92, and 6.39%, respectively), the hydrocarbon chain lengths of C_{14}–C_{17} were primarily alkanes, with 1,15-Pentadecanediol being the most prevalent oxygenated product.

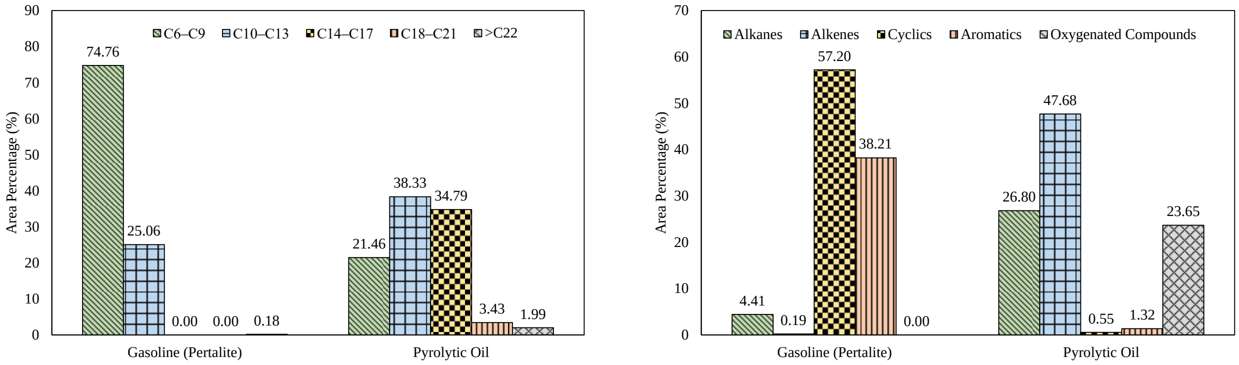

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Figure 4. (a) Chemical structure of gasoline (pertalite) and pyrolytic oil; (b) Chemical composition of gasoline (pertalite) and pyrolytic oil

Thirty-four hydrocarbon species were found in pertalite, whereas pyrolytic oil included sixty-six hydrocarbon species with thirty oxygenated compounds (Figure 4b). At 57.2% and 38.2%, respectively, cyclic and aromatic hydrocarbons made up the majority of pertalite. The most common species in pertalite were 7-Methyl-1,3,5 Cycloheptatriene (C_8H_{10}), Cyclohexane, 1,2,4-Tris (Methylene) (C_9H_{12}), and Methyl-1,3,5-Cycloheptatriene (C_7H_8), which accounted for 26.42%, 19.45%, and 8.31% of the total. On the other hand, alkene and alkane hydrocarbons made up the majority of pyrolytic oil (47.68% and 26.8%, respectively), with a sizable amount of oxygenated compounds (23.65%). The oxygen percentage in the palm kernel shell caused the existence of oxygenated compounds in the pyrolytic oil. Due to being fractionated into 96 species, no more than 10% of pyrolytic oil species was present. 1,15-Pentadecanediol ($C_{15}H_{32}O_2$) , Heptadecane ($C_{17}H_{36}$), and 1-Dodecene ($C_{12}H_{24}$) became the most dominant species in pyrolytic oil with area percentages of 9.30%, 5.45, and 5.40, respectively. Pertalite and pyrolytic oil were combined in this investigation in the following ratios: 0%, 5%, 10%, 20%, and 30%. These fuels were blended without the use of any chemical treatments. According to the literature, there is a linear relationship between the fuel blend's chemical and physical characteristics [26].

The relationship between engine speed and torque for various fuel adjustments is shown in Figure 5a. As engine speed rose, torque generally decreased. For both fuel types, there were significant torque drops between 2000 and 6000 rpm and a mild loss between 6000 and 8500 rpm. The torque of the engine fuelled with different percentages of pyrolytic oil varied at low engine speeds between 2000 and 4500 rpm; at engine speeds below 3500 rpm, the fuel containing 5% pyrolytic oil provided the least torque. In contrast, pure pertalite produced a torque that was equivalent to that of the higher concentrations of pyrolytic oil. It suggests that the heating value and oxygen content of the fuels had a combined effect, with a higher percentage of pyrolytic oil exhibiting a lower fuel heating value and a higher percentage of oxygen content. A lesser chemical energy to propel the engine piston through combustion and produce torque is indicated by a low fuel heating value. Conversely, the fuel's inherent oxygen improves combustion efficiency, which in turn raises torque. The torque generated by each fuel fluctuation was negligible while the engine was operating at high speeds (over 6000 rpm). It suggests that the impact of the fuel's oxygen content and heating value may be disregarded at high engine speeds where the combustion chamber temperature is high.

All fuel variants produced power that followed comparable patterns, with two power peaks depending on the fuel variation occurring between 3000 and 5000 rpm (Figure 5b). The power output was constrained by the friction between the cylinder and the cylinder wall while the engine was operating at low rotational speeds. The engine could generate its full power as the engine speed increased because there was less friction between the cylinder and the cylinder wall. However, the vibration got worse as engine speeds rose, which led to a loss of power. Consequently, the engine's power production peaked between 3000 and 5000 rpm, which is a medium rotational speed. Compared to mixing 5% vol. pyrolytic oil, the engine powered by pure pertalite generated more power when running at low speeds (2000–3500 rpm) but less power when running at high speeds (5500–8500 rpm). The power of the engine running on pure pertalite and fuel blendings of 10% and 20% pyrolytic oil, however, exhibited negligible changes at middle engine speed (3500–5500 rpm). Similar to torque, the engine running on 5% pyrolytic oil produced the least amount of power at both low and high rotational speeds, whereas the engine running on 30% vol. pyrolytic oil produced the least amount of power at middle rotational speeds. It shows that adding 5% pyrolytic oil decreased heating value while adding negligible amounts of oxygen for combustion, which resulted in less power being produced. In the meantime, the heating value was considerably reduced by adding 30% vol. pyrolytic oil. Despite receiving a significant amount of intrinsic oxygen from pyrolytic oil, it was unable to generate as much power at medium rotational speeds because there was not enough energy to convert it into power.

These torque-related power patterns were highly significant, with the engine running on pure pertalite generating more torque and power at low rotational speeds and less at high rotational speeds. The earlier study [27] demonstrated a similar trend when power production peaked at medium engine speeds. On the other hand, at all engine speeds, the gasoline engine generated more power than the pyrolytic oil engine. The reason for this discrepancy was the gasoline used; the reference study [27] used pertamax, a higher-grade fuel, whereas our study used pertalite.

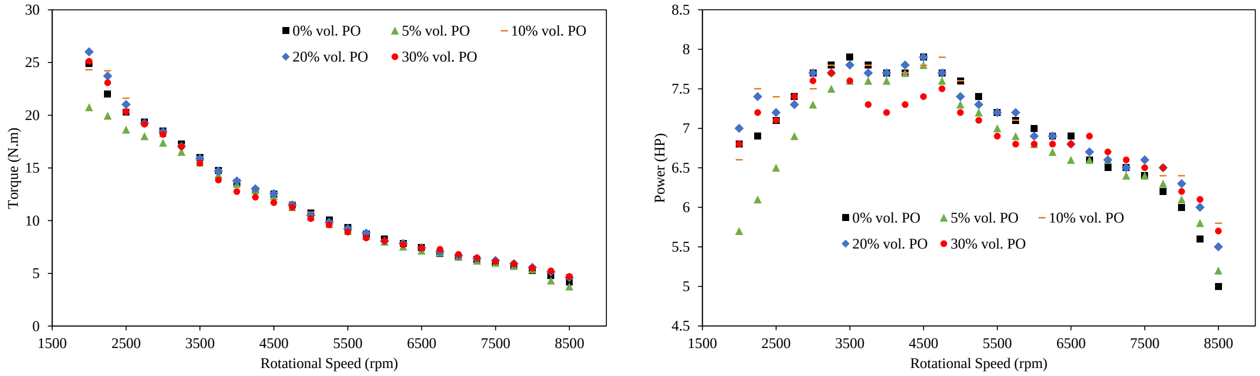

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Figure 5. (a) Torque; (b) Power

Motorcycle gasoline consumption statistics utilizing various pertalite and pyrolytic oil fuel blends at percentages of 0%vol, 5%vol, 10%vol, 20%vol, and 30%vol are compared in Figure 6. The most efficient fuel was found in the test results utilizing a fuel combination variation of 30% vol. pyrolytic oil. A motorbike might get up to 33.3 km/L or 3 L/100 km of fuel consumption using this gasoline. With a mileage of 21.7 km/liter and a fuel consumption value of 5 L/100 km, the pure pertalite variety had the lowest fuel consumption value, suggesting that pertalite fuel was less efficient. Fuel consumption was considerably reduced by adding 5% vol. pyrolytic oil, but it was only marginally reduced when pyrolytic oil was added at a rate of 30%.

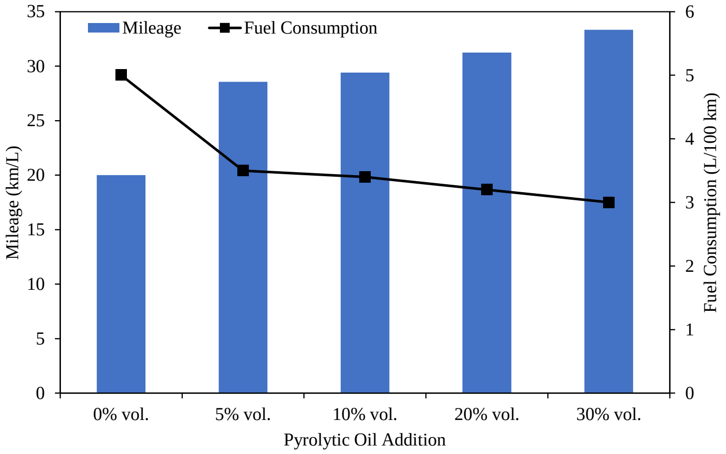

Figure 6. Mileage and Fuel Consumption

Motorcycle fuel economy is influenced by gasoline viscosity. Because pyrolytic oil has higher viscosity properties than pertalite, the fuel flow rate to the combustion chamber is slower, which results in a lower fuel consumption rate as the percentage of pyrolytic oil increased. This means that the more pyrolytic oil mixture there is in pertalite fuel, the more economical the resulting fuel consumption will be. According to Sunaryo et al. [27], gasoline used more specific fuel than pyrolytic oil. In keeping with our findings, it demonstrates that gasoline consumption was higher than that of pyrolytic oil.

The performance of a four-stroke motorcycle running on mixtures of pertalite and pyrolytic oil was comparable to that of pure pertalite. Additionally, fuel mixing might reduce the amount of gasoline used. However, particles from soot produced during the pyrolysis process are present in pyrolysis oil [28]. Fuel blending with pyrolysis oil is therefore recommended when the engine has an air-fuel mixing carburetor. Pyrolytic oil must first be improved to eliminate particles in order to reduce the possibility of a plugging in the fuel injection system when used for fuel injection in motorcycle engines.

4. Conclusion

This study demonstrates the potential of pyrolytic oil derived from plastic grocery bag and palm kernel shell as a sustainable fuel alternative for motorcycles. The co-pyrolysis process efficiently converted waste materials into renewable fuel, with product yields aligning with prior research. While pyrolytic oil blends, specifically at 10% and 20% of pyrolytic oil blending, exhibited comparable performance to pure gasoline at medium and high engine speeds, they improved fuel efficiency, making them a viable option for reducing dependence on fossil fuels. The 30% pyrolytic oil blend provided the best fuel economy, highlighting its potential for practical use in carburetor-based engines. However, the high viscosity and particulate content of pyrolytic oil highlight the need for refining processes to optimize its properties and ensure compatibility with modern fuel injection systems. These findings contribute to advancing alternative and renewable energy solutions while addressing global challenges of plastic waste and energy sustainability.

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