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Production of Diesel-Grade Fuel from Co-pyrolysis of Sawdust and Waste Plastics

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Abstract- The increasing generation of sawdust and waste plastics presents significant environmental and waste-management challenges, while the demand for alternative liquid fuels continues to grow. This study investigated the production of diesel-grade fuel through the controlled co-pyrolysis of sawdust and waste plastics in a laboratory-scale fixed-bed stainless-steel reactor. Uda softwood sawdust, Ububra-red hardwood sawdust and C-Way waste plastic bottles were selected as feedstocks based on their carbon contents and energy potential. The feedstocks were blended at varying mass proportions and co-pyrolysed under an inert nitrogen atmosphere at temperatures of 400, 600 and 800 °C. Vapours generated during thermal decomposition were passed through a condenser, and the condensable fraction was recovered as liquid fuel. Feedstock analysis showed carbon contents of 54.68% for softwood, 57.12% for hardwood and 78.19% for the waste plastic, confirming their suitability for thermochemical conversion. The experimental results demonstrated successful conversion of the blended sawdust and waste plastics into hydrocarbon liquid fuel over the investigated operating conditions. The highest liquid-fuel yield of 72 wt.% was obtained at 800 °C using equal quantities of softwood, hardwood and waste plastic (100 g each; 1:1:1 mass ratio). The process also generated char and non-condensable volatile products as secondary fractions. These findings demonstrate the technical feasibility of converting sawdust and waste plastics into diesel-grade liquid fuel through co-pyrolysis, providing a potential waste-to-energy pathway for the recovery of useful fuel from locally available solid wastes. (Co-pyrolysis; Sawdust; Waste plastics; Diesel-grade fuel; Waste-to-energy.)

I. INTRODUCTION

The rapid increase in the generation of lignocellulosic biomass residues and plastic wastes has become a major environmental concern worldwide. Large quantities of sawdust generated from wood-processing industries are commonly disposed of through open burning or uncontrolled dumping, resulting in greenhouse gas emissions and environmental degradation. Similarly, the persistent accumulation of waste plastics due to their non-biodegradable nature has intensified concerns regarding land pollution, ecosystem contamination, and ineffective waste management practices. The conversion of these abundant wastes into useful energy products has therefore become an attractive strategy for promoting sustainable waste management while reducing dependence on conventional fossil fuels [1].

Pyrolysis has emerged as one of the most promising thermochemical conversion technologies for recovering energy from carbonaceous wastes. The process involves heating organic materials in an oxygen-deficient environment to produce liquid oil, solid char, and non-condensable gases. Compared with conventional disposal methods such as incineration and landfilling, pyrolysis offers significant advantages, including resource recovery, reduced environmental pollution, and the production of valuable liquid fuels and chemical feedstocks [2]. However, the pyrolysis of lignocellulosic biomass alone often produces bio-oil with high oxygen content, relatively low heating value, high acidity, and poor storage stability, limiting its direct application as a transportation fuel [2], [3].

Co-pyrolysis of biomass and waste plastics has attracted increasing research interest because of the synergistic interactions that occur during thermal decomposition. Waste plastics serve as hydrogen-rich feedstocks that promote hydrogen transfer reactions, thereby reducing the oxygen content of biomass-derived vapours and improving the quality and yield of the resulting liquid fuel. These synergistic effects enhance the production of hydrocarbon compounds within the gasoline- and diesel-boiling ranges while suppressing the formation of undesirable oxygenated compounds. Consequently, co-pyrolysis has been

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recognised as an effective waste-to-energy technology capable of simultaneously addressing biomass and plastic waste management while producing valuable transportation fuels [1], [4], [5].

Several studies have demonstrated the feasibility of producing liquid fuels through the co-pyrolysis of biomass and plastic wastes [6]. Nevertheless, relatively few investigations have focused on the combined utilisation of hardwood sawdust, softwood sawdust, and waste plastics as feedstocks for diesel-grade fuel production using a laboratory-scale fixed-bed batch reactor. The utilisation of these locally abundant waste materials provides an opportunity to recover valuable energy resources while reducing environmental pollution associated with indiscriminate disposal [1], [5].

In this study, sawdust and waste plastics were co-pyrolysed under controlled oxygen-free conditions to investigate their suitability for diesel-grade fuel production. The feedstocks were selected based on their favourable elemental composition and energy characteristics, which justified their use for thermochemical conversion. The experimental results demonstrated the successful production of diesel-grade liquid fuel from blended sawdust and waste plastics using a laboratory-scale fixed-bed batch reactor, confirming the technical feasibility of co-pyrolysis as a sustainable waste-to-energy technology.

II. IDENTIFY, RESEARCH AND COLLECT IDEA

The research idea was developed from the increasing global concerns over environmental pollution arising from the indiscriminate disposal of sawdust and waste plastics, coupled with the growing demand for sustainable alternative energy sources. A review of existing literature showed that pyrolysis and co-pyrolysis technologies have significant potential for converting biomass and plastic wastes into valuable liquid fuels while simultaneously reducing environmental pollution. The literature also revealed that although numerous studies have investigated biomass or plastic pyrolysis independently, relatively limited attention had been given to the combined utilisation of hardwood sawdust, softwood sawdust and waste plastics for the production of diesel-grade fuel using a locally designed fixed-bed reactor. This identified knowledge gap provided the basis for the present investigation.

Extensive literature was reviewed to understand the principles of pyrolysis, reactor configurations, feedstock characteristics, process variables affecting product yield, and fuel quality assessment. Particular attention was given to the thermal behaviour of sawdust and waste plastics, co-pyrolysis mechanisms, reactor design considerations, and the physicochemical properties required for diesel-grade fuels. Previous studies were critically examined to establish the current state of knowledge and identify opportunities for improving waste-to-energy conversion through reactor development and process optimisation.

The information obtained from the literature review guided the selection of suitable feedstocks, the choice of a laboratory-scale fixed-bed batch reactor, the experimental design, and the analytical methods used to evaluate the produced liquid fuel. This systematic review ensured that the research addressed an identified scientific gap while contributing to sustainable waste management and renewable fuel production.

III. STUDIES AND FINDINGS

The experimental investigation demonstrated that sawdust and waste plastics can be successfully converted into diesel-grade liquid fuel through controlled co-pyrolysis in a laboratory-scale fixed-bed reactor. Twenty-eight experimental runs were conducted using different feedstock blending ratios and reaction temperatures. The process consistently produced three major products: liquid diesel-grade oil, solid char, and non-condensable gases, confirming the technical feasibility of the co-pyrolysis process for waste-to-energy conversion.

Feedstock characterisation showed that the waste plastic possessed the highest carbon content (78.19%) and calorific value (31.94 MJ kg^{-1}), followed by Ububra-red hardwood with a carbon content of

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57.92% and calorific value of 17.89 MJ kg^{-1}, while Uda softwood recorded a carbon content of 54.68% and calorific value of 14.76 MJ kg^{-1}. These results confirmed that the selected feedstocks possessed adequate energy potential for thermochemical conversion into liquid fuel.

The study further established that diesel-grade fuel was successfully produced under all investigated operating conditions. The maximum liquid-fuel yield of 72 wt.% was obtained at a reaction temperature of 800 °C using an equal blending ratio (1:1:1) comprising 100 g of hardwood sawdust, 100 g of softwood sawdust, and 100 g of waste plastics. The findings also showed that product yield depended on both reaction temperature and feedstock composition.

The results also demonstrated that higher liquid-fuel yield did not necessarily correspond to higher energy content. Although the highest yield was obtained at 800 °C, some experimental runs conducted at lower temperatures produced liquid fuels with higher calorific values, indicating that fuel quality depended on the combined effects of temperature and feedstock interactions rather than yield alone.

Finally, comparison of the physicochemical properties of the produced liquid fuel with conventional diesel showed that the recovered oil possessed characteristics consistent with diesel-grade fuel, confirming the suitability of co-pyrolysis of sawdust and waste plastics as a viable pathway for producing alternative liquid transportation fuel while simultaneously addressing solid waste management challenges.

IV. CONCLUSION

This study demonstrated the technical feasibility of producing diesel-grade fuel through the co-pyrolysis of sawdust and waste plastics using a laboratory-scale fixed-bed batch reactor. The successful conversion of Uda softwood sawdust, Ububra-red hardwood sawdust and waste plastic feedstocks into liquid fuel, char and non-condensable gases confirms that co-pyrolysis is an effective waste-to-energy technology capable of recovering valuable energy from abundant lignocellulosic and plastic wastes.

Feedstock characterisation established that the selected materials possessed favourable carbon contents and calorific values, making them suitable for thermochemical conversion. The experimental programme further showed that diesel-grade liquid fuel was consistently produced under the investigated operating conditions, with the highest liquid-fuel yield of 72 wt.% obtained at 800 °C using an equal blending ratio (1:1:1) of hardwood sawdust, softwood sawdust and waste plastics. These findings demonstrate the strong potential of co-pyrolysis for converting locally available waste materials into valuable liquid transportation fuel.

The study also established that liquid-fuel yield alone is not a sufficient indicator of fuel quality, as higher oil yields did not always correspond to higher calorific values. This observation highlights the importance of considering both product quantity and energy characteristics when evaluating the performance of co-pyrolysis processes.

Overall, the results confirm that the co-pyrolysis of sawdust and waste plastics provides a practical and environmentally sustainable route for producing diesel-grade fuel while simultaneously addressing the challenges of biomass and plastic waste disposal. The technology therefore represents a promising approach for waste valorisation, renewable fuel production and environmental pollution mitigation, with potential for further development and scale-up for industrial applications.

APPENDIX

Fig. 1: Image of sawdust as feedstock for co-pyrolysis.

Fig 2: Powdered Char obtained from the co-pyrolysis process

Fig 3: Diesel Oil Product obtained from twenty-eight experimental runs of co-pyrolysis

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