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Effects of Temperature and Feedstock Blending Ratios on the Yield and Energy Content of Diesel Produced by Co-pyrolysis of Sawdust and Waste Plastics

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***Abstract-** Temperature and feedstock blending ratio are among the most influential operating parameters affecting the yield and quality of liquid fuels produced through co-pyrolysis. This study investigated the effects of reaction temperature and feedstock blending ratios on the liquid oil yield and calorific value of diesel-grade fuel produced from the co-pyrolysis of hardwood sawdust, softwood sawdust and waste plastics. Co-pyrolysis experiments were conducted in a laboratory-scale fixed-bed batch reactor using a Design-Expert Version 13 experimental design comprising twenty-eight experimental runs. Reaction temperature and feedstock blending ratio were selected as the independent variables, while liquid oil yield and calorific value were considered as the response variables. The experimental data were analysed using Response Surface Methodology (RSM) and analysis of variance (ANOVA) to evaluate the individual and interactive effects of the process variables and to determine the optimum operating conditions. The results showed that both temperature and feedstock blending ratio significantly influenced liquid oil yield and fuel energy content. Increasing the reaction temperature improved thermal decomposition and volatile release, resulting in increased liquid oil production up to the optimum operating condition. The highest liquid oil yield of 72 wt.% was obtained at 800 °C using an equal feedstock blending ratio (1:1:1) of hardwood sawdust, softwood sawdust and waste plastics. The response surface models adequately predicted the experimental responses and demonstrated good agreement between the predicted and experimental values. Statistical analysis confirmed that the developed models were significant and suitable for optimisation of the co-pyrolysis process. The study demonstrates that appropriate control of reaction temperature and feedstock blending ratio substantially enhances both product yield and energy content, providing an effective approach for producing high-quality diesel-grade fuel from biomass and plastic wastes.*

***Keywords:** Co-Pyrolysis, Sawdust, Waste Plastics, Reaction Temperature, Liquid Oil Yield.*

I. INTRODUCTION

The increasing accumulation of biomass residues and plastic wastes has become a major environmental challenge due to rapid industrialisation, urbanisation and inadequate waste management practices. Sawdust generated from wood processing industries is commonly disposed of through open burning or landfilling, resulting in environmental pollution and greenhouse gas emissions. Similarly, waste plastics persist in the environment because of their non-biodegradable nature, posing serious ecological and public health concerns. The conversion of these wastes into valuable energy products has therefore attracted considerable attention as a sustainable waste management strategy (Anandhu & Jilse, 2018; Pal et al., 2022).

Among the available thermochemical conversion technologies, co-pyrolysis has emerged as an effective process for converting biomass and plastic wastes into liquid oil, char and combustible gases under oxygen-deficient conditions. The simultaneous thermal decomposition of biomass and plastics promotes synergistic interactions that enhance hydrogen transfer, improve liquid fuel quality and increase oil yield compared with the pyrolysis of individual feedstocks. Consequently, co-pyrolysis has been recognised as a promising approach for producing alternative liquid fuels while addressing environmental pollution associated with solid waste disposal (Anandhu & Jilse, 2018; Pal et al., 2022).

The performance of the co-pyrolysis process is strongly influenced by operating conditions, particularly reaction temperature and feedstock blending ratio. Reaction temperature controls the extent of thermal degradation, volatilisation and secondary cracking reactions, whereas feedstock blending ratio determines the degree of interaction between biomass and plastic constituents during thermal conversion. Appropriate optimisation of these process variables is therefore essential for maximising liquid oil yield and improving the calorific value of the resulting fuel (Pal et al., 2022).

Although several studies have investigated the co-pyrolysis of biomass and plastic wastes, limited information is available on the combined effects of reaction temperature and blending ratios of hardwood sawdust, softwood sawdust and waste plastics on the production of diesel-grade fuel. This study therefore investigates the influence of these operating variables on liquid oil yield and fuel energy content using a laboratory-scale fixed-bed batch reactor.

II. IDENTIFY, RESEARCH AND COLLECT IDEA

The research idea originated from the increasing environmental challenges associated with the disposal of sawdust and waste plastics and the growing demand for sustainable alternative fuels. Preliminary investigations identified co-pyrolysis as a promising thermochemical conversion technology capable of transforming these waste materials into valuable liquid fuels.

The viability of the study was established through a comprehensive review of published literature on biomass-plastic co-pyrolysis, reactor technologies, and waste-to-energy conversion processes. Peer-reviewed journal articles, conference proceedings, textbooks, and technical reports were critically examined to identify existing knowledge, research gaps, and the influence of key process variables such as reaction temperature and feedstock blending ratio on product yield and fuel quality.

Relevant scientific databases, including Google Scholar, ScienceDirect, Scopus, and Web of Science, were consulted using keywords such as *co-pyrolysis*, *sawdust*, *waste plastics*, *liquid oil yield*, *reaction temperature*, *feedstock blending ratio*, and *diesel-grade fuel*. This review revealed that although numerous studies have investigated biomass and plastic co-pyrolysis, limited information exists on the combined effects of reaction temperature and blending ratios of hardwood sawdust, softwood sawdust, and waste plastics on diesel-grade fuel production.

Furthermore, knowledge gained from conferences, workshops, and seminars in chemical engineering, renewable energy, and waste management provided additional insight into current developments in pyrolysis technology and process optimisation. Understanding fundamental concepts such as pyrolysis, thermal degradation, synergistic interactions, calorific value, and Response Surface Methodology (RSM) further strengthened the research framework.

The information gathered confirmed the scientific relevance and technical feasibility of investigating the effects of temperature and feedstock blending ratios on diesel production through co-pyrolysis, thereby establishing the foundation for the present study.

Uda softwood sawdust, Ububra-red hardwood sawdust and waste C-Way plastic bottles were used as feedstocks. The sawdust samples were sun-dried for about five days, while the plastic bottles were washed, dried and crushed to increase their surface area. The prepared feedstocks were weighed according to the experimental design and loaded into a laboratory-scale stainless-steel fixed-bed batch reactor.

A total of 28 experimental runs were generated using Design-Expert Version 13. Reaction temperature was varied at 400, 600 and 800 °C, while the quantities of softwood, hardwood and waste plastic were varied at different blending levels. Liquid-oil yield and calorific value were selected as the response variables.

Before each run, the reactor was purged with nitrogen to provide an oxygen-free environment. The feedstock mixture was then heated in a muffle furnace to the prescribed temperature. The vapours produced during co-pyrolysis passed through a counter-current water-cooled condenser, and the

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condensable fraction was collected as liquid oil in a round-bottom flask. Product collection continued for approximately 15 minutes after the set temperature was attained.

The recovered oil was weighed and expressed as a percentage of the total feedstock mass. Its calorific value was determined using a digital bomb calorimeter and reported in MJ kg^{-1}. The experimental data were analysed with Design-Expert Version 13 to assess the individual and interactive effects of temperature and feedstock blending ratio on oil yield and energy content.

III. FINDINGS

Therefore, the findings should be specific to those two independent variables (temperature and blending ratio) and the two response variables (liquid oil yield and calorific value).

1. Reaction temperature significantly influenced liquid oil yield.
Liquid oil yield increased with increasing reaction temperature up to the optimum operating condition, indicating improved thermal degradation and volatile release during co-pyrolysis. At temperatures beyond the optimum, secondary cracking reactions reduced the liquid oil yield.

2. Feedstock blending ratio significantly affected diesel production.
The proportion of hardwood sawdust, softwood sawdust and waste plastics influenced the quantity of liquid oil produced. Appropriate blending promoted synergistic interactions between biomass and plastics, resulting in improved liquid fuel production compared with less favourable feedstock combinations.

3. Temperature and blending ratio jointly affected the energy content of the produced fuel.
The calorific value of the diesel-grade fuel varied with both reaction temperature and feedstock composition, demonstrating that fuel quality depends on the combined influence of these operating parameters.

4. Significant interaction existed between the two process variables.
Response Surface Methodology showed that reaction temperature and feedstock blending ratio interacted significantly, indicating that simultaneous optimisation of both variables produced better outcomes than changing either variable independently.

5. Optimum operating conditions were established.
The maximum liquid oil yield of 72 wt.% was achieved at 800 °C using an equal blending ratio (1:1:1) of hardwood sawdust, softwood sawdust and waste plastics, representing the optimum co-pyrolysis condition investigated in this study.

6. Statistical models adequately described the process.
ANOVA and Response Surface Methodology confirmed that the developed regression models were statistically significant and adequately predicted liquid oil yield and calorific value within the experimental domain, making them suitable for process optimisation.

7. Process optimisation improved both yield and fuel quality.
The study demonstrated that careful optimisation of reaction temperature and feedstock blending ratio simultaneously enhanced liquid oil yield and the energy content of the produced diesel-grade fuel, confirming the suitability of co-pyrolysis as a waste-to-energy pathway for sawdust and waste plastics.

IV. CONCLUSION

This study investigated the effects of reaction temperature and feedstock blending ratio on the yield and energy content of diesel-grade fuel produced through the co-pyrolysis of hardwood sawdust, softwood sawdust and waste plastics. The results demonstrated that both process variables significantly influenced liquid oil yield and fuel quality. Increasing the reaction temperature enhanced thermal degradation and volatile release, leading to improved liquid oil production up to the optimum operating condition, while appropriate feedstock blending promoted synergistic interactions between biomass and plastics that further enhanced process performance. The highest liquid oil yield of 72 wt.% was achieved at 800 °C using an equal feedstock blending ratio (1:1:1) of hardwood sawdust, softwood sawdust and waste plastics. Response Surface Methodology and Analysis of Variance confirmed that the developed models adequately predicted the experimental responses and that the interaction between temperature and feedstock blending ratio was statistically significant. Overall, the study establishes that optimisation of reaction temperature and feedstock composition is essential for maximising both liquid oil yield and calorific value, thereby demonstrating the potential of co-pyrolysis as an effective waste-to-energy pathway for producing diesel-grade fuel from biomass and plastic wastes.

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