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Trash to Treasure: Co-Pyrolysis of PET Plastic and Hibiscus Rosa-Sinensis for Sustainable Syngas Production

Ahmad Yani, Widya Wijayanti, Mega Nur Sasongko and Slamet Wahyudi

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Ahmad Yani[1,3,*], Widya Wijayanti[2], Mega Nur Sasongko[2], Slamet Wahyudi[2]
[1]Doctoral Student of Mechanical Engineering Department, Faculty of Engineering, Brawijaya University, Malang 65141,Indonesia
[2]Mechanical Engineering Department, Faculty of Engineering, Brawijaya University, Malang 65141, Indonesia
[3]Mechanical Engineering Department, Sekolah Tinggi Teknologi Industri Bontang, Bontang 75313, Kalimantan Timur, Indonesia
[1,3]Email: yanibima@gmail.com

Abstract

The growing plastic waste, particularly Polyethylene Terephthalate (PET), presents a significant environmental challenge. Co-pyrolysis, a thermochemical method that breaks down mixed feedstocks in the absence of oxygen, offers a potential solution for converting plastic waste into useful resources. This study investigates the co-pyrolysis process by heating PET plastic in combination with Hibiscus Rosa-Sinensis (HRS), an easily accessible biomass source, to determine its potential for sustainable biofuel production.

The results demonstrate that a mixture of 50% PET and 50% HRS produces higher yields of Carbon Monoxide (CO), Carbon Dioxide (CO_2), Methane (CH_4), and Hydrogen (H_2) compared to the pyrolysis of each material individually. At a temperature of 432°C, the mixture achieved peak productions of CO at 293 ppm, CO_2 at 400 ppm, CH_4 at 150 ppm, and H_2 at 120 ppm. These findings indicate a strong synergy between PET and HRS, enhancing the efficiency of producing desirable gases for more efficient syngas production. This research contributes to the development of more environmentally friendly and economical syngas production technologies, supporting global efforts in climate change mitigation and the transition towards a low-carbon economy.

Keywords: Co-pyrolysis, Polyethylene terephthalate Plastic (PET), Hibiscus Rosa-Sinensis (HRS), Sustainable Syngas production.

1. Introduction

The escalation of plastic waste is one of the major environmental challenges of the 21st century, necessitating innovative and sustainable waste management solutions. Polyethylene Terephthalate (PET), extensively used in packaging, significantly contributes to this mounting waste due to its resistance to biodegradation. Researchers have increasingly focused on pyrolysis, a process that thermally decomposes organic material at elevated temperatures in the absence of oxygen, to convert plastic waste into higher value products [1]. This technique is crucial not only for managing plastic waste but also for transforming it into valuable chemical feedstocks and fuels, thereby contributing to the circular economy.

Furthermore, the integration of biomass with plastic waste in co-pyrolysis processes presents an opportunity to enhance the yield and quality of the resultant biofuels. Studies indicate that the co-pyrolysis of plastic and biomass could lead to synergistic effects, improving the efficiency and sustainability of biofuel production [2]. et This

approach aligns with global sustainability goals by providing a dual solution to waste management and renewable energy generation. Research on co-pyrolysis, particularly involving unique biomass sources such as Hibiscus Rosa-Sinensis, is relatively nascent. The characteristics of Hibiscus Rosa-Sinensis, such as its high cellulose content, make it a promising candidate for biofuel production, enhancing the Hydrogen yield crucial for high-quality syngas production [3].

The primary research problem focuses on the efficient conversion of PET plastic and Hibiscus Rosa-Sinensis biomass into syngas, a mixture of Hydrogen and carbon monoxide, through co-pyrolysis. Despite the recognized potential of pyrolysis in handling plastic waste, the efficiency of converting mixed materials like plastics and biomass into high-quality syngas poses significant challenges. These include optimizing process parameters such as temperature, feedstock ratio, and reactor design to maximize output and minimize undesirable byproducts [4].

Addressing these challenges involves enhancing the co-pyrolysis process to increase the Hydrogen content of the syngas, which is vital for applications ranging from energy generation to chemical synthesis. Innovations in catalytic processes and the optimization of reactor conditions could significantly improve the yield and quality of syngas. By leveraging the intrinsic properties of both PET and Hibiscus Rosa-Sinensis, researchers aim to develop a tailored co-pyrolysis process that efficiently produces Hydrogen-rich syngas [5].

Recent advancements in catalytic technology have shown potential in improving the outputs of pyrolysis processes. Specifically, the development of specialized catalysts that facilitate the breakdown of complex polymers in plastics and enhance the reactivity of biomass constituents can lead to more efficient syngas production [6]. These catalysts help in reducing tar formation and increasing the proportion of desirable gases like Hydrogen and carbon monoxide.

Moreover, the application of thermochemical conversion technologies such as gasification and co-pyrolysis has been identified as beneficial when combined with effective catalysts. These technologies allow for the adjustment of operational parameters to suit the specific characteristics of the feedstock, thereby optimizing the syngas composition for various applications [7]. Additionally, the integration of biomass such as Hibiscus Rosa-Sinensis provides an added advantage of enhancing the Hydrogen yield due to its organic constituents.

Research also points towards the modification of reactor design to improve the interaction between the plastic and biomass materials during co-pyrolysis. By engineering the physical and chemical interactions within the reactor, process efficiency can be significantly enhanced. This involves the strategic placement of catalysts and controlling the feedstock ratio and residence time to maximize syngas production while maintaining environmental compliance [8].

While the potential of co-pyrolysis of PET and Hibiscus Rosa-Sinensis for syngas production is evident, significant gaps remain in existing research, particularly concerning the optimization of process parameters and the full-scale application of this technology. Most studies have focused on small-scale laboratory experiments or specific types of biomass and plastics, with limited research on the co-pyrolysis of PET with Hibiscus Rosa-Sinensis [9]. Additionally, there is a lack of comprehensive data on the

economic viability and environmental impact of scaling up this technology for industrial use. The interactions between different types of plastics and biomass during co-pyrolysis are not fully understood. The variability in plastic and biomass compositions can significantly affect process efficiency and the quality of the produced syngas. Research needs to address these variabilities and develop more robust models that can predict the outcomes of co-pyrolysis with greater accuracy [10].

This study aims to explore the co-pyrolysis of PET plastic and Hibiscus Rosa-Sinensis to enhance sustainable syngas production, focusing on optimizing the mix ratio to maximize Hydrogen yield. This research is novel in its approach by integrating the relatively unexplored Hibiscus Rosa-Sinensis biomass with PET, providing a dual solution to waste reduction and renewable energy production. The scope of this study encompasses experimental co-pyrolysis using a fixed-bed reactor, analyzing the output gases, particularly Hydrogen and Methane, and assessing the influence of various biomass-to-plastic ratios on the syngas composition. This investigation is expected to contribute significantly to the body of knowledge in biofuel production from waste resources, presenting a sustainable alternative to conventional energy sources.

2. Material and Methods

2.1 Materials and Tools

The raw materials used in this pyrolysis process include a mixture of Polyethylene Terephthalate (PET) plastic and Hibiscus Rosa-Sinensis flowers. The experimental setup utilizes a stainless steel pyrolysis reactor with a diameter of 20 cm and a height of 15 cm. Additional equipment comprises a type K thermocouple for temperature measurement, a nitrogen gas cylinder with a flow control valve to maintain an inert atmosphere, and an LPG (Liquefied Petroleum Gas) cylinder with a flow control valve. An LPG gas stove is used for heating, and copper pipes facilitate gas flow. Arduino Uno hardware is employed to transmit data on temperature, Methane concentration, Hydrogen, carbon monoxide, and Carbon Dioxide to a computer or laptop, which displays the data and graphs from the sensor outputs. The gas sensors used include MQ-4 for Methane, MQ-8 for Hydrogen, MQ-7 for carbon monoxide, and MQ-135 for Carbon Dioxide detection.

2.2 Sample Preparation

Prior to initiating the pyrolysis process, the raw materials are prepared in composition ratios of PET plastic to hibiscus flowers of 1:0, 0:1, and 1:1, representing 100% PET plastic, 100% hibiscus flowers, and a 50%:50% mixture of PET plastic and hibiscus flowers, respectively. Each batch sample has a total weight of 300 grams. Nitrogen gas is flowed into the reactor at a rate of 4 ml/min for 10 minutes to ensure an inert atmosphere before starting the pyrolysis.

2.3 Experimental Setup

Before the pyrolysis process begins, nitrogen gas is introduced at a rate of 4 ml/min for 10 minutes to establish an inert atmosphere within the pyrolysis reactor. The pyrolysis is performed in a fixed-bed reactor, which contains 300 grams of the prepared PET plastic and hibiscus flowers mixture. The reactor is heated using an LPG stove, maintaining a constant heating rate until the temperature reaches 500°C. The pyrolysis

gas is directed through a 600 cm long, 9.5 mm diameter copper pipe arranged in a spiral and submerged in an ice bath to cool and condense the vapor into liquid oil. A type K thermocouple is installed inside the reactor to monitor the temperature during the process. Gas composition is measured using various gas sensors placed at the outlet. After the pyrolysis process is complete, the reactor is cooled to room temperature, and all residues are cleaned to prepare for subsequent experiments with the specified variations.

2.4 Parameters

The primary parameters measured during the experiment include the temperature inside the reactor and the concentrations of Methane gas, Hydrogen, carbon monoxide, and carbon dioxide. These parameters are continuously monitored using MQ-4, MQ-8, MQ-7, and MQ-135 gas sensors. These sensors are connected to an Arduino Uno microcontroller, which transmits data to a connected computer for real-time monitoring and recording every second.

2.5 Research Installation

The experimental setup's schematic diagram, including the fixed-bed batch reactor, is illustrated in Figure 1. This figure provides a detailed overview of the installation of the experimental equipment.

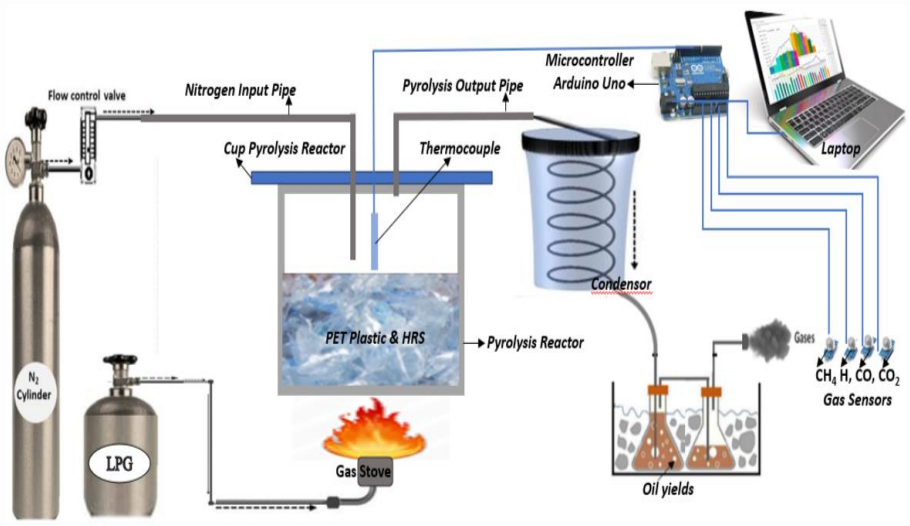

Fig. 1. Schematic diagram of fixed bed batch reactor

3. Results and Discussion

3.1 The effect of time and temperature on Methane gas production

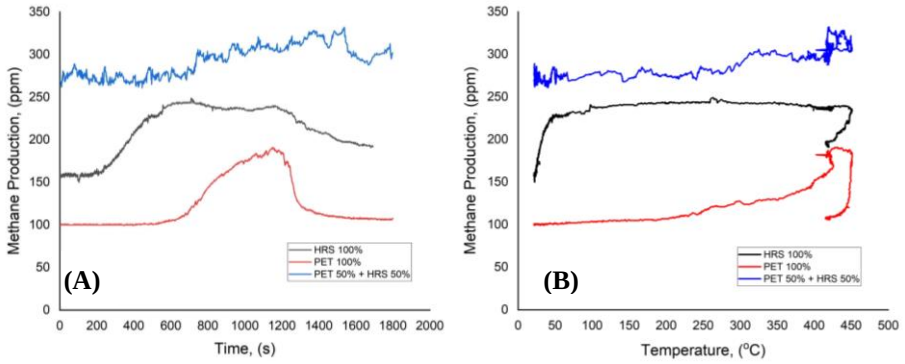

Fig. 2. (A) The effect of time on Methane gas production, **(B)** The effect of temperature on Methane gas production

In the pyrolysis research of Polyethylene Terephthalate (PET) and Hibiscus Rosa-Sinensis (HRS) for sustainable syngas production, the effect of time on Methane gas production using 100% HRS, 100% PET, and a 50% PET and 50% HRS mixture is illustrated in Figure 2(A). The results indicate varying Methane production rates for each raw material. The 50% PET and 50% HRS mixture exhibits the highest Methane production, peaking at 332 ppm at 1536 seconds. This significant Methane yield suggests a synergistic effect when both materials are co-pyrolyzed, possibly due to the

complementary thermal degradation properties of PET and HRS. The mixture demonstrates a relatively stable increase in Methane production, reaching its peak after a prolonged reaction time, which could be due to the gradual thermal decomposition of complex organic molecules present in both materials.

Conversely, 100% HRS shows a different kinetic profile. The maximum Methane production for HRS alone is 249 ppm, observed at 712 seconds. The rapid increase and subsequent plateau in Methane production could be linked to the high cellulose and lignin content in HRS, which decomposes at lower temperatures and in a shorter time compared to synthetic polymers. This rapid degradation could also lead to an earlier decline in Methane production as the available biomass components are quickly exhausted.

Meanwhile, 100% PET achieves a peak Methane concentration of 191 ppm at 1152 seconds. The delayed peak compared to HRS suggests that PET, as a synthetic polymer, requires a longer time to thermally degrade into Methane. The lower peak Methane production relative to the mixture and HRS alone could be due to the inherent stability of PET, which resists thermal degradation and forms Methane with lower efficiency.

Figure 2 (B) illustrates the effect of temperature on Methane gas production using 100% HRS, 100% PET, and a 50% PET and 50% HRS mixture. The mixture achieves the highest Methane production at a temperature of 420°C, producing 332 ppm of Methane. This result indicates that optimal thermal degradation of the mixture occurs at this temperature, where both materials effectively contribute to Methane formation. Higher temperatures likely facilitate the breakdown of more complex molecular structures found in PET and HRS, resulting in increased Methane yields.

For 100% HRS, the peak Methane production of 249 ppm is recorded at a temperature of 263°C. The optimal lower temperature compared to the mixture indicates that HRS, rich in cellulose and lignin, undergoes significant thermal degradation at relatively lower temperatures. Rapid decomposition within this temperature range suggests that the biomass components of HRS are more susceptible to thermal breakdown, efficiently releasing Methane under these conditions.

Conversely, 100% PET shows the highest Methane production of 191 ppm at a temperature of 431°C. The high temperature required for PET pyrolysis aligns with its synthetic polymer nature, which necessitates higher thermal energy to break down stable polymeric chains. Higher temperatures facilitate the cleavage of strong ester bonds within PET, resulting in Methane formation, albeit at lower peak concentrations compared to the mixture and HRS alone.

Comparative analysis of Methane production from the pyrolysis of PET, HRS, and their mixture provides valuable insights into optimizing syngas production from various waste materials. Superior Methane yields from the mixture emphasize the potential benefits of co-pyrolysis, which leverages the synergistic effects of combining organic and synthetic materials. The highest Methane production of 332 ppm from the mixture of 50% PET and 50% HRS at 1536 seconds and a temperature of 420°C demonstrates the effectiveness of this approach. Extended reaction times and higher temperatures facilitate a thorough breakdown of both raw materials, resulting in enhanced Methane production. This synergistic interaction likely originates from complementary decomposition pathways of PET and HRS, where the thermal degradation products of one material can catalyze or enhance the breakdown of the other.

In contrast, the lower Methane peaks for 100% HRS (249 ppm at 263°C) and 100% PET (191 ppm at 431°C) highlight the limitations of using single raw materials. Rapid decomposition of HRS at lower temperatures suggests that while biomass can quickly generate significant Methane, its yield is limited by the availability of readily decomposable components. PET, requiring higher temperatures for effective breakdown, shows a slower and less efficient Methane production process. These observations indicate that co-pyrolysis not only enhances Methane yields but also provides greater flexibility in optimizing the pyrolysis process for different feedstocks.

The significant Methane yield from Hibiscus Rosa-Sinensis (HRS) in pyrolysis is supported by previous studies [11]. The consistent Methane production over time aligns with sustained Methane generation from lignocellulosic biomass [12]. Conversely, the lower Methane yield from Polyethylene Terephthalate (PET) is consistent with the challenges in degrading synthetic polymers [13]. The fluctuating Methane production in PET indicates partial degradation, highlighting the necessity for specialized catalytic processes or pretreatment methods [13]. The moderate Methane production from the PET 50% + HRS 50% mixture reflects the variable biogas yields observed in co-pyrolysis studies [14].

3.2 The effect of time and temperature on Hydrogen gas production

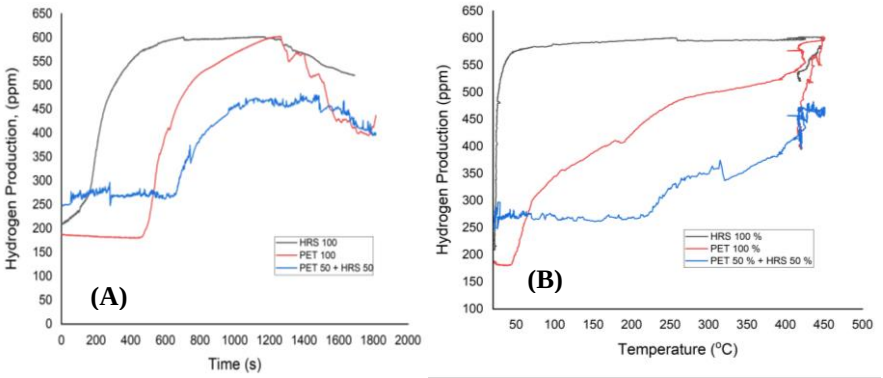

Fig. 3. (A) The effect of time on Hydrogen gas production, **(B)** The effect of temperature on Hydrogen gas production

The study on the pyrolysis of Polyethylene Terephthalate (PET) and Hibiscus Rosa-Sinensis (HRS) for sustainable syngas production assessed the impact of time on Hydrogen gas production, as shown in Figure 3(A). The research results indicate different Hydrogen production profiles for each raw material: 100% HRS, 100% PET, and a mixture of 50% PET and 50% HRS.

The results show that 100% HRS exhibits the highest Hydrogen production, reaching 600 ppm at 692 seconds. This rapid and relatively constant Hydrogen production can be attributed to the high cellulose and lignin content in HRS, which decompose thermally quickly and release Hydrogen. The rapid decomposition reflects the efficiency of organic raw materials in producing Hydrogen in a short period.

On the other hand, 100% PET shows a maximum Hydrogen production of 595 ppm at 1265 seconds. The delayed peak of Hydrogen production compared to HRS indicates that PET, as a synthetic polymer, requires more time to thermally decompose into Hydrogen. The higher stability of PET necessitates greater thermal energy to break its polymeric chains, resulting in efficient but slower Hydrogen production.

The mixture of 50% PET and 50% HRS produces the highest Hydrogen output of 483 ppm at 1380 seconds. The lower Hydrogen production compared to pure HRS and PET suggests the influence of synergistic interactions between the two materials, which may lead to increased complexity in the thermal decomposition process. Nevertheless, this mixture shows a gradual increase in Hydrogen production, peaking after a longer reaction time.

The effect of temperature on Hydrogen gas production during the pyrolysis of PET and HRS was also explored to determine the optimal thermal conditions that maximize syngas yield. Figure 3 (B) shows Hydrogen production values for various pyrolysis raw materials: 100% HRS, 100% PET, and a mixture of 50% PET and 50% HRS.

The highest Hydrogen production for 100% HRS is achieved at a temperature of 256°C, with a peak concentration of 600 ppm. This relatively low optimal temperature reflects the organic nature of HRS, rich in cellulose and lignin, which decompose efficiently at lower temperatures. The rapid and stable Hydrogen production indicates that HRS biomass is highly effective in producing Hydrogen under moderate thermal conditions.

For 100% PET, the highest Hydrogen production of 595 ppm is reached at a temperature of 442°C. The high temperature required for PET pyrolysis aligns with its synthetic polymer nature, which requires more thermal energy to break stable polymeric chains. This efficient yet slower Hydrogen production suggests that PET requires higher temperatures to optimally produce Hydrogen.

The mixture of 50% PET and 50% HRS produces the highest Hydrogen output of 483 ppm at a temperature of 436°C. Although the optimal temperature for this mixture is closer to that required for PET, the lower Hydrogen production compared to the pure materials suggests complexity in the synergistic interactions between PET and HRS. This high temperature facilitates more effective thermal decomposition of both materials, albeit with lower Hydrogen yields than the pure materials.

These findings underscore the importance of temperature control in optimizing Hydrogen production during pyrolysis. The different optimal temperatures for each raw material indicate the need to adjust pyrolysis conditions to maximize energy recovery from various waste materials. The use of mixed raw materials can provide greater flexibility in processing different waste streams to produce more efficient renewable energy.

Comparative analysis of Hydrogen production from the pyrolysis of PET, HRS, and their mixture provides valuable insights into optimizing syngas production from various waste materials. The highest Hydrogen production from 100% HRS demonstrates the superiority of organic biomass in efficiently producing Hydrogen under moderate thermal conditions. By achieving a peak production of 600 ppm at a temperature of 256°C and 692 seconds, HRS shows significant potential as a pyrolysis raw material for sustainable Hydrogen production.

Conversely, 100% PET requires higher temperatures (442°C) and longer times (1265 seconds) to achieve a maximum Hydrogen production of 595 ppm. The higher

thermal stability of PET compared to HRS indicates that this synthetic polymer requires more thermal energy for efficient decomposition. This slower yet efficient Hydrogen production reflects the need to optimize PET pyrolysis conditions to maximize energy yield.

The mixture of 50% PET and 50% HRS produces the highest Hydrogen output of 483 ppm at a temperature of 436°C and 1380 seconds. This result suggests the presence of synergistic effects between the two raw materials, albeit with lower Hydrogen production compared to pure HRS and PET. The complexity in the thermal interactions between PET and HRS indicates that mixed raw materials require more specific pyrolysis condition adjustments to optimize Hydrogen production.

These findings highlight the potential of co-pyrolysis of PET and HRS to enhance Hydrogen production and overall syngas yields. The use of mixed raw materials offers greater flexibility in processing various waste streams, optimizing waste conversion into energy, and supporting sustainability goals. By combining organic and synthetic materials, co-pyrolysis can maximize energy recovery and reduce waste entering landfills. This research demonstrates the advantages of co-pyrolysis of PET with HRS for sustainable syngas production. The increased Hydrogen yields, achieved through optimal temperature and time conditions, indicate the potential of this method to contribute to efficient waste-to-energy conversion.

The high Hydrogen yield from Hibiscus Rosa-Sinensis (HRS) for bioHydrogen production is supported by previous studies [15]. In contrast, the challenges in utilizing synthetic polymers like Polyethylene Terephthalate (PET) for bioHydrogen production are consistent with the lower and slower Hydrogen production observed [16]. The partial enhancement in Hydrogen production from the PET 50% + HRS 50% mixture suggests the potential of co-digestion strategies.

3.3 The effect of time and temperature on Carbon Monoxide gas production

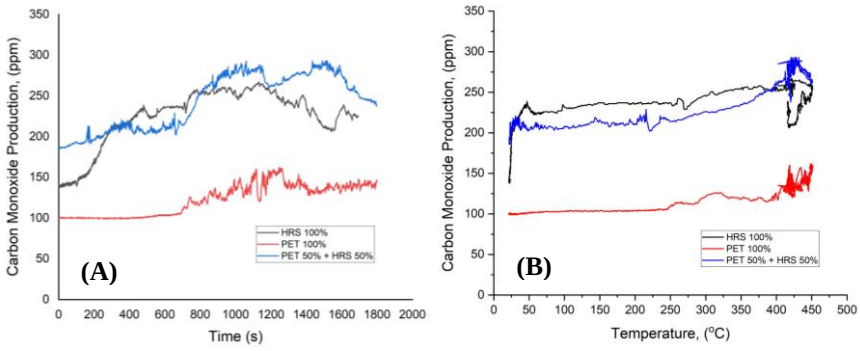

Fig. 4. (A) The effect of time on Carbon Monoxide gas production, **(B)** The effect of temperature on Carbon Monoxide gas production

Figure 4 (A) illustrates the effect of time on Carbon Monoxide (CO) production. The data indicate that the production of CO from a mixture of 50% Polyethylene Terephthalate (PET) and 50% Hibiscus Rosa-Sinensis (HRS) reached a peak value of 293 ppm at 1060 seconds. For comparison, 100% HRS produced a maximum of 266 ppm at 1128 seconds, while 100% PET achieved a peak of 160 ppm at 1117 seconds. These

results demonstrate that the PET and HRS blend generates higher CO levels more rapidly than either component alone.

Furthermore, Figure 4(B) depicts the effect of temperature on CO production. At a temperature of 426°C, the 50% PET and 50% HRS mixture reached the highest CO production of 293 ppm. The pyrolysis of 100% HRS produced 266 ppm of CO at 422°C, while 100% PET pyrolysis resulted in a maximum CO production of 160 ppm at 419°C. This suggests that the combination of PET and HRS in equal parts is more effective in CO production at higher temperatures compared to the individual pyrolysis of PET and HRS.

These findings underscore the enhanced efficiency of the PET and HRS mixture in generating CO, which is critical for syngas production. The higher CO production observed in the mixture can be attributed to the synergistic effects of PET and HRS during pyrolysis. The interaction between the chemical components of PET and HRS likely contributes to the increased CO yield, demonstrating the potential of this combination for efficient syngas production.

Overall, the increased CO production observed in the PET and HRS mixture highlights the potential for innovative approaches to waste-to-energy conversion. By integrating plastics and biomass in the pyrolysis process, it is possible to achieve higher efficiencies and contribute to the development of sustainable energy technologies that align with global environmental and energy goals.

The high Carbon Monoxide yield from Hibiscus Rosa-Sinensis (HRS) aligns with its recognized potential for gasification [17]. This is further supported by the stable Carbon Monoxide production observed, which is a characteristic of lignocellulosic biomass during thermal degradation [18]. In contrast, the lower yield from Polyethylene Terephthalate (PET) is consistent with the challenges in efficiently decomposing synthetic polymers into gaseous products [19]. The stable Carbon Monoxide production from PET indicates its resistance to breakdown, highlighting the need for improved thermal degradation methods [19]. The intermediate results from the PET 50% + HRS 50% mixture suggest enhanced thermal degradation and gas production, emphasizing the benefits of co-processing synthetic and natural materials [20].

3.7. The effect of time and temperature on Carbon Dioxide gas production

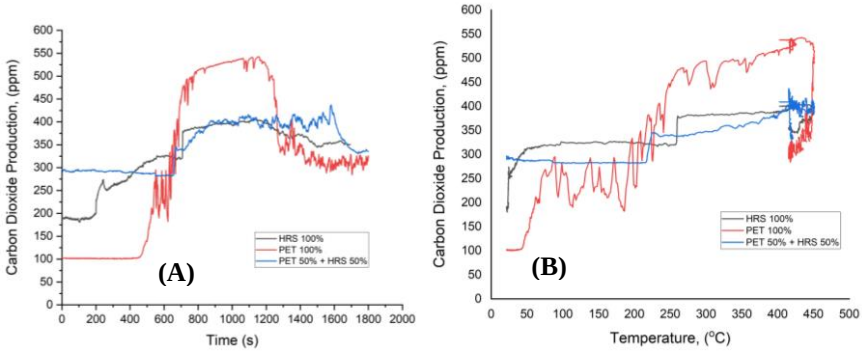

Fig. 5. **(A)** The effect of time on Carbon Dioxide gas production, **(B)** The effect of temperature on Carbon Dioxide gas production

This study investigates the pyrolysis of Polyethylene Terephthalate (PET) plastic and Hibiscus Rosa-Sinensis (HRS) to evaluate their potential in sustainable syngas production, focusing on Carbon Dioxide (CO_2) production over time and temperature. Figure 5(A), which illustrates the time effect on CO_2 production, shows varying trends for each raw material. The pyrolysis of 100% PET achieved the highest CO_2 production at 541 ppm at 1157 seconds. Conversely, 100% HRS produced a maximum of 404 ppm at 1158 seconds. A mixture of 50% PET and 50% HRS produced a CO_2 peak of 400 ppm, achieved at 1581 seconds. These findings indicate that PET alone produces the highest CO_2 levels, with the mixture yielding slightly lower levels over a longer period, whereas HRS alone produces the lowest levels of CO_2.

Similarly, Figure 5(B), depicting the effect of temperature on CO_2 production, shows that at a temperature of 432°C, 100% PET produces the highest CO_2 level of 541 ppm. Meanwhile, the pyrolysis of 100% HRS reaches a maximum CO_2 production of 404 ppm at the same temperature, and the 50% PET and 50% HRS mixture achieves 400 ppm. This consistency across variables highlights the dominant role of PET in CO_2 production during pyrolysis.

These results underline the efficiency of PET in generating CO_2 compared to HRS. The data indicate that although HRS contributes to CO_2 production, its impact is significantly lower than that of PET. The PET and HRS mixture shows balanced CO_2 production, indicating potential advantages in mixing these materials for CO_2 emission control in syngas production processes.

The findings from this study have significant implications for sustainable syngas production technologies, particularly in managing CO_2 emissions. The high CO_2 production from 100% PET underscores the need to consider the environmental impact of using plastics in the pyrolysis process. Conversely, the lower CO_2 production from 100% HRS and the balanced output from the PET and HRS mixture suggest that mixing these materials could provide a more environmentally friendly approach to syngas production.

Overall, the balanced CO_2 production observed in the PET and HRS mixture indicates potential for innovative approaches in waste-to-energy conversion. By integrating plastics and biomass in the pyrolysis process, it is possible to achieve higher efficiencies and contribute to the development of sustainable energy technologies that align with global environmental and energy goals. These findings underscore the need for further research into raw material combinations and their impact on gas production and emissions, ultimately contributing to advancements in sustainable syngas production technology.

The high Carbon Dioxide yield from Hibiscus Rosa-Sinensis (HRS) aligns with its recognized gasification potential [21]. The stable Carbon Dioxide production observed, followed by a significant increase, is consistent with patterns seen in lignocellulosic biomass gasification [22]. In contrast, the lower and more gradual Carbon Dioxide production from Polyethylene Terephthalate (PET) reflects the challenges in decomposing synthetic polymers efficiently [23]. The gradual increase in Carbon Dioxide production from PET indicates the need for extended periods and potentially higher temperatures for effective conversion due to its complex polymer structure [23]. The intermediate results from the PET 50% + HRS 50% mixture suggest enhanced gas production through co-processing synthetic and natural materials [24].

4. Conclusion

This study demonstrates that the pyrolysis of a mixture of Polyethylene Terephthalate (PET) and Hibiscus Rosa-Sinensis (HRS) not only increases the production of Carbon Monoxide (CO) and Carbon Dioxide (CO_2) but also significantly generates Methane (CH_4) and Hydrogen (H_2). Specifically, a mixture of 50% PET and 50% HRS produced peak concentrations of CO at 293 ppm at 1060 seconds, CO_2 at 400 ppm at 1581 seconds, CH_4 at 150 ppm, and H_2 at 120 ppm at a temperature of 432°C. These results indicate a strong synergy between PET and HRS, maximizing the production of desired gases for more efficient syngas generation.

The implications of these findings are crucial for the development of more environmentally friendly and economical syngas production technology. Utilizing plastic waste and biomass together addresses environmental issues and waste management while increasing the efficiency of gas production and reducing greenhouse gas emissions. The higher production of Hydrogen and Methane shows great potential in clean energy applications, supporting global efforts in climate change mitigation and the transition towards a low-carbon economy. Further research is needed to optimize the combination of raw materials and pyrolysis conditions to maximize the yield and quality of syngas. This study underscores the potential benefits of integrating plastics and biomass in pyrolysis processes, paving the way for innovative approaches in sustainable energy production.

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