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Assessment of the effect of mixing polystyrene (PS) with sawdust (SD) on copyrolysis products

ABSTRACT

The co-pyrolysis process between biomass and solid waste especially plastics has attracted significant attention in research studies as a means to enhance both the quantity and quality of bio-oil derived from biomass decomposition. In this research paper, the PS/SD co-pyrolysis was carried out for six different concentrations ranging from 0% to 100%, with increments of 20% PS, inside a small laboratory reactor at 450 ^oC and heating rate (HR) of 20.5 ^oC min^{-1}. Results showed that an increase in the proportion of PS in the blend resulted in a higher bio-oil outcome. The highest bio-oil yield was recorded at the 80PSSD blend, indicating that co-pyrolysis had a positive effect on oil production in all mixtures. The most significant positive impact was observed at the 20PSSD blend, reaching [+11.54]. Conversely, gas production showed a negative effect, with gas quantities lower than expected for all mixtures, and the most significant negative impact was at 20PSSD, with a decrease of [-11.8]. As for char outcome, there was a minimal increase in its quantity, with the highest positive impact of charcoal observed at 80PSSD, reaching [+3.44]. Consequently, it can be observed that the quantity of char produced is not significantly affected by the co-blending process.
***Keywords**: PS plastic, biomass, sawdust, co-pyrolysis, bio-oil.*

1. INTRODUCTION

The global population growth and expanding industrial operations have substantially increased energy consumption. The continued reliance on fossil fuels (FF) as the primary energy source has resulted in heightened pollution, significant greenhouse gas emissions, and considerable impacts on climate change, raising environmental and social concerns [1]. Despite the growing adoption of electric power as a cleaner alternative in various industrial applications, the dependence on FF remains inevitable [2].

Due to these previous challenges, many countries are shifting their policies towards the production of bio-fuels extracted from renewable energy sources to serve as a viable alternative to FF.

Biomass has been included on this list of energy sources, with reliance on biomass accounting for 70% of primary energy sources [3]. Biomasses, including materials like wood, crop residues, agricultural waste, energy crops, and organic industrial and household waste.

Biomasses can serve as a renewable energy source through processes like combustion, gasification, or fermentation. While bio-fuels from biomass are already in use as alternative energy sources, it's crucial to improve their low combustion efficiency to ensure their sustainable utilization in the future [4].

Nomenclature list			
20PSSD	20%PS+80%SD	HR	Heat rate
40PSSD	40%PS+60%SD	PS	Polystyrene
60PSSD	60%PS+40%SD	NSE	Negative synergistic effect
BOC	Bio-oil content	SD	Saw dust
FF	Fossil fuel	SWM	Solid waste materials

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Commercially implemented liquid bio-fuels suffer from significant disadvantages, such as a substantial proportion of oxygenated compounds may be up to 60%, limited thermal stability, increased viscosity, and acidity issues, resulting biofuel has low heating value [5]. Lately, numerous research studies have been conducted to enhance the efficiency of liquid biofuel, and one of the most significant strategies is the effectiveness of thermo chemical methods as pyrolysis, anaerobic digestion, and gasification [6]. However, the most efficient technique is pyrolysis, it improves the properties of liquid, gas, and solid fractions of pyrolysis simultaneously, the main product is BOC, which can be refined into biodiesel and blended with gasoline [7].

Although the oil obtained from plastic pyrolysis has some good characteristics similar to conventional fuels in internal combustion engines, such as high heating value and hydrocarbon content, which partially solves the issues mentioned earlier regarding bio-oils, these oils contain a high percentage of polycyclic aromatic hydrocarbons (PAHs), which pose a serious health risk to humans (cancer). This restricts the widespread use of this technology or requires costly and complex pre-treatments [8].

The utilization of co-pyrolysis (biomass with SWM) especially waste plastic shows great potential as it can effectively handle waste materials and transform them into valuable fuels or chemicals. This process involves using plastics as a catalyst of sorts to enhance the production of aromatic hydrocarbons and reduce the presence of oxygenated compounds in the liquid portion. Consequently, employing waste biomass (such as wood chips, sawdust, and branches) along with discarded plastics offers a promising approach to address various challenges [9]. Until now, scientific studies efforts have been dedicated to discovering the most favorable conditions as (feedstock type, pyrolysis mechanisms, various parameters processes, and product yield) to use the co-pyrolysis process widely scale.

The authors [10], PS/SD co-pyrolysis was conducted in FBR. The study recorded the highest bio-oil yield of 83.86% for the 75% wt PS blend; however, the highest PSE in the bio-oil yield was observed (62.33% wt, against 31.39% wt for SD alone) for the 25% wt PS blend with a value of +17.44 between the expected and experimental values. On the other hand, the NSE in the production of bio-gas for all blends ratios. The study also showed that adding PS to the mixture increased HHV to 40.21 MJ/kg while reducing the O_2 content and increasing the aromatic compounds of the bio-oil fuel.

The authors in [11] examined the effect of increasing PS content on the co-pyrolysis with co-gasification of paper biomass using a lab-scale batch reactor at a temperature 1173 K. Their results showed a positive effect on the increase in the bio-gas yield with decreasing in the char fraction. Additionally, there was an improvement in the gas quality, with the hydrogen fraction almost doubling as the PC “polystyrene content” increased from 10% to 30%.These results can be attributed to the fact that the volatile materials from the paper pyrolysis increased the bio-gas PS pyrolysis, slowed the reaction rate, leading to a decrease in the charcoal yield during co-pyrolysis.

The study [12], the researchers studied the co-pyrolysis of PS and CS ”corn stalk” biomass at 500°C in a fixed reactor and found that the maximum oil yield was obtained at a 1:3 CS to PS blend without catalyst, where synergistic effect was observed 5.75 during co-pyrolysis process.

Sanahuja et al. [13] evaluated the effect of PS/GS(grape seeds) co-pyrolysis by FBR, and they recorded that a positive synergistic effect PSE for bio-oil yield when PS in the range (5% to 40%) in the blend, also the study showed that a clear improvement in the bio-oil quality, which can be summarized as follows, maximum reduction in oxygen content to 6.3% wt of 40% wt PS compared to 14% wt GS biomass, increasing heating value to 39 MJ/kg of 20% and 40% wt PS compared to 36 MJ/kg of GS alone, increasing in PH value at 6 for 40% PS compared usually to 2-3 PH values of GS alone, which negatively affects the fuel efficiency and engine components.

In another study [14], a high calorific value was recorded 41.29 MJ/kg for the bio-oil produced from co-pyrolysis PS/ NES (non-edible seeds), using fixed reactor at a blend of 1:2 respectively, The study mentioned that this was due to an increase in the total heat flow of the co-pyrolysis process. Reduction in the oxygen content and viscosity, thereby improving the efficiency of the resulting oil compared to that produced from Karanja & Nijer NES. The authors concluded that co-pyrolysis of biomass and waste polystyrene has a successful economic direction for both plastic waste management and converting biomass to energy.

2. MATERIALS AND EXPERIMENTAL SET-UP

2.1. Feed-stocks

The co-pyrolysis process evaluated the effect of waste PS adding on SD biomass materials as six blends (0PSSD to 100PSSD) with increasment 20% of PS, SD was obtained from the wood feathers resulting from furniture manufacturing processes in carpentry workshops, Faculty of

Engineering, Minia University, Egypt The SD was a mixture of different proportions of beech wood and white musky sawdust was cut into small homogeneous samples about 1 to 2 mm average size, while PS has been collected from single-use dish waste from candy and fast food stores, then cleaned and cut into small pieces, approximately 1 to 2 cm^2 in size.

2.2. Experimental set-up

The previous two pure and four its blends feedstocks were tested in a small-scale pyrolysis reactor to convert plastic waste into liquid oil, gas, and char products Fig. (1). The reactor cylinder was made of cast iron with a thickness of 6 mm and wrapped with a loop of an electric heater, which was 2.5 meters in length and had a capacity of 3 kW. The reactor had a height of 285 mm, a diameter of 101.5 mm, and a capacity of 2.2 liters (Table 1). It was connected to a 20 mm diameter tube that passed inside a condenser tube with a length of 550 mm and a diameter of 3.5 mm. The condenser tube was equipped with two entrances for cooling water, with the bottom serving as the entry and the top as the exit. The vapors of plastic waste produced in the heating chamber at high temperatures were condensed into liquid oil in the condenser tube. Water circulated through the condenser tube at a flow rate of 1.5 L/min., and the condensed liquid oil was collected in the oil collector tank located at the bottom of the system. The uncondensed products (gases) were exhausted outside the system.

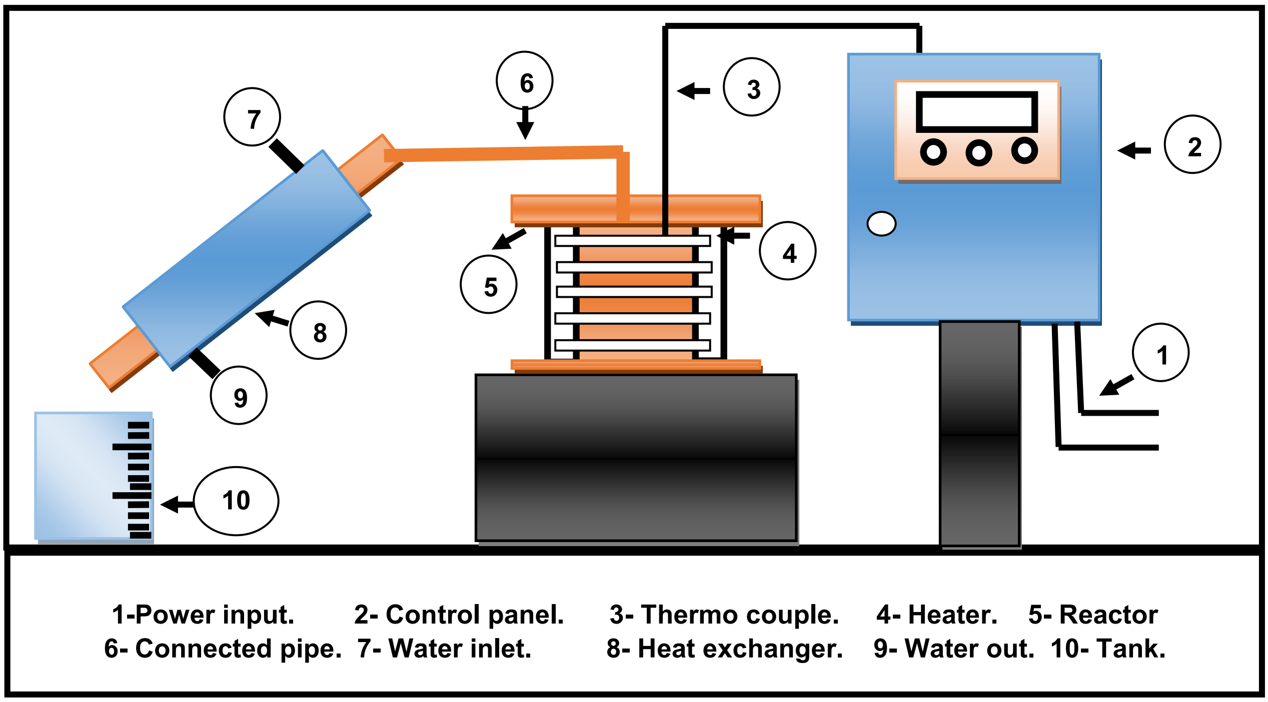

Figure 1.The schematic set up of the pyrolysis unit

Slika 1. Šematski prikaz jedinice za pirolizu

Table1. Reactor components parameters

Tabela 1. Parametri komponenti reaktora

Component		Features
Reactor properties	Long	285 mm
	Out diam.	101.5 mm
	Thickness	6 mm
	Capacity	2.2 lit
Thermocouple		type K
Heater		2.5 m & 3 kW
condenser diameter		63.5 mm
condenser length		55cm

3. RESULTS

3.1. Pure PS, and SD pyrolysis

The current experiment was evaluated the SD pyrolysis at 450 ^{o}C, 20.5 ^{o}C /min HR. This is because it is the optimal conditions for obtaining the largest amount of bio-oil (83% wt) produced from PS pyrolysis, in order to have a clear effect on improving the characteristics of the fuel resulting from PS/SD co-pyrolysis.

The figure reviewed the outcomes of the thermal pyrolysis process of individual pure materials PS, and SD, by analyzing the figure, it is concluded that PS recorded the highest oil content of up to 83% with a small product of coal and gas up to 3% and 14%, respectively, in contrast, SD recorded a product of bio-oil up to 36.7% wt, which represents a small percentage if compared to PS, while a rise in char content was observed to record 33.3% wt SD, while the content of gas as 30% wt.

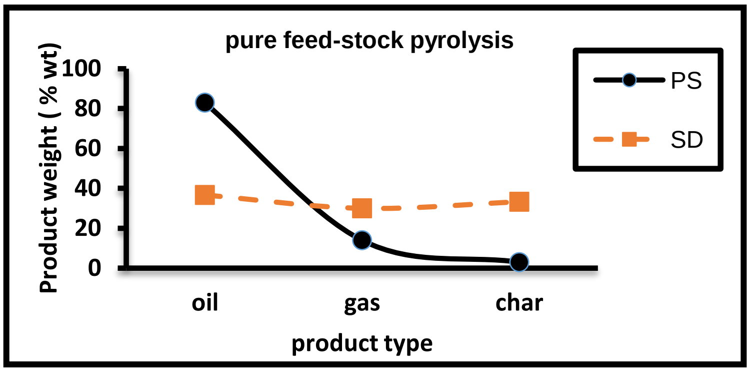

Figure 2. Pure feed stocks type's verses product yield percentage

Slika 2. Procenat prinosa proizvoda tipa čiste stočne hrane

The distribution of products in SD biomass and PS plastic pyrolysis exhibits significant differences, despite the similarity of operating conditions. This disparity can be attributed to the varying composition of biomass and plastics. Biomass pyrolysis product type is strongly influenced by the presence of cellulose, and hemicellulose, which promotes the production of bio-oil; this is due to the presence of weak bonds that are easily broken at a short range of temperatures (220 – 315 ^{o}C). While the high content of lignin (It is the second main component of biomass after cellulose and is usually in wood material from 20 to 35% depending on the type of wood. Lignin is characterized by strong bonds and a three-dimensional network that makes it a difficult and decomposition resistant material that is difficult to convert into valuable products (oil or gas) as biofuel [15]) in biomass indicates a rise in char yield [16]. On the other hand, PS plastics have a higher volatile content up to 99.6 %, which favors liquid yield [17]. Consequently, the co-pyrolysis of plastics and biomass will be a promising technique to raise the efficiency of biomass pyrolysis outcomes.

3.2. Co-pyrolysis PS/SD outcome.

Figure 3 illustrated the co-pyrolysis products of PS/SD. Upon analyzing the figure, it becomes evident that the highest bio-oil content was obtained from a blend of 75% PS and 25% SD, reaching 76.25%. Gas and char contents were 11.25% and 12.5%, respectively. The bio-oil content increased with higher percentages of PS in the blend, while the char content decreased, reaching its peak value of 27.5% in the 20PSSD blend. The blend of 20PSSD yielded the highest non-condensed gas production at 15%. As the PS percentage increased in the mixture, there was a slight decrease in biogas content ranging from 12.5% to 11.25%.

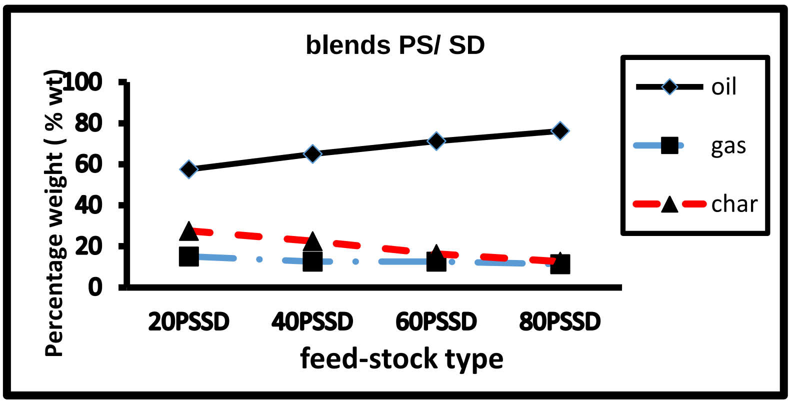

Figure 3. Blends PS/SD verses product yield percentage

Slika 3. Mešavine PS/SD u odnosu na procenat prinosa proizvoda

3.3. PS/SD Co-pyrolysis synergistic effect

Figure 4 illustrated the impact of the co-pyrolysis between PS and SD on the pyrolysis products. Figures. A, B, and C from Fig. 4 indicated that there is a PSE or NSE that confirms the presence of a new distribution in the content of the co-pyrolysis outcomes, which differs from the individual pyrolysis products of each material.

The SE is determined by comparing the actual experimental values of the co-pyrolysis product outputs with the expected theoretical values, Eq.1 is used to know the theoretical expected value, while the Eq.2 represents the extent of the impact of the joint decomposition process, if it is positive, it indicates an increase in the product yield than expected, and if it is negative, it indicates a decrease in the percentage of the product, and there are no differences indicating that the product resulting from the co pyrolysis is not affected.

$$X_{cal} = M_{SD} Y_{SD} + M_{PS} Y_{PS} \quad (1)$$

M_{SD}, M_{PS} = relative mass.

Y_{SD}/ Y_{PS} = oil yield.

$$\Delta Y = X_{exp} - X_{cal.} \quad \text{(Synergistic effect)} \quad (2)$$

Figure 4.A presented the effect of co-pyrolysis on bio-oil production. The data analysis concluded that all blends of PS/SD exhibited a PSE. Among the blends, 20PSSD blend achieved the highest PSE (+11.54) according to the table 2. The PSE decreases as the concentration of PS in the blend increases. This can be explained by the potential occurrence of internal interactions between PS and SD molecules, particularly when there is a larger proportion of SD biomass and a smaller percentage of PS present.

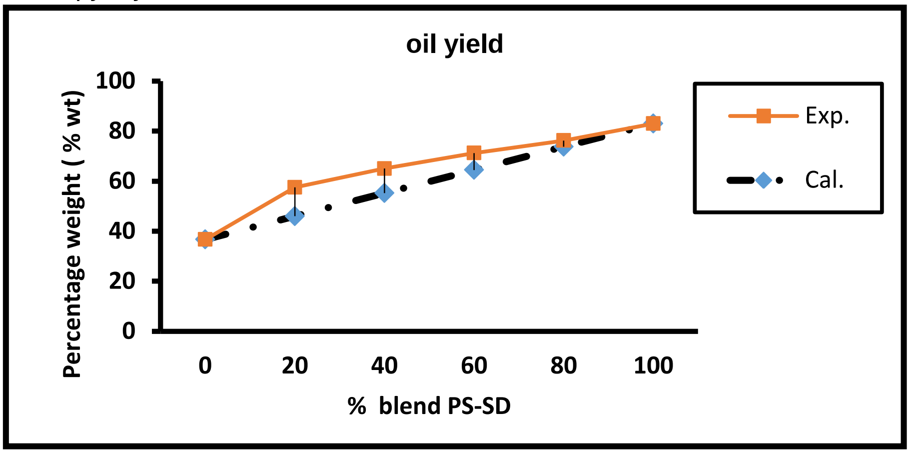

Figure 4A. Effect co-pyrolysis on bio-oil yield

Slika 4A. Efekat ko-pirolize na prinos bio-ulja

The SE of the char was evaluated in Fig. 4-B. The data showed that the PSE of all blends on the char yield resulting from the co-pyrolysis, but this effect is not noticeable, and the laboratory results are very close to the expected results.

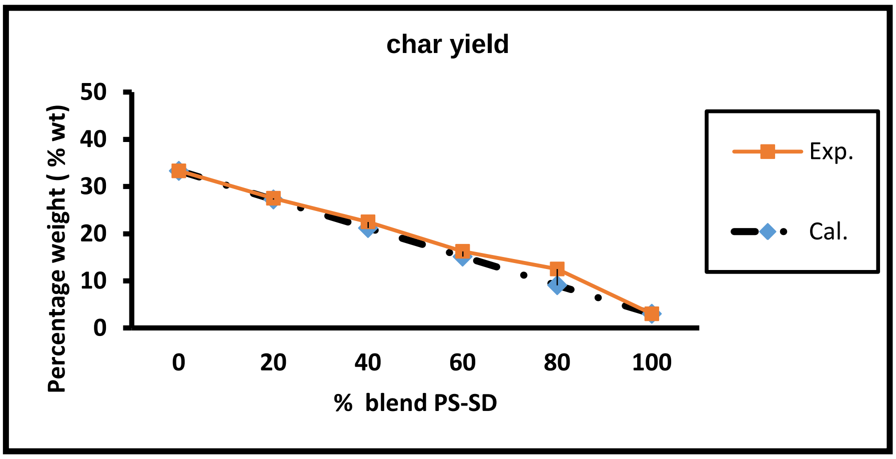

Figure 4B. Effect co-pyrolysis on bio-char yield

Slika 4B. Uticaj ko-pirolize na prinos bio-uglja

This indicates that the effect of PSSD co-pyrolysis on char production is limited to the amount of char produced from the pyrolysis of each individual. The greatest PSE (+3.44) was achieved with an 80PSSD blend.

Figure 4.C illustrates the effect of co-pyrolysis on the non-condensate gas content. It can be inferred from the presented data that the gas content exhibits a noticeable NSE on all blends. The 20PSSD blend demonstrates the highest NSE compared to the other blends. This can be attributed to the high hydrogen content in the PS component. Consequently, when a certain quantity of PS is present in the SD biomass, it causes the condensation of some gas molecules, resulting in a decrease in the gas outcome and an increase in the bio-oil yield. As the concentration of PS in the mixture increases, the NSE decreases. This decrease could be attributed to the insufficient amount of biomass pyrolysis gases, leading to a reduction in gas condensation.

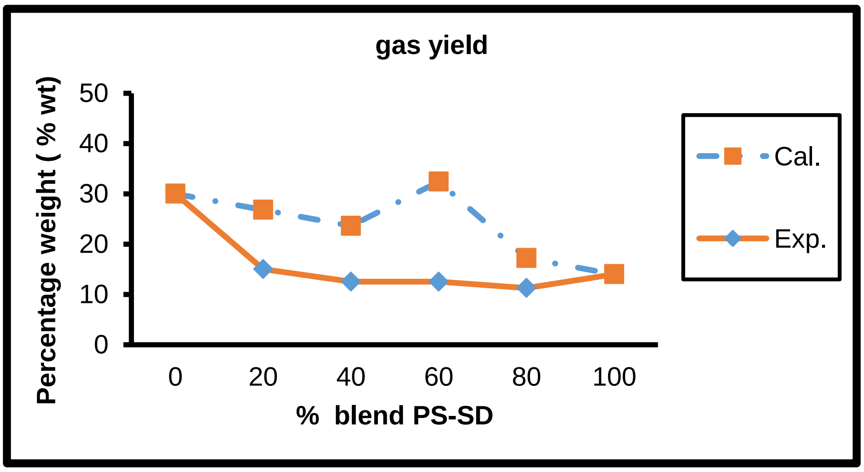

Figure 4C. Effect co-pyrolysis on bio-gas yield

Slika 4C. Efekat ko-pirolize na prinos biogasa

Table 2. Synergistic effect co-pyrolysis PS-SD outcome

Tabela 2. Sinergijski efekat ko-pirolize PS-SD ishod

Feed stock	Oil			char			gas		
	Cal.	Exp.	effect	Cal.	Exp.	effect	Cal.	Exp.	effect
SD	36.7	36.7	0	33.3	33.3	0	30	30	0
20PSSD	45.96	57.5	+11.54	27.24	27.5	+0.26	26.8	15	-11.8
40PSSD	55.22	65	+9.78	21.18	22.5	+1.32	23.6	12.5	-11.1
60PSSD	64.48	71.25	+6.77	15.12	16.25	+1.13	32.4	12.5	-19.9
80PSSD	73.74	76.25	+2.51	9.06	12.5	+3.44	17.2	11.25	-5.95
PS	83	83	0	3	3	0	14	14	0

3.4. Heating values of bio oil produced

The calorific value of fuel is the thermal energy that can be obtained from the combustion of a specific quantity of fuel. Therefore, this value serves as a clear indicator of the efficiency and quality of the fuel. Fuels with high calorific values achieve effective and economical performance, manifested in increased thermal system efficiency, reduced fuel consumption, and lower harmful emissions, in contrast to fuels with low calorific values.

Three samples of bio-oil resulting from the thermal pyrolysis of mixtures SD, 20PSSD, , and PS were analyzed to determine their high heating value (HHV). The values obtained were 17.3, 22.5, and 39.5 MJ/kg, respectively. The samples were analyzed at the petroleum refining facility of Badr Company in Egypt. The decrease in HHV of SD bio-oil is attributed to an increase in moisture content and a decrease in the carbon and hydrogen ratio, in contrast to the HHV of PS bio-oil [18]. This explains the increase in HHV with an increasing proportion of PS in the co-pyrolysis blend.

4. CONCLUSION

The study emphasized the significance of co-pyrolysis of biomass and plastics in enhancing both the quantity and quality of the biofuel produced. The subsequent conclusion was derived based on the study's findings.

1 - co pyrolysis PS and SD biomass had a positive impact on the quantity and quality of the bio-oil produced by increasing the oil content and enhancing its thermal efficiency.

2 - 20PSSD blend recorded the largest PSE in obtaining bio-oil, exceeding expectations compared to other blends. Despite having PSE as well, the same blend had the largest NSE on the quantity of gas produced. On the other hand, there was an observed stability in the char content in terms of its SE.

3 - Co pyrolysis had PSE for both char and bio-oil, resulting in the blend 40PSSB having the largest PSE on the char content, while the blend 20PSSB had the largest PSE on the oil yield. Conversely, all blends exhibited NSE on bio-gas productivity, with the blend 20PSSB recording the largest NSE on gas production compared to the other blends.

Last but not least, researchers' efforts to further control the factors affecting the pyrolysis process are still ongoing, in order to achieve a larger quantity and better quality of bio-oil.

5. REFERENCES

[1] E.Abokyi, P.Appiah, F.Abokyi, E.F.Oteng (2019) Industrial growth and emissions of CO2 in Ghana: the role of financial development and fossil fuel consumption, Energy Reports, 5, 1339 – 1353. https://doi.org/10.1016/j.egyr.2019.09.002.

[2] A.Foley, Ab.Ghani Olabi (2017) Renewable energy technology developments, trends and policy implications that can underpin the drive for global climate change, Renewable and Sustainable Energy Reviews, 68(2), 1112-1114. https://doi.org/10. 1016/j.rser.2016.12.065.

[3] A.H.Zulkafli, H.Hassan, M.Ahmad, A.Mohd Din, S. Wasli (2023) Co-pyrolysis of biomass and waste plastics for production of chemicals and liquid fuel: A review on the role of plastics and catalyst types, Arabian Journal of Chemistry, 16, 104389. https://doi.org/10.1016/j.arabjc.2022.104389.

[4] Jh.M.Aberilla, Al.Gallego-Schmid, Ad.Azapagic (2019) Environmental sustainability of small-scale biomass power technologies for agricultural communities in developing countries, Renewable Energy, 141, 493-506. https://doi.org/ 10.1016/ j.renene.2019.04.036.

[5] H.Hassan, J.K.Lim, B.Hameed (2016) Recent progress on biomass co-pyrolysis conversion into high-quality bio-oil. Bioresour Technol,. 221, 645-655. https://doi.org/10.1016/j.biortech.2016.09.026.

[6] P.M.Gvero, S.Papuga, I.Mujanić, S.Vasković (2016) Pyrolysis as a key process in biomass combustion and thermochemical conversion, *Therm. Sci.*, 20(4), 1209–1222.https://doi.org/10.2298/ TSCI151129154G.

[7] M.Ch.Chiong, Ch.T.Chong, Jo-Han Ng, Su.Sh. Lam, M-Vu Tran, W. W. F. Chong, M. N. M. Jaafar, A. Valera-Medina (2018) Liquid biofuels production and emissions performance in gas turbines: A review, Energy Conversion and Management, 173, 640-658. https://doi.org/10.1016/j.enconman.2018.07.082.

[8] E.E.Kwon, J.I.Oh, K.H.Kim (2015) Polycyclic aromatic hydrocarbons (PAHs) and volatile organic compounds (VOCs) mitigation in the pyrolysis process of waste tires using CO<inf>2</inf> as a reaction medium, *J. Environ. Manage.*, 160, 306–311. https://doi.org/10.1016/j.jenvman.2015.06.033.

[9] J.Chattopadhyay, T.S.Pathak, R.Srivastava, A.C. Singh (2016) Catalytic co-pyrolysis of paper biomass and plastic mixtures (HDPE (high density polyethylene), PP (polypropylene) and PET (polyethylene terephthalate)) and product analysis, *Energy*, 103, 513– 521. https://doi.org/10.1016/ j.energy.2016.03.015.

[10] H.Stančin, M.Šafář, J.Růžičková, H.Mikulčić, H. Raclavská, X.Wang, N.Duić (2021) Co-pyrolysis and synergistic effect analysis of biomass sawdust and polystyrene mixtures for production of high-quality bio-oils, Process Safety and Environmental Protection, 145, 1-11. https://doi.org/10.1016/ j.psep.2020.07.023.

[11] N.Déparrois, P.Singh, K.G.Burra, A.K.Gupta (2019) Syngas production from co-pyrolysis and co-gasification of polystyrene and paper with CO2, Appl Energy, 246, 1–10. https://doi.org/10.1016/ j.apenergy.2019.04.013.

[12] B.Muneer, M.Zeeshan, S.Qaisar, M.Razzaq, H. Iftikhar (2019) Influence of in-situ and ex-situ HZSM-5 catalyst on co-pyrolysis of corn stalk and polystyrene with a focus on liquid yield and quality, J Clean Prod, 237, 117762. https://doi.org/10.1016/ j.jclepro.2019.117762.

[13] O.Sanahuja-Parejo, A.Veses, M.V.Navarro, J.M. López, R.Murillo, M.S.Callén (2019) Drop-in biofuels from the co-pyrolysis of grape seeds and polystyrene, Chem Eng J, 377, 120246. https://doi.org/10.1016/j.cej.2018.10.183.

[14] K.P.Shadangi, K.Mohanty (2015) Co-pyrolysis of Karanja and Niger seeds with waste polystyrene to produce liquid fuel, Fuel, 153, 492–8. https://doi.org/10.1016/j.fuel.2015.03.017.

[15] D.Watkins, M.Nuruddin, M.Hosur, A.T.Narteh, S. Jeelani (2015) Extraction and characterization of lignin from different biomass resources, Journal of Materials Research and Technology, 4(1), 26-32. https://doi.org/10.1016/j.jmrt.2014.10.009.

[16] Z.Xiao, S.Wang, M.Luo, J.Cai (2022) Combustion characteristics and synergistic effects during co-combustion of lignite and lignocellulosic components under oxy-fuel condition, Fuel, 310, Part B, 122399. https://doi.org/10.1016/ j.fuel.2021.122399.

[17] S.D.Anuar Sharuddin, F.Abnisa, W.M.A.W.Daud, M. Kheir eddine Aroua (2016) A review on pyrolysis of plastic wastes, Energy Conversion and Management, 115, 308–326. http://dx.doi.org/10.1016/j.enconman.2016.02.037.

[18] Q.V.Nguyen, Y.S.Choi, S.K.Choi, Y.W.Jeong, Y.Su Kwon (2019) Improvement of bio-crude oil properties via co-pyrolysis of pine sawdust and waste polystyrene foam, Journal of Environmental Management, 237, 24-29. https://doi.org/10.1016/j.jenvman.2019.02.039.

IZVOD

PROCENA EFEKTA MEŠANJA POLISTIRENA (PS) SA PILJEVINOM (SD) NA PROIZVODE OD KOPIROLIZE

Proces kopirolize između biomase i čvrstog otpada, posebno plastike, privukao je značajnu pažnju u istraživačkim studijama kao sredstvo za poboljšanje i količine i kvaliteta bio-ulja dobijenog razgradnjom biomase. U ovom istraživačkom radu, PS/SD ko-piroliza je sprovedena za šest različitih koncentracija u rasponu od 0% do 100%, sa povećanjem od 20% PS, unutar malog laboratorijskog reaktora na 450 ^{o}C i brzini zagrevanja (HR) od 20,5 ^{o}C min^{-1}. Rezultati su pokazali da je povećanje udela PS u mešavini rezultiralo većim ishodom bio-ulja. Najveći prinos bio-ulja zabeležen je kod mešavine 80PSSD, što ukazuje da je kopiroliza imala pozitivan efekat na proizvodnju ulja u svim smešama. Najznačajniji pozitivan uticaj primećen je kod mešavine 20PSSD, dostižući [+11,54]. Suprotno tome, proizvodnja gasa je pokazala negativan efekat, sa količinama gasa manjim od očekivanih za sve smeše, a najznačajniji negativan uticaj je bio na 20PSSD, uz smanjenje od [-11,8]. Što se tiče ishoda ugljenika, došlo je do minimalnog povećanja njegove količine, sa najvećim pozitivnim uticajem drvenog uglja zabeležen na 80PSSD, koji je dostigao [+3,44]. Shodno tome, može se primetiti da na količinu proizvedenog ugljenika ne utiče značajno proces zajedničkog mešanja.

Ključne reči: *PS plastika, biomasa, piljevina, kopiroliza, bio-ulje*

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