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PRODUCTION OF HIGH QUALITY BIO-OIL VIA PYROLYSIS OF LIGNOCELLULOSIC BIOMASS: A REVIEW ON ROLE OF PLASTIC AND CATALYST TYPES

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Abstract:
Biomass is one of the alternatives and sustainable source of energy that exists in abundant, renewable and widely available, as well as emits particularly low CO2 content. It can be used to produce biofuels via the pyrolysis process, which is an environmentally safe way of employing biomass and solid wastes. Moreover, co-pyrolysis of biomass and plastic produced significant positive effect, as the bio-oil obtained has high calorific value close to conventional fuel. By utilizing the biomass and plastic waste as co-reactants help to reduce the fuel consumption and alleviate the environmental pollution. However, elimination of oxygenated compounds poses a considerable challenge. Catalytic co-pyrolysis is utilized to enhance the quality of biofuel produced from co-pyrolysis of biomass and plastic. The catalytic co-pyrolysis process involved two materials as feedstock and an acidic catalyst for production of biofuel. This technique promotes the production of high-quality bio-oil through acid catalyzed reduction of oxygenated compounds and mutagenic polyaromatic hydrocarbons. This paper review on the role of plastic and catalyst types for the production of high-quality bio-oil via pyrolysis of lignocellulosic biomass. This review focuses on the potential of plastic such as HDPE, LDPE, PET, PC, PVC and PS as co-feed in co-pyrolysis to produce valuable liquid fuel. Also, to study the types of zeolite-based catalyst to further improve the process and the quality of biofuels in catalytic co-pyrolysis of biomass and plastic.

***Keywords*:**
Lignocellulosic Biomass, Plastic, Co-pyrolysis, Catalytic co-pyrolysis, Zeolite catalyst

Objectives:

- To review the potential of plastic as co-feed in co-pyrolysis of biomass for the production of high-quality bio-oil
- To study the performance of zeolite-based catalyst work in catalytic co-pyrolysis of biomass and plastic.

Methodology:

Collection data for the study was conducted through extensive search for peer-reviewed academic articles published in the year 1999 to 2020 period, with extra information provided from external sources suach as government and market-research sources. The search is performed by several set of keywords in various academic databases such as Science Direct, Research Gate, Elsevier, Academia, SpringerLink, American Chemical Society (ACS) Journals and Scopus. The general keywords for searching terms are "Pyrolysis of Lignocellulosic biomass", "bio-oil, co-pyrolysis", "catalytic co-pyrolysis", "plastic" and "catalyst" and lastly, the literatures obtained were filtered according to the publication year

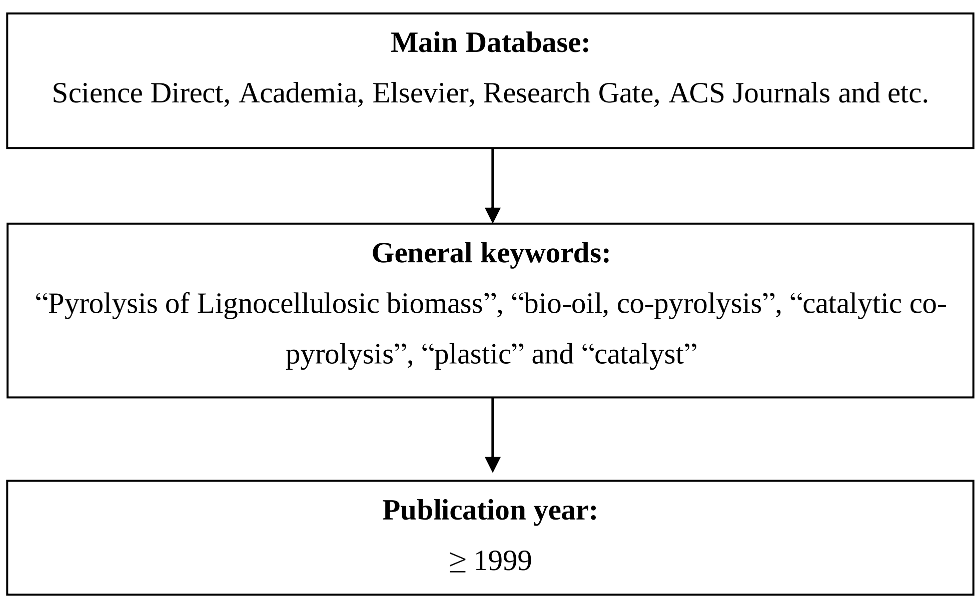

Figure 1 illustrates the process flow on the production of high quality bio-oil via pyrolysis of lignocellulosic biomass: A review on the role of plastic and catalyst types.

Results:

Table 1: Condition for operating parameters and products for three types of pyrolysis for pyrolysis of lignocellulosic biomass [27,28].

Pyrolysis Process	**Solid Residence Time (s)**	**Heating rate (K/s)**	**Particle size (mm)**	**Temp. (K)**	**Product Yield (%)**		
					Oil	**Gas**	**Char**
Slow	450-550	0.1-1	5-50	550-950	30	35	35
Fast	0.5-1.0	10-200	<1	850-1250	50	20	30
Flash	<0.5	>1000	<0.2	1050-1300	75	12	13

Table 2 : Bio-oil yield obtained from the previous studies on co-pyrolysis of biomass with plastic (HDPE,LDPE,PET,PC,PVC & PS).

Type of materials		**Characteristic**		**Compound presence**	**Bio-oil Yield (wt%)**	**References**
Biomass	**Plastic**	**Temperature**	**Blending Ratio**			
Almond shell	HDPE	500	1:1, 1:2, 2:1, 1:0	Aliphatic hydrocarbon	40-50	[47]
Sugarcane Bagasse	HDPE	600	3:2	Aliphatic compounds & Higher Carbon and Hydrogen content	63.7	[52]

Sugarcane Bagasse	LDPE	500	1:1	Less oxygenated compounds, phenol and acidic compounds	52.75	[7]
Hazelnut shells	PET	500	1:1	Mainly liquid and gas products and no char formation was observed	29.9	[49]
Walnut shells	PET	500	1:1	Mainly liquid and gas products and no char formation was observed	28.9	[49]
Rice straw	PET	550	1:1	Aldehyde, ketones, acids, aromatics, and phenol	36	[5]
Cotton stalk	PET	500	1:1	Mainly liquid and gas products and no char formation was observed	25.9	[49]
Klason annual plants & Organosolv hardwood	PC	500	1:2	significant amounts of syringol, methylsyringol and isovanillic acid	46	[50]
LignoBoost Lignin	PC	500	1:1	More guaiacol and its methyl- and ethyl-derivatives	48.5	[51]
Xylan	PVC	400-600℃	1:1	Char, Light aromatics and High oxygenated	14.9	[53]

				products		
Walnut shells	PVC	500	1:1	Mainly liquid and gas products, and a negligible amount of char	17.6	[54]
Pine cone	PS	500	1:1	Aliphatic & Aromatic hydrocarbon	52.3	[55]
Pine sawdust	PS	500	3:1	Aliphatic & aromatic hydrocarbons.	63.3	[56]
Palm shell	PS	600	3:2	Aliphatic & aromatic hydrocarbons.	68.3	[57]

Table 3: Performance of various zeolite-based catalyst on catalytic co-pyrolysis of biomass and plastic.

Catalyst types	**Preparation of catalyst**	**Catalyst Effect**	**Reference**
Microporous and mesoporous zeolite	Catalyst prepared by post-synthesis treatment.	Coke was found inside the micropores of ZSM, However, coke formation reduced up to 65% by using mesoporous catalyst. Mesoporous catalyst doubled the selectivity of mono-aromatic compounds, increased the aromatic yield and decreased the coke yield.	[58]
Metal modified zeolite	Catalyst prepared by wet impregnation method	Improve the activity of the zeolite catalyst, promote the deoxygenation of oxygenated compounds during pyrolysis and increase the content of aromatic.	[10]

Hierarchical zeolites • Micro-mesoporous composite • mesoporous	Micro-mesoporous catalyst prepared by Alkaline extraction of zeolites. Meanwhile, hierarchical mesoporous catalyst prepared by template free method.	Improved surface acidity favors large molecules catalytic. Hierarchical mesoporous zeolites exhibit high catalytic activities in cracking of large molecule, high hydrogen adsorption and high hydrothermal stability compared to Micro-mesoporous zeolite.	[59]
Low-cost mineral based catalyst • Red mud • Fly Ash • Steel waste • Industrial sludge	Mineral generally being converted into zeolite-based catalyst or added into zeolite in two-stage pyrolysis.	Delivering higher gas yields and lower viscosity bio-oils than a ZSM-5 zeolite catalyst. Also, produced significantly higher organic liquid yield and reduced gas and coke yields.	[60]

Conclusion:

The roles of plastic as co-feed and catalyst types for a production of high quality bio-oil via pyrolysis of lignocellulosic biomass were reviewed in this paper. Pyrolysis is a promising technology to convert lignocellulosic biomass into liquid biofuel, which can reduce the dependence on fossil fuels in the future. However, there are some disadvantages of pyrolysis bio-oil, such as high oxygen content, high acidity, low calorific value and poor stability. Thereby, plastics is added as an additive material or co-reactant which act as hydrogen donors in thermal co-pyrolysis. Co-pyrolysis of plastic and biomass produced a significant positive effect as the bio-oil obtained has high calorific value close to conventional fuel. Moreover, co-pyrolysis was reviewed from the point of major plastics such as PET, HDPE, PVC, LDPE, PC and PS. Study was further reviewed by the addition of zeolite-based catalyst types in catalytic co-pyrolysis of biomass and plastic. It shows an excellent aromatization and alkylation ability, which can improve the yield and selectivity of aromatics and other products contributing to enhance improvement of the bio-oil quality.