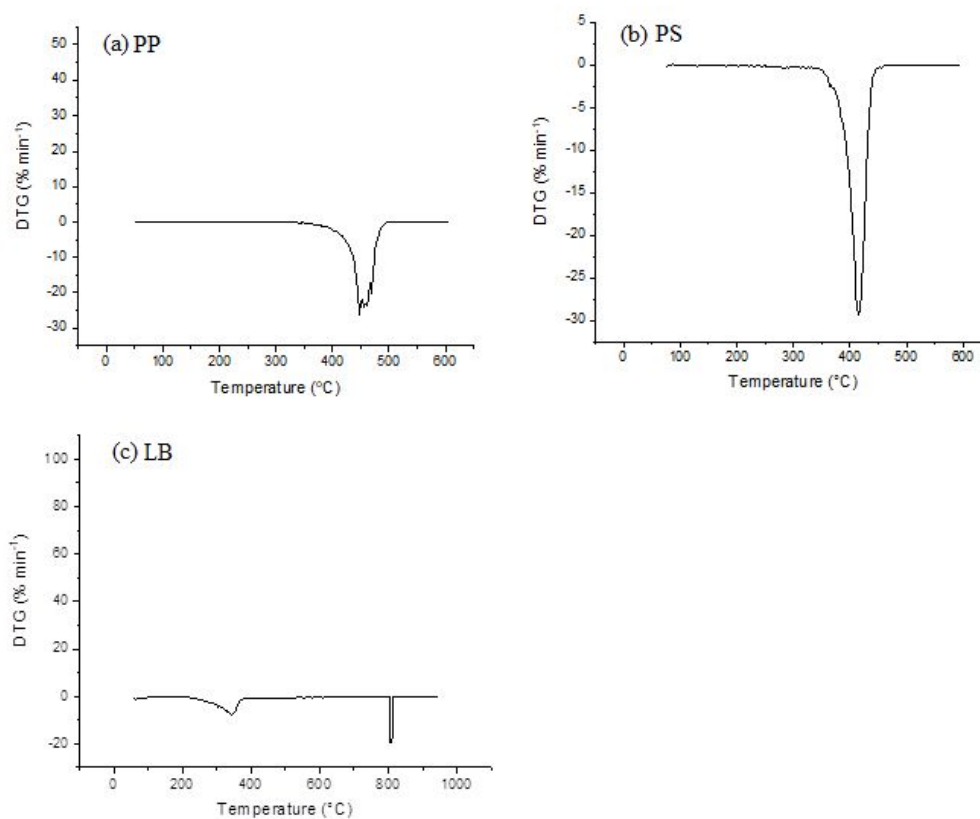


## Supplementary Data

### Catalytic co-pyrolysis of biomass and plastics (polypropylene and polystyrene) using spent FCC catalyst



**Fig. S1.** DTG curves for (a). Polypropylene (PP) (b).Polystyrene (PS) and (c). Lignocellulosic biomass (LB)

**Table S1.** Co-pyrolysis studies of biomass with plastics

S.No	Reference	Reactor used	Operating Temperature	Feed considered	Catalyst used	Product yields	Observations
1	Mullen et al. [22]	Pyroprobe pyrolyzer	650°C	Switchgrass and High-density polyethylene (HDPE) – 1 mg (total)  Biomass/plastic ratio - 1:1	HZSM-5 (15 mg)	Total aromatic yield-GC/MS response (x10 <sup>7</sup> area counts per sample mg)  –  Switchgrass – 290  HDPE - ~183  Switchgrass and HDPE blend - 341	In a series of experiments, they observed an increase in aromatics formation and slow catalyst deactivation by coke up to ~2:1 cumulative feed to catalyst loading.  However, the effect of HDPE addition from 2:1 to 4:1 cumulative feed to catalyst ratio was less beneficial due to excess coke formation inside the catalyst pores.
2	Zhang et al. [23]	Continuous Fluidized bed reactor	600°C	Black liquor lignin and polyethylene (PE); 5-200 g/h; Biomass/plastic ratio - 1:1	LOSA-1, spent FCC catalyst, $\gamma$ -Al <sub>2</sub> O <sub>3</sub> , sand – 30 g	Petrochemical yield (%C- aromatics and olefins) –  LOSA-1 - ~44%; spent FCC - ~35%; $\gamma$ -Al <sub>2</sub> O <sub>3</sub> - ~30%; Sand - ~18%;	The petrochemical yield (aromatics plus olefins) decreased in the order LOSA-1 > spent FCC catalyst > $\gamma$ -Al <sub>2</sub> O <sub>3</sub> > sand.

3	Hong et al. [24]	Microscale analytical pyrolyzer	400-600°C	Cellulose and Polypropylene - 0.8 mg (total)	ZSM-5, Desilicated ZSM-5, Al-SBA-15; Catalyst to feed ratio - 10.	Aromatic yields: 33.5 wt% with Desilicated ZSM-5; 24.62 wt% using parent ZSM-5; 7.38 wt% with Al-SBA	Synergy was observed for both desilicated ZSM-5 and Al-SBA-15. No synergy was observed with parent ZSM-5. Increase in temperature from 400 to 600°C favoured higher aromatic yields. Desilicated ZSM-5 performed better in terms of aromatic yields and deoxygenation reactions.
4	Zhao et al. [25]	Microwave oven	200-350°C	Bamboo and Polypropylene -10 g (total)	HZSM-5	~ 30-70 wt%	The optimum conditions for maximum bio-oil yield from jet fuel perspective were identified as 250°C, bamboo/PP ratio of 1:2, and feedstock/catalyst ratio of 2:1. It is also reported that significant deoxygenation reactions occurred at high catalyst loading, and excess PP addition increased the aliphatic content in the bio-oil.
5	Qi et al. [26]	Bench-scale fixed bed reactor	500-900°C	Microalgae and Polypropylene – 10 g (total)	HZSM-5	~ 30-70 wt. %	<p>i. At constant biomass/PP ratio of 1:1, and sample to catalyst ratio of 1:1, the bio-oil yield was maximum (~70 wt.%) at 500°C and aromatic formation (~77%) was maximum at 800°C.</p> <p>ii. At constant biomass/PP ratio of 1:1, and 800°C, the aromatic yield was 93.29% at feed/catalyst ratio of 1:10.</p>

6	Suriapparao et al. [27]	Microwave oven	600°C	Groundnut shell, bagasse, rice husk, prosopis juliflora, mixed saw dust and polypropylene, polystyrene – 20 g (total); Biomass/plastic ratio - 1:1	None	Bio-oil yield from PS blends – 51 to 60 wt.%, and from PP blends – 25 to 41 wt.%.	Co-pyrolysis with PS had more energy yield than PP. PS promoted the aromatic production while PP co-pyrolysis bio-oil had more aliphatic hydrocarbons.
7	Chi et al. [28]	Thermogravimetry analysis (TGA)	650°C	Cellulose and polypropylene - 0.1 mg (total); Cellulose/PP ratio – 3:1	MCM-41 and Al-MCM-41	Aromatic yield - ~15 wt.% with MCM-41 and ~30 wt.% with Al-MCM-41	Al-MCM-41 had a better deoxygenation and cracking effect than MCM-41 in minimizing the oxygenate yields. The yield of furans increased with MCM-41, and the olefin and aromatic yield increased with Al-MCM-41.
8	Parejo et al. [29]	Fixed-bed reactor	550°C	Grape seeds and polystyrene – 35 g (total)	None	40-60 wt%	The organic phase yield of the bio-oil increased up to 80% with addition of PS. There was an increase in aromatic content and decrease in phenols with addition of PS. PS addition favoured oligomerization, cyclization and hydrodeoxygenation reactions.
9.	Nguyen et al. [30]	Bubbling fluidized bed reactor	500°C	Pine saw dust and waste polystyrene foam – 200 g/hr	None	~50-80 wt%	The calorific value of bio-oil increased with increase in PS proportion. The water content and acetic acid concentration decreased with increasing PS ratio.

10	Shadangi et al. [31]	Semi-batch reactor	500-600°C	Karanja and Niger seeds, polystyrene – 40 g (total)	None	Bio-oil yield from karanja and PS blends- ~ 46 to 60 wt%; and from Niger and PS blend - 46 to 61wt%	Co-pyrolysis experiments were carried out at biomass/PS ratios of 1:1, 2:1, 4:1, and 8:1. It was reported that the feed ratio of 2:1 was suitable to produce high calorific value bio-oil with low carbon residue.
11	Rutkowski et al. [32]	Vertical pyrex reactor	500°C	Cellulose and polystyrene – 5 g (total)	None	~ 45-94 wt%	Bio-oil obtained from cellulose-polystyrene mixtures had less acid number, pour point, and density compared to bio-oil obtained from cellulose. Hydrocarbon content increased with decrease of cellulose to polystyrene ratio.
12	Hassan et al. [33]	Quartz tube	500-650°C	Torrefied wood (TW) and polystyrene – 3 mg (total)	HZSM-5	Aromatic yield varied between ~5 to 75 wt% for samples of pure biomass, plastic and their mixtures.	In catalytic co-pyrolysis of TW with PS, the aromatic yield decreased with increase in temperature. The amount of phenolics dropped from ~53% at 550°C to ~35% at 650°C when HZSM-5 was used as a catalyst. It was reported that the thermal stability of PS was more than TW.

**Table S2.** Proximate analysis of feed components (%Dry basis)

	<b>Groundnut shell biomass (LB)<sup>a</sup></b>	<b>PP<sup>b</sup></b>	<b>PS<sup>c</sup></b>
Volatile matter	77.9	~100	~99.8
Fixed carbon	19.8	0	0
Ash content	2.3	0	0.2

Refs: a. <https://biomasspower.gov.in/biomass-info-asa-fuel-resources.php>

b. D Supramono, Julianto, Haqqyana, H Setiadi, and M Nasikin, Phase separation of bio-oil produced by co-pyrolysis of corncobs and polypropylene, Earth and Environmental Science 93 (2017) 012072

c. Piotr Rutkowski, Andrzej Kubacki, Influence of polystyrene addition to cellulose on chemical structure and properties of bio-oil obtained during pyrolysis, Energy Convers. Manag., 47 (2006), pp. 716-731

**Table S3.**Percentage weight distribution of organic and aqueous phase in the bio-oil

<b>LB/PP ratio</b>	<b>Thermal co-pyrolysis (TCP)</b>		<b>Catalytic co-pyrolysis (CCP)</b>	
	Organic layer (wt.%)	Aqueous layer (wt.%)	Organic layer (wt.%)	Aqueous layer (wt.%)
0.5	71	29	72	28
1	66	34	53	47
2	31	69	39	61
<b>LB/PS ratio</b>				
0.5	88	12	93	7
1	76	24	75	25
2	63	37	67	33

**Table S4.** Percentage yields of products in catalytic pyrolysis of LB, PS and PP

<b>Feed</b>	<b>Liquid (wt%)</b>		<b>Char (wt%)</b>	<b>Gases (wt%)</b>
Groundnut shell biomass (LB)	30.45		37.82	31.73
	Organic phase	Aqueous phase		
	19.7%	80.3%		
Polypropylene (PP)	54.72		0	45.28
Polystyrene (PS)	80.02		5.26	14.73