# Co-Pyrolysis of Plastic Wastes: Effects of Temperature and Feedstock Ratio on Chemical Composition of Liquid Product

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**Abstract**

Co-Pyrolysis of Low Density Polyethylene (LDPE) and Polystyrene (PS) was carried out in a semi-batch glass reactor system. Effects of temperature and feedstock ratio on pyrolytic product yields (gaseous, liquid and solid residue) and chemical composition of the liquid were investigated. All experiments were performed with 15 g feedstock in 25 mL/min nitrogen atmosphere and 60 min duration at specified temperature. Temperature was changed from 470 to 620 °C with 50 °C break by utilizing PID controller which was setted 10 °C/min heating rate. PS in the feedstock was varied as 0, 33, 67, 100 wt. %. The liquid products were characterized by GC-MS. When PS and LDPE were mixed equally by weight at 570 °C, liquid product yield was found 85 wt. %. More PS adding in the feedstock did nearly not affect this value. It was detected that hydrocarbons which were aromatic, cyclic and aliphatic formed the peak areas's majority of the co-pyrolytic liquid. Specifically styrene was found dominant component in that liquid. Besides that, it was observed that with increasing temperature, peak areas' percentage of alkanes decreased while temperature rising didn't affect olefines' peak areas.

**Keywords:** Polystyrene, Polyethylene, Co-Pyrolysis, Chemical recycling, Plastic waste management

## 1. Introduction

To run out of fossil fuels and environmental pollution have arisen in parallel with development in modern industry. Therefore, nowadays researchers have studied on renewable, sustainable and eco-friendly energy resources which can be substitute for fossil fuels. It is possible that obtaining gasoline-range hydrocarbons from plastic wastes which are non-biodegradable.

Thermoplastic polymers acts like fluid over the degree of temperature which is specific. Typical examples of thermoplastics are polyethylene (PE), polystyrene (PS), polypropylene (PP) and polyvinylchloride (PVC). In Europe, highest amount of the thermoplastic wastes is originated from PP. Low density polyethylene (LDPE) and high density polyethylene (HDPE) follow this respectively. LDPE shows high stability to water, because of that it uses in plastic bags, plastic foils and garbage bags widely. Thermal stability and durability of polystyrene turn into it which is indispensable polymer for the industries of food, electronic, medical, toy and building. This wide using area of polystyrene causes increasing in the amount of municipal solid waste.

By following chemical recycling, plastic wastes convert to liquids and gases which can be utilised in the production of petrochemicals and plastics. Pyrolysis, as a type of chemical recyling, is thermal degradation process which is fulfilled with waste or biomass, as raw materials, in oxygen-free atmosphere.

Within the scope of this study, co-pyrolysis and individually pyrolysis of PS and LDPE were carried out in semi-batch reactor system at different temperatures (470, 520, 570, 620 °C) with 60 min residence time. PS to LDPE ratio in feedstock was varied as 2:1, 1:1, 1:2. Product yields were calculated. Besides that, liquid products were analyzed via GC-MS.

## 2. Materials and Methods

### *2.1. Materials*

PS and LDPE were used as plastic waste. In the experiments, source of PS waste was white foam trays which had been used for putting blood collection tubes in hospitals. LDPE as F2-12 type was supplied from Petkim Petrokimya Holding A.Ş. Any pre-treatment was not practiced for LDPE. However sliced PS foam was dried in oven at 125 °C throughout 120 min before pyrolysis.

### *2.2. Pyrolysis of Plastic Wastes*

Feedstock (PS/LDPE/(PS+LDPE)) had been put in the reactor before the experiments, and vaporized product was taken continuously. Whole experiments were maintained at specified temperature throughout 60 min. The setup was shown in Fig. 1.

## 3. Results and Discussion

### *3.1 Yields of pyrolysis products*

Maximum liquid yield was reached as 70 wt. % at 520 °C for LDPE and as 90 wt. % at 570 °C for PS approximately. Since these feedstocks had different optimum temperatures for liquid product, it was not guessed optimum temperature for liquid product which was obtained co-pyrolysis of LDPE and PS. Therefore effect of temperature on the plastic mixture which included equal amount of PS and LDPE was investigated. As shown in Fig. 2 (a), Maximum liquid product yield of the co-pyrolysis was obtained as 83.5 wt. % at 570 °C. Koo et al. (1991) also studied on the co-pyrolysis of polyethylene and polystyrene waste which were equal amount in the feed. Since they also reached the maximum liquid yield at 600 °C in the result of the co-pyrolysis experiments, this work supported to our result. Considering Fig. 2 (b), it can be seen clearly that more PS adding in the feedstock did nearly not affect this value.

### *3.2 Chemical Composition of liquid product*

It was detected that hydrocarbons which were aromatic, cyclic and aliphatic formed the peak areas's majority of the co-pyrolytic liquid. It was observed that with increasing temperature, peak areas' percentage of alkanes decreased while temperature rising didn't affect olefines' peak areas (Fig. 3(a)).

It was deduced from the GC-MS results that polystyrene was the only source of aromatic compounds in the co-pyrolytic liquid. That is, peak areas of aromatic compounds in the co-pyrolytic liquid increased when the amount of polystyrene in the feed mixture increased as well. In a smilar manner, the sole source of aliphatic and non-aromatic cyclic hydrocarbons in the co-pyrolytic liquid was LDPE. Accordingly, it was expected that peak area of these components in the co-pyrolytic liquid reduced with increase in polystyrene in the feed (Fig. 3(b)).

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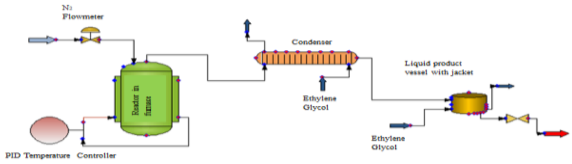


**Figure 1.** Chemcad drawing of the experimental setup

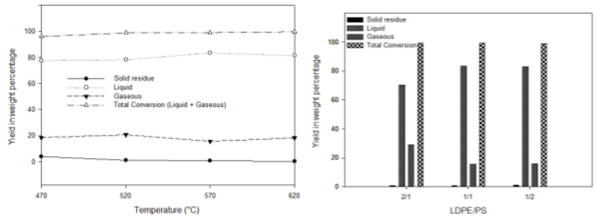


**Figure 2.** Effects of temperature **(a)** and feedstock ratio **(b)** on co-pyrolytic products yield

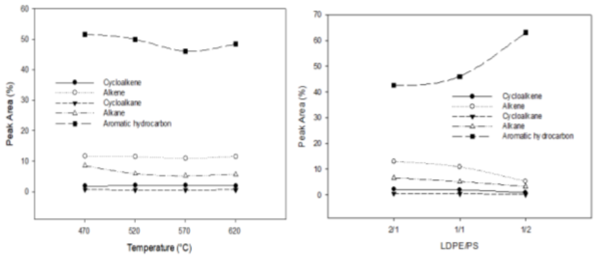


**Figure 3.** Effects of temperature **(a)** and feedstock ratio **(b)** on co-pyrolytic liquid product composition

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