



# Polypropylene effect on pyrolysis of polymer mixtures

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## Motivation

The constant increase in plastic production, from which polypropylene (PP) and high-density polyethylene (HDPE) are amongst the most produced/consumed worldwide, has caused concerns about the increase in fossil carbon consumption and in the accumulation of plastic waste with consequences to the environment (Plastics Europe, 2020).

One method that has been addressed to face these issues and to optimize the current management of plastic waste (Figure 1) is chemical recycling, as the processes associated to this type of recycling, are capable of processing contaminated or mixed plastics, that would otherwise be incinerated or landfilled, converting them into high-value products and therefore, helping to promote the reduction of landfill usage and a more circular economy (B.Kunwar et al., Renew.Sustain.Energy Rev., vol.54, pp.421-428, 2016).

Plastic pyrolysis has been identified in many contexts, as a viable and promising method to handle plastic waste. Extensive work is often done on the thermal degradation of single type pure plastics, as mixed contaminated plastics tend to show some operational problems and poor efficiency (S. Dayana et al., Energy Convers. Manag., vol. 115, pp. 308–326, 2016). Nonetheless, as mixed waste plastics are cheap and widely available, it's highly important to understand the interaction that single waste type plastics can have in these mixtures and how to create methodologies to allow the efficient pyrolysis of mixed waste type plastics.

Thus, this work focuses on the study of the thermal co-pyrolysis of 2 different types of waste plastics, HDPE and PP, to assess the effect that the PP waste has when it's combined with HDPE waste.

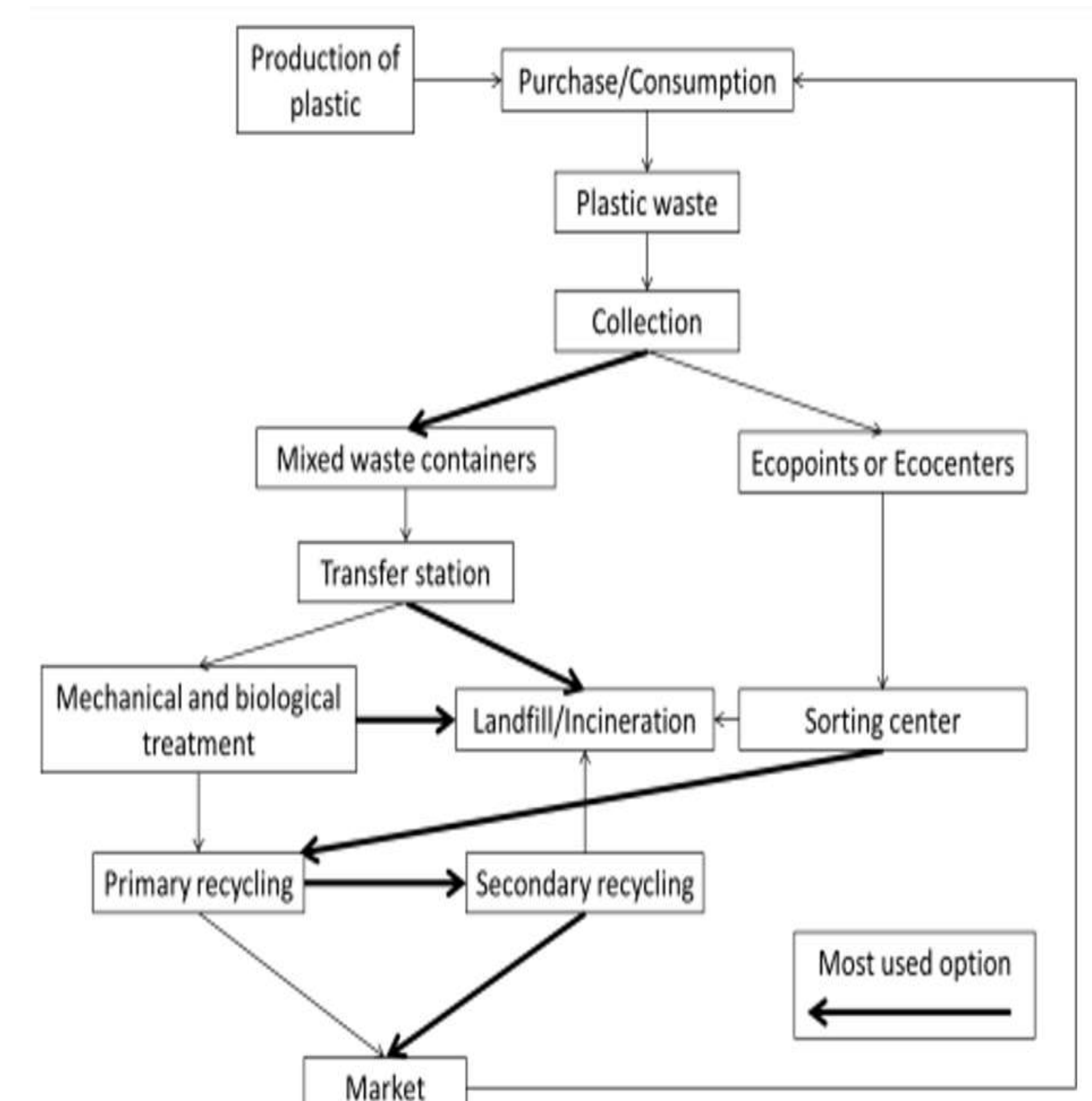


Figure 1- Current management of plastic waste.

## Methods and Results

Experiments using waste single type plastics (PP from water cups and HDPE from a detergent bottle), both separately and mixed, were carried-out in a simultaneous thermal analyzer (DSC-TG) and in a semi-batch bench-scale reactor. Before use, all samples were cleaned and crushed/shredded into small size particles with a granulometry between 2-4 mm using a cutting mill Retsch 2000.

### Thermogravimetric analysis (TGA)

The experiments were performed in a Perkin-Elmer simultaneous thermal analyzer 6000 in dynamic conditions with a sample size of around 20 mg in alumina pans under a nitrogen flow of 20 ml/min.

The temperature was initially stabilized at 40 °C for 10 minutes and then heated at 10°C/min, up to 700°C; this temperature was maintained for 10 minutes, before cooling. Blank experiments with empty pans were used to establish adequate DSC baselines.

The data of the thermogravimetric analysis are depicted graphically in Figure 2.

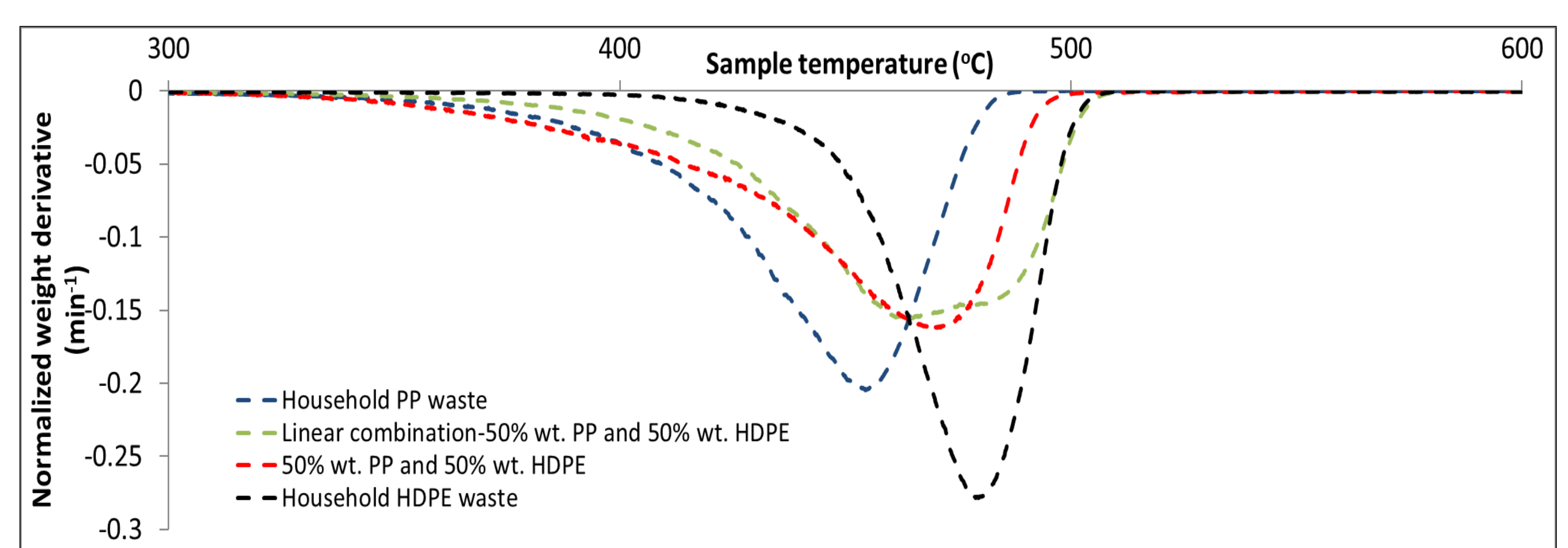


Figure 2- Thermal analysis of single and mixed waste thermoplastics

### Hybrid semi-batch reactive distillation system

A lab-scale semi-batch reactive distillation system previously described was used (E. Santos et al., Catalysis Today, vol. 379, pp. 212–221, 2021). The temperature inside the reactor was measured continuously and the products (heavy mixture, liquid, and gas) were separated. Liquid products were analyzed in a Perkin-Elmer Clarus 680 gas chromatograph.

In a typical run, around 5 g of the reactant was introduced into a Schlenk-type glass reactor of 0.1 dm<sup>3</sup>. The reactor was placed in an oven and connected to a liquid collection system, topped by a condenser cooled by water at 20 °C. The outlet of the condenser was connected to a gas burette. The system was filled with nitrogen and the reactor was heated, at a rate of 10 °C/min, up to 500°C, which was kept for 90 minutes.

Product yields were calculated by weighing the corresponding fractions, except for gas yield which was computed by difference.

The main results are represented in Figure 3.

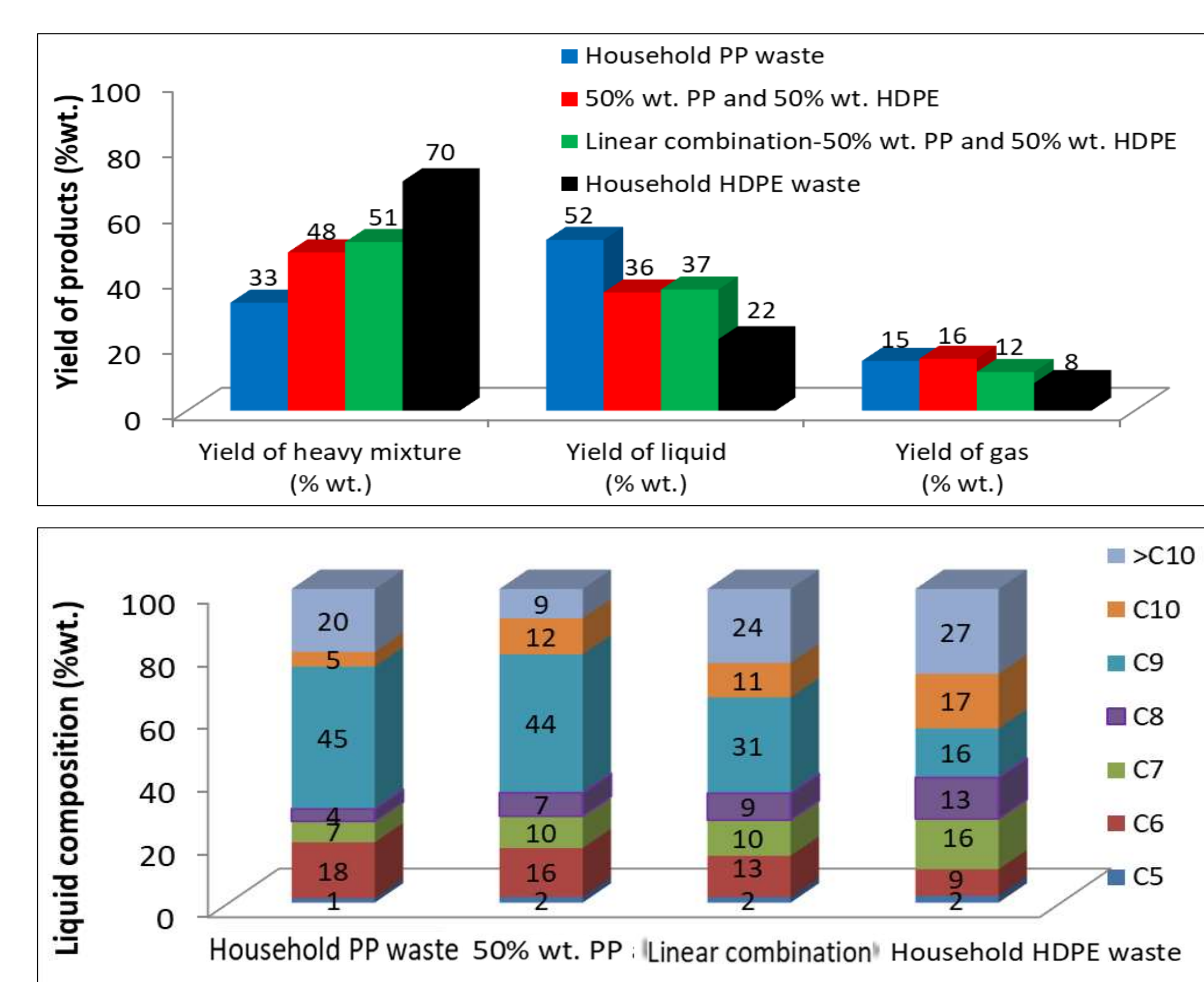


Figure 3- Yield and composition of the liquid products obtained in the semi-batch reactive distillation system.

## Main conclusions:

- PP plastics degrade at lower temperatures than the HDPE plastics, having, therefore, a higher conversion, mostly in light liquid products;
- PP incorporation tends to decrease the degradation temperatures of HDPE while increasing the liquid yield;
- Interaction between the two plastics can result in a much lower endpoint temperature and higher C5-C10 fraction in the liquid product, than what would be expected;
- It's feasible to perform viable pyrolysis with high-quality light products from low-quality waste polymers, which can promote a more circular economy, while also minimizing the harmful impacts of the conventional cycle of consumption and production of plastics.