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Pyrolysis of polycoated cardboards

Rijo B.[1], Briceno J.[1], Godinho T.[1,*], Lemos.F[1], Lemos M.A.N.D.A.[1]

[1]CERENA, Chemical Engineering Department, Instituto Superior Técnico, Lisboa, Portugal;
* tiago.dos.santos.carrasco.godinho@tecnico.ulisboa.pt;

Motivation

Currently, it's generated worldwide over 2 billion tons of municipal solid waste (MSW) annually, with this expected to grow to about 3.4 billion tons by 2050. This increase will drastically add to problems, such as global warming and environmental pollution (World bank, "Trends in Solid Waste Management", 2022).

From this waste, a significant fraction of it (51% wt.) is thought to be composed of plastic, paper, cardboard, metal, and glass, which are mostly dumped or disposed of in some form of landfill or incineration (Figure 1). Thus, it's thought that the improvement in the current management of waste, from poly-coated cardboards, which are materials in high demand in the present society, as these are composites with a plastic coat combined with other materials that can be used as a reliable packaging material, can help to minimize those problems and to increase the recycling rate in the MSW sector (J.E.Rodríguez et al., Fuel, vol.149, pp.90-94, 2015).

Chemical recycling, most specifically the pyrolysis process, it's thought to be a feasible method to recycle composites and allow the production of chemicals and fuels and recover the aluminum while 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).

Therefore, this work focuses on the study of an innovative pyrolysis process of two types of composite packaging materials, coffee paper cups, and tetra pak, to evaluate their viability for being used as a feedstock for chemical recycling process.

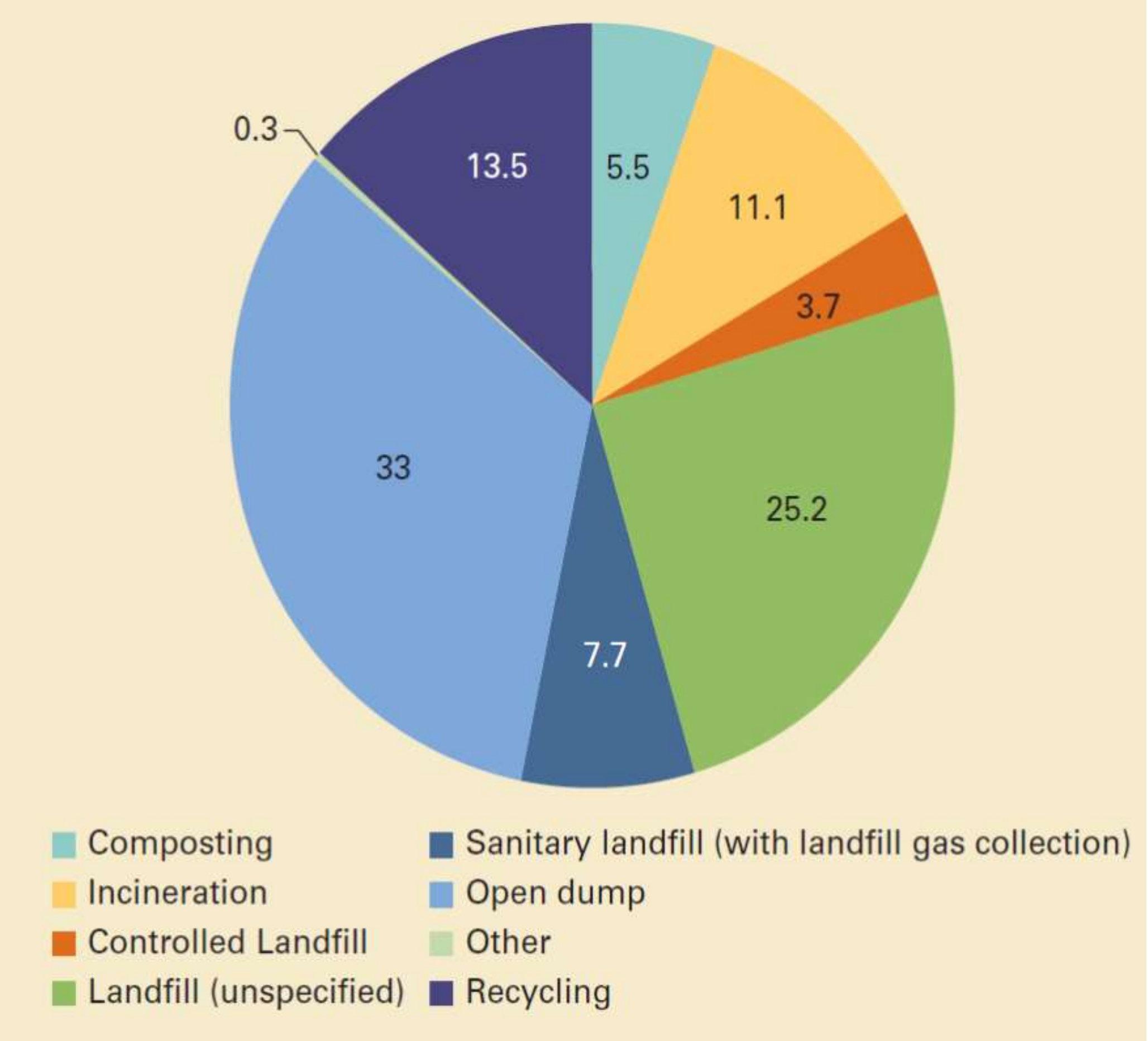

Figure 1- Global treatment and disposal of waste (% wt.). Source: World bank, "Trends in Solid Waste Management", 2022.

Methods and Results

Experiments using composite packaging materials and a reference cardboard material, were carried-out in a separate way 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 of about 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 10 mg in alumina pans under a nitrogen flow of 20 ml/min.

The temperature was heated at 10ºC/min, from ambient temperature up to 550ºC; 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.

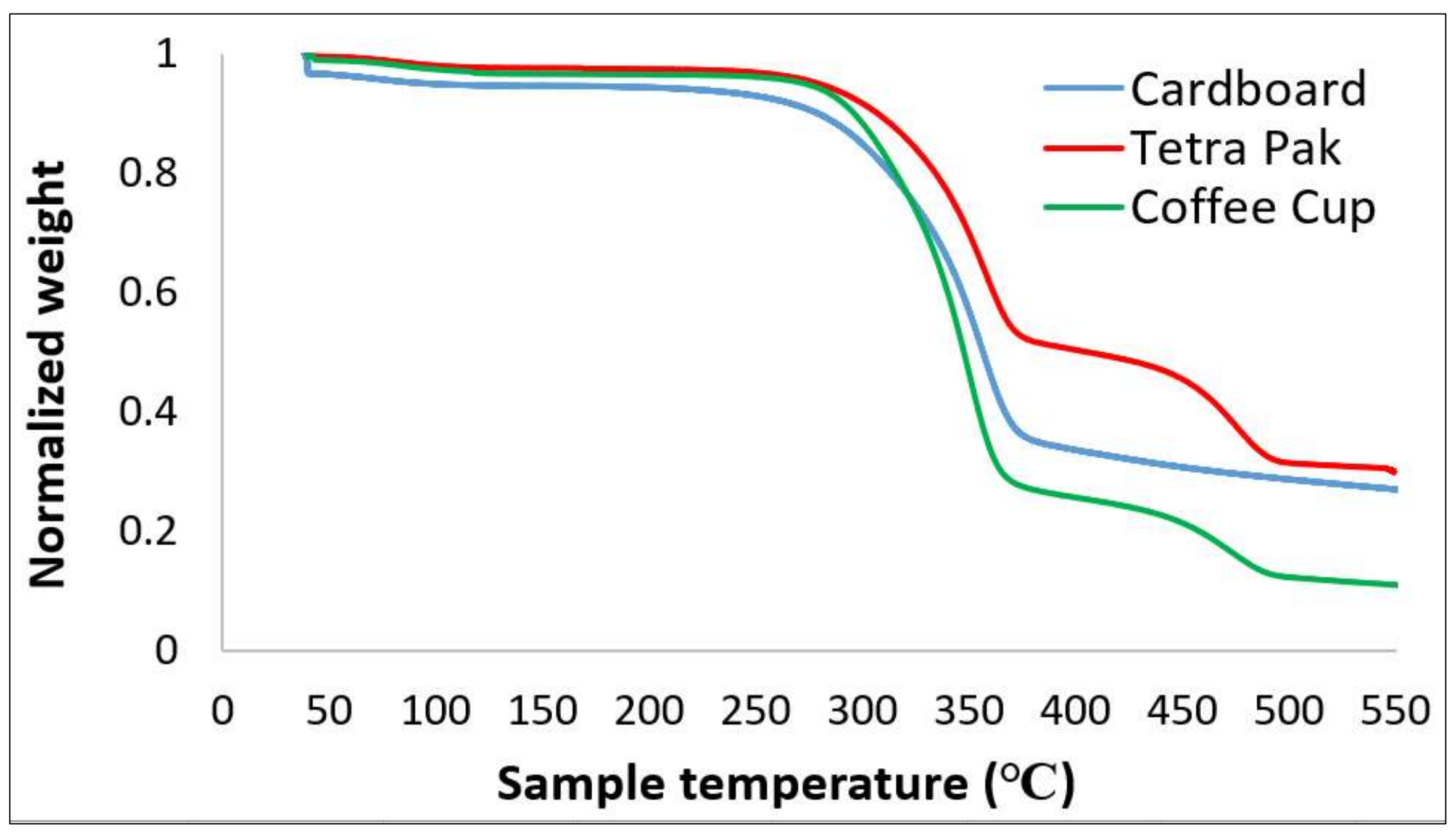

Figure 2- Thermal analysis of composite packaging materials.

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 10 g of the material was introduced into a Schlenk-type glass reactor of 0.1 dm³. The reactor was placed in an oven and connected to a liquid collection system, topped by a condenser cooled by water at 20 ºC. 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 ºC/min, up to 500ºC, which was kept for 30 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.

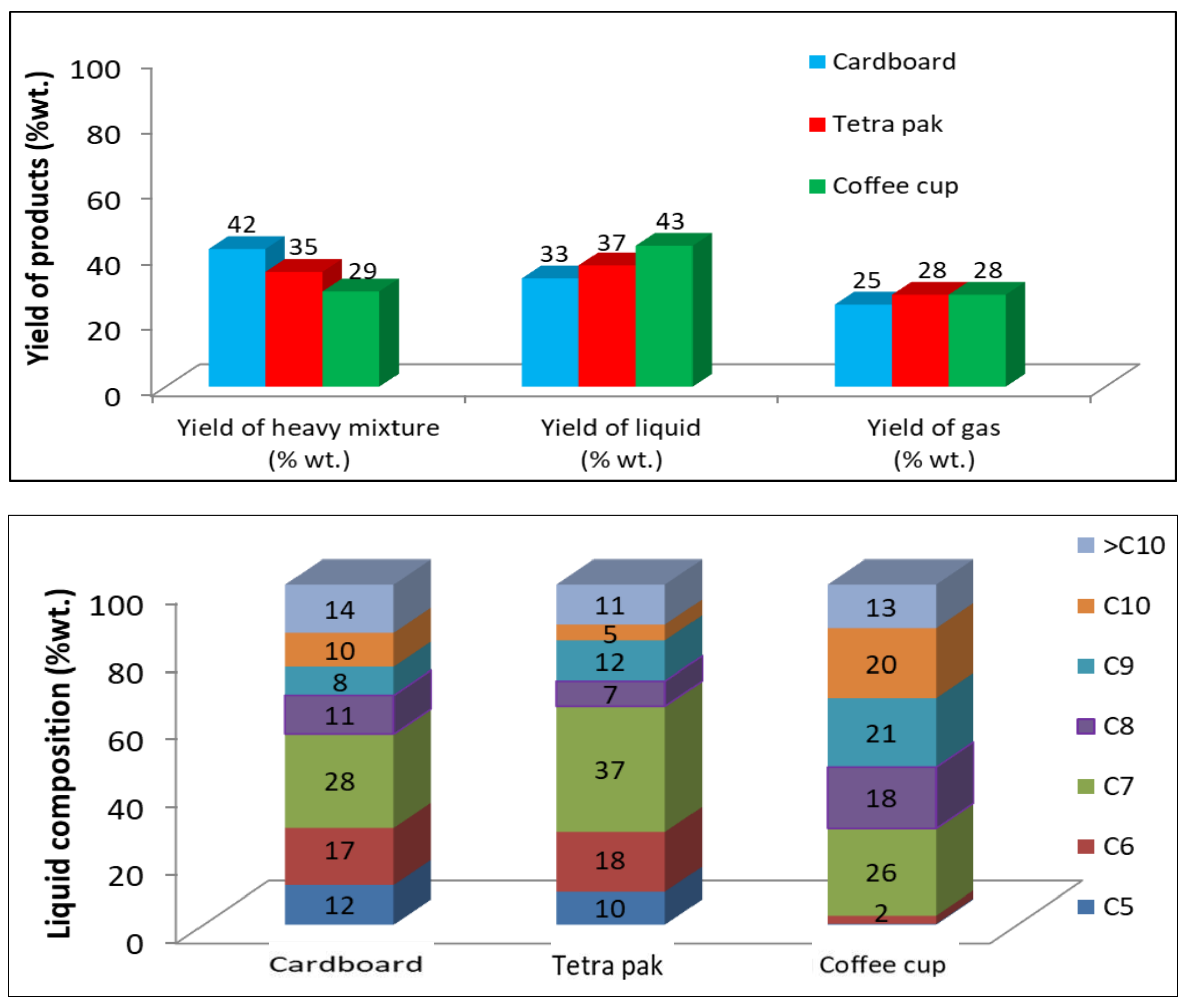

Figure 3- Yield and composition of the liquid products obtained in the semi-batch reactive distillation system.

Main conclusions:

- Tetra pak produces the highest amount of pyrolytic residue, mostly aluminium, which remained intact, while the coffee cup produces the least amount, which may suggest that for a scale up process, due to the biomass composition being inconsistent, the presence of plastic and other materials may help to reduce the amount of residue produced;
- Both composite materials show a two-step mass loss process, corresponding at low temperatures to the biomass degradation and at high temperatures to the plastic degradation;
- The conversion into gases and liquid products, for all the three materials, is higher than 50% wt., being this higher when the material has plastic content, as this is more easily cracked and consistent than the biomass, which also translates into a higher quantity of lighter distillates and a more easily controlled process;
- It's feasible to perform a viable pyrolysis with high-quality light products from composite packaging materials, and at the same time separate the aluminium from the char in an efficient way.

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