



**HAL**  
open science

## Thermal treatment of fiber-free multilayer packaging solid residue: synergism and effects on volatiles yield

Abdul Rehman Khurram, Marion Carrier, Francisco Javier Escudero Sanz,  
María González Martínez

### ► To cite this version:

Abdul Rehman Khurram, Marion Carrier, Francisco Javier Escudero Sanz, María González Martínez. Thermal treatment of fiber-free multilayer packaging solid residue: synergism and effects on volatiles yield. WasteEng2024 - 10th International Conference on Engineering for Waste and Biomass Valorisation, Aug 2024, Sendai, Japan. hal-04740197

**HAL Id: hal-04740197**

<https://imt-mines-albi.hal.science/hal-04740197v1>

Submitted on 16 Oct 2024

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

# THERMAL TREATMENT OF FIBER-FREE MULTILAYER PACKAGING SOLID RESIDUE: SYNERGISM AND EFFECTS ON VOLATILES YIELD

K. ABDUL REHMAN<sup>1</sup>, C. MARION<sup>1</sup>, E. JAVIER<sup>1</sup>, G. MARIA<sup>1</sup>

<sup>1</sup> CNRS UMR 5203, Université de Toulouse, IMT Mines Albi, Campus Jarlard, 81013 Albi CT Cedex 09, France .

## 1. Keywords

Multilayer Packaging, Recycling, Thermal treatment, Reactivity kinetics

## 2. Highlights

- Potential of thermal treatment of multilayer packaging after cellulose recovery
- Synergism observed between different components of the multilayer packaging.

## 3. Purpose

With growing population and urbanization, depletion of fossil reserves and greenhouse gases emissions are becoming major concerns worldwide [1], [2]. On the other hand, municipal solid waste is increasing with the economic growth [3]. Therefore, recycling of this waste to reduce the resource utilization and waste accumulation is paramount. Among municipal solid waste, packaging contributes a big amount due to its growing demand with the population. The amount of packaging waste has increased by 16.6% between 2012 and 2020 [4].

Multilayer packaging is utilized to enhance the shelf life of food and for various other purposes. In comparison to the mono-layer packaging, less material is consumed to achieve the desired properties, thus achieving the sustainability goals with the focus on less material utilization and food consumption. However, the waste produced by multilayer packaging, due to its composition, is complex and difficult to recycle, which negates the positive effects of multilayer packaging towards sustainability [5].

This study focuses on (i) the valorisation of multilayer packaging waste through different thermal techniques to select the most adapted chemical recycling process to minimize environmental impacts and on (ii) the synergistic observations occurring between components under various operating conditions.

## 4. Materials and methods

Multilayer packaging waste after recycling of cellulose and recycled cellulose fibers were kindly supplied by Grenoble INP – Pagora UGA. The particle size of the feedstock was reduced to <1mm using a cryogenic grinder, 16775 Freezer Mill (Spex Sample Prep) after the careful evaluation of the non-dimensional numbers: the thermal Biot number and the Pyrolysis number. Proximate and ultimate analyses of the feedstock were carried out using Labsys Evo 1600 (SETARAM Instrument) and Flash 2000 (Thermo Scientific) respectively. LabSys Evo 1600 thermogravimetric analytic (TGA) system was also used to assess the thermal degradation of the feedstock. A sample mass of  $20 \pm 2$  mg was placed into a 100  $\mu$ L platinum crucible for the TGA. The reactions were carried out from 30 to 1000 °C at a heating rate of 5, 10, 15 and 20 °C/min under O<sub>2</sub> and inert atmosphere of N<sub>2</sub> with a flow rate maintained at 6 L/min in TGA for combustion and pyrolysis respectively. To minimize the secondary vapor solid interactions and the impact of mass and heat transfer during the pyrolysis process, smaller quantities of samples and lower heating rates were used [6]. For each heating rate, a blank TGA test was carried out under the same conditions to remove the buoyancy effect. A distributed reactivity

kinetic analysis was conducted following the classic isoconversional kinetic approach, the Friedman's method. Equation 1 was used to determine the distributed and global activation energy.

$$\ln \left[ \beta_i \left( \frac{d\alpha}{dT} \right)_{\alpha,i} \right] = \ln(A_\alpha \cdot f(\alpha)) - \frac{E_\alpha}{RT_{\alpha,i}} \quad \text{Eq. 1}$$

where  $\beta_i$  is the heating rate,  $T_{\alpha,i}$  is the temperature at which the extent of conversion  $\alpha_i$  is determined at  $\beta_i$ ,  $A_\alpha$  is the pre-exponential factor,  $f(\alpha)$  the reaction model,  $E_\alpha$  the global activation energy and R the gas constant.

## 5. Results and discussion

Pyrolysis and combustion conversion of solid residues, obtained from the water demixing of multilayer packaging, have been studied in this work. Plastics was the major fraction of the solid residues left after the demixing of the multilayer packaging followed by aluminium and cellulose fibers.

Proximate and ultimate analyses of the samples have been carried out to determine the composition and elemental percentages of the waste. The evaluation of initial volatiles matter has been correlated to both pyrolytic and combustion volatiles yields, which could predict the amount of bio-oil obtained from pyrolysis process according to Dai et al. [7]. Higher volatile content leads to greater yield of bio-oil from pyrolysis. Similarly, the high carbon and hydrogen contents are expected to be beneficial to product quality. Most of the cellulose fibers degraded before 400 °C whereas the major degradation, afterward, was ought to polyethylene. Aluminium was not affected by the pyrolysis process due to the high melting point (660 °C).

The scrutiny of reactivity kinetics trends has permitted to highlight the existence of synergistic mechanisms between the components of the waste material. Both negative and positive synergistic effects have been observed. The analysis of decomposition stages of raw materials, mixed and individual components provide a better understanding of co-pyrolysis and co-combustion events confirming the recent results obtained by Chen et al. [8].

## 6. Conclusions and perspectives

Pyrolysis of multilayer packaging waste is an efficient approach in terms of carbon and hydrogen reactivity use comparatively to the industrial techniques. The kinetic study confirmed the potential of the solid residue as a feedstock for the energy and value-added chemicals and will be utilised for the design and optimisation of reactors.

## 7. References

- [1] Mahmood, Hamayoun, et al. "Glycerol assisted pretreatment of lignocellulose wheat straw materials as a promising approach for fabrication of sustainable fibrous filler for biocomposites." *Polymers* 13.3 (2021): 388.
- [2] Tariq, Alisha, et al. "Functionalized organic filler based integrated membranes for environmental remediation." *Chemosphere* 303 (2022): 135073.
- [3] Yuan, Haoran, et al. "Study of synergistic effects during co-pyrolysis of cellulose and high-density polyethylene at various ratios." *Energy conversion and management* 157 (2018): 517-526.
- [4] Eurostat, European Commission, 2020. (n.d.). [dataset]. [https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Packaging\\_waste\\_statistics](https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Packaging_waste_statistics)
- [5] Kaiser, Katharina, Markus Schmid, and Martin Schlummer. "Recycling of polymer-based multilayer packaging: A review." *Recycling* 3.1 (2017): 1.
- [6] Gunasee, Sanjana D., et al. "Pyrolysis and combustion of municipal solid wastes: Evaluation of synergistic effects using TGA-MS." *Journal of Analytical and Applied Pyrolysis* 121 (2016): 50-61.
- [7] Dai, Leilei, et al. "Pyrolysis technology for plastic waste recycling: A state-of-the-art review." *Progress in Energy and Combustion Science* 93 (2022): 101021.
- [8] Chen, Yan, et al. "Synergistic effects and products yield analyses based on co-pyrolysis of poplar tree and rape stalks with polyethylene terephthalate and polypropylene." *Journal of the Energy Institute* 112 (2024): 101461.