

Article

Plastic Devolatilisation Kinetics During Isothermal High-Temperature Pyrolysis: Focus on Solid Products (Part I)

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Abstract: Incineration remains Europe’s main practice for plastic packaging waste treatment, primarily due to the limitations of mechanical recycling technology. Consequently, research and development of more sustainable and flexible approaches are of high importance. Thermochemical conversion of polypropylene, polystyrene, and municipal plastic packaging mix via high-temperature flash pyrolysis (1000 °C/s) is studied in this research, focusing on the kinetics and yields of the devolatilisation stage. The primary stage results in the formation of volatile organic compounds considered intermediate products for carbon black production. The experiments were conducted in a pressurised wire mesh reactor, investigating the influence of temperature (600–1200 °C), residence time (0.5–10 s), and pressure (1–25 bar). The positive effect of temperature on the volatile yield was observed up to 2–5 s. The devolatilisation stage was completed within a maximum of 5 s at temperatures ranging from 800 to 1200 °C. The pressure was determined to be a kinetically limiting factor of the process to up to 800 °C, and the effect was not present at ≥ 1000 °C. Raman spectroscopy measurements revealed that pyrolytic carbon deposited on the post-experimental meshes is structurally similar to the industrially produced carbon black. The kinetic data and developed model can be further applied in the upscale reactor design.

Keywords: plastic packaging waste; flash pyrolysis; devolatilisation; carbon black; single first-order reaction model; kinetic modelling; activation energy; compensation effect



Academic Editor: Dan Boina

Received: 20 January 2025

Revised: 13 February 2025

Accepted: 15 February 2025

Published: 18 February 2025

Citation: Kiminaite, I.; Wilhelm, S.; Martetschläger, L.; Eckert, C.L.B.; Berenguer Casco, M.; Striugas, N.; Fendt, S. Plastic Devolatilisation Kinetics During Isothermal High-Temperature Pyrolysis: Focus on Solid Products (Part I). *Polymers* **2025**, *17*, 525. <https://doi.org/10.3390/polym17040525>

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1. Introduction

Sustainable handling of plastic waste (PW) remains a critical challenge in the 21st century. Extensive consumption of single-use plastic products, non-biodegradability, and economic and technical barriers in recycling processes are the main factors contributing to PW accumulation and environmental pollution [1]. According to Our World in Data, approximately 450 million tons of plastic waste is generated annually worldwide [2], with around 50 million tons in Europe. Figure 1 summarises the trends of PW treatment methods in EU27+3 in 2010–2020. Yet, heat energy recovery through incineration serves as the main strategy [3], which is unappealing due to the excessive generation of greenhouse gases and toxic substances [4]. On the other hand, a high share of PW is still directed to landfill disposal, which severely contaminates the natural biosphere and is considered a waste

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