# Modular Synthesis and Characterization of Bio-Based Polyester Foams through Polycondensation

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## INTRODUCTION

Foams are indispensable in today's world especially when it comes to environmental sustainability. We developed a modular and sustainable solution for self-foaming bio-based polyester foams [1]. Controlling the crosslinking density through the polyol used and varying the backbone through the bio-based dicarboxylic acids allows different foam properties to be realized, while the water formed during the polycondensation reaction acts as a foaming agent.

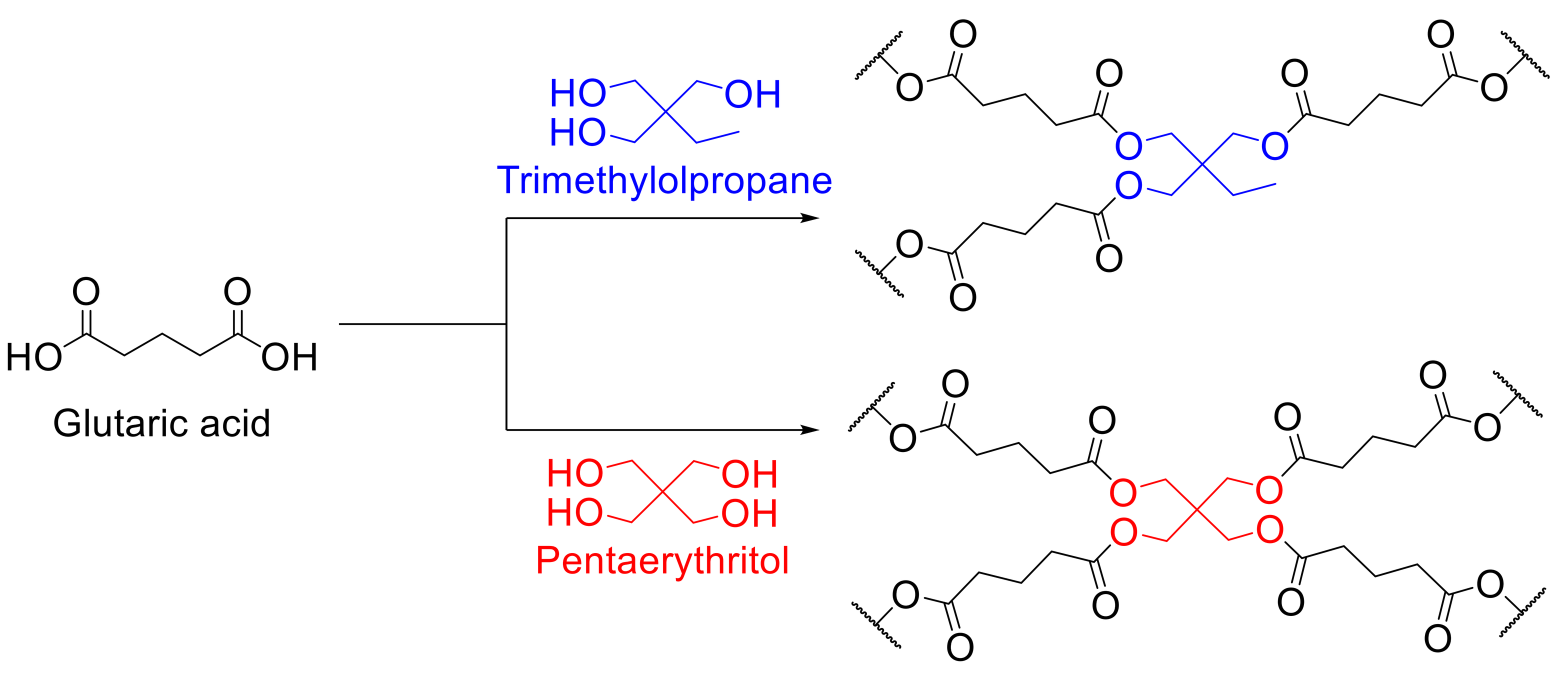


**Figure 1**: *Controlling crosslinking density by using different polyols as crosslinkers in the polycondensation reaction.*

## RESULTS AND DISCUSSION

- By varying the reaction temperature and monitoring mass loss due to water evaporation, the reaction kinetics can be determined.
- Following the reaction, the infrared vibration bands of the carboxylic acid shift to those of the ester.

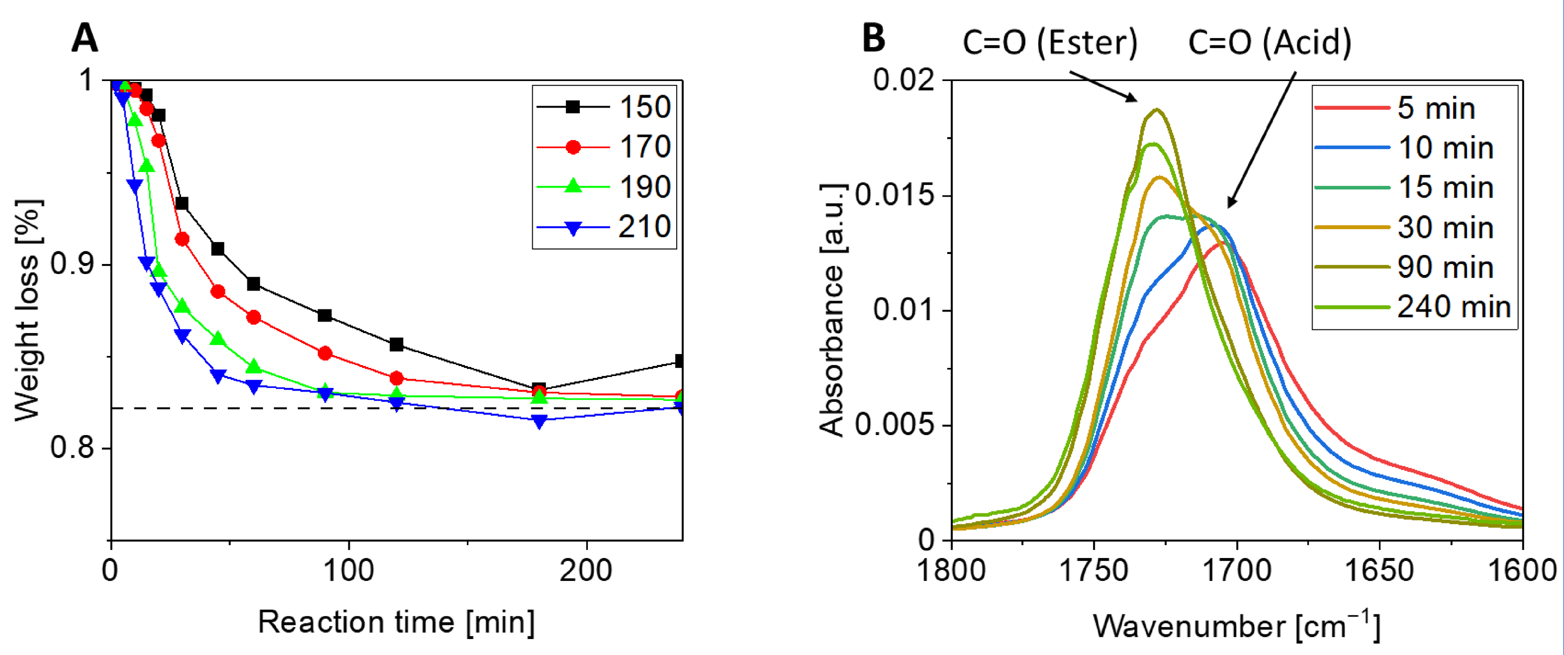


**Figure 2**: *Weight loss over time and temperature, the dashed line indicates 100 % conversion (A), and corresponding IR spectra at selected times (B).*

- The foam density can be controlled by the filling degree of the mould, limited by the foam not filling the complete volume or spilling.

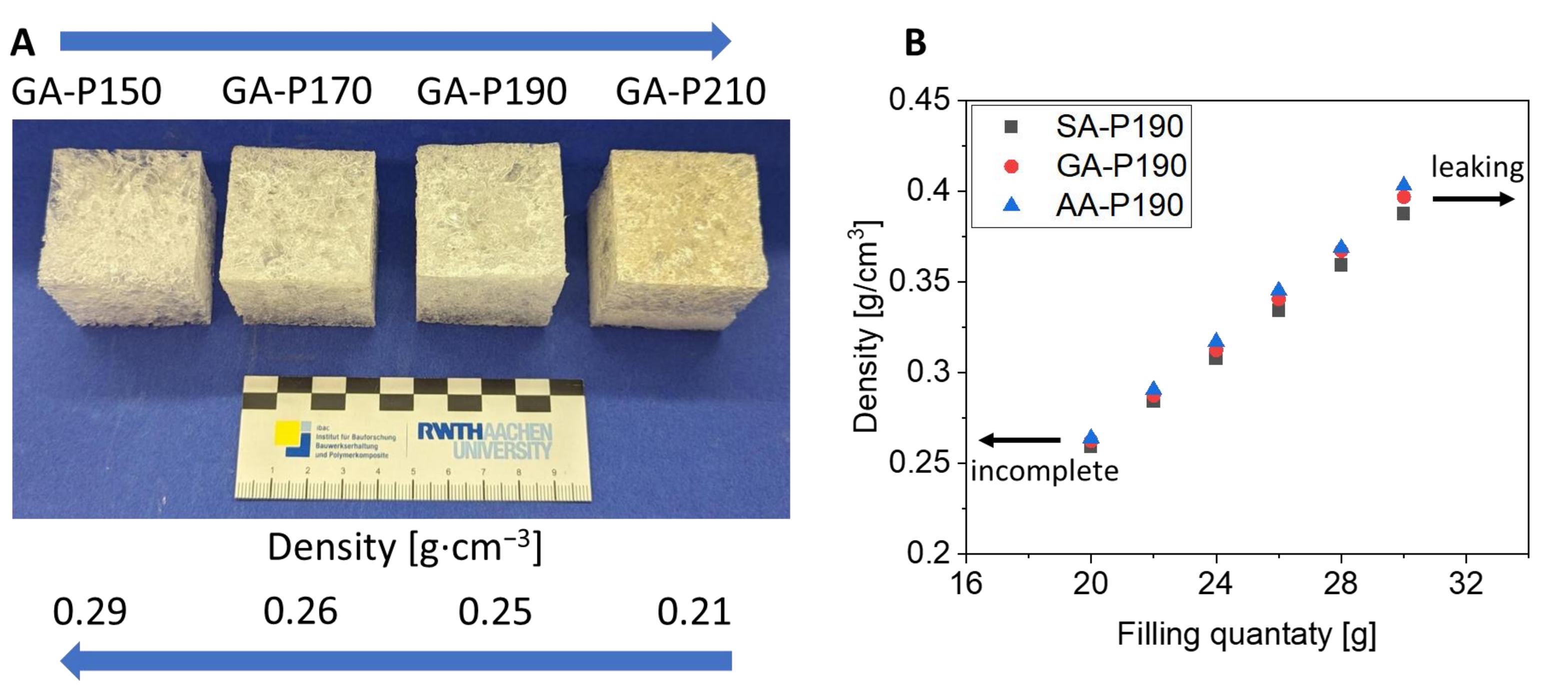


**Figure 3**: *Temperature variation in the GA-P system (A) and range of density variation at 190 °C of the different systems (B).*

- Thermal conductivity was measured by observing the sample temperature change while heating the specimen from the bottom.

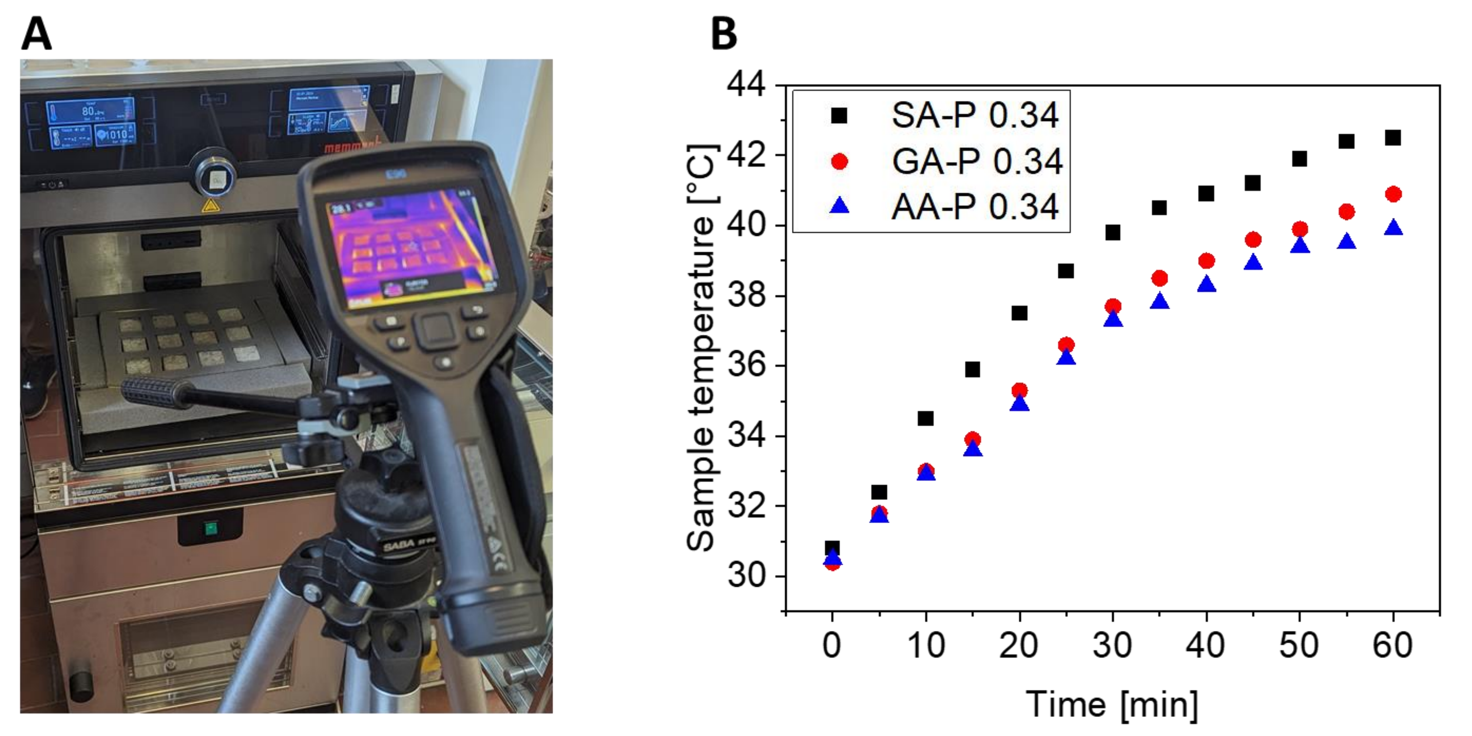


**Figure 4**: *Concept (A) of sample temperature measurement and the corresponding sample temperature within 60 min (B).*

- The foams demonstrated high flame resistance when exposed to a methane flame.
- Upon ignition, they burned slowly and without dripping, in contrast to conventional foams such as EPS or PUR.

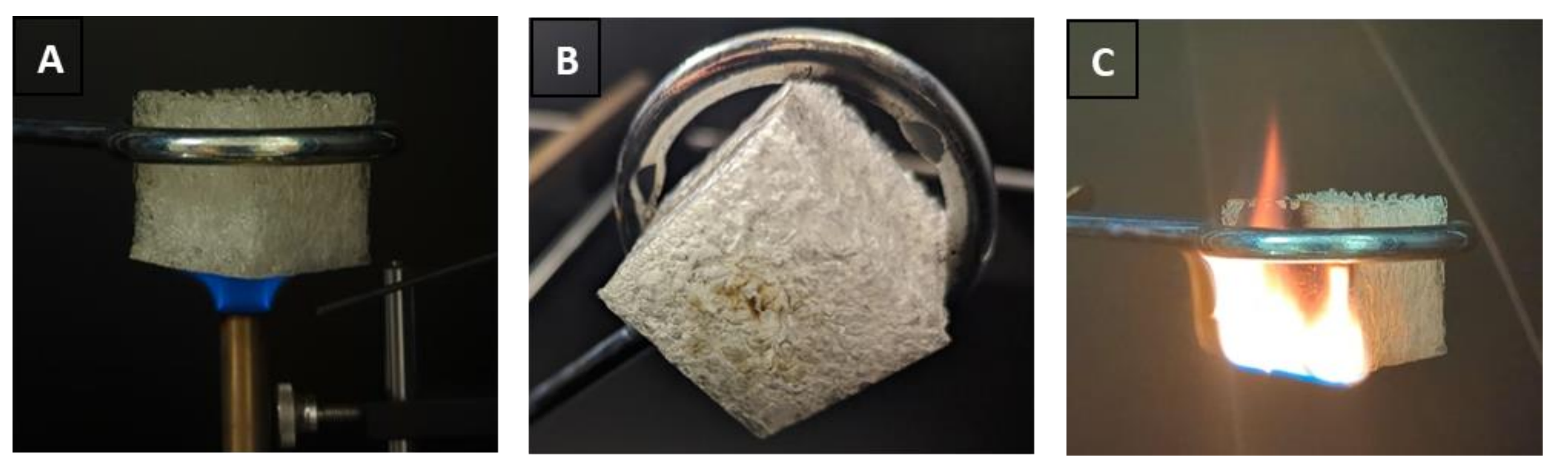


**Figure 5**: *Test specimen during (A) and after flaming five times (B) for 10 s with a methane flame. Longer exposures of 30 s ignite the foam (C), which then burns slowly without dripping.*

- SEM images show dense cell walls without microporosity.
- Higher-density foams have thicker walls and smaller pore sizes.

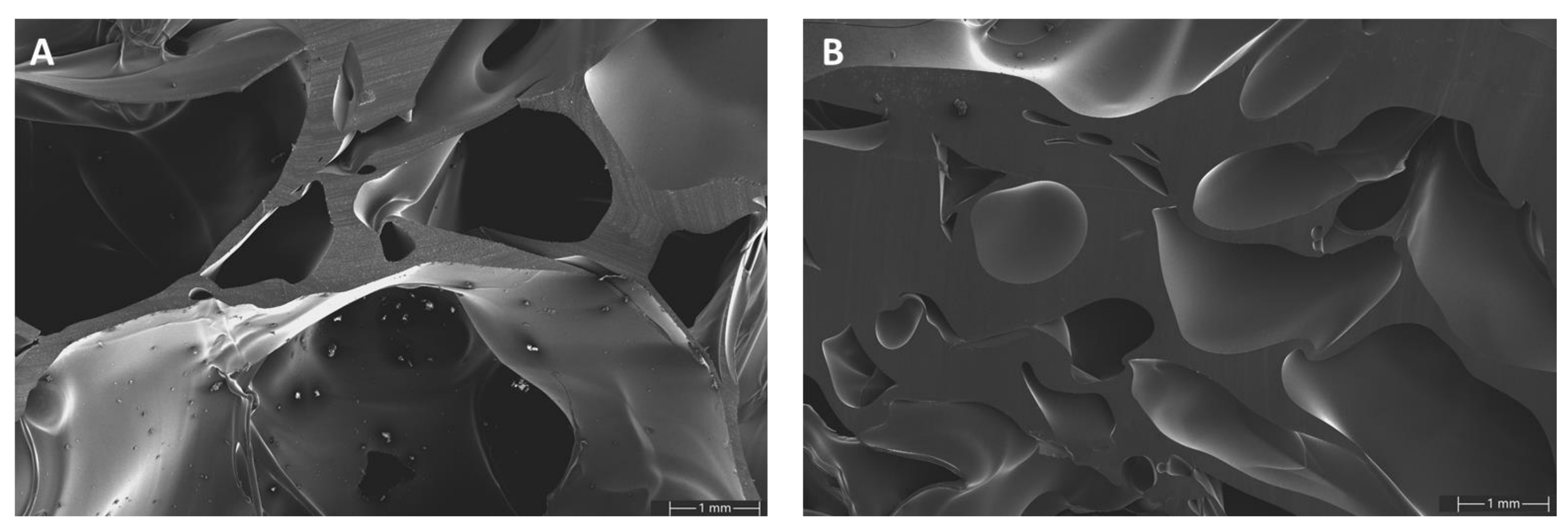


**Figure 6**: *SEM images of the foam structure of GA-P190 with a density of 0.26 g/cm³ (A) and 0.38 g/cm³ (B).*

## CONCLUSION AND OUTLOOK

- A bio-based polyester system was developed, using water generated during the reaction itself as a foaming agent without using isocyanates or other harmful substances.
- By varying dicarboxylic acids and polyols, the foam density, flexibility, and thermal behaviour can be precisely adjusted from soft to rigid materials.
- The foams show high thermal stability and exceptional flame resistance, burning up to 40 times slower than conventional polyurethane foams.
- Future research may focus on replacing currently non-bio-based components (e.g., trimethylolpropane, pentaerythritol) with fully renewable alternatives to achieve 100% bio-based formulations.

## REFERENCES

[1] Weitenhagen F.; Weichold, O. Preparation, Reaction Kinetics, and Properties of Polyester Foams Using Water Produced by the Reaction as a Foaming Agent. *Polymers* **2025**, *17*(9), 1266.

## ACKNOWLEDGEMENTS

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