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Assessing the Effect of Processing Parameters on Biodegradable Polymer Blends Using a Prototype Extruder

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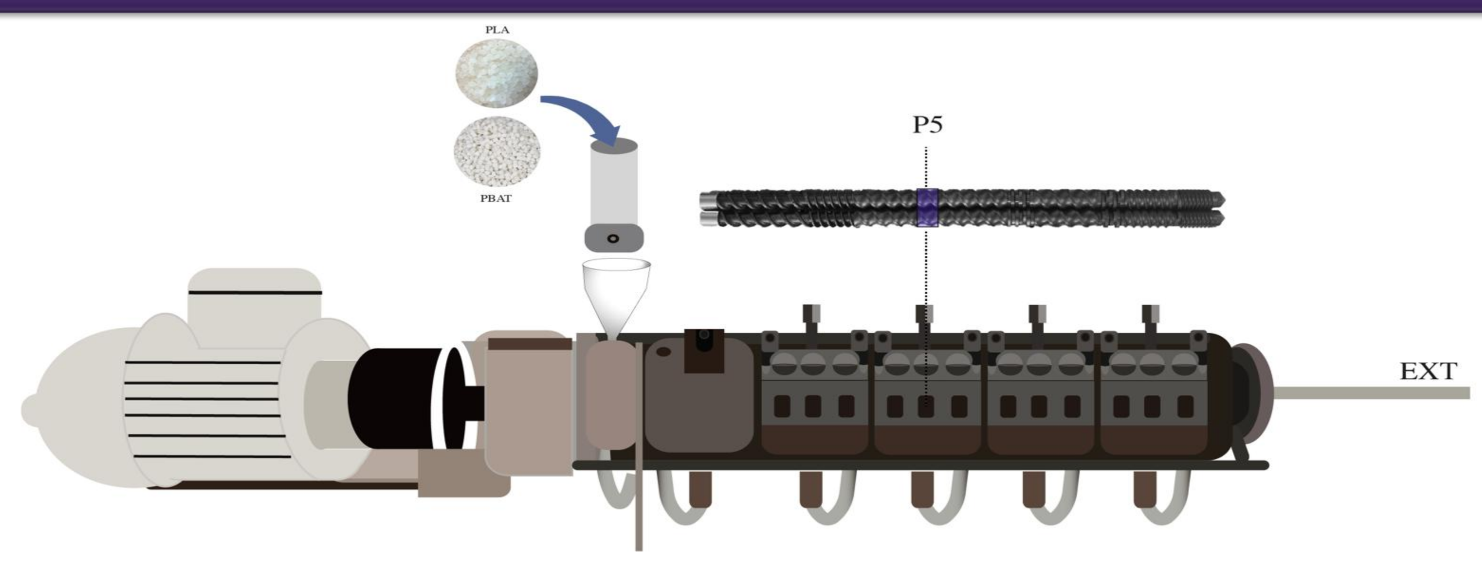
INTRODUCTION & AIM

The growing demand for sustainable materials is driving both academia and industry to replace conventional oil-based polymers with biodegradable alternatives. Blending biopolymers is an effective strategy to tailor and improve the mechanical, thermal, and processing properties of these systems. However, differences in the nature of the components can make it challenging to develop polymer blends with good morphology and thermal stability, potentially affecting their overall performance. In this study, two biodegradable polymers – polylactic acid (PLA) and poly(butylene adipate-co-terephthalate) (PBAT) - were blended, and their morphological, rheological, and structural evolution during extrusion was analyzed. An experimental prototype extruder was used, which enabled in-line monitoring of the blends throughout the extrusion process. After the experimental tests, Ludovic®, a simulation software for extrusion processes, was used to better understand how processing parameters affected the blends [1].

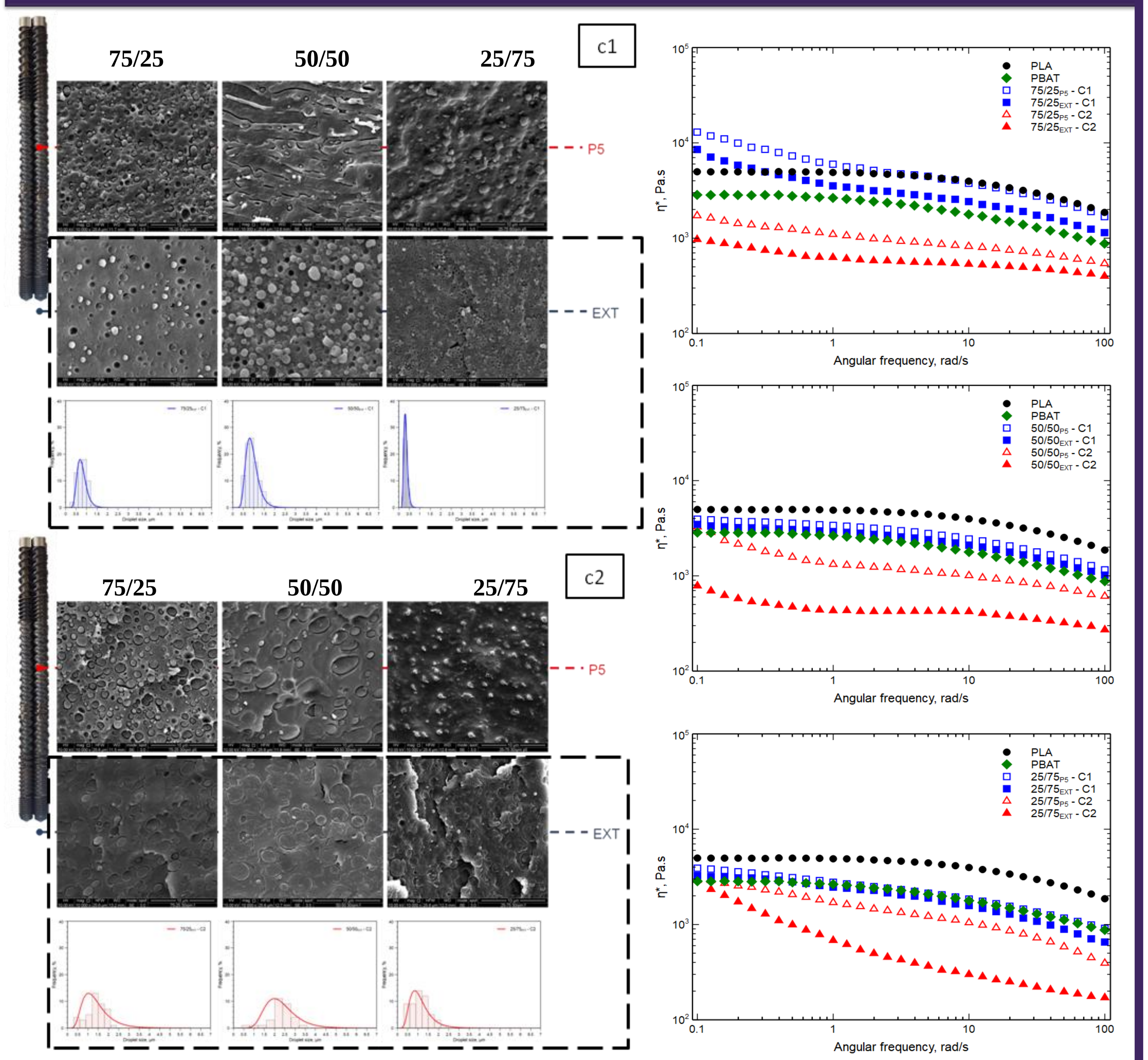
Aim of this work was to identify new strategies for optimizing the extrusion process of these blends for future applications. Therefore, this combined approach offers useful insights for improving the performance of biodegradable blends in industry.

MATERIALS AND METHODS

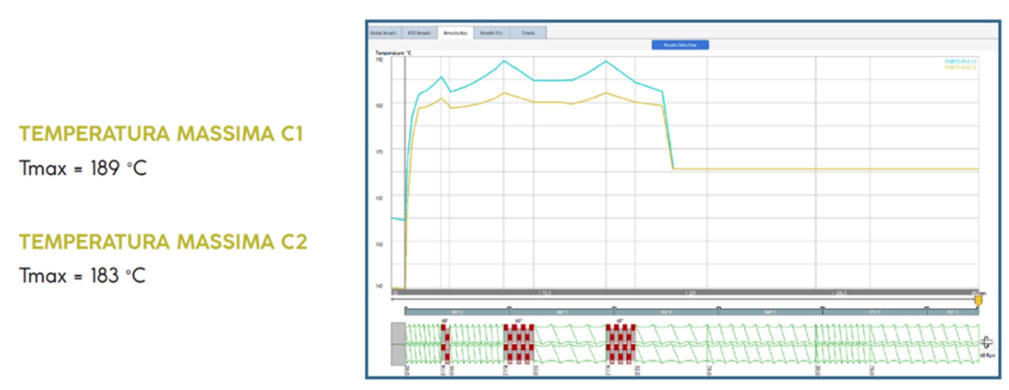


PLA and PBAT polymers were blended using a prototype extruder, as illustrated in the figure above. The blends were prepared at concentrations of 25 wt% and 50 wt% for each component. The first number indicates the PLA content, while the second corresponds to the PBAT content. The temperature profile was identical for both processing conditions: 145–150–155–160–165–170–180 °C. In condition 1 (C1), the screw speed was set to 60 rpm and the feeder speed to 280 g/h. Conversely, in condition 2 (C2), the screw speed was reduced to 30 rpm, while the feeder speed was set to 90 g/h. All characterizations were performed on samples collected at position P5 after extrusion. Prior to processing, all samples were dried under vacuum at 70 °C overnight.

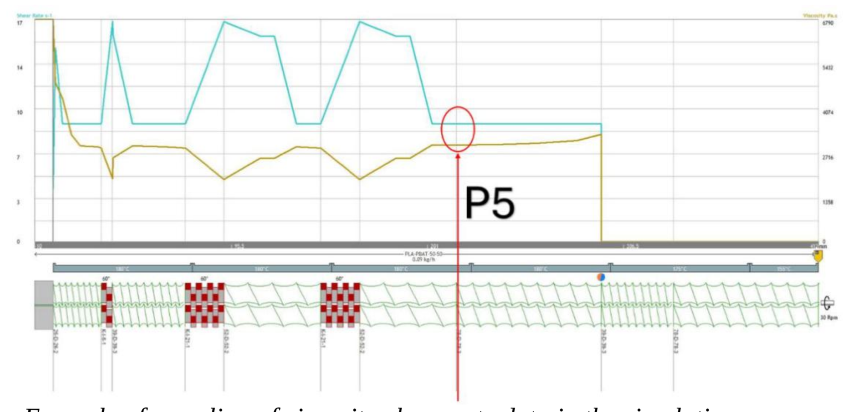
RESULTS & DISCUSSION



In both cases two immiscible phases are clearly visible in the blends, with a clear morphological evolution between sample P5 and the extruded sample and, especially, with a different distribution of the dispersed phase in the two process conditions adopted. On the other hand, the rheological results also showed different behaviour in the two conditions: in C1, the blends shows a slight decrease in viscosity mainly due to a slight thermomechanical degradation that occurs during processing. On the other hand, in C2, the blends were also subjected to thermomechanical degradation during processing, but more pronounced due to the probably excessive residence time. This behaviour was also confirmed by simulation analysis. Indeed, when Carreau-Yasuda was applied, it did not fit (see 1). However, the use of a correction taking into account the residence time allowed the experimental data to be fitted with the simulation data (see 3). This means as the residence time plays a key role in these system.

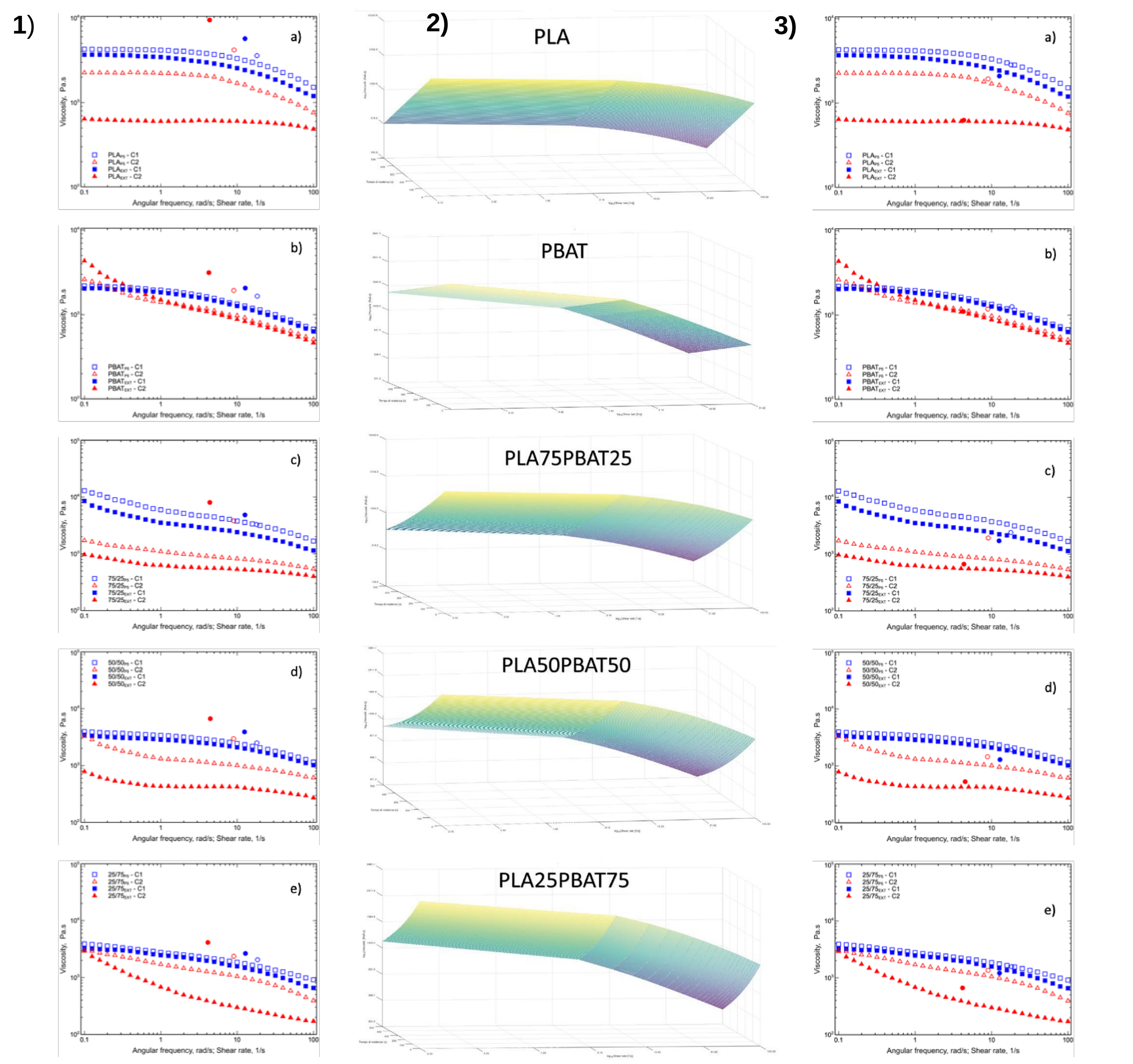


Evolution of Temperature along the twin-screw extruder.



Example of sampling of viscosity-shear rate data in the simulations..

	PLA	PBAT	75/25	50/50	25/75
Residence time (s) – C1	167.8	174	169.4	171	172.6
Residence time (s) – C2	472.6	493.8	477.6	482.8	488



1) *Experimental flow curves for a) PLA, b) PBAT, c)75/25, d) 50/50 and e) 25/75 under C1 and C2 conditions are illustrated using square and triangular markers, respectively, and compared with simulated values represent by round markers ;*
2) *Response surface of the corrected Carreau–Yasuda equation taking into account also residence time;*
3) *Experimental flow curves for a) PLA, b) PBAT, c)75/25, d) 50/50 and e) 25/75 under C1 and C2 conditions are illustrated using square and triangular markers, respectively, and compared with the values achieved with the Carreau-Yasuda corrected methods and represent by round markers;*

REFERENCES

1. Gigante V., Aliotta L., Dal Pont B., Titone V., Botta L., La Mantia F.P., Lazzeri A., **Polymer Testing**, 2023