Enzymatic Depolymerization Against Polymers Structure and Properties in the Perspective of Biochemical Recycling

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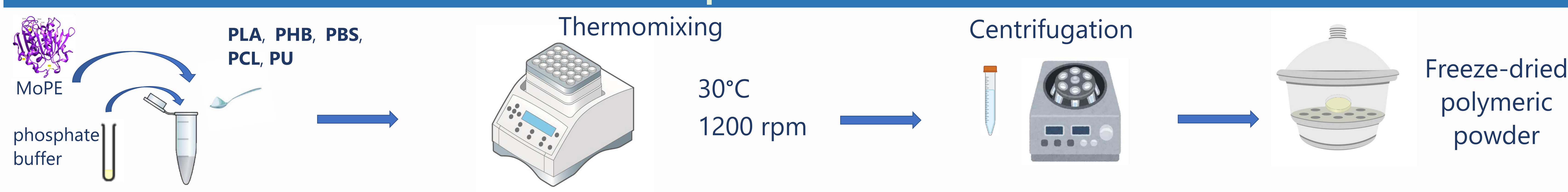
Introduction

Biochemical recycling *via* enzymatic depolymerization is an alternative, sustainable approach to produce oligomers or monomers for new polymers or other value-added products [1], [2]. Even for biodegradable polymers, enzymatic depolymerization becomes promising since their degradation kinetics in real environmental conditions is found slow [3] – [5]. In this context, a psychrophilic esterase (MoPE) from the Antarctic bacterium *Moraxella* sp. was tested based on its ability to degrade *via* hydrolysis reactions a variety of biodegradable and non-biodegradable, semi-crystalline polymers [1].

Experimental Part



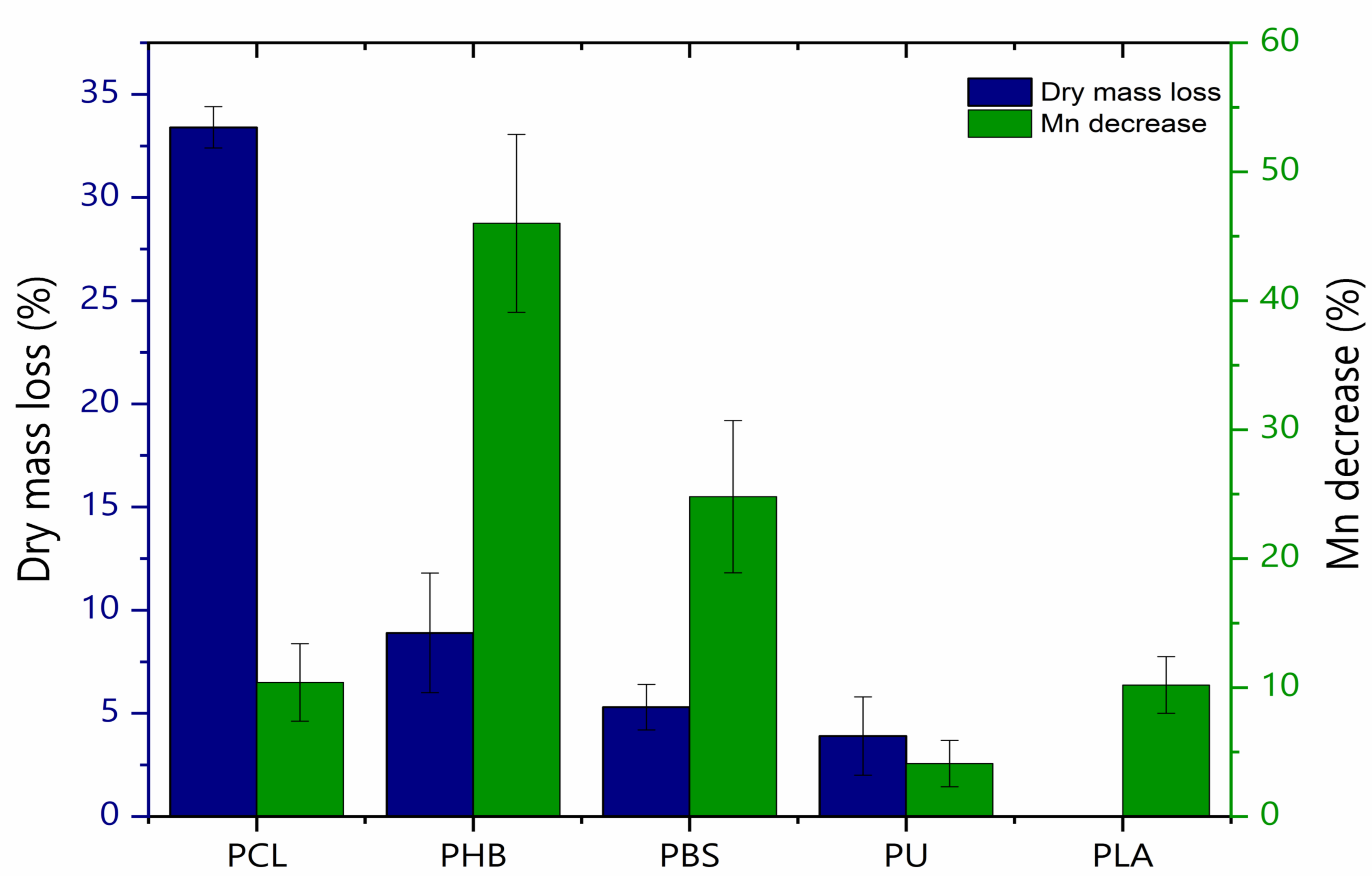
Results and Discussion

Characterization of the target polymers and **ranking** based on the most important properties (T_g, x_c, $\overline{M_n}$) **affecting enzymatic degradation**.

Polymer	T_g (°C)	x_c (%)	$\overline{M_n}$ (g/mol)
PLA	59	11	100600±300
PHB	-4	49	177400± 8100
PCL	-64	45	73700± 600
PBS	-32	64	16100± 900
PU	150	-	66500± 500

Property	Polymers Ranking
T_g	**PCL < PBS < PHB < PLA < PU**
x_c	PBS > PHB > PCL > PLA > PU
$\overline{M_n}$	PHB > PLA > PCL > PU > PBS

The enzymatic degradation **efficiency** was evaluated based on the determined **dry mass loss,** the $\overline{M_n}$ and the **PDI** decrease.

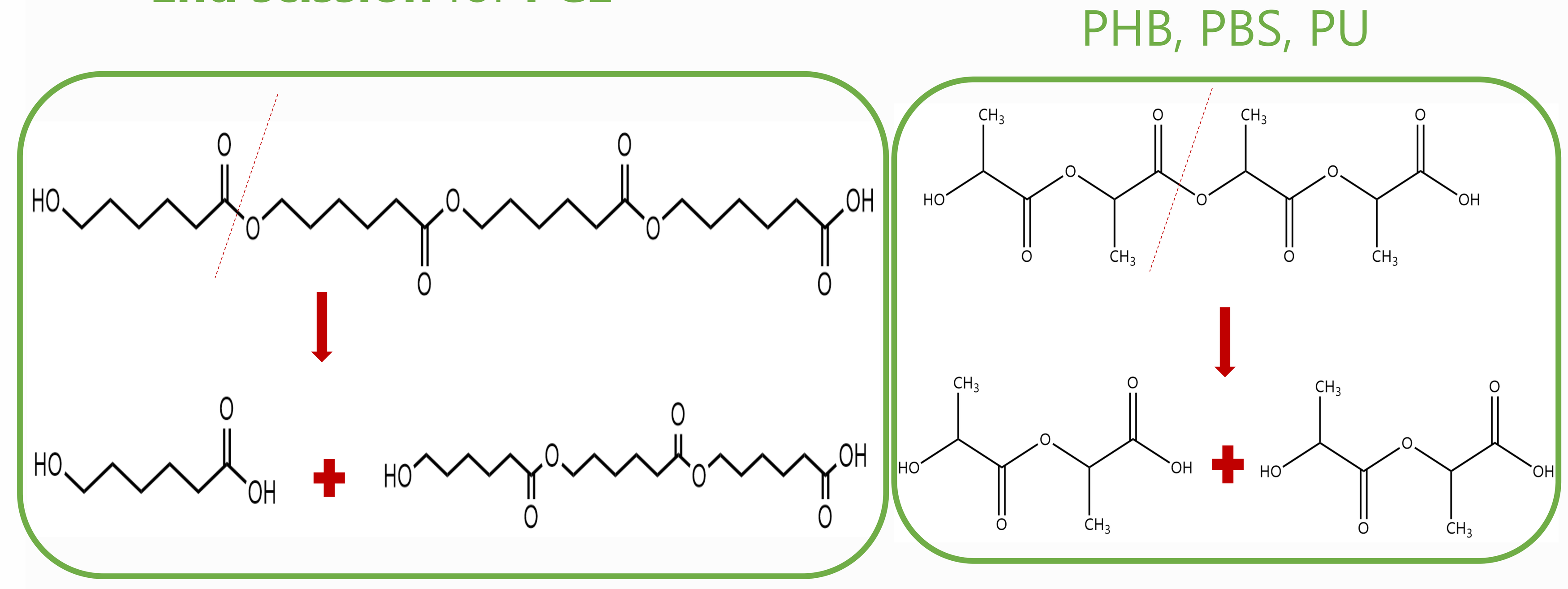


30°C > T_g → **Higher segmental mobility** in the amorphous regions → **High degradation rate**

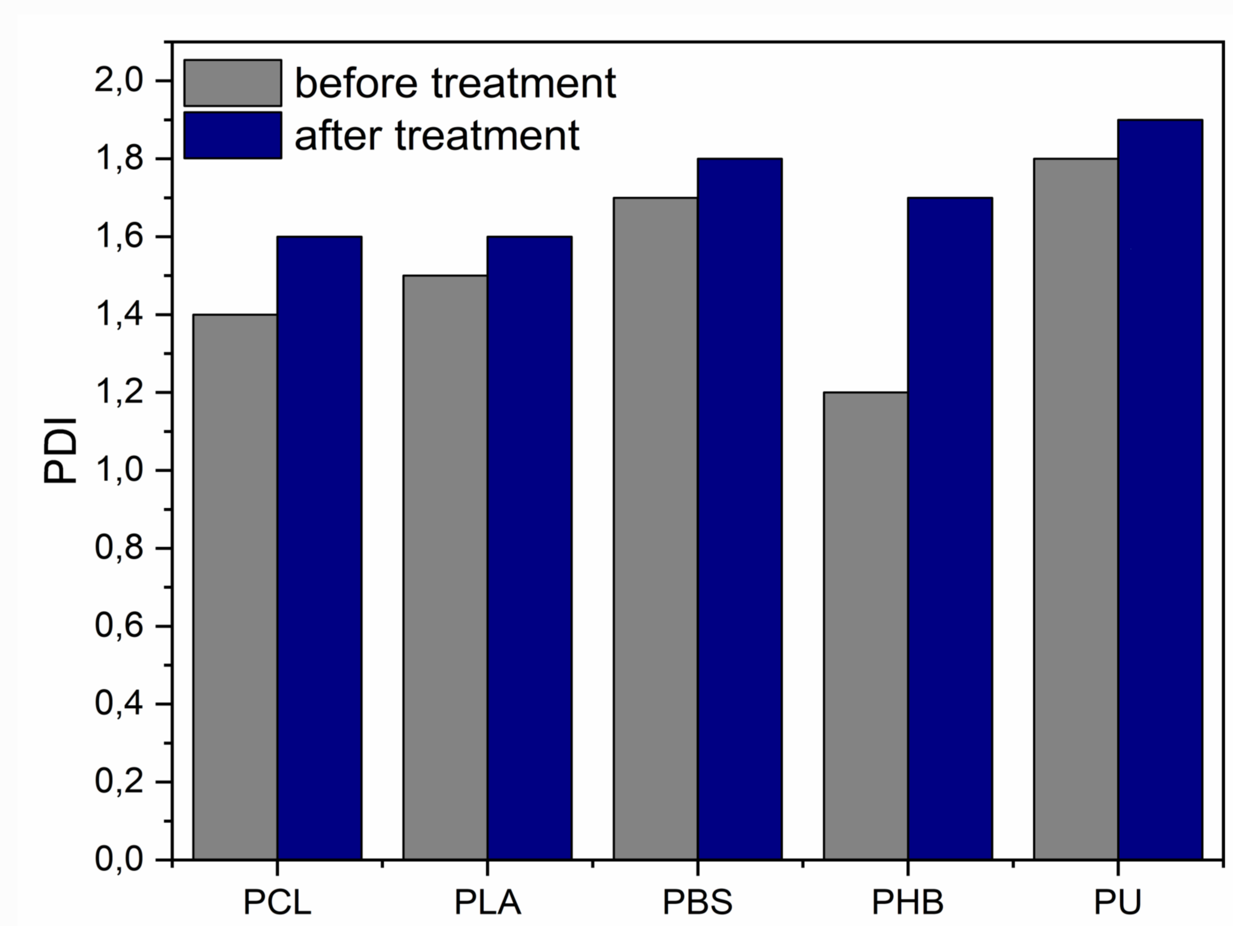
30°C < T_g → **Decreased water diffusion** rate and segmental mobility → **Lower degradation rate**

✓ **End scission** for **PCL**

✓ **Random scission** for **PLA,** PHB, PBS, PU



Slight MWD broadening



Conclusions

MoPE was found efficient to hydrolyze biodegradable and non-biodegradable polymers with a broad range of x_c from 11 up to 64%, indicating the ability of the enzyme to degrade highly crystalline polymers. The polymers' glass transition temperature was found the most crucial factor for the hydrolysis rate.

References

[1] E. Nikolaivits, G. Taxeidis, C. Gkountela, S. Vouyiouka, V. Maslak, J. Nikodinovic-Runic, E. Topakas. J. Hazard. Mater. 2022; 434: 128900

[2] E. Nikolaivits, B. Pantelic, M. Azeem, G. Taxeidis, R. Babu, E. Topakas, M. Brennan Fournet, J. Nikodinovic-Runic. Front. Bioeng. Biotechnol. 2021; 9: 535.

[3] C. Gkountela, S. Vouyiouka. Macromol. 2022; 2: 30-57.

[4] E. Rudnik, D. Briassoulis. J. Polym. Environ. 2011; 19(1): 18-39.

[5] G. Gallet, R. Lempiainen, R. Karlsson. Polym. Degrad. Stab. 2001; 71(1):147–151.

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