BIODEGRADABLE PLA/PHBV POLYMER BLENDS FOR SUSTAINABLE PACKAGING IN THE FOOD INDUSTRY

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INTRODUCTION

Nearly half of the global production of fossil fuel-based polymers is used for food packaging, and their non-biodegradability leads to significant environmental impacts. Therefore, polymers derived from renewable sources have become essential for developing sustainable packaging materials, especially in the food industry. Biodegradable polymers such as polylactic acid (PLA) and poly(3-hydroxybutyrate-*co*-3-hydroxyvalerate) (PHBV) have proven to be promising alternatives to conventional plastics. However, due to the limited functional properties of individual polymers, particular emphasis is placed on polymer blends to improve their performance and expand their application potential.

PREPARATION AND METHODS

PLA/PHBV polymer blends were prepared in different ratios: *m*(PLA)/*m*(PHBV) = 85/15, 80/20, 75/25, 70/30, 65/35. by melt mixing in Brabender kneader at 170 °C. For characterisation of the prepared polymer blends, plates and foils were prepared. The plates were obtained via pressing of polymer blends previously placed inside a metal mold on a Fontune Holland hydraulic press at 170 °C, under a pressure of 20 kPa for five minutes and cooling on a Dake Model 44-226 press. Pure PLA and PHBV were used as control samples.

ATR-FTIR (Perkin Elmer Spectrum One): Measured at room temperature in the wavenumber range 4000–650 1/cm and spectral resolution of 4 1/cm

DSC (Mettler Toledo DSC 3+ Star e System): Two heating cycles (-50 to 200 °C, heating rate °C/min) in nitrogen atmosphere

DMA (HR 30 Rheometer, TA Instruments): Temperature range -30 to 150 °C, heating rate 3 °C/min, 10 µm amplitude, air atmosphere.

TGA (Mettler Toledo TGA/DSC 3+ Star System): Measured from 25 to 700 °C, heating rate 10 °C/min, nitrogen atmosphere.

SEM (VEGA3 TESCAN): Morphological characteristics; cross-sections of cryogenically fractured surfaces; magnification 500X

Mechanical Properties (AllroundLine Zwick): Tensile testing at 10 mm/min, grip separation 50 mm, T = 25 °C.

Water Vapor Permeability, WVP: Measured using the Herfeld method.

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RESULTS

ATR-FTIR

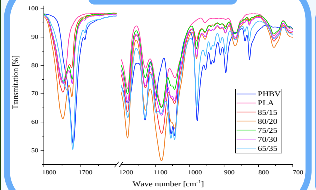


Fig. 1. ATR-FTIR analysis results of polymeric blends PLA/PHBV

DSC

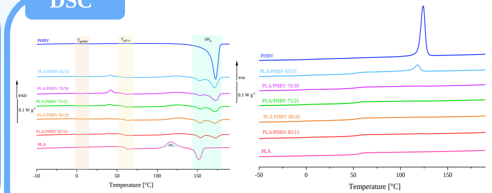


Fig. 2. DSC thermograms of polymeric blends PLA/PHBV

Table 1. DSC results of polymeric blends PLA/ PHBV

Samples	$T_{g,PHBV}$/°C	$T_{g,PLA}$/°C	$T_{cc,PHBV}$/°C	$T_{cc,PLA}$/ °C	$T_{m,PLA}$/ °C	$T_{m,PHBV}$/°C	T_c/°C	$\chi_{c,PLA}$/%	$\chi_{c,PHBV}$/%
PHBV	5.1	/	/	/	/	171.9	125.1	/	89.5
65/35	0.6	57.3	/	/	152.3	170.9	118.1	11.6	31.2
70/30	1.6	58.2	42.0	124.1	153.2	172.8	/	6.7	21.9
75/25	1.5	58.7	40.5	125.4	153.4	171.5	/	13.8	13.8
80/20	1.2	58.8	37.3	126.5	153.4	171.2	/	28.2	8.7
85/15	1.4	58.2	/	128.1	153.7	172.1	/	46.1	3.5
PLA	/	60.2	/	116.9	151.4	/	/	26.3	-

DMA

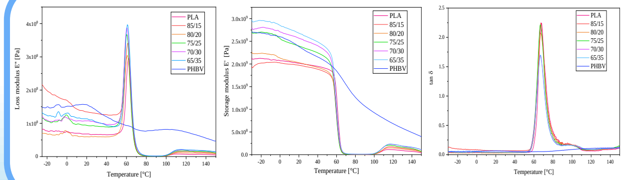


Fig. 2. DMA results of polymeric blends PLA/PHBV: a) loss modulus, b) storage modulus, c) tan δ

TGA

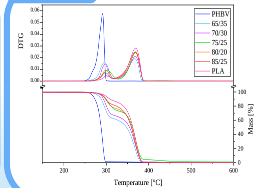
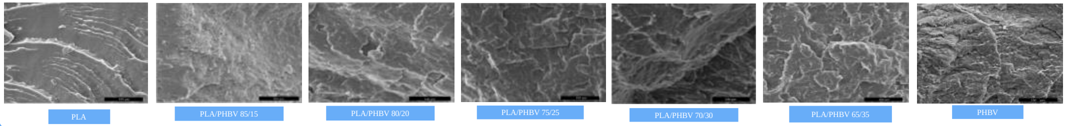


Fig. 4. TGA thermograms of polymeric blends PLA/PHBV

Table 2. TG and DTG results of polymeric blends PLA/PHBV

Samples	TG					DTG	
	T_{onset}/°C	T_{end} /°C	Δm_{PHBV}/%	Δm_{PLA}/%	$R_{600°C}$ /%	$T_{maxPHBV}$/°C	T_{maxPLA}/°C
PHBV	284.1	312.6	99.5	/	0.4	292.4	
65/35	282.1	378.1	37.4	61.6	0.7	296.2	367.6
70/30	287.4	380.5	32.8	65.8	0.6	299.3	369.2
75/25	290.5	380.3	32.8	65.8	2.7	305.4	369.8
80/20	287.0	380.1	23.1	76.1	0.2	300.4	369.7
85/15	281.5	379.8	18.9	80.6	0.2	298.6	368.7
PLA	348.7	377.1	/	99.2	0.8	/	370.4

SEM magnification 500x



MECHANICAL PROPERTIES

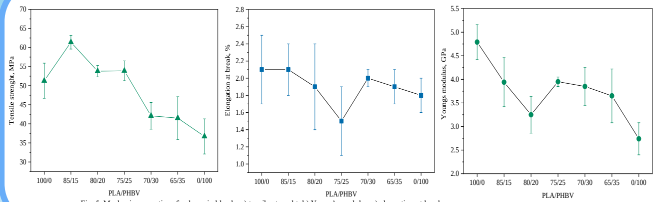


Fig. 5. Mechanic properties of polymeric blends: a) tensile strenght, b) Young's modulus, c) elongation at break

WVP

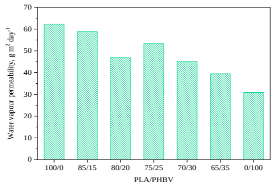


Fig.6. Water vapour permeability of polymeric blends PLA & PHBV

CONCLUSION

PLA and PHBV are semi-crystalline polymers, with PLA exhibiting a lower degree of crystallinity than PHBV. In PLA/PHBV polymer blends, PHBV functions as a nucleating agent, facilitating the crystallization of PLA. Increasing the PLA content in these blends leads to a shift in FTIR absorption bands toward higher wavenumbers, attributed to intermolecular interactions between PLA and PHBV. DSC analysis reveals the presence of two distinct glass transitions, indicating partial miscibility between the polymers. TGA analysis shows a two-step thermal decomposition process in PLA/PHBV blends, with a decline in thermal stability as PHBV content increases. SEM micrographs reveal a homogeneous morphology, suggesting interfacial adhesion between PLA and PHBV.

Increasing the PHBV content enhances the barrier properties of the blends due to the inherently hydrophobic nature of PHBV. The mechanical properties of PLA/PHBV blends show a clear trend: as the PHBV content increases, the tensile strength and Young's modulus decrease, indicating reduced stiffness and strength. However, elongation at break increases, suggesting improved ductility, which could enhance flexibility in applications requiring toughness.

Overall, PLA/PHBV blends demonstrate promising potential for food packaging applications, particularly at lower PHBV concentrations.