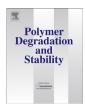


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Long-term properties and end-of-life of polymers from renewable resources



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ABSTRACT

The long-term properties and end-of-life of polymers are not antagonist issues. They actually are inherently linked by the duality between durability and degradation. The control of the service-to-disposal pathway at useful performance, along with low-impact disposal represents an added-value. Therefore, the routes of design, production, and discarding of bio-based polymers must be carefully strategized. In this sense, the combination of proper valorisation techniques, i.e. material, energetic and/or biological at the most appropriate stage should be targeted. Thus, the consideration of the end-of-life of a material for a specific application, instead of the end-of-life of a material should be the fundamental focus. This review covers the key aspects of lab-scale techniques to infer the potential of performance and valorisation of polymers from renewable resources as a key gear for sustainability.

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Abbrevi	iations	PBS	Poly(butylene succinate)
		PCL	Polycaprolactone
AFM	Atomic Force Microscopy	PE	Polyethylene
AIDS	Acquired Immune Deficiency Syndrome	PET	Poly(ethylene terephtalate)
ASTM	American Society for Testing Materials	PGA	Poly(glycolic acid)
ATP	Adenosine Triphosphate	PHAs	Polyhydroxyalkanoates
DETA	Dielectric Thermal Analysis	PHB	Polyhydroxybutirate
DMTA	Dynamic Mechanical-Thermal Analysis	PHBV	Poly(hydroxybutyrate-co-valerate)
DSC	Differential Scanning Calorimetry	PHV	Polyhydroxyvalerate
EN	European Standards Organisation	PLA	Poly(lactic acid)
FTIR	Fourier Transformed Infrared Spectroscopy	PLGA	Poly(lactic-co-glycolic acid)
GC	Gas Chromatography	PP	Poly(propylene)
GPC	Gel Permeation Chromatography	PVA	Poly(vinyl alcohol)
HV	Hydroxyvalerate	PVC	Poly(vinyl chloride)
ISO	International Standard Organisation	PS	Polystyrene
LCA	Life Cycle Assessments	PSW	Plastic Solid Waste
LMWC	Low Molecular Weight Compounds	SEM	Scanning Electron Microscopy
MALDI-	TOF-MS Matrix-Assisted Laser Desorption-Ionization	TE-EC	End-Chain Transesterifications
	Time-of-Flight Mass Spectrometry	TE-MC	Middle-Chain Transesterifications
MODA	Microbial Oxidative Degradation Analyser	TEM	Transmission Electron Microscopy
NMR	Nuclear Magnetic Resonance	TGA	Thermogravimetric Analysis
OIT	Oxidation Induction Time	TPS	Thermoplastic Starch
PBAT	Poly(butylene adipate terephthalate)	UV	Ultraviolet
PBF	Poly(butylene fumarate)		

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1. Sustainability of polymers from renewable resources

Plastics currently account for about 20% by volume of municipal solid waste. Even more, they are not only generating so much waste, but are also becoming extinct due to finite petroleum-based reserves. It is estimated that the global resources of oil, natural gas and coal are limited and the economic impact could be exhausted in a near future, as prices will rise as these resources are more limited [1]. Due to the oscillation of oil prices and the problem of the accumulation of waste, which has led to hard environmental policies, polymers from renewable resources may become a sustainable solution. Actually, this market has experienced a high expansion, being the focus of lots of research studies [2], in many sectors of application, such as food packaging, agriculture and biomedicine, among other.

Food packaging applications aim at substitute traditional polymers [3,4] by bio-based polymers such as poly(lactic acid) (PLA) [5–8] or polyhydroxyalkanoates (PHA) [9,10], along with other polymers [11–13], blends [14–16], or nanocomposites [17–31]. The focus is devoted to the combination of appropriate processability, good durability [32–34] barrier properties [35–38,24,39,40], and tuned biodegradability [33,41–46], as well as to add value with natural additives [47], the combination of coatings [48,35,36,49–58], and multilayers [37,38,59–63,31,64,65], or even the production of edible [66–70,58,71,72,57,58,73,74] or active properties [75–87]. Agricultural applications [88] consider the use

of polymers from renewable resources as films for mulching and protection [88–92], drug delivery [93–103], or goods as twines. strings, filaments and clips [104]. Biomedical applications based on polymers from renewable resources [105,106], are based on their biodegradability and biocompatibility with low-impact form substance after degradation [107-109], for applications such as tissue engineering [110–121], which ensure cell proliferation [122–124,119,125–128], controlled drug delivery [129–142], wound dressing [143–159,117,160–163]. In all cases, all polymers require a tuned balance between their performance during service life, and their degradation behaviour after use, that is, between the long-term properties and their end-of-life. Nevertheless, polymers from renewable resources still involve relatively high production costs and, frequently, they show underperformed properties for each application in contrast to their petroleum-based counterparts. In addition, concerns are growing into the society about the use of long-life polymers in products in which a short-life is expected. Therefore, there is an engagement to base the research in appropriate production-service-waste management mainstreams on an equitable commitment of the three pillars of sustainability, i.e. People (social pillar), Planet (environmental pillar) and Profit (economic pillar) [164].

Specifically, the sustainability of polymers from renewable resources, i.e. bio-based polymers, is a topic which has been approached from several perspectives due to its importance and impact on wealth, environment and technological development

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