



Review

The chemomechanical properties of microbial polyhydroxyalkanoates

Bronwyn Laycock^{a,b,*}, Peter Halley^{a,b,1}, Steven Pratt^{a,2}, Alan Werker^{c,3}, Paul Lant^{a,4}^a School of Chemical Engineering, The University of Queensland, St Lucia, Qld 4072, Australia^b Australian Institute for Bioengineering and Nanotechnology, The University of Queensland, Brisbane, Qld 4072, Australia^c AnoxKaldnes AB, Klosterängsvägen 11A, SE-226 47 Lund, Sweden

ARTICLE INFO

Article history:

Received 1 February 2012

Received in revised form 26 June 2012

Accepted 26 June 2012

Available online 16 July 2012

Keywords:

Biopolymer

Polyhydroxyalkanoates

Microbial polyesters

Poly((R)-3-hydroxybutyrate)

Poly((R)-3-hydroxybutyrate-co-3-hydroxyvalerate)

Mechanical properties

ABSTRACT

Microbially produced polyhydroxyalkanoates (PHAs) are fully biodegradable biopolyesters that have attracted much attention recently as alternative polymeric materials that can be produced from biorenewable and biowaste resources. The properties of these biological polymers are affected by the same fundamental principles as those of fossil-fuel derived polyolefins, with a broad range of compositions available based on the incorporation of different monomers into the PHA polymer structure, and with this broad range tailoring subsequent properties. This review comprehensively covers current understanding with respect to PHA biosynthesis and crystallinity, and the effect of composition, microstructure and supramacromolecular structures on chemomechanical properties. While polymer composition and microstructure are shown to affect these properties, the review also finds that a key driver for determining polymer performance properties is compositional distribution. From this review it follows that PHA–PHA blend compositions are industrially important, and the performance properties of such blends are discussed. A particular need is identified for further research into the effect of chemical compositional distribution on macromolecular structure and end-use properties, advanced modeling of the PHA accumulation process and chain growth kinetics for better process control.

© 2012 Elsevier Ltd. All rights reserved.

Contents

1. Introduction	538
2. Overview of PHA production	539
2.1. PHA production in pure cultures	539
2.2. PHA production in mixed cultures	539
2.3. Other production techniques	540
2.4. Conclusions	540
3. PHA fundamentals	540
3.1. Biosynthesis	540

* Corresponding author at: School of Chemical Engineering, The University of Queensland, St Lucia, Qld 4072, Australia. Tel.: +61 7 3346 3188; fax: +61 7 3346 3973.

E-mail addresses: b.laycock@uq.edu.au (B. Laycock), p.halley@uq.edu.au (P. Halley), s.pratt@uq.edu.au (S. Pratt), Alan.Werker@anoxkaldnes.com (A. Werker), paul.lant@uq.edu.au (P. Lant).

¹ Fax: +61 7 3346 3973.

² Fax: +61 7 3346 7843.

³ Fax: +46 46 133201.

⁴ Fax: +61 7 3365 4728.

3.2.	Granule structure and development	541
3.3.	Mechanism of polymerization	542
4.	Crystal structures of PHA	544
4.1.	The α -form crystals of PHA	545
4.2.	The β -form crystals of PHA	545
4.3.	Isodimorphism in P(3HB-co-3HV) copolymers	546
5.	Notes on the analysis of crystallinity in PHA copolymers	548
6.	Crystallization kinetics	550
6.1.	Equilibrium melting temperature	550
6.2.	PHA crystal growth kinetics	550
6.3.	Analysis of crystallization kinetics and mechanism	551
6.4.	Effect of blends on crystallization rates	552
7.	Molecular weight control	552
8.	Control of monomer distribution and microstructure	553
9.	Comonomer sequence compositional distribution	554
9.1.	Characterization of comonomer compositional distribution	555
9.2.	Solvent fractionation	556
9.2.1.	Solvent fractionation of P(3HB-co-3HV)	556
9.2.2.	Solvent fractionation of other PHAs	557
10.	PHA-PHA blends	559
11.	Mechanical properties of PHA	561
11.1.	Properties of pure culture PHA	561
11.2.	Properties of mixed culture PHA	562
11.3.	Properties of "block" copolymeric PHA	564
11.4.	Physical techniques for the modification of PHA mechanical properties	565
11.5.	Effect of additives	566
11.6.	PHA blends	566
11.7.	PHA processing	567
12.	Outlook	567
12.1.	Modeling of PHA accumulation process and chain growth kinetics	567
12.2.	Compositional distribution and mechanical properties	567
12.3.	Full characterization of mixed culture PHA	568
	Acknowledgments	568
	Appendix A. Physical properties of mixed culture PHA	569
	Appendix B. Effect of polymer composition on mechanical properties of PHA – data sampled from the literature	571
	References	574

2D	two-dimensional
3D	three-dimensional
^{13}C	carbon-13
3HB	3-hydroxybutyrate
3HD	3-hydroxydecanoate
3HDD	3-hydroxydodecanoate
3HHx	3-hydroxyhexanoate
3H2MB	3-hydroxy-2-methylbutyrate
3H2MV	3-hydroxy-2-methylvalerate
3H4MV	3-hydroxy-4-methylvalerate
3HO	3-hydroxyoctanoate
3HP	3-hydroxypropionate
3HPE	3-hydroxy-4-pentenoate
3HTD	3-hydroxytetradecanoate
3HV	3-hydroxyvalerate
4HB	4-hydroxybutyrate
ACP	acyl carrier protein
Ae	aerobic
ADF	aerodynamic feeding
AFM	atomic force microscopy
An	anaerobic

BOD	biochemical oxygen demand
CCD	chemical compositional distribution
CH_2	methylene group
CoA	coenzyme A
COD	chemical oxygen demand
Da	Dalton
DMTA	dynamic mechanical thermal analysis
DO	dissolved oxygen
DOC	dissolved organic carbon concentration
DSC	differential scanning calorimetry
DP	degree of polymerization
E_a	activation energy
EBPR	enhanced biological phosphorus removal
ESI-MS	electrospray ionization multistage mass spectrometry
F_{BB}	fraction of the BB diad sequence in a P(3HB-co-3HV) copolymer
F_{BV}	fraction of the BV diad sequence in a P(3HB-co-3HV) copolymer
F_{VB}	fraction of the VB diad sequence in a P(3HB-co-3HV) copolymer

Download English Version:

<https://daneshyari.com/en/article/5208444>

Download Persian Version:

<https://daneshyari.com/article/5208444>

[Daneshyari.com](https://daneshyari.com)