Document details

Applied Biochemistry and Biotechnology
Volume 170, Issue 3, June 2013, Pages 690-709

Preparation and characterization of polyhydroxyalkanoates macroporous scaffold through enzyme-mediated modifications (Article)

Ansari, N.F.[a], Amirul, A.A.[ab]

[a]School of Biological Sciences, Universiti Sains Malaysia, 11800 Minden, Penang, Malaysia
[b]Malaysian Institute of Pharmaceutical and Nutraceutical, MOSTI, 11700 Halaman Bukit, Gambir, Penang, Malaysia

Abstract

View references (37)

Polyhydroxyalkanoates (PHAs) are hydrophobic biodegradable thermoplastics that have received considerable attention in biomedical applications due to their biocompatibility, mechanical properties, and biodegradability. In this study, the degradation rate was regulated by optimizing the interaction of parameters that influence the enzymatic degradation of P(3HB) film using response surface methodology (RSM). The RSM model was experimentally validated yielding a maximum 21 % weight loss, which represents onefold increment in percentage weight loss in comparison with the conventional method. By using the optimized condition, the enzymatic degradation by an extracellular PHA depolymerase from Acidovorax sp. DP5 was studied at 37 C and pH 9.0 on different types of PHA films with various monomer compositions. Surface modification of scaffold was employed using enzymatic technique to create highly porous scaffold with a large surface to volume ratio, which makes them attractive as potential tissue scaffold in biomedical field. Scanning electron microscopy revealed that the surface of salt-leached films was more porous compared with the solvent-cast films, and hence, increased the degradation rate of salt-leached films. Apparently, enzymatic degradation behaviors of PHA films were determined by several factors such as monomer composition, crystallinity, molecular weight, porosity, and roughness of the surface. The hydrophilicity and water uptake of degraded salt-leached film of P(3HB-co-70%4HB) were enhanced by incorporating chitosan or alginate. Salt-leached technique followed by partial enzymatic degradation would enhance the cell attachment and suitable for biomedical as a scaffold. © 2013 Springer Science+Business Media New York.

Author keywords

Enzymatic degradation | Experimental design | PHA depolymerase | Polyhydroxyalkanoates | Surface modification

Indexed keywords

Compendex keywords: Biodegradable thermoplastics | Biomedical applications | Conventional methods | Depolymerase | Enzymatic Degradation | Monomer compositions | Polyhydroxyalkanoates | Response surface methodology

Engineering controlled terms: Biocompatibility | Biodegradation | Biomechanics | Copolymerization | Degradation | Design of experiments | Leaching | Mechanical properties | Medical applications | Optimization | Scanning electron microscopy | Surface treatment | Tissue

Engineering main heading: Scaffolds (biology)

EMTREE drug terms: polyhydroxyalkanoic acid | tissue scaffold

EMTREE medical terms: Acidovorax, article, biodegradability, cell adhesion, comparative study, controlled study, enzymatic degradation, enzyme active site, enzyme activity, enzyme modification, film, hydrolysis, hydrophilicity, incubation time, molecular weight, nonhuman, pH, porosity, reaction time, response surface method, scanning electron microscopy, water transport, weight reduction

MeSH: Biodegradation, Environmental, Carboxylic Ester Hydrolases, Hydrophobic and Hydrophilic Interactions, Hydroxybutyrates, Microscopy, Electron, Scanning, Molecular Weight, Polyesters, Polyhydroxyalkanoates, Spectroscopy, Fourier Transform Infrared, Tissue Scaffolds

Species Index: Acidovorax

Chemicals and CAS Registry Numbers:

Carboxylic Ester Hydrolases, 3.1.1.-; Hydroxybutyrates; Polyesters; Polyhydroxyalkanoates; poly(3-hydroxyalkanoic acid) depolymerase, 3.1.1.-

ISSN: 02732289
Source Type: Journal
Original language: English

DOI: 10.1007/s12010-013-0216-0
PubMed ID: 23604967
Document Type: Article

References (37)

View in search results format >

All | Export | Print | E-mail | Save to PDF | Create bibliography

1 Doi, Y.
(1990) *Microbial Polyesters*. Cited 1383 times.
VCH New York

2 Tran, R., Dey, J., Gyawali, D., Zhang, Y., Yang, J.
(2010) *Biomaterials for MEMS*, pp. 1-32. Cited 2 times.
M. Chiao & J. C. Chiao (Eds) Pan Stanford Publishing Book

3 Abe, H., Doi, Y., Aoki, H., Akehata, T.
Solid-state structures and enzymatic degradabilities for melt-crystallized films of copolymers of (R)-3-hydroxybutyric acid with different hydroxyalkanoic acids
(1998) *Macromolecules*, 31 (6), pp. 1791-1797. Cited 169 times.
View at Publisher

4 Renard, E., Walls, M., Guérin, P., Langlois, V.
Hydrolytic degradation of blends of polyhydroxyalkanoates and functionalized polyhydroxyalkanoates
(2004) *Polymer Degradation and Stability*, 85 (2), pp. 779-787. Cited 57 times.
doi: 10.1016/j.polymdegradstab.2003.11.019
View at Publisher

5 Hiraishi, T., Taguchi, S.
Enzyme-catalyzed synthesis and degradation of biopolymers
(2009) *Mini-Reviews in Organic Chemistry*, 6 (1), pp. 44-54. Cited 20 times.
http://www.ingentaconnect.com/content/ben/mroc/2009/00000006/00000001/art00005
doi: 10.2174/157019309787316139
View at Publisher

fermentation and enzymatic degradation
Faezah, A.N. , Rahayu, A. , Vigneswari, S.
(2011) World Journal of Microbiology and Biotechnology

Degradation of commercially important polyhydroxyalkanoates in tropical mangrove ecosystem
Sridewi, N. , Bhubalan, K. , Sudesh, K.
(2006) Polymer Degradation and Stability

Microbial degradation and physico-chemical alteration of polyhydroxyalkanoates by a thermophilic Streptomyces sp.
Phithakrotchanakoon, C. , Rudeekit, Y. , Tanapongpipat, S.
(2009) Biologia

View all related documents based on references

Find more related documents in Scopus based on:

Authors > Keywords >

6 Chen, G., Ushida, T., Tateishi, T.
Scaffold design for tissue engineering

(2002) *Macromolecular Bioscience*, 2 (2), pp. 67-77. Cited 446 times.
doi: 10.1002/1616-5195(20020201)2:2<67::AID-MABI67>3.0.CO;2-F

View at Publisher

7 Guzmán, D., Kirsebom, H., Solano, C., Quillaguamán, J., Hatti-Kaul, R.
Preparation of hydrophilic poly(3-hydroxybutyrate) macroporous scaffolds through enzyme-mediated modifications

(2011) *Journal of Bioactive and Compatible Polymers*, 26 (5), pp. 452-463. Cited 8 times.
doi: 10.1177/0883911511419970

View at Publisher

8 Suh, S.W., Shin, J.Y., Kim, J., Kim, J., Beak, C.H., Kim, D.-I., Kim, H., (...), Choo, I.-W.
Effect of different particles on cell proliferation in polymer scaffolds using a solvent-casting and particulate leaching technique

(2002) *ASAIO Journal*, 48 (5), pp. 460-464. Cited 43 times.
http://journals.lww.com/asaiojournal/pages/default.aspx
doi: 10.1097/00002480-200209000-00003

View at Publisher

9 Feng, L., Wang, Y., Inagawa, Y., Kasuya, K., Saito, T., Doi, Y., Inoue, Y.
Enzymatic degradation behavior of comonomer compositionally fractionated bacterial poly(3-hydroxybutyrate-co-3-hydroxyvalerate)s by poly(3-hydroxyalkanoate) depolymerases isolated from Ralstonia pickettii T1 and Acidovorax sp. TP4

(2004) *Polymer Degradation and Stability*, 84 (1), pp. 95-104. Cited 29 times.
doi: 10.1016/j.polymdegradstab.2003.09.016

View at Publisher

10 Vigneswari, S., Vijaya, S., Majid, M.I.A., Sudesh, K., Sipaut, C.S., Azizan, M.N.M., Amirul, A.A.
Enhanced production of poly(3-hydroxybutyrate-co-4-hydroxybutyrate) copolymer with manipulated variables and its properties

(2009) *Journal of Industrial Microbiology and Biotechnology*, 36 (4), pp. 547-556. Cited 38 times.
doi: 10.1007/s10295-009-0525-z

View at Publisher

11 Braunegg, G., Sonnleitner, B., Lafferty, R.M.
A rapid gas chromatographic method for the determination of poly-β-hydroxybutyric acid in microbial biomass

(1978) *European Journal of Applied Microbiology and Biotechnology*, 6 (1), pp. 29-37. Cited 811 times.
doi: 10.1007/BF00500854

View at Publisher

12 Ramachandran, H., Nurhezreen, M.I., Sipaut, C.S., Amirul, A.A.
(2011) *Applied Biochemistry and Biotechnology*, 10, pp. 9180-9188.

13 Tang, C.Y., Chen, D.Z., Yue, T.M., Chan, K.C., Tsui, C.P., Yu, P.H.F.
Water absorption and solubility of PHBHV/HA nanocomposites

(2008) *Composites Science and Technology*, 68 (7-8), pp. 1927-1934. Cited 29 times.
doi: 10.1016/j.compscitech.2007.12.003

View at Publisher

14 Timmins, M.R., Lenz, R.W., Fuller, R.C.
Heterogeneous kinetics of the enzymatic degradation of poly(β-hydroxyalkanoates)

(1997) *Polymer*, 38 (3), pp. 551-562. Cited 39 times.
http://www.journals.elsevier.com/polymer/
doi: 10.1016/S0032-3861(96)00530-7

View at Publisher

15 Doi, Y., Mukai, K., Kasuya, K., Yamada, K.
Biodegradation of biosynthetic and chemosynthetic polyhydroxyalkanoates
(1994) *Biodegradable Plastics and Polymers*, pp. 39-51. Cited 31 times.
Y. Doi & K. Fukuda (Eds) Amsterdam: Elsevier Science B.V

16 Kasuya, K.-i., Inoue, Y., Yamada, K., Doi, Y.
Kinetics of surface hydrolysis of poly[(R)-3-hydroxybutyrate] film by PHB depolymerase from Alcaligenes faecalis T1

(1995) *Polymer Degradation and Stability*, 48 (1), pp. 167-174. Cited 54 times.
doi: 10.1016/0141-3910(95)00026-I

View at Publisher

17 Sudesh, K., Abe, H., Doi, Y.
Synthesis, structure and properties of polyhydroxyalkanoates: Biological polyesters

(2000) *Progress in Polymer Science (Oxford)*, 25 (10), pp. 1503-1555. Cited 1210 times.
doi: 10.1016/S0079-6700(00)00035-6

View at Publisher

18 Ci, S.Q., Chen, S., Liu, D.B., Xia, H.M.
(2006) *World Journal of Microbiology and Biotechnology*, 22, pp. 729-735. Cited 2 times.
10.1007/s11274-005-9098-9 1:CAS:528:DC%2BD28XmsVWqsLg%3D

19 Liu, H., Zhang, H., Chen, S., Liu, D., Xia, H.
Purification and properties of a poly (β-hydroxybutyrate) depolymerase from Penicillium sp.

(2006) *Journal of Polymers and the Environment*, 14 (4), pp. 419-426. Cited 7 times.
doi: 10.1007/s10924-006-0031-6

View at Publisher

20 Vijayalakshmi, K., Suseela, R.
(2010) *African Journal of Microbiology Research*, 4, pp. 2388-2396.
1:CAS:528:DC%2BC3MXjtlagtA%3D%3D

21 Sadocco, P., Nocerino, S., Dubini-Paglia, E., Seves, A., Elegir, G.
Characterization of a poly(3-hydroxybutyrate) depolymerase from Aureobacterium saperdae: Active site and kinetics of hydrolysis studies

(1997) *Journal of Environmental Polymer Degradation*, 5 (1), pp. 57-65. Cited 20 times.

22 Iwata, T., Doi, Y., Nakayama, S.-I., Sasatsuki, H., Teramachi, S.
Structure and enzymatic degradation of poly(3-hydroxybutyrate) copolymer single crystals with an extracellular PHB depolymerase from Alcaligenes faecalis T1

(1999) *International Journal of Biological Macromolecules*, 25 (1-3), pp. 169-176. Cited 50 times.
doi: 10.1016/S0141-8130(99)00031-8

View at Publisher

23 Abe, H., Doi, Y.

Structural effects on enzymatic degradabilities for poly[(R)-3- hydroxybutyric acid] and its copolymers

(1999) *International Journal of Biological Macromolecules*, 25 (1-3), pp. 185-192. Cited 74 times.
doi: 10.1016/S0141-8130(99)00033-1

View at Publisher

24 Jeya, M., Nguyen, N.-P.-T., Moon, H.-J., Kim, S.-H., Lee, J.-K.

Conversion of woody biomass into fermentable sugars by cellulase from Agaricus arvensis

(2010) *Bioresource Technology*, 101 (22), pp. 8742-8749. Cited 25 times.
doi: 10.1016/j.biortech.2010.06.055

View at Publisher

25 Numata, K., Abe, H., Iwata, T.

Biodegradability of poly(hydroxyalkanoate) materials

(2009) *Materials*, 2 (3), pp. 1104-1126. Cited 21 times.
http://www.mdpi.com/1996-1944/2/3/1104/pdf
doi: 10.3390/ma2031104

View at Publisher

26 Wang, Y.-W., Mo, W., Yao, H., Wu, Q., Chen, J., Chen, G.-Q.

Biodegradation studies of poly(3-hydroxybutyrate-co-3-hydroxyhexanoate)

(2004) *Polymer Degradation and Stability*, 85 (2), pp. 815-821. Cited 67 times.
doi: 10.1016/j.polymdegradstab.2004.02.010

View at Publisher

27 Philip, S., Keshavarz, T., Roy, I.

Polyhydroxyalkanoates: Biodegradable polymers with a range of applications

(2007) *Journal of Chemical Technology and Biotechnology*, 82 (3), pp. 233-247. Cited 383 times.
doi: 10.1002/jctb.1667

View at Publisher

28 Saito, Y., Nakamura, S., Hiramitsu, M., Doi, Y.

Microbial synthesis and properties of poly(3-hydroxybutyrate-co-4-hydroxybutyrate)

(1996) *Polymer International*, 39 (3), pp. 169-174. Cited 122 times.

View at Publisher

29 Tokiwa, Y., Calabia, B.P.

Degradation of microbial polyesters

(2004) *Biotechnology Letters*, 26 (15), pp. 1181-1189. Cited 169 times.
doi: 10.1023/B:BILE.0000036599.15302.e5

View at Publisher

30 Li, Z., Lin, H., Ishii, N., Chen, G.-Q., Inoue, Y.

Study of enzymatic degradation of microbial copolyesters consisting of 3-hydroxybutyrate and medium-chain-length 3-hydroxyalkanoates

(2007) *Polymer Degradation and Stability*, 92 (9), pp. 1708-1714. Cited 24 times.
doi: 10.1016/j.polymdegradstab.2007.06.001

View at Publisher

31 Bayari, S., Severcan, F.
FTIR study of biodegradable biopolymers: P(3HB), P(3HB-co-4HB) and P(3HB-co-3HV)

(2005) *Journal of Molecular Structure*, 744-747 (SPEC. ISS.), pp. 529-534. Cited 34 times.
doi: 10.1016/j.molstruc.2004.12.029

View at Publisher

32 Xu, J., Guo, B.-H., Yang, R., Wu, Q., Chen, G.-Q., Zhang, Z.-M.
In situ FTIR study on melting and crystallization of polyhydroxyalkanoates

(2002) *Polymer*, 43 (25), pp. 6893-6899. Cited 135 times.
doi: 10.1016/S0032-3861(02)00615-8

View at Publisher

33 Rodríguez-Contreras, A., Calafell-Monfort, M., Marqués-Calvo, M.S.
Enzymatic degradation of poly(3-hydroxybutyrate-co-4-hydroxybutyrate) by commercial lipases

(2012) *Polymer Degradation and Stability*, 97 (4), pp. 597-604. Cited 15 times.
doi: 10.1016/j.polymdegradstab.2012.01.007

View at Publisher

34 Sabir, M.I., Xu, X., Li, L.
A review on biodegradable polymeric materials for bone tissue engineering applications

(2009) *Journal of Materials Science*, 44 (21), pp. 5713-5724. Cited 249 times.
doi: 10.1007/s10853-009-3770-7

View at Publisher

35 Sultana, N., Wang, M.
(2011) *International Conference on Biomedical Engineering and Technology IPCBEE*
11 IACSIT Press Singapore

36 Yu, L., Dean, K., Li, L.
Polymer blends and composites from renewable resources

(2006) *Progress in Polymer Science (Oxford)*, 31 (6), pp. 576-602. Cited 1043 times.
doi: 10.1016/j.progpolymsci.2006.03.002

View at Publisher

37 Freier, T., Kunze, C., Nischan, C., Kramer, S., Sternberg, K., Saß, M., Hopt, U.T., (...), Schmitz, K.-P.
In vitro and in vivo degradation studies for development of a biodegradable patch based on poly(3-hydroxybutyrate)

(2002) *Biomaterials*, 23 (13), pp. 2649-2657. Cited 134 times.
doi: 10.1016/S0142-9612(01)00405-7

View at Publisher

Amirul, A.A.; School of Biological Sciences, Universiti Sains Malaysia, Malaysia; email:amirul@usm.my