International Journal of Science and Research (IJSR)
ISSN: 2319-7064
ResearchGate Impact Factor (2018): 0.28 | SJIF (2018): 7.426

PHA: An Alternative to Plastic

Gagandeep

Abstract: ***PHAs are biogenic polyesters that can be naturally accumulated in microbial cultures as their energy reserves to overcome the environmental stress which is also be biodegradable polymers. The medium- chain -length PHA mcl-PHA) polymers composed of C6 to C16 hydroxyl fatty acids or aliphatic carbon sources.***

1. Introduction

Landfills and floating plastic debris are major concern for environment .An alternative to petrochemical plastics are PHAs being biogenic polyesters that can be naturally accumulated in microbial cultures as their energy reserves to over-come environmental stress. Naturally adapted microbes in situ field trial is considered as an important approach in bioremediation.
Polyhydroxyalkanoate (PHA)

2. Degradation and its Properties

Mechanical integrity of plastics invariably depends on their high average molecular-weight, any significant extent of degradation the average molecular weight of the polymer where degraded fragile surface inevitably weakens the material and is susceptible to fracture by stress induced by humidity or temperature changes and abrasion against sand [1].Extensively degraded plastics become brittle enough to fall apart into powdery fragments on handling which not visible to the naked eye and can undergo further degradation (generally via microbial-mediated biodegradation) with the carbon in polymer being converted into CO2 (and incorporated into marine biomass) by breaking it up into monomer .When this process goes onto completion and all the organic carbon in the polymer is converted, it is referred to as complete mineralisation [2 3 4]

Natural biodegradable polymers [5 6] (PHA) next generation polymers as they are biodegradable, eco-friendly(Non petroleum based biological polyesters) and biocompatible(important in the natural resources) PHAs are biogenic polyesters that can be naturally accumulated in microbial cultures .In order to overcome the environmental stress a large number of bacteria remain in contaminated environment which can accumulate PHA as their energy reserves.PHA properties are also similar to those of polyethylene (PE) and polypropylene (PP) [7 8] . PHA are classified on the basis of number of repeating units in the polymers. Short-chain-length PHA (scl-PHA) is the polymer that contain monomers of C3 to C5 hydroxyl fatty acids e.g.polyhydroxybutyrate (PHB) and hydroxyvalerate (PHV). The medium- chain -length PHA mcl-PHA) polymers composed of C6 to C16 hydroxyl fatty acids or aliphatic carbon sources [7 9]

Many microorganisms accumulate PHA as intracellular energy reserve of carbon inclusions when the carbon is in excess to the other nutrients such as nitrogen, sulfur, phosphorus and oxygen [10 11]

Microbial degradation of plastics is caused by enzymatic activities that lead to a chain cleavage of the polymer into monomers The lipase, proteinase K, extracellular and the intracellular dehydrogenases involved in biological degradation of plastics[12] by a thermophilic bacterium (Bacillus brevis)[13] ,and Pseudomonas putida[14].

The occurrence of biodegradation is mainly due to the PHA degrading enzymes which is known as PHA depolymerase that are secreted by microorganisms to hydrolyze water-insoluble PHA into water-soluble forms so that it can be utilized by these microorganisms [8]. PHA depolymerase is an enzyme made up of a catalytic domain and a substrate-binding domain. Both these domains are connected by a linker domain. The substrate binding domain of the enzyme binds to the crystalline PHA material. Subsequently, the catalytic domain starts to cleave the polymer chain[15] .PAH-degrading consortia, the regulatory mechanisms of various ring-structured PAH biodegradation as well as the co-metabolic biodegradation of PAHs from environmental samples[16 17] a variety of microorganisms .The new approach of advancements in molecular biology can aid in the detection of PAH-degrading DNA–DNA hybridization has been directly applied to detect and monitor the crucial populations recovered from the environment [18 19] . Laurie and Jones [20]detected two distinct PAH catabolic genotypes from aromatic hydrocarbon-contaminated soil using quantitative (i.e. microorganisms swim away from the compound).Both cases require concentration gradients of the attractant or repellent for a chemotactic response to occur. Some toxic organic compounds are chemoattractant for different bacterial species, such as Pseudomonas sp. and Ralstonia sp. [21] [22],which could lead to improved degradation.

The conversion of styrene to polyhydroxyalkanoate (PHA) by Pseudomonas putida CA-3 provides a new and unique link between an aromatic environmental pollutant and aliphatic PHA accumulation. Due to its biodegradable nature, PHA has a broad range of applications, including medical applications such as wound management, drug delivery, and tissue engineering [23 24]. Furthermore, PHA is composed of chiral hydroxy acids that have potential as pythons for anti-human immunodeficiency virus drugs, anticancer drugs, antibiotics, and vitamins [25 26].

Investigations into the biodegradation of styrene have resulted in the elucidation of biochemical pathways and molecular control of styrene degradation [27]. P. putida CA-3 is capable of the complete mineralization of styrene[28] . It does so by epoxidation of styrene and isomerization of the epoxide to phenylacetaldehyde, which is further oxidized to phenylacetic acid [28]. Phenylacetic acid is converted to

phenylacetyl-coenzyme A (CoA), which is further oxidized to acetyl-CoA[29] [27] .

The chemotaxis of Pseudomonas putida towards naphthalene and salicylate is a plasmid-encoded phenomenon, encoded by the catabolic plasmid NAH7 [30]residing within this strain. A chemotaxis gene region has been identified from P. putida that was found to be homologous to chemotaxis, flagellar and mobility genes from some other bacteria[31] .

Genetically Engineered Microorganisms (GEM) in India as well as due to inability of the microbial genome to degrade all the components of pollutants in different environments and climatic conditions, seeding of naturally adapted microbes in situ field trial is considered as an important approach in bioremediation[32] .

References

[1] George, G.A., 1995. Weathering of polymers. Metals Forum 19, 145–161. Gilan, I., Hadar, Y., Sivan, A., 2004. Colonization, biofilmformation and biodegradation of polyethylene by a strain of R. ruber. Appl. Microbiol. Biotechnol. 65, 97–104
[2] Andrady, A.L., 1994. Assessment of environmental biodegradation of synthetic polymers: a review. J. Macromol. Sci. R. M. C 34 (1), 25–75.
[3] Andrady, A.L., 1998. Biodegradation of plastics. In: Pritchard, G. (Ed.), Plastics Additives. London, Chapman Hall
[4] Eubeler, J.P., Zok, S., Bernhard, M., Knepper, T.P., 2009. Environmental biodegradation of synthetic polymers I. Test methodologies and procedures. Trend. Anal. Chem. 28 (9), 1057–1072.
[5] Arshady, R. *Biodegradable Polymers*; Citus Books: London, 2003.
[6] Gunatillake, P.; Mayadunne, R.; Adhikari, R. Recent developments in biodegradable synthetic polymers. Biotechnology Annual Review **2006**, *12*, 301–347.
[7] Kim & linz Microbial degradation of polyesters: a review on extracellular poly-(hydroxyalkanoic acid) depolymerase.Polym Degrad Stab, 59: 317–325(2001).
[8] Rehn, H.B., Hamid, H.S. and Owen, O.D. Photochemical and thermal crosslinking of polymers.J Macromol Sci Rev Macromol Chem Phys, 36: 671–719(2003).
[9] Sudesh , E.R. & Zarzur, S. Plastic debris ingested by a Blainville's beaked whale, Mesoplodon densirostris Washed ashore in Brazil. Aquat. Mammal, 25(1): 21-24(2000).
[10] Madison, Mueller, R.J. Biological degradation of synthetic polyesters enzymes as potential catalysts for polyester recycling Proc Biochem, 41: 2124–2128(1999)
[11] Reddy, Scott, G. Photo-biodegradable plastics: their role inthe protection of the environment Polym Degrad Stab, 29:135–154(1990)
[12] Ghosh SK, Pal S, Ray S (2013) Study of microbes having potentiality for biodegradation of plastics. Environ Sci Pollut Res Int 20: 4339-4355.
[13] Tomita K, Kuroki Y, Nagai K (1999) Isolation of thermophiles degrading poly (L-lactic acid). J Biosci Bioeng 87: 752-755.
[14] Anthony SD, Meizhong L, Christopher EB, Robin LB, David LF (2004) Involvement of linear plasmids in aerobic biodegradation of vinyl chloride. Appl Environ Microbiol 70: 6092-6097.
[15] Numata K., Kikkawa Y., Tsuge T., Iwata T., Doi Y., Abe H. Enzymatic Degradation Processes of Poly[(*R*)-3-hydroxybutyric acid] and Poly[(*R*)-3-hydroxybutyric acid-*co*-(*R*)-3-hydroxyvaleric acid] Single Crystals Revealed by Atomic Force Microscopy: Effects of Molecular Weight and Second-Monomer Composition on Erosion Rates. Biomacromolecules. 2005;6:2008–2016. doi:10.1021/bm0501151.
[16] Watanabe, K. (2001) Microorganisms relevant to bioremediation. Curr. Opin. Biotechnol. 12, 237–24
[17] Watanabe, K. and Baker, P.W. (2000) Environmentally relevant microorganisms. J. Biosci. Bioeng. 89, 1–11
[18] Sayler, G.S. et al. (1985) Application of DNA–DNA colony hybridization to the detection of catabolic genotype in environmental samples.Appl. Environ. Microbiol. 49, 1295–1303
[19] Guo, C. et al. (1997) Hybridization analysis of microbial DNAfrom fuel oil-contaminated and noncontaminated soil. Microbial Ecol. 34,178–187
[20] Laurie, A.D. and Jones, G.L. (2000) Quantification of phnAc and nahAc in contaminated New Zealand soils by competitive PCR. Appl. Environ. Microbiol. 66, 1814–1817
[21] Grimm, A.C. and Harwood, C.S. (1999) NahY, a catabolic plasmid-encoded receptor required for chemotaxis of Pseudomonas putida to the aromatic hydrocarbon naphthalene. J. Bacteriol.181, 3310–3316
[22] Bhushan, B. et al. (2000) Chemotaxis and biodegradation of 3-methyl-4-nitrophenol by Ralstonia sp. SJ98. Biochem. Biophy. Res.Commun. 275, 129–133
[23] Lee, S. Y. 1996. Bacterial polyhydroxyalkanoates. Biotechnol. Bioeng. 49:1– 14.
[24] Zinn, M., B. Witholt, and T. Egli. 2001. Occurrence, synthesis and medical application of bacterial polyhydroxyalkanoate. Adv. Drug Delivery Rev. 53: 5–21.
[25] de Roo, G., M. B. Kellerhals, Q. Ren, B. Witholt, and B. Kessler. 2002. Production of chiral R-3-hydroxyalkanoic acids and R-3-hydroxyalkanoic acid methylesters via hydrolytic degradation of polyhydroxyalkanoate synthesized by Pseudomonads. Biotechnol. Bioeng. 77:717–722
[26] Ohashi, T., and J. Hasegawa. 1992. New preparative methods for optically active -hydroxycarboxylic acids, p. 249–268. In G. N. Sheldrake, A. N. Collins, and J. Crosby (ed.), Chirality in industry. John Wiley & Sons, New York, N.Y
[27] O'Leary, N., W. A. Duetz, A. D. W. Dobson, and K. E. O'Connor. 2002. Induction and repression of the sty operon in Pseudomonas putida CA-3 during growth on phenylacetic acid under organic and inorganic nutrient limiting continuous culture conditions. FEMS Microbiol. Lett. 208:263–268.
[28] O'Connor, K., C. M. Buckley, S. Hartmans, and A. D. W. Dobson. 1995. Possible regulatory role for non-

aromatic carbon sources in styrene degradation by Pseudomonas putida CA-3. Appl. Environ. Microbiol. 61:544–548.
[29] O'Leary, N. D., K. E. O'Connor, W. Duetz, and A. D. W. Dobson. 2001. Transcriptional regulation of styrene degradation in Pseudomonas putida CA-3. Microbiology 147:973–979.
[30] Grimm, A.C. and Harwood, C.S. (1997) Chemotaxis of Pseudomonas sp. to the polyaromatic hydrocarbon, naphthalene.
Appl. Environ. Microbiol. 63, 4111–4115
[31] Ditty, J.L. et al. (1998) Identification of a chemotaxis gene region from Pseudomonas putida. FEMS Microbiol. Lett. 159, 267–273
[32] Shome, B.R., Shome, R., Bandyopadhyay, A.K., 1996. Strain improvement of hydrocarbonoclastic bacterial isolates from Mangals of Andaman. Current Science 70, 15±18.