



Biodegradable Biopolymers: An Overview On Polyhydroxyalkanoates

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Petroleum based plastics have been produced by the chemical industries since the early 1930s. These products are part of a very important group of materials, because their high molecular weight and low reactivity make them suitable for cases in which durable and inert materials are needed. But these advantageous properties of plastics are also their disadvantages, since they do not degrade and thus, they remain unchanged at the site of disposal. Therefore, over the past years, the use of plastics for different purposes and in various equipments has caused many problems related to disposal of solid wastes. It has been shown that petroleum based plastics accumulate in the environment at a rate of 25 million tons per year. Considering the growing problems caused by disposal of petroleum based plastics, that are non-degradable and remain in environment for many years, and in order to reduce the amount of plastic waste, worldwide programs such as recycling, incineration and source reduction have been initiated. Beside these strategies, which have their own special problems, biodegradable plastics have been the focus of extensive researches. In fact, biodegradable polymers, which are after disposal decomposed by many enzymes existing in the environment, offer the best solution to the environmental hazard caused by conventional plastics.

Biodegradable plastics which are produced by different microorganisms can be divided into four classes: polysaccharides, polymers of amino acids, naturally occurring polyesters, and semi-synthetic polyesters. Among these biopolymers, a polymer which is durable, biodegradable, recyclable, and produced from renewable resources such as carbohydrates, is ideal. Among the candidates for biodegradable plastics, a group of biopolymers called poly-3-hydroxyalkanoates (PHAs) belonging to the class of naturally occurring polyesters meet these ideal qualities. Poly-3-hydroxyalkanoates (PHAs) are a family of intracellular polyesters produced by a wide variety of microorganisms. They are water insoluble, relatively resistant to aqueous hydrolysis, and biodegradable. They can be produced from renewable resources, and are potentially recyclable. These polymers have mechanical properties which are similar to those of some highly applicable petrochemical plastics like polyethylene (PE) and polypropylene (PP).

Polyhydroxyalkanoates are natural carbon and energy storage of microorganisms that are produced when cells encounter nutritional deficiencies, like lack of sulfur, phosphorus, oxygen, magnesium and nitrogen, but in the presence of an excessive carbon source. These biopolymers are stored in the form of granules by the bacteria and the observation of the granules as refractile bodies in the bacterial cells under the microscope goes back at least to year 1888.

Regarding the number of carbon atoms in the monomer, Polyhydroxyalkanoates can be divided into three groups. First group is the one in which monomers contain 3 to 5 carbon atoms and called short chain length (scl) PHAs. Second group, called medium chain length (mcl) PHAs, includes those polymers with 6 to 14 carbon atoms in the monomer and scl-co-mcl PHAs is the third group with repeat-unit monomers containing 3 to 14 carbon atoms.

Biosynthesis of PHAs is done by certain polymerases which are responsible for the polymerization of hydroxyacyl-coA monomer precursors into the PHA polymers. These enzymes are called PHA synthases (PHASs), and it has been shown that these enzymes are the key enzymes which determine the type of PHA synthesized by the microorganism. With respect to the primary structures deduced

from the nucleotide sequences of the coding genes, the substrate specificities of the enzymes and the subunit composition, four major classes of PHA synthases namely Class I, II, III, and IV can be distinguished. It has been demonstrated that various microorganisms harbor different PHA synthases.

Even though PHAs can have a wide range of applications, their actual use has been limited by their high price compared with conventional plastic materials. To date, various PHAs have been used for different applications. Some PHAs are used to produce many devices including sutures, suture fasteners, meniscus repair devices, rivets, staples, screws, bone plates and bone plating systems, surgical mesh, repair patches, slings, cardiovascular patches, heart valves, vascular grafts, spinal cages, urological stents, barrier material for guided tissue regeneration in periodontitis and many other devices. PHAs are also suggested as drug carrier and have been used to prepare various novel transdermal drug delivery systems or biodegradable controlled antibiotic release systems. In fact, their biodegradability and biocompatibility make them highly applicable for these purposes. Today, many strategies including addition of inhibitors which prevent degradation of PHAs in producer cells, using precursor substrates which enhance production of the biopolymers and manipulation of host cell genome are used to overproduce PHAs. Another beneficial strategy is recombinant gene expression, which is performed using recombinant host cells like *E. coli*, transgenic plants or insect cells of *Spodoptera frugiperda* with modified fatty acid metabolism pathways.

In conclusion, it is obvious that PHAs continue to attract increasing industrial interest as renewable, biodegradable, and biocompatible thermoplastics that can be used for marine, medical and agricultural applications.

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