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BIOPLASTIC: A BETTER ALTERNATIVE TO PLASTICS

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ABSTRACT

Bioplastics are long chain of monomers joined with each other by ester bond; these plastics are thus considered as polyesters. Bioplastics are classified in to variety of types. Out of all the most common is PHA (Polyhydroxyalkanoate), which remains as a carbon and/or energy storage material in various microorganisms under the condition of deficient nutritional element. There are variety of bioplastic applications to the society and industries. This review paper is intended to provide information about alternative to conventional plastics for the betterment of earth environment.

KEYWORDS: Bioplastics, Plastics, Polyhydroxyalkanoate

INTRODUCTION

Plastics are used in almost every place such as, in routine house hold packaging material, in bottles, cell phones, printers etc. It is also utilized by manufacturing industries ranging from pharmaceutical to automobiles. They are useful as synthetic polymer because, their structure can be chemically manipulated to a number of strengths and shapes to obtain higher molecular weight, low reactivity and long durable substances. Plastics are important material as they are durable and cost efficient to everybody. Plastics have become a large environmental problem. In fact, "Americans go through 25 billion plastic bottles each year". Unfortunately, these plastic bottles along with other forms of plastic accounts for "25 per cent" of the total volume of landfills and cause pollution. The plastics that do residue in landfills degrade very slowly, which can cause the original products to remain in our landfills for hundreds or even thousands of years (Unmar and Mohee, 2008).

Nowadays, people are more aware about the harmful effects of petrochemical derived plastic materials in the environment. Researchers have conducted many researches for managing plastic waste on earth by finding eco-friendly alternative to plastics. This ecofriendly alternative is bioplastics, which are disposed in environment and can easily degrade through the enzymatic actions of microorganisms. The degradation of biodegradable plastics give rise to carbon dioxide, methane, water, biomass, humic matter and various other natural substances which can be readily eliminated (Azios, 2007).

Bioplastics

Bioplastics are not just one single substance, they comprise of a whole family of materials with differing properties and applications. According to European Bioplastics, a plastic material is defined as a bioplastic if it is either biobased, biodegradable, or features both properties.

Biobased

The term "biobased" means that the material or product is (partly) derived from biomass (plants). Biomass used for bioplastics stems from e.g. corn, sugarcane, or cellulose.

Biodegradable

Biodegradation is a chemical process during which micro-organisms that are available in the environment convert materials into natural substances such as water, carbon dioxide, and compost (artificial additives are not needed). The process of biodegradation depends on the surrounding environmental conditions (e.g. location or temperature), on the material and on the application (Kerry and Butler, 2008).

THE MAJOR ADVANTAGES OF BIOPLASTICS

Following are the advantages of bioblastics (Pilla, 2011):

Potentially a Much Lower Carbon Footprint

It should be pointed out that the carbon footprint of a bioplastic is crucially dependent on whether the plastic permanently stores the carbon extracted from the air by the growing plant. A plastic made from a biological source sequesters the CO_2 captured by the plant in the photosynthesis process. If the resulting bioplastic degrades back into CO_2 and water, this sequestration is reversed. But a permanen bioplastic made to be similar to polyethylene or other conventional plastics stores the CO_2 forever. Even if the plastic is recycled many times the CO_2 initially taken from the atmosphere remains sequestered.

Lower Energy Costs in Manufacturing

On the otherhand, plastics are made from ~4% of the oil that the world uses every year. With oil scarcity the manufacture of plastics becomes increasingly exposed to fluctuating prices.

Do Not Use Scarce Crude Oil

In contrast, each kilogram of plastic typically requires 20 kilowatt hours of energy to manufacture, more than the amount needed to make the same weight of steel. Almost all this comes from fossil sources.

Reduction in Litter and Improved Compostability from Using Biodegradable Bioplastics

The best understood advantage of biodegradable bioplastics lies in the reduction of permanent litter. Plastic single use shopping bags are the most obvious example of how plastics can pollute the environment with huge and unsightly persistence. A large fraction of the litter in our oceans is of disposable plastic bags. Cities and countries around the world are taking action against the litter, sometimes by banning non-degradable plastic bags entirely.

METHODS OF PRODUCTION OF BIOPLASTIC

From Microorganisms

The occurrence of polyhydroxy alkanoic acids as storage polymers in prokaryotic cells is now known to be very widespread indeed. They are water-insoluble compounds. Many bacteria produce an intracellular carbon and energy storage compound - poly-β-hydroxybutyric acid (PHB) - in relatively large quantities. While this property is absent from enteric species, it is widely found in Pseudomonads and related species including the plant symbiont Rhizobium and also in nitrogen-fixing Azotobacter spp. Accumulation is normally a response to unbalanced growth in the presence of excess carbon and energy source. Under appropriate conditions the polymer can amount to more than 50-80 per cent of cell dry weight. The storage product is found as granular inclusion bodies within the cytoplasm. However, many of these compounds represent in relatively small amounts or because of their short chain lengths or other properties are unsuitable as potential bioplastics. Among species synthesizing PHB and PHV are some Archae including *Haloferax mediterranea*. These halophilic bacteria might present advantages for production as their culture requirements of salinity and relatively high temperature provide little opportunity for growth of contaminants. In species such as *Azotobacter vinelandii*, simultaneous production of large amounts of exo-polysaccharide diverts substrate to alternative products and makes recovery of PHB difficult. Development of high-yielding mutant strains resulted in conversion rates of 65 percent for PHB and eventual PHA yields of 71 per cent dry weight (Ackermann and Babel, 1997).

From Plants

The major limitation associated with the production of bioplastics in bacteria is the high cost when compared to the petroleum-derived plastics. Potentially, in turn, the plant offers an alternative approach to synthesize these bulk commodity products at low cost. Whereas PHA production in bacteria and yeast requires costly fermentation process with an external energy sources such as electricity, in plant systems it is considerably less expensive as it relies on water, soil nutrients, atmospheric CO_2 and sunlight. In addition, a plant production system is much more environment friendly. While in bacteria PHB synthesis and its accumulation is limited in the cystol, in plants PHB can be produced in a number of subcellular compartments like cystol, plastids, mitochondria and peroxisomes (Bastoli, 1998). Arabidopsis thaliana was the first plant to be used for PHA production. In Arabodopsis, a small amount of PHB production was first demonstrated by expressing in its cytoplasm two enzymes (acetoacetyl-CoA reductase and PHB synthase) from the bacterium *Ralstonia eutropha*.The polymer produced was of high molecular weight and similar in structure and properties to PHB but the yield was low and plants were stunned in growth. The yield was later increased from 1% to 14% dry wt. By expressing PHB biosynthetic pathways in the plastids. The achievement was ground breaking, producing one transgenic plant with 14% dry wt. of PHB in its leaves. Later on, low amount of medium chain length PHA copolymers were synthesized in peroxysomes by polymerization of 3-hydroxyacyl-CoA intermediate generated by degradation of fatty acids in peroxisomes of Arabdiopsis plant. After the success of synthesizing PHB in plants, PHB copolymers were produced in both *A. thaliana* and seeds of *Brassica napus* (oilseed rape). This was one of the most remarkable feats of metabolic engineering yet performed in plants, requiring the expression of four bacterial genes (ilvA, phaArc, phaBrc, phaCrc) and modification of independent metabolic pathways (fatty acid and amino acid synthesis). A number of other plants like Nicotiana, Brassica, Gossypium, Medicago and Elaeis have also been well exploited for synthesizing a variety of PHAs. In tobacco, by expressing in its plastids phaA and phaB genes of *R. Eutropha* and phaC gene of *Aerommas caviae*, it was also possible to produce 0.09% dry weight of PHAs. The yield was ten time more as produced in cytoplasm on Nicotiana if phaA gene alone from bacterium *R. Eutropha* and phaC gene from *R. Eutropha* and phbC gene from *A. caviae* were expressed. Plastic is often used to improve the mechanical properties of fibre-based composites. In case of cotton, *R. Eutrphapha* genes when successfully expressed in the cystol of its fibres, the fibres from its transgenic plants contained 0.34% PHB, which was sufficient to improve the insulating properties of the fibre. Similarly, in stems of transgenic flax (*Linnum usitatissimum*), bioplastic has also been produced with an aim to improve the quality of fibre rather than providing a plant source of PHB for extraction. Interestingly, seed production as well as plant growth and morphology were found to be enhanced in these transgenic plants. At commercial level, the approach to convert plant sugar into plastic was first adopted by Cargil, an agricultural business giant, and Dow Chemicals in corn and other plants to produce a plastic called PLA (polylactide). Later on, other companies including ICI (Imperial Chemical Industry) developed ways to produce a second plastic, called PHA. Like PLA, it is made from plant sugar. Whereas PLA requires a chemical step outside the organism to synthesize it, PHA naturally accumulates within microbes as granules that constitute up to 80% of single cell mass. Following this, big industrial giants like Monsanto tried to produce PHA using another approach –growing plastics in the plants. This required the modification of genetic make-up of agricultural crops and was achieved by the collaboration of researchers at Michigan State University and James Madison University in 1992 when they genetically engineered *A. thaliana* plant to produce a brittle type of PHA. The hope behind green plastics research is to find methods of producing commercially viable replacement for petrochemical polymers through the metabolically engineered action of plants. Thus, researchers have turned toward plants as being a potentially cheaper and more convenient method of producing renewable, biodegradable plastics.

BIOPLASTIC AND SOCIAL BENEFITS

What makes bioplastic especially important is that petroleum oil price is increasing tremendously and its stock will end in the near future. It is important for the global community to have an alternative for the product derived from petroleum oil such as plastics. PHAs at least will be a solution for the most of the industries and society, which largely depend on materials made from plastic. No new inventions can escape from the limitations and drawbacks and bioplastics too have some drawbacks. The most important drawback for PHA production is its production cost, but the good news is that the price of PHA production is decreasing, whereas, petroleum oil price is increasing constantly (Kumar et al. 2010). As a result, the gap between the petroleum oil and PHA are becoming very narrow. The first potential application of PHA polymers was recognized in the 1960s. PHA patents cover a wide range of PHAs products such as coating and packaging, bottles, cosmetic containers, golf tees, and pens (Webb, 1990). PHAs have also been processed into fibers, for a non woven fabrics material (Son et al. 1996). PHAs can be used for all sorts of biodegradable packaging materials, including composting bags, food packaging, sanitary articles like diapers and fishing nets (Javed and Gruys 2002), biodegradable rubbers (Walle et al. 2001). PHAs are also used to develop scaffold for tissue engineering (Simmon et al. 2002), and also posses numerous applications in pharmacy and medical science.

CONCLUSIONS

Bioplatics have evolved into an innovative area of research for scientists around the world. This progressive development has been driven by a need for environmentally friendly substitutes for materials derived from fossil fuel sources. In addition, recent high prices for crude oil, and the potential market for agricultural materials in bioplastics are driving an economic push toward expanding the bioplastic industry and provide better alternative for sustainable development of the future environment.

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