ACTA SCIENTIFIC MICROBIOLOGY (ISSN: 2581-3226)

Volume 2 Issue 6 June 2019

Mini Review

Bio-Plastics: The Suitable and Sustainable Alternative to Polyethylene based Plastics

Swati Ojha* and Sumeet Kapoor

Indian Institute of Technology Delhi, Hauz Khas, New Delhi, India

***Corresponding Author:** Swati Ojha, Indian Institute of Technology Delhi, Hauz Khas, New Delhi, India.

Received: April 04, 2019; **Published:** May 23, 2019

DOI: 10.31080/ASMI.2019.02.0254

Abstract

This review article gives an outline on bio-plastics; their advantages over the conventional plastics, their growth industrially. Despite being known to have very obvious environmental advantages over the conventional plastics, the synthesis of bio-plastics in the industrial sector is still in its very nascent stage owing to the lack of standardization process globally and also the large scale synthesis process is still very expensive for the industries. In this review, various ways of synthesis of different types of bio-plastics have been discussed. In this context, it is expected that the use of genetically modified organisms capable of producing bio-plastics may prove to be a very economical and a useful way of synthesis in the near future.

Keywords: Bio-Plastics; Environmental; Organisms

Introduction

Bioplastics are organic plastics synthesized or produced from biological sources which have airtight and waterproof properties. These are basically biomaterials produced by a range of microbial sources and/or plants under different and sometimes starved nutrient and environmental conditions. These biomaterials or polymers of carbon based compounds are bio-degradable and environment friendly. Some of these even possess superior qualities like biocompatibility than conventional plastics and this property makes them very beneficial for particularly; medicine and food industry; where packaging material should be biocompatible and biodegradable [1]. Adding to it, they have several other advantages such as, (i) they have much lower carbon footprint than conventional plastic which is a petroleum derived product, (ii) they are independent, made from renewable resources, (iii) synthesis of bio-plastics is an energy efficient process than the synthesis of conventional plastics, (iv) bio-plastics generate less greenhouse gases and contains no toxins, hence are eco-safe; compared to their petrochemical counterparts, they have a potential to reduce nearly 80% of global warming [2]. On the other hand, petroleum derived plastics leads to a "land-fill problem" (about 40% of produced plastics are discarded into land-fills every year), not bio-degradable, biggest environmental problem of conventional plastics is their accumulation in the oceans which in the recent studies has shown to be very toxic for the aquatic animals, according to a report approximately 43% of marine mammal species, 86% of sea-turtle, and 44% of sea-birds are susceptible to ingesting marine plastic debris [3]. Moreover, conventional plastics may take upto 1000 years to degrade and during that period they emit potentially harmful green-house gases such as CO_2 and CH_4.

Owing to the environmental/economic and social reasons mentioned above, the researchers and scientists have now focused their attention towards synthesis of bio-plastics. The bio-plastic industry is still in its initial stages of development and occupy a very small but emergent share in the market. European market is continuously expanding, and it ranks highest in the field of research and development of bio-plastics. Asia is the major production hub of bio-plastics, and in 2017 more than 50% of the total bio-plastics were produced in Asia. Japan has been the leader in bio-plastics industry and the bio-plastics are extensively used in the automobiles and electronics industry as well [4]. Whereas regions such as USA and Latin America have now started to invest in bio-plastics industry. Owing to their beneficial use in packaging materials, catering products, electronics, automotive, agriculture/horticulture, and toys to textiles, it is estimated that the global demand would increase per year by 19%.

This slow growth of bio-plastics industry can be attributed to the lack of Standardization process of bio-plastics. Though it was initiated in Europe and USA, but till date there is no standardized and universal practice on the definition of bio-plastics. There is no legislature to regulate the amount of renewable compound present in the bio-plastic to be called as a "bio-plastic". However, scientists follow "plastic spectrum" which helps them in decision-making about the plastic selection (Figure 1). According to this spectrum [2], bio-based bio-plastics which are completely bio-degradable plastics are at extreme right of the spectrum and are most preferable while PVC (Polyvinyl Chloride) based toxic plastics are at extreme left which should completely be avoided.

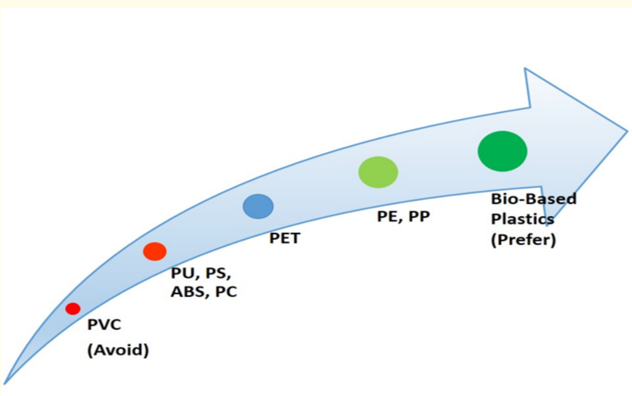

Figure 1: Plastic Spectrum. Red Color indicates the level of hazard and this kind of plastic should be completely avoided, on the other hand, green color indicates eco-friendly bio-based plastic which is much more preferable. PVC (PolyVinyl Chloride), PU (Polyurethane), Ps (Polystyrene), ABS (Acrylonitrile butadiene styrene), PC (Polycarbonate), PET (Polyethylene terephthalate), PE (Polyethylene), PP (Polypropylene). (Adapted from Arikan and Ozsoy, 2015).

Besides this, bio-plastics often suffer from thermal instability, brittleness, difficult heat saleability, low melt strength, high water vapor and oxygen permeability and poor mechanical properties. Other disadvantages include: Bio-plastics may contaminate the recycling process if not separated from conventional plastics and all bio-plastics are not compostable at home like organic food waste but it may require an industrial composting treatment. The synthesis of bio-plastics cost approximately twice more than the conventional plastics, their large scale production is still a challenge. However, researchers are continuously searching for the cheaper and effective ways to produce bio-plastics like, (i) by developing recombinant strains, (ii) improving the fermentation process by using inexpensive carbon sources as substrates such as sugar cane molasses, corn syrup, corn steep liquor etc., (iii) improving downstream processing steps, (iv) improving product recovery steps like solvent extraction, digestion, dispersion [5,6]. Thus to improve the effectiveness of bio-plastics, new bio-polymers and production technologies are regularly being researched.

Classification of bio-plastics

Broadly, bio-plastics may be categorized into three classes based on their origin and process of production [4].

Bio-polymers directly extracted from biomass; such as starch and cellulose based polymers and casein and gluten based biopolymers.

Starch is the major storage form of glucose in plants. It is comprised of two components; amylose (glucose units are linked to another glucose molecule by α-1,4 linkage in a straight chain) and amylopectin (glucose units are highly branched linked by α-1,6 linkage). The one unique property of starch is its hydrophilicity; it can be oxidized and reduced and can engage in the formation of hydrogen bonds, ethers or esters. Because of this property, when starch is mixed with some other hydrophobic plolymers, it increases its degradation rate such as in "plastarch material" [7].

Cellulose is the most abundant naturally occurring polysaccharide and is obtained from delignification from wood pulp. Cellulose based bio-plastics such as "cellophane film" are biodegradable and are synthesized by some chemical treatment of cellulose xanthate. The esterification or etherification of free hydroxyl groups of cellulose based derivatives makes them an efficient bio-plastic [8].

Pectin is another macromolecule constituted of galactouronic acid linked by α-1,4 linkage. The carboxyl groups can be easily esterified with methanol and this ratio of esterified or non-esterified determines the property of pectin based bio-plastic [9,10]. Chitin is the second most abundant polymer found in nature after cellulose. They are the structural components of the exoskeleton of arthropods or in the cell walls of fungi and yeasts. Extraction of purification of chitin leads to the production of chitosan which is further used for synthesis of bio-plastic [11]. Other polymers used as plastics include some protein based biodegradable polymer such as soy protein, corn protein (Zein), wheat protein (gluten), casein, collagen, gelatin protein etc. [12].

Bio-polymers synthesized by using renewable monomers; such as Poly-lactic acid synthesized from Lactic acid.

PLA based plastics are produced from fermentation of starch rich substances like maize, wheat, corn into lactic acid. PLA based bio-plastic are thermoplastic, biodegradable polyester having enough capacity for packaging purposes. The strength and properties of packaging material made of PLA based bio-plastic depends on the ratio of two optical isomers (D or L) of lactic acid monomers. 100% L-PLA results in high crystallinity and 90%D/10%L-PLA result in polymerizable melt [13]. "Mulch film" is one such example of PLA based bio-plastic [14].

Polyhydroxy-alkanoates (PHA) are produced by bacterial fermentation of lipids or sugars. Bacteria store their carbon and energy in the form of PHA. In industries, they are prepared by optimizing the conditions for sugar fermentation by bacteria. PHA is more ductile and less elastic and mainly used in the medicinal industries. To improve their properties, the researchers combine PHA with different monomers so as to give enhanced properties [4]. PHB (polyhydroxy-butyrate) is one such PHA produced by many bacterial species such as *Alcaligenes eutrophus, Bacillus megaterium, Methylobacterium rhodesianum, Pseudumonas putida* etc. The bacteria produce PHB either under nutrient deprivation or along with the growth in the media. Its properties are similar to the polypropylene plastics and their production is increasing every year [15]. PHB has a melting point higher than 130 degree Celsius and is completely biodegradable.

Polyamide 11 is the biopolymer obtained from natural oil such as from castor seeds. It is marketed under the trade name of "Rilsan B" and is not completely bio-degradable. It is used in automotive fuel lines, electrical cable, gas pipes, shoes, catheters etc. [1].

Bio-polymers produced by microorganisms or genetically modified bacteria; such as polyhydroxy alkenoate.

Microorganisms produced by genetic modification of microorganisms may be a great source of bio-plastic synthesis. GM fungi, bacteria, algae, plants have already been proved to be an efficient bio-plastic producer [5]. These recombinant strains are genetically modified so as to give a high yield of bio-plastics. The genetically modified strains have various advantages over the naïve ones such as high cell density, use of cheap carbon source for fermentation may be preferred which further makes the synthesis of bio-polymers profitable.

Conclusion

Bio-plastic industry is still in its very native stage because of certain shortcomings such as lack of a universal standardization process, high production cost, low recovery, etc. There is a lot of scope in this industry; such as the use of genetically modified organism may improve the production process with the use of less expensive media and high recovery process. Also, there is an urgent need to standardize all details of bio-plastics like for production, their usage, their composition, waste management and risk assessment. Bio-plastic production in sufficient quantity and that too in an energy efficient process could be a promising biotechnological application which may bring a revolution where harmful plastic may be replaced by eco-friendly bio-plastic.

Bibliography

1. Jabeen N., *et al*. "Bioplastics and food packaging: a review". *Cogent Food and Agriculture* 1 (2015): 1-6.
2. Arikan EB and Ozsoy HD. "A Review: Investigation of Bioplastics". *Journal of Civil Engineering* 9 (2015): 188-192.
3. Agnieszka G., *et al*. "Biodegradable polymer for food packaging- factors influencing their degradation and certification types-a comprehensive review". *Chemistry and Chemical Technology* 5 (2011): 115-122.
4. Stephen EC., *et al*. "Trends on Bio-synthesis of plastics". *Advances in Biotechnology and Microbiology* 10 (2018): 1-10.
5. Bharti SN and Swetha G. "Need for bioplastics and role of biopolymer PHB: A short review". *Journal of Petroleum and Environmental Biotechnology* 7 (2016): 272-274.
6. Sushmitha BS., *et al*. "Bioplastics- A review". *International Journal of Modern Trends in Engineering and Research* 3 (2016): 411-413.
7. Flieger M., *et al*. "Biodegradable Plastics from Renewable Sources". *Folia Microbiology* 48 (2003): 27-44.
8. Peterson K., *et al*. "Potential of Biobased Materials for Food Packaging". *Trends in Food Science and Technology* 10 (1999): 52-68.
9. May CD. "Industrial Pectins: Sources, Production and Applications". *Carbohydrate Polymer* 12 (1990): 79-99.

10. Malathi AN., *et al*. "Recent trends of Biodegradable polymer: Biodegradable films for Food Packaging and application of Nanotechnology in Biodegradable Food Packaging". *Current Trends in Technology and Science* 3 (2014): 73-79.

11. Rinaudo M. "Chitin and Chitosan Properties and Application". *Polymer Science* 31 (2006): 603-632.

12. Averous L and Pollet E. "Biodegradable Polymer Environmental silicate nano-bio composites". Green Energy Technology, Springer Verlag, London (2012).

13. Rasal RM., *et al*. "Poly (lactic acid) modifications". *Progress in Polymer Science* 35 (2010): 338-356.

14. Sorrentino A., *et al*. "Potential Perspective of Bionanocomposites of Food Packaging Applications". *Trends in Food Science and Technology* 18 (2007): 84-95.

15. Gouda MK., *et al*. "Production of PHB by a Bacillus megaterium strain using sugarcane molasses and corn steep liquor as sole carbon and nitrogen sources". *Microbiology Resources* 156 (2001): 201-207.

Volume 2 Issue 6 June 2019