P: ISSN NO.: 2394-0344
E: ISSN NO.: 2455-0817
Remarking
Vol-II * Issue-VIII* January- 2016

Green Chemistry and Bioplastics

Renu Gupta
Assistant Professor,
Deptt. of Chemistry,
Lucknow Christian Degree College, Lucknow

Abstract

The green chemistry revolution is providing an enormous number of challenges to those who practice chemistry in industry, education and research. With these challenges however, there are an equal number of opportunities to discover and apply new chemistry, to improve the economics of chemical manufacturing and to enhance the much-tarnished image of chemistry. Plastics have moulded the modern world and transformed the quality of life. The innovation towards bio plastic has great potential to benefit the environment and allied areas such as biomedical devices, packaging etc. by creating new scenario for the competitive market throughout the globe. Bio plastic is composed of biopolymers produced by living organisms. They are generally made up of monomer units of nucleic acid, amino acids and sugars. Leading chemists are now taking the initiative to change modern day chemistry to helpprotect our environment without changing the lifestyles that everyone has become accustomed to. In a society where everything is going green and so is chemistry, green chemistry, which is also known as sustainable chemistry, ". . . is the design of chemical products and processes that reduce or eliminate the use or generation of hazardous substances". Some biopolymers viz. cellulose, Polylactic acid (PLA), naturally occurring starch based polymers and Poly-3-hydroxybutyrate (PHB) can be used as plastics, replacing the need for polystyrene or polyethylene based synthetic plastics. Biopolymers have been shown to degrade 10 to 20 times faster than traditional plastics without leaving hazardous materials. They are biocompatible, eco-friendly materials which may be tailored to specific needs. This effort will be helpful in waste minimization, recycle and reuse of enormous biomass viz. agricultural waste as well as reduction in pollution load which are essential demand of a sustainable society and clean climate.

Keywords: Bio-plastics, Biopolymer, Packaging, Biocompatibility, Cost-Effectiveness, Clean Climate.

Introduction

Sustainable development is now accepted by governments, industry and the public as a necessary goal for achieving societal, economic and environmental objectives. Within this, chemistry has a key role to play in maintaining and improving our quality of life, the competitiveness of the chemical industry and the natural environment. This role for chemistry is not generally recognized by government or the public. In fact chemicals, chemistry and chemists are actually seen by many ascauses of the problems. The European Chemical Industry Council (CEFIC) survey in1994 showed that 60% of the general public had an unfavourable view of the chemical industry and in the USA, a survey carried out for the Chemical Manufacturers Association (CMA) in 1993 showed that only 25%are favourably disposed towards the industry. The pharmaceutical and plastic sectors scored better than the chemical industry as a whole, possibly because the general public are more aware of their products and their benefits. The chemical industry is consistently regarded less favourablythan the petroleum, gas, electricity, lumber and paper industries. The main reasons given for unfavourable opinions of the chemical industry are concerns over adverse environmental impact, transport, safety and waste. Less than one third of those that the chemical industry is concerned about protecting the environment and less than one half believed thatthe chemical industry is working hard to develop techniques to solve environmental problems The challenge for chemists and others is to develop new products, processes and services that achieve the societal, economic and environmental benefits that are now required. This requires anew approach which sets out to reduce the materials and energy intensity of chemical processes and products, minimise or eliminate the dispersion of harmful chemicals in the environment, maximise the use of renewable resources and extend the durability and recyclability of products-in a way which increases industrial competitiveness.

The exponential growth of the human population has led to the accumulation of huge amounts of non-degradable waste materials across our globe. The presence of non-biodegradable residues is affecting the potential survival of many species in the biosphere. Conventional synthetic plastic and polymeric products such as polyethylene and polypropylene persist for many years after disposal and constitutes significant portion of the total municipal solid waste generated in different countries (Tharanathan, R.N 2003). Garbage containing plastics needs large landfill lands for proper dumping while burning of plastics may emit toxic gases viz. dioxin, furans, carbon mono-oxide etc. Plastic waste presents challenges and opportunities to societies regardless of their sustainability awareness and technological advances. In a society based on reduce, recover, regenerate, recycle and reuse (5 R's) aspects for environmental sustainability, innovative processes of waste handling and managing techniques may be used to minimize the adverse implications of plastic waste. For this reason, several researches have been targeted to develop eco-friendly and bio-degradable polymeric materials that can be readily eliminated from the biosphere, and have designed novel strategies aimed for tailor made applications. Bio plastics are manufactured using biopolymers which are present in, or created by, living organisms (Bismarck, A *et al* 2002). These include polymers from renewable sources that can be polymerized to create bio plastics and are biodegradable.

Biodegradable Plastics

Biodegradable plastics are becoming a new trend because they are believed to be friendlier to our environment. Biodegradable plastics are plastics that will decompose in both aerobic and anaerobic environments. Unlike conventional plastics, "a genuine biodegradable plastic will beconverted to carbon dioxide, water and compost, without leaving any persistent or toxic residue"(Unmar & Mohee, 2008). Biodegradable plastics have the ability to significantly decrease the quantity of plastics within our land fills, and also eliminate toxins within our air from the burning of conventional plastics (Unmar & Mohee, 2008). Biodegradable plastics are made from renewable raw materials, and are presently found invarious forms with different degrees of degradability. One of the most frequently used forms of biodegradable plastics is termed as *hydro biodegradable plastic*. Unlike conventional plastics, which are comprised of polymers of high molecular weight, these hydro biodegradable plastics are comprised primarily of starches that are found in plants or food, although some contain a small percentage of synthetic polymers. When hydro biodegradable compounds are degraded, the originalproduct reduces to water, Carbon dioxide, methane, and biomass (Azios, 2007). Although methane and carbon dioxide are considered greenhouse gases, this additive effectupon the cumulative level of the planet's greenhouse gases is considered to be negligible by most researchers. This is because landfills are specifically designed to capture any released methane, so any methane released will be confined within the land fill. The carbon dioxide that is produced is also not looked at as a contributor of greenhouse gases because the plant that the hydro biodegradable plastic was made from consumed carbon dioxide, so the release of carbon dioxide during the decomposition is thought of as an even exchange (Azios, 2007). However, there are many other forms of biodegradable plastics that are still made exclusively from non-renewable petroleum by-products, similar to conventional plastics. This form of biodegradable plastic is termed *Oxo biodegradable*. The primary difference between Oxo biodegradable plastics and conventional plastics is that these products degrade more quickly. Oxodegradable plastics break down into water, carbon dioxide, and biomass when exposed tosunlight, heat, and other stresses. Oxo biodegradables do break down much quicker than conventional plastics, but they still require the same fossil fuels during their manufacture and emit the same degree of greenhouse gases as conventional plastics (Azios, 2007).

Types of Bio Plastic on the Basis of their Origin

Bio plastic are special type of biomaterial composed of variety of biodegradable polymers originating from different sources and materials (Table 1).

Starch Based Plastics

Starch is a cost effective, easily available, annually renewablematerial derived from corn, wheat, potatoes, rice andother crops. Starch contain samylase and amylopectin, at ratios that vary with the starch source. This variation in polymer units provides a natural mechanism for regulating starch material properties (Jopski, T 1993; Martin, O*et al* 2001). Starch when harvested is turned into a white, granular product. Biodegradable starches can be processed using conventional plastic technologies such as injection moulding, blow moulding, film blowing, foaming, thermoforming and extrusion (Lorcks, J. 1998). The process changes the starch from a lactic acid monomer into a polymer chain called polylacitide (PLA) or polygloycolic (PGA). Both PLA and PGA are crystalline polymers and effectively used for synthesis of bio plastics. Starch based plastics constitutes about 50 percent of the total bio plastic market. Starch is used for many non-food items such as making paper, cardboard, textile sizing, and adhesives. Starched based plastics have already been processed into eating utensils, plates, cups and other products. Starched based plastics have ability to absorb humidity, hence are widely applied for production of drug capsules (Ledward, D.A. 1998).

Bacteria Based Plastics

Bacteria are used to create a different type of biodegradable plastics using the polymer chain polyhydroxyalkanoate (PHA). PHA is produced inside bacteria cells. The bacteria are harvested after they are grown in the culture, and then created into biodegradable plastics. The mechanical properties of their resins can be altered depending on the needs of the product. Development of PHA materials in nonwoven biodegradable polyesters meant for disposable products such as drapes, gloves and surgical gowns, which may be thrown away after one use. The PHA fibres may also degrade aerobically and an aerobically, can be digested under alkaline conditions (Frisoni, G*et al* 2001).

Soy Based Plastics

Soy based plastics use another renewable alternative material used for biodegradable plastics. Soybeans are composed of protein with limited amounts of fat and oil. Protein levels in Soybeans range from 40-55%. The high amount of protein means that they must be properly plasticized when being formed into plastic materials and films. Thebio plastic films produced are used for manufacture of food coatings, freestanding plastics (used for bottles), automobile parts etc.

Miscellaneous Biopolymers for Bio Plastic

Poly-lactic acid (PLA) is a polyester made up from lactic acid. It is a transparent bio plastic used for non-medical applications such as packaging (film, thermoformed containers, and short–shelf lifebottles). PLA degradesprimarily by hydrolysis and can be converted into compost in municipal compost facilities. Poly (ε-caprolactone), *PCL,* is a thermo plastic biodegradable polyester synthesized by chemical conversion of crude oil, followed by ring-openingpolymerization. PCL has good water, oil, solvent, and chlorine resistance, a low meltingpoint, and low viscosity, and is easily processed thermally. To reduce manufacturing costs, PCLmay be blended with starch-for example, tomake trash bags. By blending PCL with fibre formingpolymers (such as cellulose), hydro entanglednonwovens (in which bonding of a fibre web into a sheet is accomplished by entanglingthe fibres by water jets), scrub-suits, in continence products, and bandage holders have been produced. The rate of hydrolysis and biodegradation of PCL dependson its molecular weight and degreeof crystallinity. However, many microbes in nature produce enzymes capable of complete PCL biodegradation (Salmoral E. M. *et al* 2000).

Poly-3-hydroxybutyrate (PHB) are polyester produced from renewable raw materials. Their characteristics are similar to those of petrochemical plastic.It produces transparent film at a melting point higher than 130^{O} and is biodegradable without residue. Polyamide 11 (PA 11) is also a biopolymer derived from vegetable oil. PA 11 is not biodegradable. It is used in high performance applications–automotive fuel lines, pneumatic airbrake tubing, electrical anti-termite cable sheathing, oil & gas flexible pipes & control fluid umbilical, sports shoes, electronic device components, catheters, etc.

Carboxymethyl cellulose (CMC), Hydroxyethyl cellulose (HEC), Poly (aspartic acid) and Poly-(glutamic acid) are known as Water-soluble polymers which have been applied as detergentbuilders, scale inhibitors, flocculants, thickeners, emulsifiers, and paper-sizing agents.They are also found in several household articles such as, cleaning products, foods, toothpaste, shampoo, conditioners, skin lotions and textiles. The largest volumes of water-soluble polymers are prepared fromacrylic acid, maleic anhydride, methacrylic acid, and various combinations of the semonomers. With the exception of their oligomers, these polymers are not biodegradable. Poly (vinyl alcohol) is the only water soluble polymer that is regarded as biodegradable and is currently used in textiles, paper andpackaging industries as paper coatings, adhesives, and films (Simon, J. *et al* 1998).

Bio Plastics and Bio-Economy

Bio plastics are an integral part of the green chemistry sector. They offer manifold market opportunities as major outlets for renewably sourced chemicals for innovative high-tech as well as mass-market applications. Plastics are indispensable in our daily life. Approximately 265,000,000 tonnes of them are produced and used annually. Today, bio plastics from renewable resources only account for a very small share of the total market (<1 percent), but the rapid advances in biotechnology and biochemistry will further push forward this fast growing market. To the present day, bio plastics production capacities have already expanded with double-digit growth figures every year. Innovative technological approaches like the bio refinery and theconcept platform chemicals will further transform industrial production of renewable plastics.

Bio Plastics - Technology Overview

The majority of today's available production technology for green chemicals and plastics is based on the use ofplants rich in carbohydrate. Cereals (e.g. corn), starch plants (e.g. potatoes, tapioca), sugar-richplants (beets, cane), or oil plants (e.g. rapeseed, sunflower) provide the basis toprocess feed stocks. In future, the bio plastic industry aimsto further apply fermentation technologies that allow for the utilisation of other biogenic input based on non-food crop sources. In particular, the production of cellulosic sugars and ethanols is regarded a very promising technological approach.

Bio Plastic: Advantages and Biocompatibility

Bio plastic and biopolymers has several advantages over conventional synthetic plastic. Like it reduce the pollution (toxic emissions) and environmental damage as well as degradation of biodegradable polymers produces acidic intermediates, which neutralize the ammonia content, thus reduceodour problems. Bio plastic has also proven its applicability in biomedical sector (Swift, G. 1998). Biodegradable polymers has shown potential for use in intracellular delivery and sustained release of therapeutic drugs to the acidic environments of tumors, inflammatory tissues and intracellular vesicles that hold foreign matter. Degradation of the biopolymer in a living system does not produce inflammation-causing acid, but instead generates membrane-permeable products that allow all of the polymer's byproducts to diffuse outside the cell. That means byproducts shouldn't accumulate in a patient's tissue and cause in flammation. The greatest advantages of using biopolymers derived plastic articles from renewable feed stocks are their low cost (Narayan, R.*et al* 1999). Natural fibers are advantageous over synthetic one because they are less expensive and more readily available (Tharanathan, R.N 2003). The expansion of flax fiber incorporation in to automobile parts is a positive development for Canada's agriculture industry, particularly in its diversification efforts. Another application of natural fiber reinforcement has been developed inthe china reed fiber to reinforce transport pallets.

Conclusion

Biomaterials are natural products that are synthesized and catabolised by different organisms and that have foundbroad biomedical and biotechnological applications. They can be assimilatedby many species (biodegradable) and do not causetoxic effects in the host (biocompatible) conferring upon them a considerable advantage with respect to other conventional synthetic products. Bio plastics are a special type of biomaterial with tailor made applications. The commercialization of cost effective bio plastic articles having relatively short-uselifetime is needed to generalize their application in society. A holistic effort and innovative research is also necessary for suitability assessment of bio plastic finished products to improve their biocompatibility, tensile strength and degradation mechanism. Bio plastic industry has a positive future, driven mainly by the environmental benefits of using renewable resource feedstock sources. Mass awareness programme and collaborative research is essential for development and commercialization of bio plasticwith optimum technical performance, and full biodegradability for sustainable future.

Acknowledgement

Authors are thankful to the Head, Department of Chemistry, Lucknow Christian Degree College, Lucknow for their encouragement and continuous support.

Table 1
Biopolymers Used for Preparation of Bio plastic

S. No.	Biopolymer	Natural Sources	Properties
1.	**Biopolymers from Living Organisms**		
	Cellulose	Wood, cotton, corn, wheat etc.	The polymer is made up of glucose. It is the main component of plant cell walls.
	Soy Protein	Soybeans	Protein which naturally occurs in the soy plant
	Starch	Corn, potatoes, wheat, tapioca etc.	This polymer is one way carbohydrates are stored in plant tissue. It is a polymer made up of glucose. Absent in animal tissues.
	Polyesters	Bacteria	These polyesters are created through naturally occurring chemical reactions that are carried out by certain types of bacteria.
2.	**Polymerizable Molecules**		
	Lactic acid	Beats, corn, potatoes and others.	Produce through fermentation of sugar, feedstock such as beats, and by converting starch in corn, potatoes or other starch sources. It is polymerized to produce polylactic acid, a polymer that is use to produce plastic.
	Triglycerides	Vegetable oils	These form a large part of the storage lipid found in plant and animal cells. Vegetable oils are one possible source of triglycerides that can be polymerized into plastic.

References

1. Ledward, D.A. 1998. Properties and applications of compostable starch-based materials. *Trends in Food Science and Technology.* 41: 402-405.
2. Lorcks, J. 1998. Properties and applications of mater-bi starch-based materials. *Polymer Degradation and Stability.* 59(1-3): 245-249.
3. Martin, O., Schwach, E., Averous, L. Couturier, Y. 2001. Properties of biodegradable multilayer films based on plasticized wheat starch. *Starch*. 53(8): 372-380.
4. Nakasaki, K., Ohtaki, A., Takano, H. 2000. Biodegradable plastic reduces ammonia Emissions during composting. *Polymer Degradation and Stability.* 70: 185-188.
5. Narayan, R., Pettigrew, C. 1999. ASTM standards help define and grow a new biodegradable Plastics industry. *ASTM Standardization News.* December: 36-42.
6. Orhan, Y., Buyukgungor, H. 2000. Enhancement of biodegradability of disposable polyethylene in controlled biological soil. *International Bio deterioration and Biodegradation.* 45: 49- 55.
7. Park, S.Y., Lee, B.I., Jung, S.T., Park, J.H. 2001. Biopolymer composite films based on kcarrageenan and chatoyant. *Materials Research Bulletin.* 36: 511-519
8. Salmoral, E.M., Gonzalez, M.E., Mariscal, M.P. 2000. Biodegradable plastic made from bean Products. *Industrial Crops and Products.* 11: 217-225.
9. Schroeter, J. 1998. Creating a framework for the widespread use of biodegradable polymers. *Polymer Degradation and Stability.* 59(1-3): 377-381.
10. Simon, J., Muller, H., Koch, R., Muller, V. 1998. Requirements for biodegradable water soluble Polymers. *Polymer Degradation and Stability.* 59(1-3): 107-115.
11. Swift, G. 1998. Prerequisites for biodegradable plastic materials for acceptance in real life Composting plants and technical aspects. *Polymer Degradation and Stability.* 59(1-3): 19-24.
12. Tharanathan, R.N. 2003. Biodegradable films and composite coatings: Past, present, and Future. *Trends in Food Science and Technology.* 14: 71-78.
13. Azios, T. (2007, December). A primer on biodegradable plastics. Christian Science Monitor. Retrieved from Academic OneFile database.
14. SUnmar, G., &Mohee, R. (2008). Assessing the effect of biodegradable and degradable plastics on the composting of green wastes and compost quality *BioresourceTechnology*, 99, 6738-6744.