

GREEN POLYMER CHEMISTRY: AN APPROACH TOWARDS SUSTAINABLE ENVIRONMENT

Zoology

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ABSTRACT

Green polymers, are those produced using green chemistry. According to the International Union of Pure and Applied Chemistry (IUPAC) definition, green chemistry relates to the "design of chemical products and processes that reduce or eliminate the use or generation of substances hazardous to humans, animals, plants, and the environment." Thus, green chemistry prevents pollution at its source. The term green chemistry was coined in the 1990s. Natural polymers are usually green bioproducts. On the other hand bioplastics are plastics made from biomass such as corn, sugarcane etc. These substances have been increasingly used saving fossil fuels, reducing CO₂ emission and plastic wastes. The plastic which is available in market is very dangerous as it is non-biodegradable. Biodegradability of Bioplastics has been widely needed to be publicized in society. Due to this demand for packaging is rapidly increasing among retailers and the food industry at large scale to use bioplastic. Therefore, it is the demand of the day that biodegradable plastics should be produced and used at a large scale to fulfil demand of increasing population. The present review deals with all the points regarding, the applications, production, types, challenges, sustainability, and use of cheap substrates for bioplastics production.

KEYWORDS:

Bioplastics, Fermentation, Polyhydroxyalkanoates, Green Chemistry, Biodegradability and UPAC.

INTRODUCTION

In 1920, the Noble laureate Herman Staudinger recognized that natural and man made polymers are produced according to the same methodology. Where a very large number of small monomer molecules are linked together to produce large macro molecules with high molecular weight this process called polymerization process. This type of polymerization also comes under green chemistry, a term coined in 1990s.

Bio plastics are plastics in which all carbon is derived from renewable feed stocks. They may or may not be biodegradable. Bio based plastics contain both renewable and fossil-fuel-based carbon. The percentage of bio based ingredients and the conditions, under which the bio based product may biodegrade, if at all, vary widely. According to the American Society for Testing and Materials (ASTM), a bio based material is: An organic material in which carbon is derived from a renewable resource via biological processes. Bio based materials include all plants and animals biomass derived from CO₂ recently fixed via photosynthesis as per definition of a renewable resource. In the production of polymers important green principles of polymer production are:

- High resource effectiveness and maximizing the content of a raw material in the product
- A clean (no-waste) production process
- No use of auxiliary substances such as organic solvents and blocking groups etc.
- High energy efficiency in manufacturing of materials and applications
- Use of renewable resources and renewable energy
- No health and environmental hazards by minimizing toxicity
- High safety standards
- Low carbon footprint
- Controlled product lifecycles with effective waste recycling [1]

Process of bio-plastic production

Products on the market are made from a variety of natural feed stocks including corn, potatoes, rice, tapioca, palm fiber, wood cellulose, wheat fiber and bagasse. Products are available for a wide range of applications such as cups, bottles, cutlery, plates, bags, bedding, furnishings, carpets, film, textiles and packaging materials. In the US, the percentage of bio based ingredients required for a product to be referred to as bio based, is defined by the USDA on a product-by-product basis. ILSR has recommended that the USDA set a minimum threshold of 50 percent bio based content for products to be considered bio based. In addition, the use of renewable resources for green polymer production should not compete with food production, should not promote intensified farming or deforestation, and should not use transgenic plants or genetically modified bacteria; biodegradable polymers should not produce inhalable spores or nanoparticles. [2]

There are three basic strategies to produce renewable plastics:

1. Using biomass and/or carbon dioxide to produce 'renewable oil' and green monomers for highly resource- and energy-effective polymer manufacturing processes
2. Through living cells, which are converted into solar-powered chemical reactors, using genetic engineering and biotechnology routes to produce biopolymers and bio-based polymers
3. By activation and polymerization of carbon dioxide

Using processes that are even more energy-efficient, biomass can be directly converted into renewable coal and oil. Agricultural and forestry wastes already are used to produce renewable monomers. Processes have been developed to convert carbon dioxide into carbon monoxide, methanol, formic acid, and formaldehyde. Vegetable oils can be used to produce biodiesel and glycerol as a byproduct, which can be used to make a variety of monomers such as propane diol, acrylic acid, and even epichlorohydrin for the production of epoxy resins.

Carbohydrates, terpenes, proteins, and polyesters are chemically modified and used in polymer processing and applications. Natural fibers provide excellent fiber reinforcement for thermosets and thermoplastics. Micro fibrillated cellulose has been used in polymer nanocomposites, including applications in medical implants. Lignin serves as renewable energy source in paper manufacturing, as filler for cement, and in various polymers and rubbers. Thermoplastic lignin mixed with natural fibers (Arboform) combines the advantages of wood and synthetic thermoplastics. A bio hybrid has been using starch as a blend component with polyolefins and compostable polyesters (Ecoflex). Chitosan and polylactic acid have numerous medical applications. Casein is used as a binder and as an adhesive.[3]

Renewable monomers are already substituting for "oil-made" monomers. The ever-present plastic bottles are just one example. In 2011, Coca-Cola Co. announced a goal to make plastic bottles from 100% bio-based materials. Recyclable PET "Plant Bottles," which use up to 30% bio-based monomers, were introduced in 2009, and can still be recycled.

Overall, it is definitely possible for plastic production to meet the demands of green chemistry for lean and clean production: solvent-free processes with efficient use of resources, and no byproduct formation, waste, or exploitation of renewable resources. Will we take advantage of the possibility? As Abraham Maslow once said, "One's only failure is failing to live up to one's own possibilities." Let's not fail!

Sampling of compostable Food Service Ware Products

A biodegradable material is, according to the Biodegradable Products Institute (BPI), "where under the right conditions the microbes in the environment can break down the material and use it as a food source". In other words, a biodegradable plastic is completely mineralized by microorganisms. Biodegradable plastics are not necessarily bio-based.

The renewable polymers are obtained either from natural polymers are by polymerization or biobased monomus as shown in figure 1 (Mulhaupt, 2012).

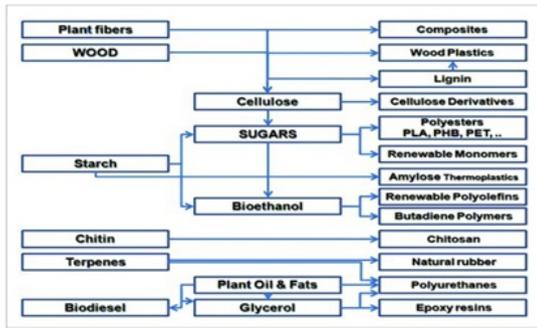


Figure 1. Renewable Bio Polymers and Biobased Polymers upon Carbohydrate and Terpene (Mulhaupt, 2012).

Potential Benefits of Bio plastics, Problems with Petro-Plastics are summarized in table -1.

Table 1: Comparison of bio plastic and petro plastic waste.

Benefits of Biopolymers	Petro-Plastic Woes
Can replace many harmful conventional plastics	Non-renewable(geological timeframes to produce but 1 to 10 years to consume)
Can be fully biodegradable (capable of being utilized by living matter)	Health impacts (polymers differ)
Can be made from a variety of renewable resources	Generally non biodegradable with devastating affects on ocean life
Can be composted locally into a soil amendment	Demand and production skyrocketing
Can contribute to healthier rural economies	Plastics industry supports more drilling
	Recycling and reuse low

One final positive thought about biopolymers is their potential to address CO₂ in our atmosphere – there are a lot of smart phones and computing devices in everyday modern life [6,7,8].

Biobased and biodegradability are not the same. Some biobased products can biodegrade in municipal or commercial composting facilities, home composting, and aquatic and roadside environments, others will only biodegrade in very specific environments and some will not biodegrade at all. In North America the BPI is the third-party certifier for products that are compostable in commercial composting facilities. To receive the BPI Compostable Logo, products must meet the ASTM Standards D6400 (for Compostable Plastics) or ASTM D6868 (for Compostable Packaging). According to the BPI, to be certified, a product must:

- Disintegrate rapidly during the composting process (so that no large plastic fragments will wind up on the composters' screens when the process is finished).
- Biodegrade quickly under the composting conditions.
- Not reduce the value or utility of the finished compost. The humus manufactured during the composting process will support plant life.
- Not contain high amounts of regulated metals.
- Bio plastics have many benefits over petro-plastics, but several challenges also lie ahead.[4,5]

CHALLENGES FOR BIOPLASTICS

Challenges with development and widespread acceptance of bio plastics include:

- Concern over genetically modified organisms (GMOs)
- Desire for sustainably grown biomass
- Need to develop composting programs and infrastructure
- Concern with nanocomposites and fossil-fuel-plastic blends
- Lack of adequate labeling
- Concern over contamination of recycling systems [9,10,11]

Conclusions and future prospects

Mineral oil prices will get increase substantially in the next century, imposing the world to consider alternatives for petrochemical plastics. The renewable nature and biodegradability of bio plastic make them appropriate resources to substitute synthetic plastics in many applications. Currently their production is expensive, but these plastics are only in their first stage of commercial development. Further research on recombinant microbial strains, mixed cultures, efficient fermentations, recovery /purification and the use of inexpensive substrates can substantially reduce the production cost. Therefore, the future of bio plastics depends on the efforts towards fulfilling price as well as performance requirement. Microbial synthesis of bio plastic seems to be an inexhaustible game; we can either make homo polymers with diversified monomers, or copolymers or block copolymers of various combinations. Because of their special characteristics and broad biotechnological applications, bio plastics have an extremely promising future.

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