Biodegradable polymers are a solution for a green and sustainable world

SirsenduGayen

(Assistant Professor, Department of Chemistry, Vivekananda College, Thakurpukur, Kolkata-700063, E-mail: sgayensrci@gmail.com, Mobile: 9836715703)

Abstract

Biodegradable polymers are substances whose chemical and physical properties weaken and completely disintegrate when exposed to microorganisms, aerobic, and anaerobic processes. Synthetic polymers, which are mostly manufactured from petroleum, have serious environmental problems. because they take a long time to decompose and cannot be recycled. As a result, they significantly worsen the problem of how to dispose of solid trash, and on occasion, they put wildlife in risk because of plastic that it ingests or gets tangled in. Natural polymers made from plants offer a long-term and environmentally responsible solution to the current plastic waste problem. Biodegradable polymers, such as polysaccharides and proteins from plants, animals, and microbes, are useful and offer a variety of advantages over synthetic polymers made from petroleum. By reducing reliance on fossil fuels and the positive environmental effects that go along with it, such fewer carbon dioxide emissions, bio-based polymers provide significant advantages. A sustainable polymer should be produced in a way that is less harmful to the environment than making a polymer from petroleum. It would produce less pollution than its petroleum-based relative and need less non-renewable energy and water to make. This paper underlines the value of biopolymers as a sustainable approach to dealing with plastic pollution and provides an overview of the current research and development being done in the area of biodegradable polymers.

Keywords: Plastic pollution,Synthetic polymer, degradation, biopolymer, environmental issues, sustainable solution

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Introduction:

In the case of conventional petroleum-derived plastics, the durability characteristics that make plastics ideal for many applications, such as in packaging, building materials, and goods, as well as in hygiene products, can also lead to waste-disposal issues because these materials are not easily biodegradable and because of their resistance to microbial degradation, they build up in the environment. This information has sparked interest in biodegradable polymers [1]. The term was originally used in a biology text in 1961 to explain how microorganisms break down materials into their fundamental components of carbon, hydrogen, and oxygen [3]. According to the International Union of Pure and Applied Chemistry (IUPAC), a biodegradable polymer is one that can be broken down by biological activity and has its molar mass decrease as a result. More specifically, biodegradable polymer ought to eventually break down into water and carbon dioxide [4]. Non-biodegradable polymers are those that cannot be broken down by microorganisms in the environment. It's possible for plastic or a polymer to deteriorate but not biodegrade, for instance if it's broken down by light [9].

The significance of biodegradable polymer is highlighted by growing worries about the volume of polymer waste that results from use, which is difficult to recycle and has been "endlessly" in the planet since its creation. Biodegradable polymers are typically preferred above alternative degradation processes for environmentally digestible polymers since microorganisms are present everywhere on Earth. Biodegradable polymers naturally derive from natural polymers like starch, cellulose, protein, etc., whose use has a long human civilizational history [4].

Types of biodegradable polymers:

Three categories of biodegradable polymers are distinguished based on where they were generated: synthetic polymers obtained from renewable resources, naturally produced renewable polymers, and synthetic polymers derived from petroleum-based resources [8].

All living things in nature make natural biodegradable polymers. Biodegradable polymers include those found naturally in cellulose, lignin, starch, chitin, collagen, gelatin, hyaluronic acid, dextran, heparin, xanthan, elastin, fibrin, pectin, and polyhydroxyalkanoates[8]. Biodegradable polymers can be roughly divided into two broad types[10].

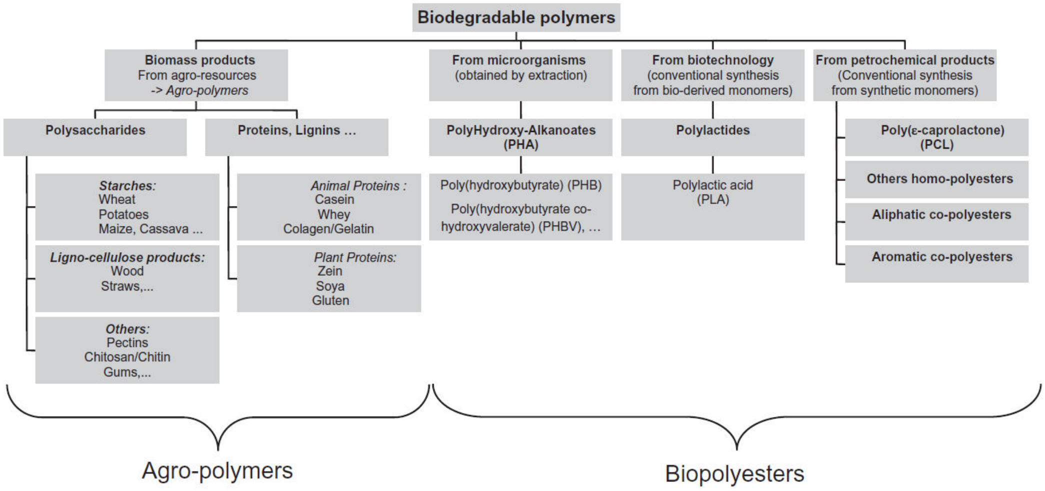

Fig1: Classification of the main biodegradable polymers [8,10]

Few synthesis of Biodegradable Polymers:

Polyesters are among the most significant and extensively researched classes of biodegradable polymers. Direct condensation of alcohols and acids, ring opening polymerizations (ROP), and metal-catalyzed polymerization processes are a few of the different ways polyesters can be made [21].

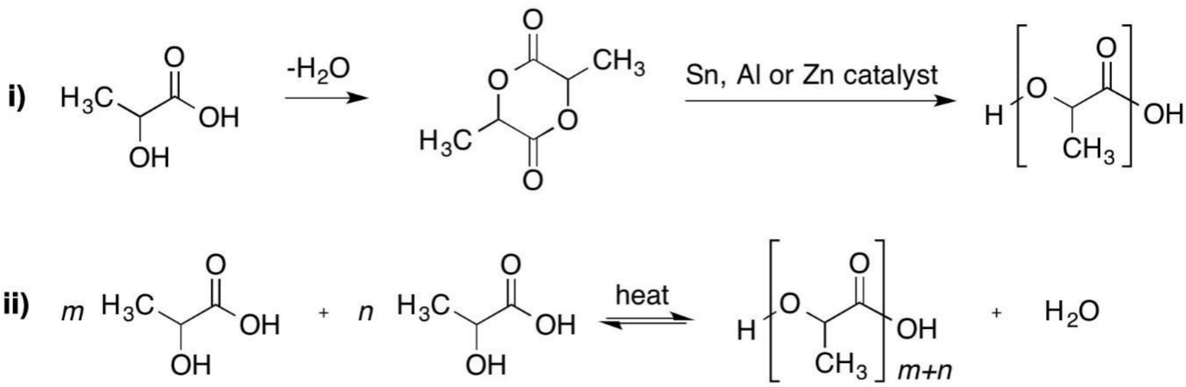

Fig2: Polyester formation using lactic acid. i) Condensation of lactic acid into dimeric lactide followed by ring-opening polymerization ii) Direct condensation of lactic acid [22].

Semicrystalline polyester poly(e-caprolactone) (PCL) has a melting point of about 55–60 °C. Since PCL can be produced from the inexpensive starting material e-caprolactone, it is of tremendous interest [5].

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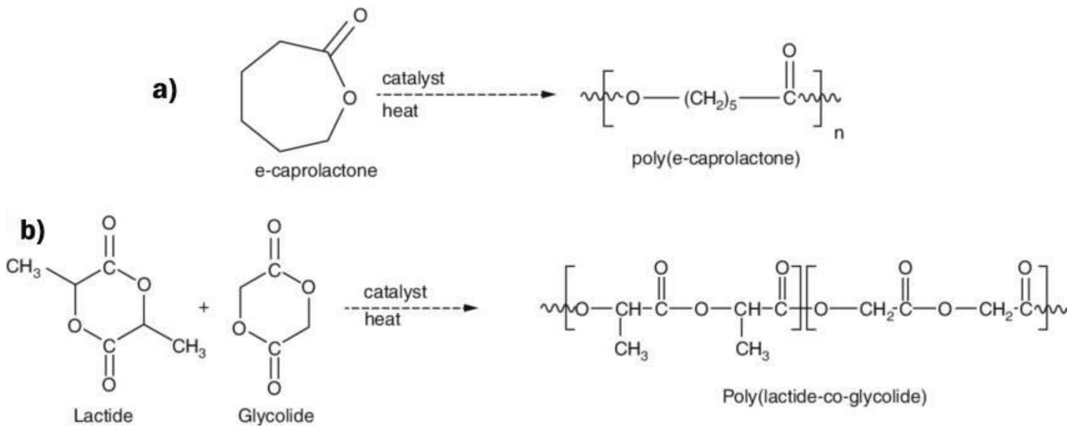

Fig 3. Synthesis of commonly used synthetic biodegradable polymers: (a) poly(caprolactone), (b) poly(lactide-co-glycolide) [5-6]

Biodegradation of biodegradable polymers:

The chemical dissolution of compounds caused by the enzymatic activity of microorganisms is referred to as the biodegradation of biodegradable polymers. As a result, the chemical composition, mechanical, and structural characteristics change, and metabolic products—environmentally benign substances including methane, water, biomass, and carbon dioxide—are produced. The biodegradation of polymers is depicted in Figure 4[11].

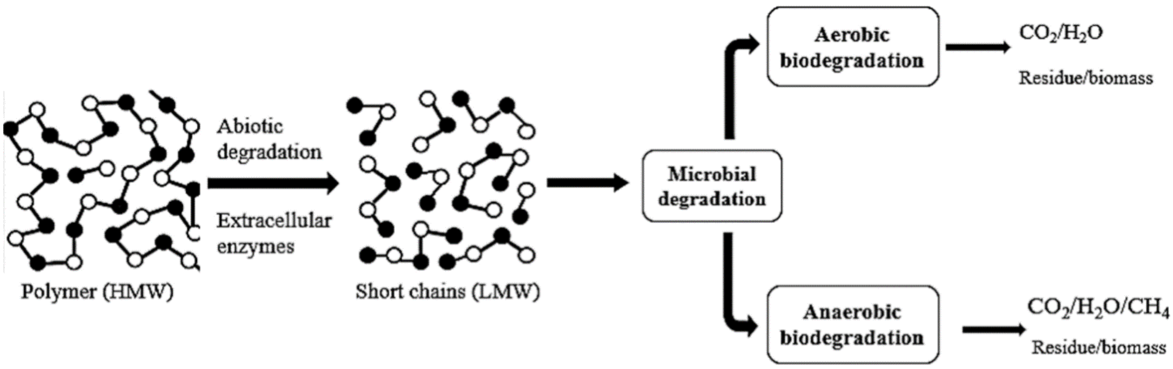

Fig 4: The chemical biodegradation diagram [11].

Applications and uses:

Biodegradable polymers are highly sought-after in a number of industries, including packaging [14], agriculture [13], and medicine [12]. Controlled medication delivery and release is one of the most active areas of biodegradable polymer research. Numerous applications for biodegradable polymers exist in the biomedical industry, particularly in the areas of drug delivery and tissue engineering [15–16]. Nano medicine and drug delivery are two areas where biodegradable polymers are highly sought-after. The main advantage of a biodegradable drug delivery system is that the drug carrier can direct the release of its payload to a particular location in the body before degrading into harmless materials that are then removed from the body through normal metabolic processes [17]. Biomaterials and biodegradable polymers are also highly sought-after for tissue engineering and regeneration. The ability to regenerate tissue with the use of synthetic materials is known as tissue engineering. The development of such systems can be used to grow tissues and cells in vitro or create new structures and organs in vitro using a biodegradable scaffold [18]. Biodegradable polymers are frequently utilised in packaging materials in addition to in medicine [1]. Significant effort is also being made to replace petrochemical-derived products with ones that can be produced from biodegradable resources. Polylactic acid, or PLA, is one of the most often used polymers for packaging [19].

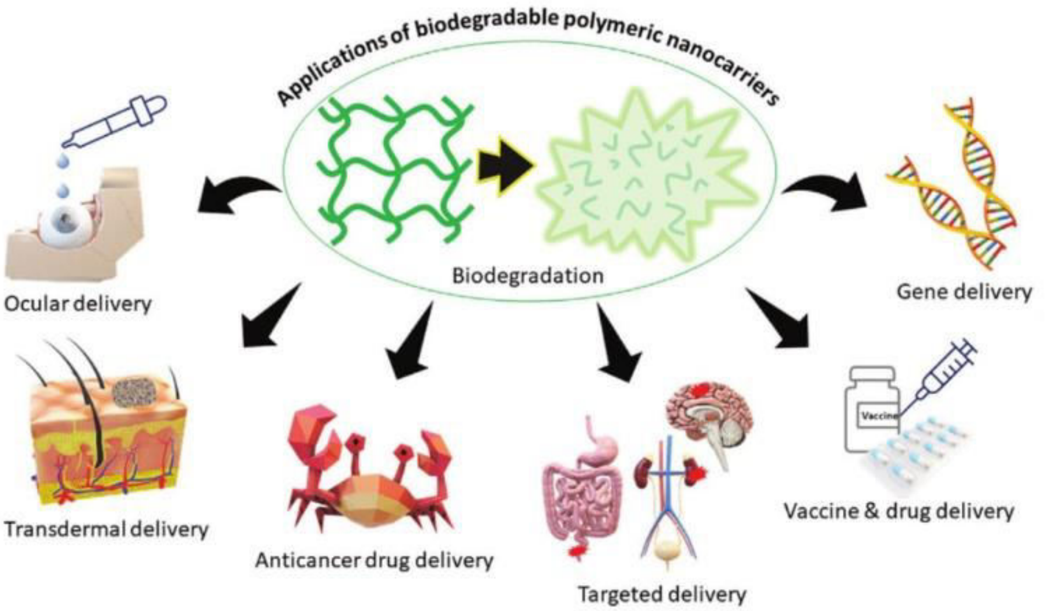

Fig5: Examples of some advanced applications of biodegradable polymers and their nanostructures in disease treatment [20].

Conclusions:

Leading chemists are currently taking the effort to alter contemporary chemistry to aid in environmental protection without altering the way of life that everyone has grown accustomed to. Green chemistry is a set of principles that aims to improve the environmental and animal health of chemical products without having a detrimental impact on the economy. Polymers are among the many goods and operations that follow environmentally friendly guidelines. Due to its potential uses in the sectors of environmental preservation and the maintenance of physical health, biodegradable polymers have drawn a lot more interest in recent years. Future success of each biopolymer depends on both its ability to compete and how ready society is to pay for it. The likelihood of development in the field of biopolymers is optimistic.In some circumstances, biodegradable polymers could take the place of conventional plastic materials. These polymers can be disposed of using waste management strategies like composting, soil application, and biological wastewater treatment because of their biodegradability. The use of biodegradable plastics is growing in popularity as a result of their alleged environmental friendliness. Biodegradable plastics have the power to dramatically reduce the amount of plastic waste in our landfills and to remove airborne contaminants caused by burning traditional plastics.

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