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The Role of Biopolymers in Obtaining Environmentally Friendly Materials

Rodolfo Rendón-Villalobos, Amanda Ortíz-Sánchez,
Efraín Tovar-Sánchez and
Emmanuel Flores-Huicochea

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Abstract

Polymeric materials have had a boom in the global industry over the past two decades, because of its adaptability, durability, and price so much so that now we cannot imagine a product that does not contain it. However, many synthetic polymers that have been developed are mainly derived from petroleum and coal as raw material, which make them incompatible with the environment, since they cannot be included in what is a natural recycling system. Aware of the environmental impacts that produce synthetic polymers, a solution could be the mixtures with different types and sources of biological materials, called biopolymers, such as starch, cellulose, chitosan, zein, gelatin among others and that gradually replace synthetic polymers to address and resolve these problems. The development of new applications, such as composite materials by incorporation of alternative materials, found in nature that has similar properties to oil-based polymers, but its main feature is its biodegradability and offering competitive to current material costs. In this sense, various investigations are aimed at decreasing the amounts of plastic waste and to manufacture products with less aggressive environment since the synthetic plastics are difficult to recycle and can remain in nature for over a century.

Keywords: biopolymers, biodegradability, friendly materials

1. Introduction

Use of polymers has increased significantly over other types of materials, this more than anything because of its many possible applications, true reflection of the ease offered to the design of new compositions with very different properties.

However, conventional polymers remain subject to very specific investigations, primarily aimed at improving their properties, as well as modifications that allow the expansion of its range of applications.

That is, materials can be prepared with very different properties, for example, polymers with a great structural rigidity, due to a high proportion of aromatic structures in the molecular skeleton or flexible polymers with chains exclusively of the concatenation of aliphatic groups.

These polymers are primarily used for their advantages being chemically inert, lightweight, durable, comfortable and hygienic, and submit versatility of shape and size. It is undeniable that the introduction and advancement in the technology of synthetic polymer-based petroleum have brought many benefits to humanity.

But nevertheless, to be synthetic compounds, nonbiodegradable and based on petroleum, use poses serious ecological problems, mainly due to the environmental pollution they cause, by manufacturing and incineration as its contribution to the generation and accumulation of waste.

Since the last decades there has been a growing demand of friendly products environment, promoting the development of biodegradable materials based on biopolymers as lipids, polysaccharides, and proteins, which have been studied being renewable raw materials and inexpensive considered as an alternative to plastic nonbiodegradable and based on petroleum.

The replacement of synthetic plastics by biodegradable materials to obtain friendly products environment has not been achieved so far. However, if some synthetic polymers are replaced by other natural, in specific applications such as films, foams, covering, dishes, cups, spoons, and bags.

2. Classification of polymers

Although there are several elements that can be molecules of synthetic organic polymers, the main elements are carbon (C), hydrogen (H), oxygen (O), and nitrogen (N).

According to the process of obtaining, the polymers may be classified in to the following types:

- Synthetic polymers are obtained by polymerization processes from raw materials of low molecular weight, for example nylon, polystyrene, polyvinyl chloride, and polyethylene.
- Semisynthetic polymers are the resultant product of chemical processes of some natural polymers. Examples of these are nitrocellulose, etonita, vulcanized rubber, to name a few.

- Natural polymers obtained directly from the plant or animal kingdom, for example, cellulose, starch, protein, natural rubber, nucleic acid, chitin, lignin, among others.

Within this classification, the synthetic-based polymers have induced the accumulation of plastic in our environment, pollution sources of atmospheric, visual, and also contamination of soil and marine environments [1].

Thus, natural polymers, also known as polymers, are in complete growth, although their properties limit their applications compared to conventional polymers, but nevertheless, the market for biodegradable polymers is growing every year [2, 3] mainly by increasing access limited to nonrenewable fossil resources has contributed toward finding renewable natural sources for chemical synthesis of polymers with similar properties those based on petroleum, but its main feature is its biodegradability.

2.1. Biodegradable polymers

Biopolymers are a new generation of materials that are still in development and that have attracted attention as possible replacement-based materials of conventional plastics due to an increased interest in sustainable development [4–6].

These have been part of humanity since it exists, being that have been part of basic daily needs as fundamental as food and clothing, as well as medical materials, packaging, food additives, engineering plastics, chemicals for water treatment, among many others [7, 8].

Biopolymers used to obtain biodegradable materials have diverse provenances, such as products from vegetable origin (starches, celluloses, pectins, chitosan, zein, etc.); animal origin (casein, whey protein, and gelatin); microbial products (polyhydroxybutyrate and polyhydroxyvalerate) and chemically synthesized polymers from the monomers of natural origin (polylactic acid) [9, 10].

Natural polymers more prominent have been sugar derivatives, polysaccharides, being starch the most used and representative. This is a thermoplastic biodegradable polymer highly hydrophilic, low cost, and high availability [11]. Starch is found in a variety of tissues botanicals, including fruits, seeds, leaves, and tubers [12]. It consists essentially of a mixture of polysaccharides comprised of amylose and amylopectin and, a minority fraction (from 1 to 2%) not forming glycosidic [13]. Most starches in their glycosidic structure is made up of 20% amylose and the remaining 80% amylopectin.

Some application with this biopolymer has been its combination with synthetic polymers (such as polyvinyl alcohol, polyethylene), plasticizers (glycerin, sorbitol), nitrogenous bases, etc., to obtain a material partially biodegradable.

However, there are others polysaccharides obtained from various sources of natural resources (e.g., cellulose and chitosan) that also have been used by both its structure and its functional diversity [14].

The mixture of chitosan with aldehydes produces a harder material, biodegradable, insoluble in water and with high resistance to fats and oils [15]. Cellulose derivatives obtained by

chemical modification by esterification of glucose, such as carboxymethylcellulose (CMC), hydroxypropylcellulose, and methylcellulose (MC), are used as food additives in the case of CMC, and in the pharmaceutical industry, the MC and hydroxypropylcellulose are used in pharmaceutical tablets for sustained release of granules.

The most important sectors that are intended to the biodegradable polymers are as follows:

- Containers and bags used in stores.
- Disposables (razors, dishes, spoon, and other items).
- Electric and electronic (computers, photography).
- Automotive (internal lining, mudguards).
- Sanitary (prosthesis).
- Agricultural (plastic greenhouses).

However, the market of biodegradable polymers is an alternative market or replacement, intended to replace as a percentage of conventional materials for biodegradable materials. The demand is being generated from own production companies, appealing to a more ecological sense and responsible consumption, through the use of biodegradable materials. Nevertheless, given the evolution of the oil market with a view to 2020, it is estimated that replacement could reach almost 10% by weight, this involves managing areas for the cultivation of raw materials of which biopolymers are obtained and may present in a way as competitors in agricultural area for biofuels, livestock feed, and human food.

Even if the biopolymers are widely distributed in the nature, only limited number of plants and animals are used extensively for the production of commercial biopolymers. It points to a “exploitation” of natural resources that if not treated as a “management” of these; could become an excessive and irresponsible consumption on natural resources. So, all renewable resource must be replenished twice to meet the needs of current and future generations, and then, things that sustain life should also last in time, should be sustainable.

2.2. The role of sustainable in the use of biopolymers

The effects of pollution from nonbiodegradable plastics have been found in both terrestrial ecosystems and water, which has changed behavior, morphology and physiology of individuals, the distribution and abundance of populations, the structure of communities and dynamics of ecosystems. The increasing incorporation of these materials and its impact on the environment are due largely to having resistance to corrosion, weathering, and degradation by microorganisms.

Every year several million tons of plastic are produced in the world, for example, it has been documented that global production in 2013 increases to 299 million tons [16]. On the other hand, the deposition of plastic particles less than 5 mm has increased in the ecosystems, which may be acrylic, polyethylene, polypropylene, polystyrene, etc., and can have an impact on different levels of ecological organization having a knock-on effect and affecting biodiversity in terms of genes, species, or ecosystems.

Therefore, recent studies focus on finding new technologies to use biodegradable natural products (natural polymers), allowing replace conventional materials and significantly reduce the production and accumulation of garbage (plastic). The integrated use of natural resources as a source of conservation and recycling, becomes an excellent choice and innovation in the development of new biodegradable products.

Also, biopolymers have the characteristic of being thermoplastics and have properties similar to petroleum-based plastics. Its total biodegradation by bacteria that produce, fungi, and algae yield products such as CO₂, water and then composted is a great advantage over synthetic [17].

Biopolymers synthesized by microorganisms, polyhydroxyalkanoates (PHA), have the characteristic of being biodegradable, with physical properties similar to petroleum-based plastics (e.g., are rigid, brittle, or flexible). This has led to an increased research on studies with PHA, and it is proved by [18] Lemoigne (1926), since he documented that the bacteria *Bacillus megaterium* yields PHA and it has been that more than 300 bacteria can produce this biopolymer.

Species such as *Alcaligenes latus*, *Azotobacter vinelandii*, *Herbaspirillum seropedicae*, *Pseudomonas oleovorans*, and *Wautersia eutropha* are mostly used, because they are easily grown and can accumulate a large amount of PHA in the form of granules within the bacterial cell, and up to 90% of the biomass. Despite this, tracking new producing strains, optimization in strategies culture and the production of PHA using strains of recombinant bacteria, remains challenging to reduce production costs and increase productivity using various strategies.

With emphasis on reducing environmental degradation caused by unnatural polymers, innovation studies are performed on cultivation technologies, processing, and application. The studies focus on using plants available as side products in agriculture to obtain biopolymers, for example: *Ananas commusus*, *Hevea*, *Lycopersicon esculentum*, *Manihot esculenta*, *Opuntia ficus-indica*, *Saccharum*, *Solanum quitoense*, *Zea mayz*.

Plants are an excellent alternative in the production of biopolymers, because they can be grown in large tracts of land generating high levels of biomass, as they use sunlight as an energy source.

The disturbances caused by high levels of pollution produced by plastic are another factor that set in crisis the biodiversity of genes, species, and ecosystems on the planet. Therefore, the effort to search for new alternatives of natural polymers, which allow contaminated environments return to their state of pre-disturbance, is essential. More studies are necessary with an integrative approach to enable sustainable development, defined as “which meets the needs of the present generation without compromising the ability of future generations to provide their own needs” [19, 20]. This sustainable development is a key element for the management of natural resources [21], involving environmental, economic and social aspects.

To take a direction to the management systems of natural resources more sustainable, it is necessary to adjust the economic model with the conviction that security, the welfare, and survival of the planet depend on these changes [19]. Thus, from the 1960s, it began to start to have a sense of comprehension of serious environmental problems, and therefore, the consequences for economic and social development [19, 22], resulting several years later in the

approval of the global Earth Charter and the formation of the World Commission on Environment and Development. This commission presented in 1987 the Brundtland Report which is distinguished by describing for the first time the concept of sustainable development.

Conservation of biodiversity in the world is crucial not only in the socioeconomic and industry development of a country, but also maintain environmental stability, including the protection of water resources, flora and fauna [23]. Particularly, forest biodiversity focusing in the struggle for the sustainable conservation of biodiversity embedded in the convention on biological diversity (CBD), because the forests contain most photosynthetically active biomass and contain the greatest diversity of species in terrestrial ecosystems, in addition to providing an important source of food, medicines, energy and building materials, provides esthetic and cultural values [23].

Returning to the above, we have a disorderly growth and an imminent ecological, social and environmental imbalance, insomuch is established a direct correlation between economic growth and environmental degradation. Thus, there is a need to develop synergies between economic subsystems, social, and environmental [24].

It is necessary to have an ecological mentality and changing consumption patterns; guide efforts towards the efficient use and recycling of resources; develop more efficient technologies that mainly use renewable resources; conserve natural ecosystems and promote the participation of all social actors [21, 22, 24]. With this new model, imbalance can be handled with a holistic approach to the development [24].

Currently, there is a need to evaluating socioenvironmental system and guide actions and policies for the sustainable management of natural resources. The concept of sustainability or sustainable development is clearly on the basis of assessment of sustainability [20]. Indicators are a central element in practice the concept of sustainability. They represent a link between the theoretical development of the concept and its practical application [21].

The concept of sustainable development has gained attention locally, nationally, and internationally to guide planning and policy in the transition to the sustainable development. This performs every aspect of human life, one of which is education. Education for sustainability was recognized by the UNESCO in 1975, and today, it is found that this can help to change attitudes and behavior of people as consumers, producers, and citizens to carry out their responsibilities. Agenda 21, (Action plan proposed by the United Nations Organization), reaffirmed the importance of education for sustainability and the need to consider all social, economic, and political aspects of sustainable development, in addition to environmental protection [22].

3. Conclusions

Due to the characteristic features of biodegradability, eco-friendly manufacturing processes and its wide application ranges, biopolymers are important alternatives to unsustainable products.

Therefore, it is noted that all efforts on obtaining materials from sustainable sources, which also have a high rate of biodegradation in the environment, occupying roles, and displacing traditional plastics, are of great importance, in order to restore the environment that has been damaged so far by the indiscriminate use of synthetic polymers and prevent deterioration onwards.

But nevertheless, obtaining these biopolymers must be based on an integrated environmental perspective to increase the sustainability of materials and processes throughout its lifetime, obtaining materials from products that do not compete with traditional food sources, and also reduce dependence on non-renewable resources in long term.

Author details

Rodolfo Rendón-Villalobos^{1*}, Amanda Ortiz-Sánchez², Efraín Tovar-Sánchez² and Emmanuel Flores-Huicochea¹

*Address all correspondence to: rrendon@ipn.mx; rendonrodolfo23@gmail.com

1 National Polytechnic Institute, Center for Development of Biotic Products, Yautepec, Morelos, Mexico

2 Autonomous University of Morelos, Biodiversity and Conservation Research Center, Cuernavaca, Morelos, Mexico

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