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A review on biodegradable polymers: Used as packaging Materials

Vaishnavi A. Harkal [1,*] and Swati P. Deshmukh [2]

[1] *Department of Pharmacy, Shraddha Institute of Pharmacy Washim, Maharashtra, India.*
[2] *Department of Pharmacology, Shraddha Institute of Pharmacy Washim, Maharashtra, India.*

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Abstract

In current years littering of plastics and the problem associated with their chronic inside the environment have end up a primary awareness in the each studies and information. There is high need of biodegradable polymers and especially in the discipline of packing and additionally want to create biodegradable polymers for traditional packaging material. The current review paper focuses towards the various types of biopolymer sources that are available in nature which are able to reduce the risk of environment damage through the use of alternative of plastics as a packaging material. This review present review of the exclusive biodegradable polymers and records about biodegradable polymers which are degraded by way of microorganisms and additionally include biodegradation technique. The excellent of biopolymers can be expressed as distinct properties like gas barrier, thermal and mechanical barrier, and moisture barrier properties. Biopolymers may be classified into classes in keeping with natural, synthetic and based totally on repeating units. Biodegradable polymers can be used as an approach to the troubles posed via plastics as they effortlessly degrade inside the surroundings and also mimic the properties of traditional polymers. Starch, cellulose based totally biodegradable zero waste plastics can update with non-renewable plastics with comparable packaging properties. Some of organic substances can be incorporated into biodegradable polymers materials with the maximum common being PLA, PCA, protein, starch cellulose etc. This overview additionally nation the biodegradable polymers bundle of food programs and utilized in other discipline and which merchandise are made from this.

Keywords: Biopolymers; Starch; Food packaging; PLA

1. Introduction

The rapid increase in international plastic production puts our health and the environment at extreme risk. Due to their irreversible properties, the accelerated production of plastic manufactured using synthetic polymers raises environmental concerns [1]. In particular, plastic is considered the most widely used packaging material [2]. Plastics are created by combining polymers with a variety of additional chemicals, such as dyes, stabilizers, and processing aids. Synthetic plastics have been considered the substances of the destiny remaining century, however these days they're causing serious environmental issues [3]. The principle dangers of synthetic polymers are their long degradation system and manufacturing primarily based on non-renewable raw substances [4]. Alternatives consist of polymers which can be biodegradable or produced from renewable resources. Consequently, the manufacturing and use of biodegradable polymer materials are growing considerably, which may additionally assist reduce environmental troubles associated with waste polymer substances [5].

The word biopolymer comes from the Greek words bio and polymer, meaning essence or living organisms [6].Biopolymers are large macromolecules composed of many repeating unit. Long chains of polymeric bimolecular are commonly produced by life organizations[7].The monomer units of these polymers are joined together through covalent bonds to form large architectural works. Some examples of biopolymers are DNA, RNA, fatty acids, gelatine, keratin,

* Corresponding author: Vaishnavi A. Harkal

cellulose, starch, etc. There are many different types of biopolymers (DNA, RNA) capable of gene transfer material from generation to generation [8].

Cellulose and starch are the main building materials of plants. These polymers compared to synthetic plastics, they have been on earth for billions of years. Synthetic polymers while similar and random structures, biopolymers are arranged into well-defined structures. Therefore, biopolymers involve a process in which large chains are broken down into smaller chains under the influence of biological factors [8].

1.1. Why need of biodegradable polymers:

The new and cutting-edge trend is to use blends of different biopolymers such as starch-PLA Blends; starch PCL blends and so on, which might be synthetic in nature [9].There are many benefits to developing the biodegradable plastics. Starch-based plastics have been proved to be extra environmentally pleasant. Starch-based biodegradable plastics were shown to degrade 10 to 20 times faster than traditional plastics [10]. While conventional plastics are burned, they invent toxic fumes which can be destructive to human being's health and the environment. If any biodegradable films are burned, there is little, if any, poisonous chemicals or fumes launched into the air. Biodegradable plastics had been proved to improve soil excellent. This manner is achieved as the microorganisms and bacteria inside the soil decompose the material, and it really makes the ground extra fertile [10]. Ultimately there's a restriction to how many times a bit of plastic may be recycled, so there'll ultimately there could be waste produced. The cost of recycling plastics, in terms of power ,cane drastically better than virgin resin. Toxic gases may be liberating from burning waste plastics as a way to harness the energy for production.

2. Properties of bioplastic for packaging application

2.1. Gas barrier properties

In food packaging enterprise, particular Gas stress conditions are required to withstand shelf life and to maintain excellent of food for the duration of the manner of garage. In most packaging packages, the gas mixture consists of oxygen, nitrogen, carbon dioxide or mixture of those gases [11]. Gas barrier properties of bio plastics are intently related to their permeation capacity [12].In meals packaging industry one of the main necessities is, to maintain water and oxygen permeability throughout the shelf existence of thermally processed meals material[13,14]

2.2. Thermal and mechanical properties

Thermal and mechanical properties are vital in which they determine suitability of bio plastic for positive software. Food Packaging enterprise requires polymers with high gas barrier properties wherein as aggressive mechanical residences are required for automobile enterprise. Diverse strategies are applied inside the processing of bio plastics like plasticization, blending with polymer, changing bioplastic to thermoplastic for enhancing properties. Plasticization technique can adjust thermal and Mechanical Properties of bio plastics, with the aid of increasing thermal degradation temperature of bio plastic [11, 15].

2.3. Moisture barrier properties

Bio or bio-based substances are essentially hydrophobic, and this character reduces moisture barrier assets of natural polymer [12,11].Undesired results of water absorbance of packaging materials consequences moisture regain of dry food or surface drying of frozen food, those may be avoid with films which have appropriate moisture barrier capacity. Moisture resistant films can be evolved through external coating of hydrophobic/ water resistant material along with polyester, wax, and fatty acids and cross linking of fabric with inorganic fillers, mixing of fabric with moisture resistant material or reinforcement with herbal fibres consisting of jute [16, 17]. Barrier properties depends morphological properties of the fabric inclusive of crystalline and chain conformation. As crystalline of material will increase barrier properties of material [18].

2.4. Biodegradability of polymers

Biodegradable plastics are one of the ecologically sound materials that have been developed currently inside the packaging enterprise. Biodegradability of a polymer approach that a material (e.g. a constituent/substance, completed Product or waste) is capable of being broken down into smaller compounds by using the action of obviously occurring microorganisms like micro organism, fungi or algae inside the environment wherein biodegradation is occur. The procedure of biodegradation is inspired by using the environmental situations (e.g. Temperature, moisture, available vitamins and ph) that the material and microbes are uncovered [12].

Bio degradation as process may be explained in two steps

First step characterised as degradation or de fragmentation, which is initiated with the aid of warmness, moisture, microbial enzymes. Second step is bio degradation, which transforms longer molecular substance into smaller compounds, initiated by means of certainly occurring enzymes, and acids. Once the molecules are decreased to an appropriate length, the substance can be absorbed through the organism's cellular partitions where they're metabolized for energy [18].This biodegradation technique produces carbon dioxide or methane. Polymer degradation can also occur either due to photo degradation, microbial action or by means of chemical action. Oxon degradation is a kind of degradation which makes use of oxidation and additive technology to boost up bio degradability of a polymer. Additives manage degradation system in a predictable manner; bio degradation is generally initiated either via light, heat or microorganisms [19].

2.5. Biopolymers for packaging application

Biodegradable polymers are described as materials able to present process decomposition into carbon biomass, CO_2, H_2O methane, etc. by means of the movement of microbiological enzymes and different factors. These biopolymers are associated with using renewable raw materials such as polysaccharides and proteins extracted from marine, agricultural, animal, or microbial resources [11].

The following are biomaterials used in packaging applications:

- Protein-based biomaterials
- Lipid- and composite-based biomaterial
- Polysaccharide-1.Protein based biomaterial

2.5.1. Protein based biomaterials

Proteins have effortlessly and efficiently been used for films and coating. Protein movies have excellent strength and flexibility. They are safe in nature, for this reason they may be used for the packaging of greens, end result, eggs, meats, and plenty of different applications; The coating marketers For protein consist of milk protein, gluten, gelatine, and so forth. Protein-based films and coating materials have high-quality barrier Properties [20].

Soy protein

Soy based plastics use some other alternative material used for biodegradable plastic. The high amount of protein approach that they must be nicely plasticized whilst being shaped into plastic substances and films .The films produced are commonly used for food coatings, however greater lately, freestanding plastics used for bottles had been shaped from the plasticized soybeans [21].Soy proteins are used for making adhesives and coatings for paper and Cardboard [22].Soy protein isolate (SPI) gives low barrier as well as oil resistance residences in paper coating packaging applications. It can be used for the packaging of food and the lifestyles of meals to be preserved may be prolonged [23]. In order to create bioplastic sheets for packaging purposes, soy proteins are also used in this process. Soy protein based totally Films are greater transparent, flexible, smooth and less costly than other protein primarily Based bioplastics [24]. SP extensively utilized in toddler formulation and baked meat, and dairy products [25].

Whey protein

Whey protein is a by product of the manufacture of cheese. It has excellent gas barrier residences and resistance in opposition to oils. To improve fuel barrier properties, whey protein is used as a coating material inside the packaging of paper. It additionally reveal advantages over sizing agents and pigments [26]. Whey protein isolate turned into used to create edible films that had been then plasticized using glycerol [27].

2.5.2. Lipid and composite biomaterial

Lipid compounds consist of organic fatty acids or esters, oils, and many others. which have a excessive molecular weight but are insoluble in water [28]. Commonly, those packaging materials are wax lined to reinforce their water resistance, in addition to increase this half-life of products used in packaging [29]. Paraffin waxes are applied in a molten nation to growth their water vapour barrier Properties [30]. Waxes are broadly used in food and drink packaging packages. Lipid coatings have exquisite structural and moisture barrier residences but they have hazards like cracking of the surface texture, the presence of small holes like pinholes, and brittleness [31]. composite coating is used as a multilayer coating or is applied in emulsion form to remove cracks. It gives a very good barrier for moisture, which improvise the

residences in hydro colloidal solution [32]. The processing Techniques may also have an effect on the fuel barrier properties of coating substances.

2.5.3. Polysaccharide based biomaterials

Polysaccharides are not unusual biodegradable polymers which can be most considerable in nature, they may be discovered as complex carbohydrate structures and are bound by way of a glycoside bond inside the predominant structural units of plant [32]. Polysaccharideprimarily based membranes had been extensively utilized in suitable for eating and no edible packaging industries.

Starch

Starch is a hydrocolloid polymer, and is normally located in a category of carbohydrate because it incorporates carbon, hydrogen and oxygen of ratio 6:10:5 [33]. Starch in its local form is hardly ever usable because of its brittleness low mechanical belongings which end up in negative film forming potential. Those shortcomings are overcoming by plasticization and mixing with different polymers [34]. Starch is a polysaccharide and is exceptionally sensitive toward moisture. It has exact water vapour properties and terrible mechanical residences, which limits its software in meals Packaging. A starch spinoff, that's mostly used inside the food industry, is thermo-plastic starch (TPS), as it is able to be used for obtaining distinct materials.

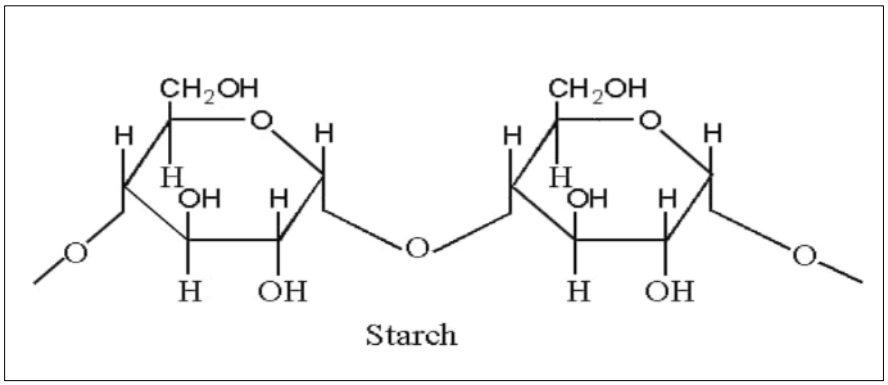

Figure 1 Structure of starch

Starch primarily based plastics are in particular harvested from wheat, potatoes, rice, and corn. Of those four starches, corn is the maximum typically used and is the least pricey starch [21]. . Starch is used for plenty non-food objects including making paper, cardboard, textile sizing, and adhesives [22]. Starched based plastics have already been processed into consuming utensils, plates, cups and other merchandise [22].

Figure 2 Starch based packaging material

Cellulose

Cellulose is the most abundant organic molecule on earth, and is a main aspect in plant cell walls. Wood, paper, and cotton are considerable in cellulose. The glucose in cellulose is connected by using β glycoside bonds, unlike the glycoside bonds determined in glycogen and starch. Shape and array of hydroxyl institution found in cellulose tends to shape robust hydrogen bonded crystal shape. The glucose repeat devices are connected in the β configuration by assessment with the alpha configuration in starch. This lets in the chains to crystallize in linear conformation inside the shape of exceedingly crystalline, excessive component ratio and sub-micron diameter micro-fibrils which can be aligned along the cellulose fibre called single fibre. Derivatives of cellulose which include carboxymethyl cellulose, methylcellulose, cellulose acetate, Ethylcellulose,carboxyethyl cellulose, and many others are used as packaging applications. Amongst of those derivatives, cellulose acetate is widely used as bakery an meals packaging packages. Cellulose acetate offers low resistance to moisture and gases. For the Improvement of Films cellulose should go through a plasticisation technique.

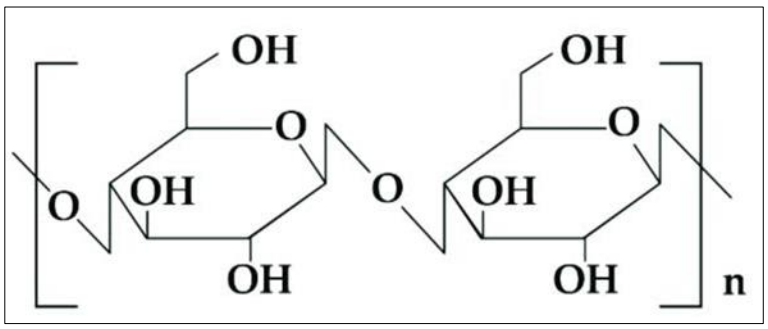

Figure 3 Structure of cellulose

Cellulose has a wide variety of programs within the paper, textile, and pharmaceutical industries. It acts as a bioadhesive and mucoadhesive in drug delivery structures[35]. It also acts as a coating material, and thickening and stabilizing retailers in pharmaceutical industries[36]. The primary software of cellulose fibbers is in textile industries where it acts as reinforcement in chemical filters [37]. Cellulose ether based derivatives are used as a sizing, levelling, and thickening agent within the Textile pulp industry [38]. for example, sodium carboxymethyl cellulose is used as a sizing agent[39]. The sizing agent performs an essential function within the guidance of a uniform colloidal suspension with water in printing and dyeing application[40].

Figure 4 Cellulose based packaging material

Polylactic acid

PLA is bio poly ester which can be Separated from fermented plant starch Which is 100% renewable and compostable [12]. The presence of – CH3 institution symbolize PLA as a hydrophobic material . The transformed sugar from the starch permits for the fermentation technique which produces lactic acid monomers, polymerization of lactic acid produce PLA.

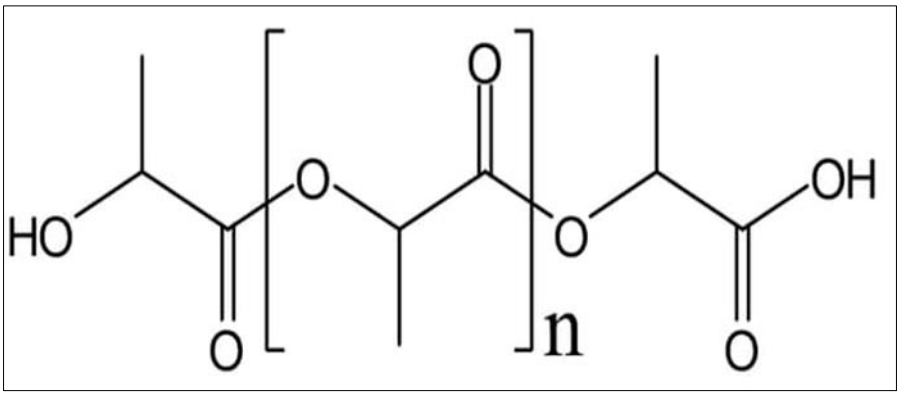

Figure 5 Structure of PLA

PLA is a sustainable alternative to petrochemical-derived products, for the reason that lactates are produced by using the microbial fermentation of agricultural by-products, mainly the carbohydrate wealthy materials. The yield of lactic acid from one of a kind microorganisms and one of a kind sources. PLA is turning into a growing opportunity As a inexperienced food packaging Material because it turned into determined that in many situations its performance turned into higher than Synthetic plastic substances. PLA is typically received from polycondensation of D or L-lactic acid or from ring Opening polymerization of lactide, a cyclic dimer of lactic Acid. Properties that make PLA a very good food packaging material are their high molecular Weight, water solubility resistance, desirable technique capability, i.e., clean to method by using thermoforming and biodegradability. Processed PLA comes inside the form of films, boxes and coatings for paper and paper forums. PLA can be similarly recycled via chemical conversion back to lactic acid after which repolymerized. even though PLA seems to be Potential biodegradable polymer to be utilized in packaging of various food Product , it exhibits sure boundaries in unmodified shape, viz. It is greater brittle and degrades without problems at tremendous temperature rise.

Figure 6 PLA based packaging material

2.6. Products made from Bipolymer

- Foamed products : Starch based totally foams are water sensitive, and brittle so wide variety of processes required for the suitability of material to cold or hot liquid Surroundings [41,42].
- Blown films (barrier films) : established packaging packages for bio plastics are buying baggage, which even have a Secondary use as a bag to acquire compostable kitchen and garden waste. Oil derived polymer Reveals high mechanical and barrier residences as well as transparency.
- Coated papers : Coating of paper and cardboard laminates with bio plastics ends in new packaging with desirable Moisture and fats or oil resistance. Paper based totally substances have suitable mechanical properties but Gas permeability is high and also water sensitive[43,44].
- Thermo foamed containers : Thermoformed inserts are used for production chocolate boxes, trays for fruit, vegetables, meat and eggs (also foamed), tubs for dairy produce, margarine and sandwich spread, bottles, nets

or pouches for fruit and vegetables. Blister packs, in which the movie is carefully formed to observe the profile of the packaged product, also can be produced.

3. Conclusion

This review checked out the study of biopolymers and their software in packaging substances. Their ecofriendly behavior makes them suitable in various applications in distinctive areas. Biodegradable plastics are one of the most progressive materials being developed inside the packaging enterprise. It changed into discovered that biopolymer-based packaging can beautify the shelf life of a product with the aid of lowering the lack of colour, keeping the dietary and sensory characteristics, and decreasing microbial contamination of the product at some point of distribution, shipping, and garage. Despite the fact that biopolymers were tested to have top applications in the end result and vegetable enterprise, its use within the dairy enterprise is still underrated. This evaluate take a look at is to offer a outline of synthetic biodegradable polymer which may be used inside the place of biodegradable packaging. If we try to update all commodity plastics with biodegradable alternatives which will gain a greater sustainable destiny, we want to alternate the manner we cope with plastics in popular. For this reason the above review describe the exclusive biodegradable materials that can play role at once or not directly in improvement of biodegradable packaging.

Compliance with ethical standards

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Disclosure of conflict of interest

There is no conflict of interest.

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