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Review Article

Biodegradable Plastic Material Production and Applications

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ABSTRACT

Biopolymer packaging materials are becoming more popular in the pharmaceutical business as a result of environmental concerns. Because they are biodegradable, biocompatible, and non-toxic, these biopolymers—which come from renewable resources—are perfect for a range of pharmaceutical uses. Biopolymers are essential in controlled-release drug delivery formulations, particularly for biopharmaceutical and customized medications. Three-dimensional networks of polymers called hydrogels are essential for simulating real tissues and enabling stimuli-responsive medication release with negligible side effects. Diffusion-controlled, degradation-controlled, or environmentally driven release are some of the formulation techniques. Through controlled degradation, biodegradable systems—such as polymers like poly (lactic acid) and poly (glycolic acid)—help deliver drugs in a sustainable manner. While stimuli-responsive designs react to changes in the environment, osmotic delivery systems use osmotic pressure to control drug release. Using biopolymers in pharmaceutical packaging is consistent with environmentally responsible methods.

INTRODUCTION

Pharmaceutical packaging materials are a collection of several components that surround pharmaceutical products from the point of production to the point of consumption, such as eco-friendly halogen and pharmaceutical-grade barrier films. Therefore, the science, art, and technology of enclosing or safeguarding products for distribution, storage, sale, and usage-including printed material used in the finishing of a pharmaceutical product-can be summed up as pharmaceutical packaging. From the point of manufacturing until it is utilized or administered, it provides identity, presentation, protection, information, and convenience in an economical manner. The purpose and kind of material used determine the kind of pharmaceutical packaging that is utilized. Ultimately, testing of specific materials, sterilization, storage, and stability

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studies must be used to assess all packaging materials.

Packaging

A class of materials derived from fossil fuels; plastics are used in the majority of economic sectors. Their over use is harming marine ecosystems irreparably, contributing to greenhouse gas emissions during burning, and prolonging their permanence in landfills. Every year, some eight million tons (Mt) of plastic enter the ocean, with effects felt from the top to the bottom. These substances penetrate terrestrial, atmospheric, and aquatic systems, move amongst them, build up in the ecosystem, and eventually make their way up the food chain to humans. An estimated 400 million tons of greenhouse gas emissions are caused by plastics annually. By 2050, this sector alone will account for 20% of global oil production if current production rates continue. Therefore, it is necessary to produce biomaterials from plant or animal biomass that, if at all possible, do not conflict with the population's requirement for food. Biologically based, biodegradable, or possessing both qualities are examples of bioplastics.

MATERIALS AND METHODS

i. **Starch:** A plentiful, inexpensive, and yearly renewable source of natural polymers, starch is a very desirable raw material for the creation of bioplastics. Granules of starch, a carbohydrate polymer of D-glucose, are found in many plants, including corn, wheat, rice, tapioca, and potatoes. It is composed of two main components: amylose, a linear or sparsely branched polymer with a molecular weight of 105–106, and amylopectin, a highly multiple-branched polymer attached to amylose starch with a molecular weight of 107–109. Because microorganisms can easily digest these molecules, bioplastics with a high starch content have great biodegradability or composability.

ii. **Glycerol:** Glycerol is an alcohol that is produced when triglycerides are hydrolyzed or when soap and biodiesels are made. In a variety of personal care products, including toothpaste, mouthwash, shaving cream, and soaps, it serves as an emollient, humectant, solvent, and lubricant. Because of their weak hydrogen bonds, bioplastics are known to be weak. Glycerol affects their plasticity because it enhances elasticity while decreasing stiffness because to the weak and distant hydrogen bond. Glycerol decreases the solid structure and internal hydrogen bonding of bioplastic in addition to altering its plasticity.

iii. **Citric acid:** Citric acid is a colorless, weak organic acid. It has a sour flavor and works as a preservative. It has numerous uses in the personal care, medical, and food and beverage industries, among others. Its inclusion in the mixture will lessen the bioplastic's brittleness.

iv. **Gelatine:** This type of collagen comes from animals. It is a crystalline substance that is translucent, colorless, and flavorless. It is primarily used for gelatinization in the food and beverage industries. The personal care and pharmaceutical industries also use it.

v. The South American tuber cassava root is the source of tapioca, a starch. In many South American, Asian, and African nations, the cassava root is a staple crop and is relatively easy to grow.

vi. Because tapioca is almost all starch, it is almost entirely composed of carbohydrates.

vii. The main structural element of plants is cellulose, a glucose polymer with a −1, 4-linkage configuration. The cellulose polymer has significant shear and tensile strength due to its −1, 4 linkages, which enables it to crystallize in a linear configuration with a

high degree of intermolecular hydrogen bonding. Because of its chemical makeup, cellulose can be purified for use as a dietary ingredient. Of all the bear components, cellulose is presumably the least soluble because it is insoluble in hot, diluted acids and alkalis as well as cold or hot water.

PREPARATION OF BANANA PEEL

After separating the fresh banana from the peel and washing it with tap water, the peels were shredded into 20mm pieces and soaked in a solution of 0.2 M Na2S2O5 for 45 minutes. Na2S2O5 acts as a disinfectant, antioxidant, and preservative agent. The peels were rinsed and heated on a hot plate for 30 minutes. The paste was ltered and baked at 80℃ for 12 hours.

PREPARATION OF BIOPLASTICS FILM WITH ADDITION OF CELLULOSE

Glycerol is used as a plasticizer in the production of bioplastics from banana starch to improve the plastic's molding capabilities and minimize its brittleness. For the first control formulation, 25 g of tapioca powder was placed in a beaker and cooked with 100 ml of distilled water for 20 minutes while agitated with a magnetic stirrer. Then, 3 ml of (0.1N) HCL, 3 ml of glycerol, 2 ml of acetic acid, and cellulose (3g, 6g, and 9g) were added to the combination

The mixture was then cooked until it formed a gel. The gel was distributed uniformly on a petri dish and dried in an oven at 150℃ for an hour. The same procedure was followed for the other samples. Table 1 summarizes the formulation of bioplastics made from banana peel. The bioplastic layer was peeled off the petri dish once it had cooled. The thickness was controlled by connecting the mass of solution to the area of the plate, and a roller was driven down into the mixture to ensure that it was evenly distributed throughout the mold. The sample's thickness was determined using a dial thickness gauge with an accuracy of 0.01 mm (Jirukkakul, 2016).

Table 1: Formulation of banana peel starch bioplastics

Formulation (n)	Tapioca Powder (g)	Banana peel (g)	Glycerol (ml)	Acetic acid (ml)	Hydrochloric Acid (ml)
Cellulose (g)					
Control	25	3	3	2	3
3	25	3.	3.	2	3
6	25	3	3	2	3
9	25	3	3	2	3

Synthesis of gelatin grafted copolymer (W-1).

The gelatin-g-poly (vinyl acetate-co-acrylonitryle) copolymer was manufactured using the general processes described by Ali et al., 2015 [23] and Soleimani et al., 2012 [17], with some changes. Sample W-1 was synthesized in a three-necked reactor equipped with a mechanical stirrer assembly and regulated on a water bath. Gelatin (1.0 g) was added to the reactor along with 50 mL of double distilled water and heated with stirring until a clear solution was formed at 70°C. Lutensol XL-100 (0.50 g) was added to the clear solution as an emulsifier. After 2 minutes, potassium persulfate (0.10 g) was added to the reactor as an initiator, and the mixture was agitated for 5 minutes. A mixture of VAM (23 mL) and acrylonitrile monomer (3 mL) was made in a separate beaker. This 26 ml monomer mixture was

continually supplied to the reactor at a rate of 1 ml per minute. After adding all of the monomers, the reaction was run for 90 minutes at 80 degrees Celsius to guarantee that it was completed completely. The liquid polymer product was obtained and placed into a petri plate. After cooling for 30 minutes, the liquid polymer was applied to the glass sheet with an applicator. A thin film sheet of copolymer was produced and studied using FTIR and TGA-DSC.

Preparation of nanocomposites biopolymer (W-2)

NBP was generated using the same method as stated above for sample W-1. However, once the reaction was completed, 0.040 g of nickel doped ZnO nanoparticles were introduced to the reactor. and allowed to proceed for an additional 15 minutes. A thin film of this liquid polymer blend was distributed as a plastic sheet using an applicator and then examined.

Application of Biopolymers in the formulation of Dosage Forms with Modified Release

Compared to synthetic polymers, biopolymers often have a more complicated chemical structure and are biocompatible. They are readily adaptable to the creation of controlled release matrices. Biopolymers' vulnerability to microbial contamination is their main disadvantage. These polymers are typically non-toxic, biocompatible, and biodegradable. One important tool for altering, managing, or sustaining delivery is hydrogel. They are made up of three-dimensional, insoluble (bio)polymeric networks that can be engineered for stimulus-response release and are able to absorb substantial volumes of water or biological fluids. Because their chemical building blocks are comparable, hydrogels imitate natural tissues rather well and have less inflammatory and toxic effects than other synthetic biomaterials. Water-binding qualities are provided by the hydrophilic character of biopolymers. A three-dimensional network made up of additional chemical or physical cross-links aids in maintaining structural integrity in an aquatic environment.

Application of biopolymers in the pharmaceutical industry

Pharmaceutical goods have long employed biopolymers as excipients, including thickeners, disintegrants, fillers, and binding agents. Several biopolymers are listed for usage in pharmaceuticals in the Pharmaceutical Handbook of Excipients. Biopolymers are used in the majority of pharmaceutical dosage forms, such as parenteral, topical (gels and ointments), nasal sprays, oral, ophthalmic, and lung administration. Many studies are being conducted on traditional drug forms in an effort to increase therapeutic performance, lower costs, improve drug stability and efficacy, and increase patient adherence to prescribed therapy. Biopolymers are prominent in pharmaceutical research because they are a vast spectrum of chemicals with a variety of properties, are naturally occurring, and can be produced easily. Recently, biopolymers have been utilized for the controlled delivery of biological molecules like proteins, peptides, and vaccines, in addition to their many uses in conventional dosage forms.
Pharmaceutical dosage forms can be roughly categorized into the following categories depending on the active ingredient's release rate,

rate of accomplishment, and duration of activity following administration: Both traditional and modified-release pharmacological formulations are available. Modern non-traditional drug dosage forms, such as drug delivery systems (DDS), drug carriers, and drug carrier systems, are a very diverse collection of intricate systems and unique carriers of active ingredients.

Carriers for biological therapeutic substances (active ingredients derived from contemporary biotechnological techniques/biopharmaceutical medications) include well-known natural excipients as well as specially created synthetic excipients with "improved" protection and targeting properties. Natural and semi-synthetic excipients are still widely used, nevertheless. Biopolymers are widely used because of their good physiological tolerance and well-understood characteristics (long-term service experience). They are also used because new synthetic substances must undergo costly and time-consuming safety testing before being used by humans. This makes it more difficult to evaluate them quickly, with the exception of employing animal and in vitro models.

Reduce

The ability of environmentally friendly packaging materials to reduce package bulk is one of their properties. As a result, less degradation product is dumped needlessly. Furthermore, some formulations cannot be overpackaged due to specific legal requirements. For instance, it is preferable to utilize numerous dosage containers rather than single-use containers and one large bottle of formulation rather than several tiny bottles. The three most crucial elements of cutting down on pharmaceutical packaging materials are as follows.

- Cutting down on packaging waste;
- Endorsing environmentally responsible advertising initiatives;
- Improving transportation effectiveness

Reuse

Reuse is the ability of environmentally friendly packaging materials to be used repeatedly. Using packaging material in its original form is part of this attribute. For instance, several cleaning solutions and products from The Body Shop are offered in reusable or returnable containers. Likewise, purchasing milk in reusable bottles helps to prevent the production of plastic trash.

RESULT AND CONCLUSION

Vinyl acetate and acrylonitrile monomers were combined to create a gelatin-based grafted copolymer. This grafting method was carried out using the free radical polymerization mechanism using an initiator (potassium per sulfate). The copolymers were investigated using FTIR and TGA-DSC methods. FTIR peaks at 1250, 1680, and 1440 cm-1 verified the grafting of monomers onto the gelatin backbone. The TGA and DSC data revealed the thermal degradation and melting temperatures of the copolymer and nanocomposite biopolymer. TGA study revealed that nanocomposite biopolymer has a lower breakdown rate than simple grafted polymers. DSC demonstrated that nanocomposite biopolymer has a higher melting point than unblended copolymer. The soil burial method was employed to estimate the biodegradability of these polymers. The biodegradation examination of the produced samples revealed that nanocomposite biopolymer had a significantly lower % weight loss than copolymer. Nanocomposite biopolymers have low biodegradation rates and are moisture resistant. Grafting proved to be an effective method for inducing microbial resistance in natural polymers. It was determined that

nanocomposite biopolymers give resistance to fungi and bacteria, and so these nanocomposite polymers can be successfully used to manufacture food packaging materials and disposable medical products. Bioplastics' good contribution to protecting pharmaceutical products, and hence the environment, is an area that can be researched.

Bioplastics derived from plant or animal biomass provide an alternative to manufactured plastics. In this study, banana leftovers were used to produce thermoplastic starch. To extract starch and cellulose from the leftovers, physical and chemical procedures were used. The results of the experiments led to the conclusion that starch possesses properties comparable to those described in prior studies. The plasticizer utilized affects both the WVP and mechanical qualities of the material. While cellulose is commonly used as a filler to boost strength, it can also raise WVP, which is not desirable in packaging materials. The biodegradability test revealed that the material degrades under the evaluated conditions. The formulation with the lowest WVP was obtained using glycerol, a common reference in food packaging applications. The finest mechanical qualities were obtained by combining glycerol and sorbitol. Although the developed formulations do not constitute a definitive replacement for currently available synthetic plastics, the findings of this study serve as a reference for future work in which other formulations are evaluated with the goal of producing bioplastics that can compete with synthetic plastics.

As the global environment deteriorates, sustainable materials have become increasingly important. Consider using biopolymers from renewable sources instead of petroleum-based polymers to address sustainability concerns. As environmental consciousness has grown, there is a greater need for biodegradable/degradable packaging materials. Biopolymers have a wide range of applications in pharmaceutical products, from their traditional use as excipients (binding agents, fillers, thickeners, and disintegrants) in most pharmaceutical forms to recent benefits for the controlled delivery of biological substances (proteins, peptides, and vaccines). Biopolymers play an important role in personalized medicine, particularly for biopharmaceutical products and tissue engineering. Biopolymers' diverse and distinguishing properties, as well as their non-toxicity, biodegradability, and biocompatibility, make them ideal carriers for modified and targeted drug delivery, which will significantly contribute to future medical practice advancements, not only in controlled release of therapeutic compounds but also in the development of regenerative medicine.

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