**International Journal of Research in Science & Engineering**
**ISSN: 2394-8299**
Vol: 02, No. 04, June-July 2022
http://journal.hmjournals.com/index.php/IJRISE
**DOI:** https://doi.org/10.55529/ijrise24.1.9

# Advances in the Modification of Natural Polymers for Applications in Food Packaging and Preservation

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**Received:** 05 April 2022 **Accepted:** 20 June 2022 **Published:** 21 July 2022

***Abstract: Synthetic plastics are polymers produced from petrochemicals and are typically used as packaging materials. They are portable, lightweight, and strong. The main issue with synthetic plastics is that they cannot degrade, which is why natural polymers, also known as biopolymers, have emerged. By using biopolymers, synthetic plastics' toxic effects on the environment are reduced. Although it is nearly impossible to completely replace all conventional polymers with environmentally friendly materials, natural polymers may be used in many industries including the food and packaging materials sector. Natural resources like plant and animal waste are commonly used as raw materials to create environmentally friendly packaging. However, there are some disadvantages to natural plastics, such as poor water absorption and a weak defence against microbial attack. Natural polymers must be modified to achieve desired properties and extend shelf life. This study examines the most popular techniques for modifying natural plastics for use in the preservation and packaging of food.***

***Keywords: Natural Polymers, Bioplastics, Food Packaging.***

## 1. INTRODUCTION

As items are stacked on racks adjacent to one another and compete for the attention of potential customers, their packing design is increasingly being acknowledged for its marketing worth. If the packaging has a decent design, eye-catching images, and informative labels regarding its contents, it can provide a great customer experience. Although certain commodities are clearly harmful, the packaging of a bad product may lure potential consumers more than a healthy food encased in an unappealing wrapper. (Tajeddin and Arabkhedri, 2020). Packaging is a crucial component of the food business since it protects the qualities of food throughout storage (Mesgari *et al*, 2021).

Polymers are huge molecular structures made up completely of rings or chains with several monomer units. Polymers can be synthetic (derived from fossil fuels) or natural (derived from plants) (derived from plant and animal tissues). Owing to their inherent qualities, both natural and synthetic polymers are extensively used in a wide range of industries (Tajeddin *et al*, 2020). Plastics are widely used in the packaging industry because of their ease of moulding and transformation. Plastics and their various properties enable a wide range of packaging options, including shape, colour, size, weight, function, printing, and so on. Due to their desired qualities, including stability, toughness, and ease of processing, polymers are now an essential component of contemporary life (Yadav *et al*, 2018). Plastics are preferred for packaging by manufacturers because they are lightweight, malleable, and can be moulded into any shape using a variety of techniques such as, extrusion, blow molding, casting, lamination, etc. These qualities enable the packaging of unusual products that do not fit into conventional or basic containers. synthetic plastics are beneficial for a variety of packaging materials component due to their barrier features, which aid to maintain product freshness, avoid contamination, and extend shelf life (Tajeddin *et al*, 2020).

There are applications for packaging in a variety of industries, including the medical sector, pharmaceuticals, food, electronics, etc. Food packaging is designed to protect and conserve the quality of foods without sacrificing their look, taste, smell, or nutritional value because safety, preserving, and appearance are the three main roles of a package. Additionally, it serves to tell customers about the food's composition and nutritional facts (Tajeddin *et al*, 2020). Petroleum plastics, also known as synthetic polymers, are some of the most commonly used packaging materials in the food industry. Polyethylene terephthalate (PET), low and high-density polyethylene (LDPE and HDPE, respectively), polypropylene (PP), polyvinyl chloride (PVC), and polystyrene (PS) are examples of such polymers.

However, there are several drawbacks to using petrochemical polymers (plastics), including their poor water vapour transmission rate and severe environmental impact. The inability of these polymers to degrade or compost, which has a significant negative influence on environmental issues like pollution and global warming, is their biggest drawback (Tajeddin

 

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*et al*, 2020). Interest in recycling, use of biodegradable polymers, and environmental protection has increased as a result of the difficulty faced in the disposal of petroleum resources and their non-renewable status. Material degradation results in structural and morphological changes that can significantly alter the characteristics of polymer materials. Plastics production and processing are energy-intensive activities that produce a significant amount of greenhouse gases and contribute significantly to global warming. Sea lives are severely harmed by the dumping of non-biodegradable plastics such as water and food containers, straws, bags, etc. (Kadam *et al*, 2013).

Owing to the availability and capacity to imitate chemical environments, natural polymers are in high demand for the development of innovative packaging materials. However, their poor mechanical and thermal properties produce unstable materials, which is a disadvantage. Blending different natural polymers with certain natural additives can help to solve these issues (Charles *et al*, 2021). Additional qualities are required in several applications of biopolymers, such as food packaging and biomedical devices, where microbial contamination can cause major difficulties for public health and safety. This paper seeks to review several ways that natural polymers can be modified to enhance antioxidant and antimicrobial properties to appreciate their usage as food packaging and preservative materials.

## 2. NATURAL POLYMERS

Natural polymers are those formed from organic materials, such as starch, cellulose, RNA (ribonucleic acids), chitin, and other types of biomass. Synthetic polymers can be replaced with environmentally beneficial natural polymeric materials. This is because they are made of renewable raw materials, agro-industrial waste, and biodegradable components. They are also desirable due to their accessibility and affordability.

Natural polymers are often formed from polysaccharides, proteins, or lipids. They can be laminated or created as composites to improve the characteristics of biopolymer materials. Furthermore, biopolymer materials having significant antioxidant and/or antibacterial characteristics can be made edible and/or active. These biodegradable polymers are derived from cassava, chitosan/chitin, gums, maize, pectin, potatoes, starches, straw, wheat, wood, and so on.

One reason why natural polymers have gained popularity is that they can be obtained from abundant and renewable natural sources. Polysaccharides are abundant in nature and can be obtained from algae (e.g., alginates), plants (e.g., pectin, guar gum), microbes (e.g., dextran, xanthan gum), and animals (e.g., chitosan, chondroitin), etc. Figure 1 depicts some common raw materials used in the production of natural polymers. Monosaccharide polymers have many advantageous properties, including high stability, nontoxicity, hydrophilicity, biodegradability, gel-forming properties, and ease of chemical modification (Rajeswar *et al*, 2017).

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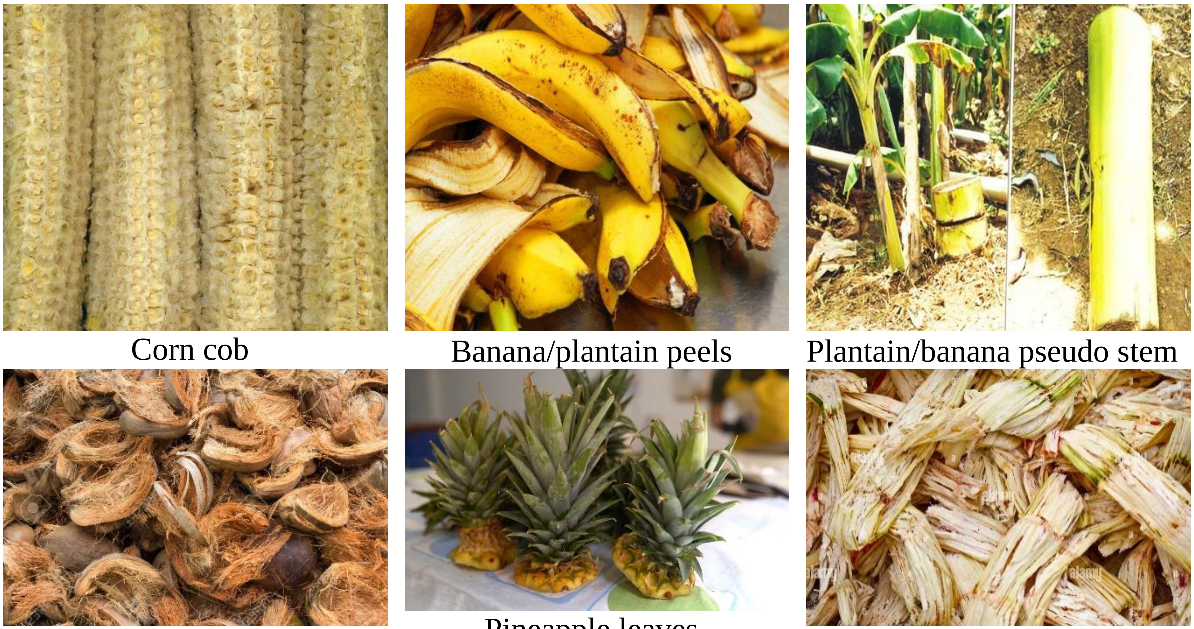
Plants and animals can both produce natural polymers. Biopolymers with plant origin include Cellulose, Hemicellulose, Glucomannan, Agar, Starch, Pectin, Inulin, Rosin, Guar gum, Locust bean Gum, Gum Acacia, Karaya gum, Gum Tragacanth, Aloe Vera gel, etc; while Chitin, Alginates, Carrageenans, Psyllium, and Xanthum gum are natural polymers with animal origin. These materials' unmatched qualities, such as nontoxicity, biodegradability, chelating, anticoagulant, antioxidant, and antimicrobial characteristics as well as biocompatibility, have proven useful for the development of bioactive materials. Microorganisms can also produce biopolymers through the fermentation of modified bioresources like PHAs, and biomass can be produced directly from a variety of plants (Kadam *et al*, 2013). The least harmful polymers to the environment are natural ones. It is appropriate for use in takeout boxes, plates, cutleries, and ice cream cups because it is strong and does not deform easily. It will not suffocate food and is heat- and water-resistant (Tajeddin *et al*, 2020).



Corn cob | Banana/plantain peels | Plantain/banana pseudo stem

Coconut husk | Pineapple leaves | Sugarcane bagasse

Figure 1: Images of some materials commonly used for bioplastic production

## 2.1 Problems with Natural Polymers

Biodegradable packaging films are gaining popularity due to their biodegradability, which makes them excellent contenders in the packaging market and helps address sustainability while maintaining and safeguarding environmental quality. However, there are a number of important problems and constraints that must be addressed by researchers if natural packaging materials are to be used more widely and continue to advance. (Assad *et al* 2020). Natural polymers' primary drawbacks are their subpar physicochemical characteristics, which include

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poor thermal and barrier properties, low thermoplasticity, brittle mechanical strength, etc. These flaws prevent them from being widely commercialised.

A material's ability to become moldable at a certain temperature and then transform back into a solid upon cooling is known as thermoplasticity. One long-term goal in the effort to create a more sustainable circular economy is the use of natural resources as raw materials for the manufacture of polymers. The natural polymers must possess thermoplastic properties in order to successfully process such materials using current industrial-scale technologies or even recycling procedures and according to the findings of Muller *et al* (2019), natural polymers are not thermoplastic. However, natural polymers derived from biomass resources like cellulose, lignin, and chitin can be made thermoplastic through the use of chemical and physical modification techniques. The polymeric materials used in conventional forming processes like injection moulding, extrusion, and drawing must be able to melt or soften at a specific temperature and must then harden when cooled. (Piringer and Baner, 2008).

Again, there is a problem of microbial contamination accumulated in natural materials due to 10% or more moisture content present in them which can only be prevented by proper modification or polymer blending (Gandhi *et al*., 2019). Infusing oils, resins, cellulose, vitamins, and water into plastics is necessary to further enhance their qualities and characteristics.

## 3. MODIFICATION OF NATURAL POLYMERS FOR FOOD PACKAGING

### 3.1 Moisture Resistance Modification

Moisture resistance is one of the physical properties of polymers as they are capable of absorbing moisture from the environment through hydroxyl groups that exist in their structure (Halip *et al*, 2019). Low moisture resistance is problematic because it can cause matrix cracking, dimensional instability, and deterioration of the natural polymer's mechanical properties. According to most studies, natural polymers absorb more water than synthetic polymers. As a result, treatments are required to reduce the hydrophilic nature of natural polymers while also increasing their dimensional stability. For instance, to achieve low moisture absorbance in natural polymes, the natural cellulosic polymer can be copolymerized with ethyl acrylate in the presence of potassium persulfate as an initiator (Thakur *et al*., 2012). This will result in a copolymer with a more moisture, chemical, and thermal resistant after grafting. The use of benzoyl peroxide to impart water resistance in natural polymers has also been reported (Kamel *et al*, 2008).

### 3.2 Antimicrobial Property Modification

Antimicrobial packaging is the integration of antimicrobial ingredients into polymeric materials to suppress bacteria growth in food articles (Han, 2003). By inhibiting the growth of

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dangerous germs, this sort of packaging improves food quality, safety, and shelf life. The prevalence of worldwide food-borne epidemics has decreased as a result of the use of antimicrobial agents in food packaging. The consumer's preference for fresh, minimally processed, and additive-free food products also increased the appeal of the antimicrobial packaging (Asgher *et al* 2020). Some antimicrobial substances used to preserve food are chemically created or obtained from bacteria, plants, and animal residues. These could consist of chitosan, enzymes, essential oils, and pure plant extracts from various sources. Essential oils such as phenolic compounds and terpenoids, derived from various plants are the most common source of antimicrobial substances and are commonly referred to as antimicrobial agents (Ruiz-Navajas *et al*., 2013). Various mechanisms are involved in the action of essential oils on microbial cells such as destroying enzyme structures, damaging phospholipid bilayers, and compromising bacterial genetic makeup.

According to the review reports of Mesgari *et al* (2021), the unique antimicrobial properties of chitosan and its ability to carry different active ingredients makes it a suitable modifying agent for food packaging materials. Integrating chitosan with metallic nanoparticles can be employed in the development of antimicrobial packaging materials. Thermal stability, barrier characteristics, antioxidant, and antimicrobial packaging are all advantages of this method. One of these nanoparticles is titanium dioxide, which releases reactive oxygen species, killing microorganisms by destroying their cell walls and extending food shelf life.

In bioplastic packaging, antimicrobial compounds may be released as a result of osmosis, electrostatic interactions between the polymer and antimicrobial agents, structural changes caused by antimicrobials, and ecological conditions. Despite its advantages, minute quantities of antimicrobial compounds should be used in formulations of natural plastics, this will extend the shelf life of a product by gradually releasing antimicrobial molecules into the food over time (Avila-Sosa *et al*., 2012).

### 3.3 Antioxidant Property Modification

Consumer preferences for safer and healthier goods has prompted scientists to devise alternative preservation methods. Several strategies have been used to reduce lipid oxidation, such as adding antioxidants directly to foods or incorporating them into packaging films (Asgher *et al*, 2020). Foods like fresh red meat or fish products cannot be packaged without oxygen. Adding antioxidants directly to foods has limitations since they stop working when they are chemically consumed, and food starts deteriorating more rapidly (Navikaite-Snipaitiene *et al*., 2018).

The practice of adding antioxidants to the formulation of packaging materials is currently being developed to increase the stability of foods that are sensitive to oxidation. Bioactive molecules have been extensively researched for this objective, especially plant essential oils. Excellent antibacterial and antioxidant qualities can be found in essential oils.

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However, due to their greater flavor, essential oils cannot be used as food preservatives. To solve this issue, bioactive compounds are used to create edible films that activate the unique features (Vilela *et al*., 2018).

According to certain researchers, the inclusion of specific antioxidants into chitosan films demonstrated excellent antioxidant abilities, and the antioxidant capacity of natural polymers increase with increasing quantity of antioxidants (Siripatrawan and Noipha, 2012). Examples of such antioxidants are thyme oil (Pires *et al*., 2011); coriander oil (Pires *et al*., 2013), rosemary essential oils (Gómez-Estaca *et al*, 2009), etc.

## 4. CONCLUSION

In response to the environmental degradation caused by the consistence accumulation of petroleum-based plastic wastes in landfills, natural polymer-based packaging materials have gained considerable momentum and interest because of their renewability and biodegradability. The globalization of markets has also made it increasingly important for food packaging materials to exhibit extended shelf-life and preservation properties. However, the primary drawback of natural plastic packaging materials working as a barrier at the moment is their permeability, which calls for attention and additional study to make them resistant to gases, water vapor, and some organic compounds. However, the inclusion of several additional biopolymers in the form of composites or blends improves these substandard films. Since the effectiveness of natural plastics depend on polymers and other materials used as additives to enhance functional qualities, efforts are concentrated on the creation of the ideal combination of ingredients to improve the properties of bioplastics.

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