

Recent advances in functionalized starch-based biodegradable films and edible coatings for sustainable food packaging

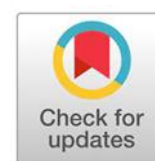
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Abstract

Growing environmental concerns, increasing food packaging waste, and the demand for sustainable materials have accelerated the development of biodegradable packaging alternatives. Among biopolymers, starch has emerged as one of the most abundant, renewable, cost-effective, and biodegradable materials for producing biofilms and edible coatings. This review highlights the potential of starch as a versatile raw material for sustainable food packaging applications, emphasizing its biodegradability, film-forming ability, and industrial significance. The increasing utilization of starch-based materials is expected to expand starch production and promote its application across diverse industrial sectors. Furthermore, recent advances in starch modification have significantly improved the mechanical, barrier, and functional properties of starch-based films without substantially increasing production costs, thereby enhancing their commercial viability. Overall, starch-based biodegradable packaging materials offer an eco-friendly solution to address environmental pollution, food preservation, consumer safety, and the growing demand for sustainable packaging technologies.



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Introduction

Starch serves as a major carbohydrate source in the human diet and is primarily produced and stored as reserve food material within plant cells, including roots, underground modified stems such as tubers, corms, rhizomes, fruits, and seeds (Bertoft, 2017; Vilpoux et al., 2019). Native starch is predominantly composed of amylose and amylopectin, accounting for approximately 98% to 99% of its composition, with minor quantities of non-starch components such as lipids, proteins, and minerals (Horstmann et al., 2017). Amylose primarily consists of linear macromolecules, although certain starch varieties may exhibit unusually long branched chains (Bertoft, 2017). The molecular weight of amylose ranges from approximately 1.5×10^5 Da to

2.6×10^6 Da, encompassing a diverse spectrum of short to long-chain structures (Lin et al., 2018).

In contrast, amylopectin is a highly branched polymer that significantly contributes to the crystalline structure of starch granules, with a molecular weight ranging between 1×10^7 Da and 5×10^8 Da (Thompson, 2000).

Starch constitutes approximately 80% of the dry weight of aroid corms. The Araceae family, comprising more than 100 genera and over 1,500 species, both wild and cultivated globally, is recognized as an important source of starch. Among these, *Colocasia esculenta* (taro), *Alocasia macrorrhizos* (giant taro), *Amorphophallus campanulatus* (elephant foot yam), and *Xanthosoma sagittifolium* (cocoyam) are widely cultivated as vegetables, valued for their nutritional and medicinal

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properties. Aroid starch is characterized by its relatively small granule size (approximately 1-30 μm), which is advantageous for a range of commercial applications, including food, pharmaceuticals, cosmetics, textiles, and biodegradable packaging. However, native starch granules generally exhibit strong hydrophilicity, limiting their effectiveness as Pickering stabilizers or in stabilizing emulsions, where they are often inefficient. Moreover, the lack of comprehensive data on the physical, chemical, functional, and mechanical properties of aroid starch remains a significant barrier to its widespread industrial application.

Starch is abundantly present in a variety of plant sources, including potato (*Solanum tuberosum*), cassava (*Manihot esculenta*), corn (*Zea mays*), rice (*Oryza sativa*), wheat (*Triticum aestivum*), and barley (*Hordeum vulgare*) (Yazid et al., 2018). Additionally, several underutilized crops serve as important starch sources, including aroids, *Eleusine coracana*, *Dioscorea esculenta*, *Lasia spinosa*, and *Nelumbo nucifera* (Gautam et al., 2021; Chiranthika et al., 2022). Globally, the major extractable starch sources are distributed as follows: maize accounts for approximately 70% (primarily produced in the Americas, China, and Europe), potatoes 12% (mainly Europe), wheat 8% (Europe and Australia), tapioca 9% (Southeast Asia and South America),

with rice, sorghum, and other crops comprising the remaining 1%.

Starch is stored in semi-crystalline granules that are insoluble in cold water and exhibit a spherulitic structure, characterized by alternating amorphous and crystalline or semi-crystalline lamellae (Carvalho, 2011; Figure 1). The primary differences in starch granules among various plant species lie in their shape and size, which can vary considerably. X-ray diffraction techniques are commonly used to analyze starch crystallinity and to classify it into A-, B-, and C-type polymorphic forms (Mutungi et al., 2012). Among these, the most commonly observed crystalline structures in native starch are A- and B-types. A-type crystallinity is typically associated with cereal starches, while B-type is predominantly found in tuber starches, though it may also occur in some maize starches (Dhital et al., 2011). A-type starch crystallinity is characterized by tightly packed amylopectin double helices with minimal water content, resulting in a denser and more stable crystal structure. In contrast, B-type crystallinity features more widely spaced double helices, creating larger water channels within the crystalline regions of the starch granule. C-type crystallinity represents an intermediate form between A and B and is generally found in legumes such as peas and various beans, as well as in other root-derived starches (Cai et al., 2014).

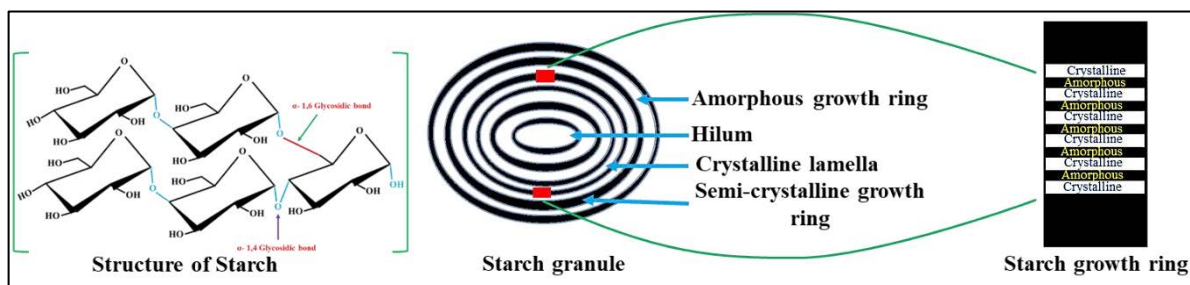


Figure 1. Structure of starch granules (molecular) with amorphous and crystalline lamella

Application of starch

Starch is a polysaccharide that serves as an energy reserve in plants and is widely utilized in both food and industrial applications (Figure 2). In the baking industry, starch functions as a binding agent and plays a critical role in determining the structure and textural properties of final products. Additionally, it serves as an effective thickening and gelling agent in various food-processing applications (Park et al., 2018). One notable application of starch is in the

development of edible films for coating fruits. These films serve as protective barriers against moisture loss, gas exchange, oxidation, and solute migration in both climacteric and non-climacteric fruits, thereby helping to maintain their sensory and nutritional quality (Paes et al., 2008; Dhall, 2013). Beyond the food sector, starch is also extensively used in industrial fermentation processes, the paper and textile industries, biodegradable packaging, and

agricultural applications. In agriculture, starch-based materials are used in eco-friendly applications such

as biodegradable mulch films and controlled-release fertilizers.

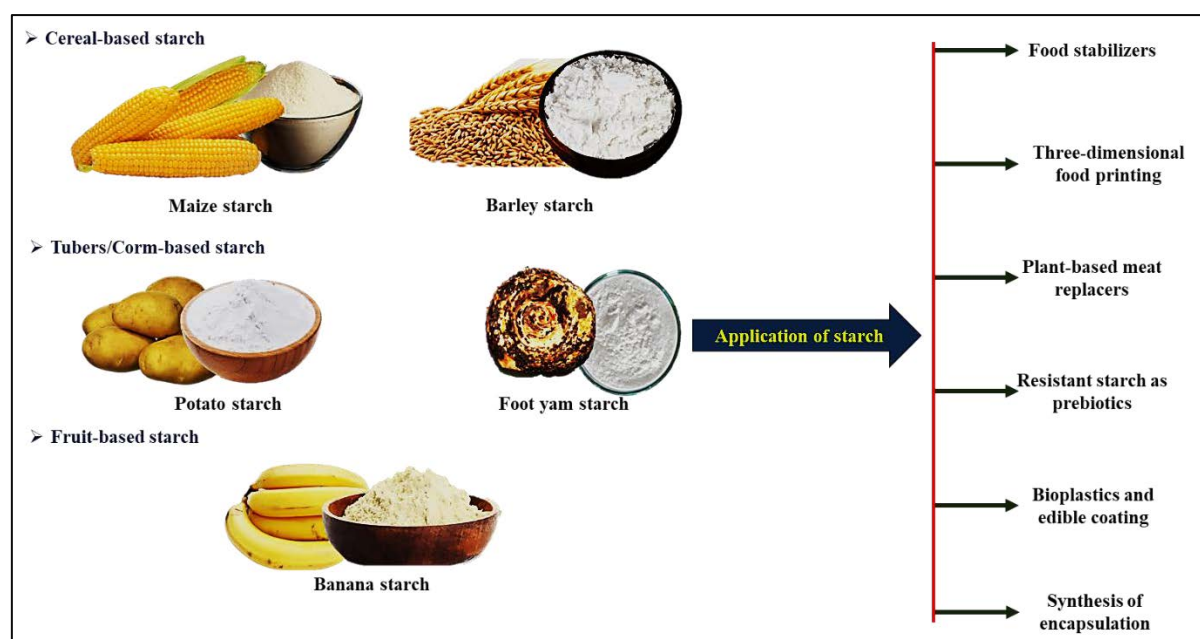


Figure 2. Sources and applications of starches in different industrial sectors

Modification of starch

Starch modification involves applying various transformation techniques to impart desired properties for specific industrial applications. These techniques alter the structure of native starch molecules to enhance their flexibility, functionality, and physicochemical characteristics, thereby improving their performance in industrial settings (Krithika and Ratnamala, 2019). The structural, physicochemical, and functional properties of starch can be modified through physical, chemical, or biological methods.

Physical modification

Physical modification of starch involves altering the physical characteristics of native starch granules without affecting their chemical structure (BeMiller,

2018). These modifications are achieved through the application of physical forces such as moisture, heat, shear, radiation, and sonication, as well as processes such as acid hydrolysis (Din et al., 2017). Although acid hydrolysis is often categorized as a physicochemical modification, it involves the partial breakdown of starch molecules by acids such as hydrochloric acid (HCl) or sulfuric acid (H₂SO₄), thereby altering molecular structure. Physical modifications offer several advantages, including cost-effectiveness, safety, and environmental sustainability. These methods also enable the development of starches with tailored properties suitable for specific industrial applications (Punia, 2020). An overview of starch modification through physical methods is illustrated in Figure 3.

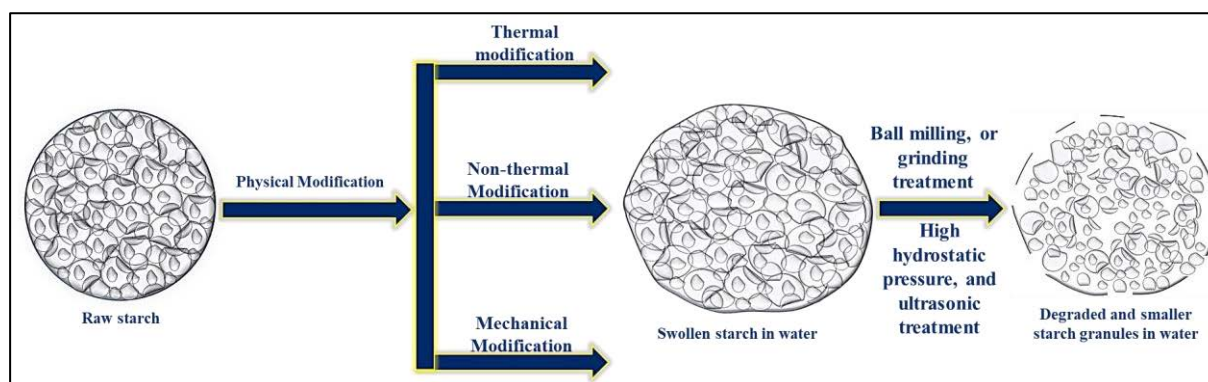


Figure 3. Modification of starch by physical methods

Chemical modification

Chemical modification involves the introduction of new functional groups into the backbone of the starch molecule. Researchers have focused on substituting hydroxyl groups in starch with functional groups such as acetyl, phosphate, or succinyl groups to achieve desired attributes (Haq et al., 2019). Chemical modification techniques gained considerable attention in the early 1940s, including cross-linking, esterification, acid hydrolysis, etherification, grafting, and oxidation. These chemical modifications allow for the tailored customization of starch to meet the specific requirements of food and industrial applications by improving properties such as viscosity, thermal and shear stability, solubility, and resistance to retrogradation (Chen et al., 2015).

Cross-linking is a commonly employed technique for modifying native starch, utilizing various cross-linking agents, including sodium trimetaphosphate (STMP; $\text{Na}_3\text{P}_3\text{O}_9$), sodium tripolyphosphate (STPP; $\text{Na}_3\text{P}_3\text{O}_{10}$), epichlorohydrin (EPI; $\text{C}_3\text{H}_5\text{ClO}$), and phosphoryl chloride (POCl_3). These agents facilitate the formation of intermolecular ether or ester linkages between the hydroxyl groups present in starch molecules (Koo et al., 2010). Esterification refers to the process of adding ester groups to starch molecules through the reaction of an organic acid

(RCOOH) with an alcohol (ROH) (Otache et al., 2021). The acid hydrolysis of starch primarily targets the amorphous regions of starch granules while preserving the crystalline areas, thereby enhancing packing under compression and accounting for the increased starch strength in formulations that include acid-modified starches (Angellier et al., 2004). The etherification of starch involves substituting the hydroxyl groups on the dehydroglucose monomeric units with ether linkages (St-OR) through a nucleophilic substitution reaction between an alkyl halide and an alkoxide. Grafting chemically modifies starch via graft copolymerization, enabling it to bond with synthetic polymers rather than merely form a physical mixture. The success of grafting reactions has been validated through techniques such as NMR (Nuclear Magnetic Resonance), FTIR (Fourier Transform Infrared Spectroscopy), TGA (Thermogravimetric Analysis), and elemental analysis. Additionally, starch modification through oxidation can lead to depolymerization, enhancing hydrophilicity, disrupting molecular linearity and crystallinity, and reducing retrogradation and gelatinization enthalpy. This is achieved by introducing carbonyl and carboxyl groups into the native starch structure via oxidation with an oxidizing agent (Vanier et al., 2017). Chemical modifications of starch are shown in Figure 4.

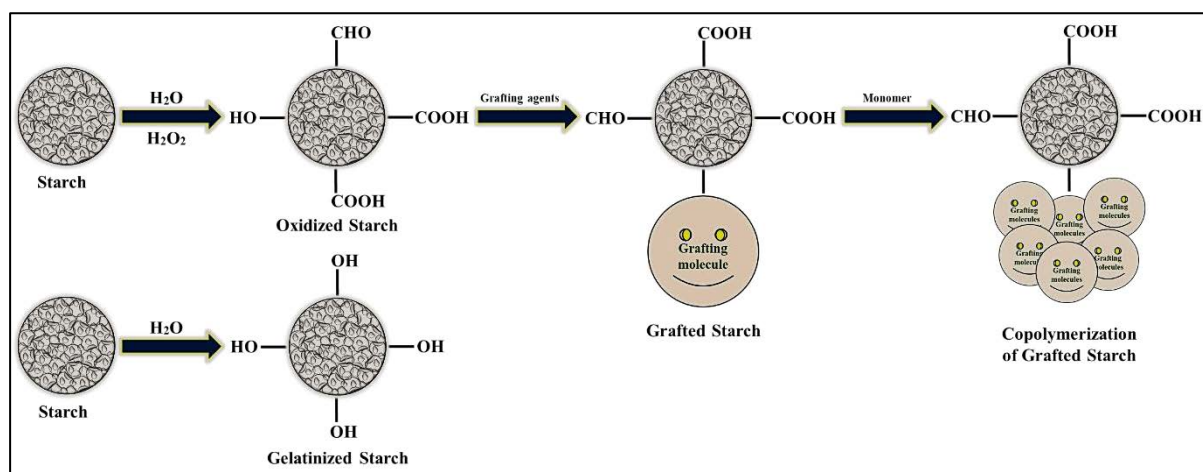


Figure 4. Modification of starch by using chemicals

Enzymatic modification

Enzymatic modification alters the structure of starch, including variations in molecular mass, branch chain length, and the amylose/amylopectin ratio, resulting from enzyme reactions with gelatinized starch (Park et al., 2018). Enzymatic modifications are advantageous due to their high specificity, safety,

and mild reaction conditions. Common enzymes involved in starch modifications include 4- α -glucanotransferase/Amylomaltase, maltogenic amylase, amylosucrase, cyclodextrin glycosyltransferase, and β -Amylase (Bangar et al., 2021).

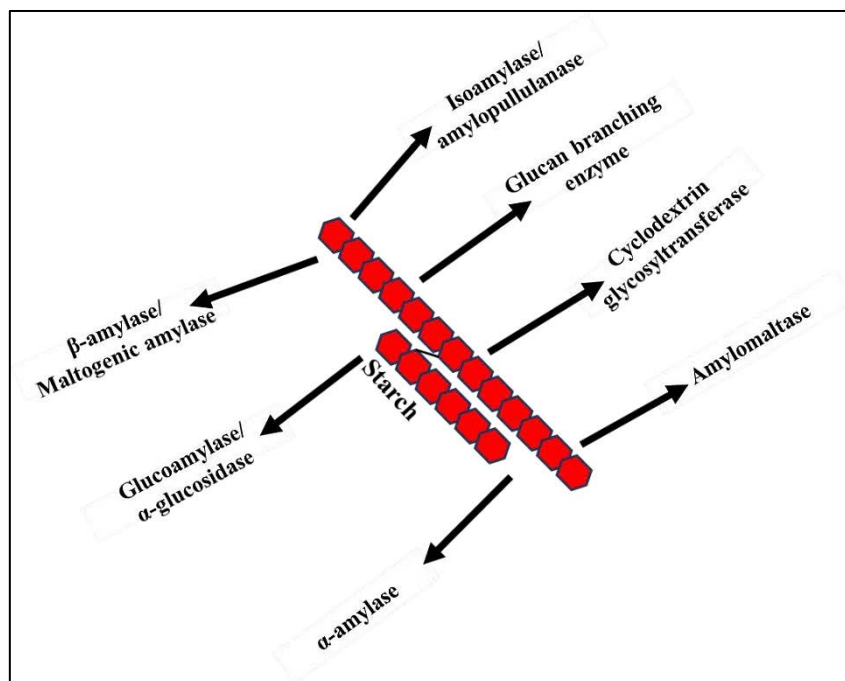


Figure 5. Enzymatic modification of starch

These enzymes can be classified into five primary types based on their structural characteristics and reaction specificities. Type I includes cyclodextrin glucanotransferase, which belongs to the glycoside hydrolase (GH) 13 family. Type II encompasses

amylomaltase (AM) and the disproportionating enzyme (D-enzyme), both members of the GH77 family, although they differ in terms of substrate specificity and catalytic activity. Type III consists of the glycogen debranching enzyme, which also

belongs to the GH13 family. Type IV includes an enzyme isolated from the hyperthermophilic bacterium *Thermotoga maritima*, classified within the GH13 family. Finally, Type V comprises enzymes derived from thermophilic and hyperthermophilic organisms, which belong to either the GH57 or GH77 families (Chen et al., 2023). The enzymatic modification of starch typically involves the cleavage of existing glycosidic bonds and the formation of new ones. 4- α -GT facilitates both intermolecular and intramolecular glycosylation reactions. The distribution of branch chain length, amylose content, and molecular weight is crucial for understanding the structural modifications of starch induced by 4- α -GT (Bangar et al., 2021). Starch modification through enzymatic action is shown in Figure 5.

Application of modified starch in the food packaging industry

Modified starch is widely used in the food packaging industry for its improved functional properties and its ability to serve as a packaging material (Figure 6). The role of food packaging has become increasingly important in the food supply chain, as it protects food products throughout processing, storage, and

transportation (Singh et al., 2023; Kumar et al., 2021). While traditional packaging materials such as plastic, paper, glass, metal, and composites offer certain advantages, they also present limitations for food preservation. In contrast, edible packaging made from natural food-grade polymers, such as polysaccharides, proteins, or lipids, offers a safer and more sustainable alternative (Mohamed et al., 2020; Zhao et al., 2021). Modified starch can also serve as a coating material to enhance barrier properties, preventing the ingress of gases, moisture, oxygen, and other contaminants, thereby extending the shelf life of packaged food (Shah et al., 2016). Additionally, modified starch can be used to develop biodegradable and eco-friendly packaging materials that reduce the risks of toxicity and pollution (Shaikh et al., 2021). Starch-based adhesives containing nano-starch and phenolic compounds such as tannic acid and curcumin are widely used as sizing and binding agents in food packaging applications. Additionally, modified starches are incorporated into surface sizing formulations to enhance the smoothness and quality of paper materials (Adewale et al., 2022).

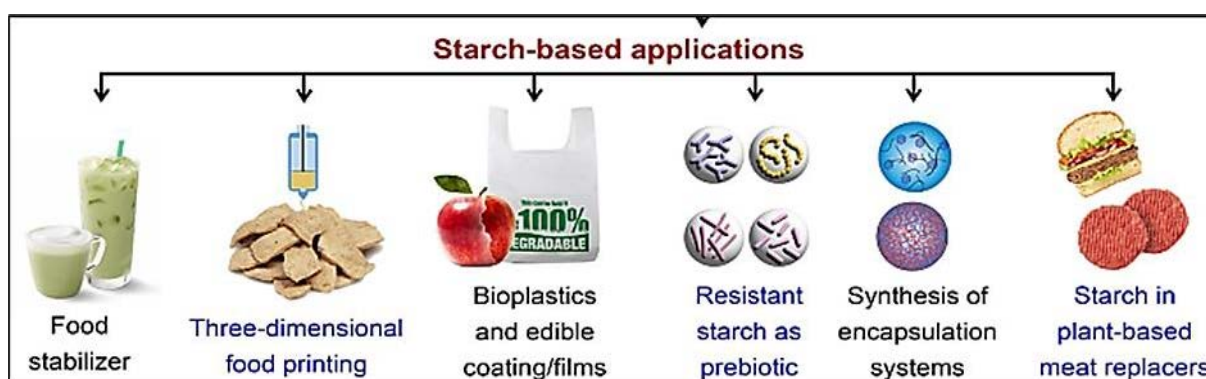


Figure 6. Application of modified starch

Advantages and disadvantages of plastics

Plastic materials, derived from both thermosetting and thermoplastic polymers, are widely utilized across various industries. Thermosetting polymers undergo an irreversible chemical transformation upon heating, becoming rigid and solid, and cannot

be remelted or reshaped once set. In contrast, thermoplastic polymers soften when heated above a specific temperature, allowing them to be reshaped multiple times without undergoing chemical change. Common thermoplastic polymers in food packaging include polyolefins, polystyrene, polyester, nylon,

polycarbonate, and vinyl polymers. These materials are favoured for their mechanical strength and reliability, which are critical attributes for packaging applications (Grigore, 2017; Marsh & Bugusu, 2007). However, their non-biodegradable nature raises serious environmental concerns and potential risks to human health (Bhuyar et al., 2018). Polyethylene, primarily composed of carbon and hydrogen, is particularly resistant to microbial degradation and remains persistent in the environment. Additionally, plastics often contain additives such as diethylhexyl phthalate (DEP), bisphenol-A, and other phthalates, which have raised health concerns due to their potential toxicity (Behera et al., 2022).

Despite these concerns, plastics offer several advantages, particularly in transportation, construction, and packaging, where they contribute to substantial material and energy savings (Andrady and Neal, 2009) (Table 1). Their lightweight nature makes them particularly advantageous for transportation (Awoyera & Adesina, 2020), and their production is characterized by durability, low cost, water resistance, and lower energy requirements than alternatives, thereby reducing reliance on heavy chemicals (Al-Salem et al., 2017). Plastic bags, in

particular, are versatile and flexible packaging materials (Hahladakis and Iacovidou, 2018). Some plastics are recyclable, which helps to reduce environmental pollution by minimizing emissions of CO₂, methane, NH₃, CO, HCl, and C₂H₄ (Klemes et al., 2020). Additionally, the barrier properties of plastics, which protect food from external contaminants, are determined by the permeability of the packaging material to gases and vapours.

However, the use of plastics has serious drawbacks, as shown in Table 1. Because they are non-biodegradable, plastic materials accumulate in landfills and oceans, posing long-term hazards (Dilkes-Hoffman, 2019). Some plastics contain harmful chemicals, such as phthalates and bisphenol-A (BPA), which can bioaccumulate and be biomagnified through the food chain, posing risks to both human and environmental health (Alabi et al., 2019). Resource exploration required for plastic production can lead to habitat destruction and ecosystem disruption (Trathan et al., 2014). The widespread occurrence of plastic pollution in oceans and coastal areas directly affects commercial fishing, aquaculture, and tourism (Thushari and Senevirathna, 2020).

Table 1. Advantages and disadvantages of commercial plastics

Commercial plastics		
Advantages	Disadvantages	References
Plastic is lightweight.	Non-renewable.	Singh et al. (2022)
Excellent finishing, easy melding.	Soft.	Jiang et al. (2024)
Excellent toughness and strength.	Carcinogenic	Saini et al. (2020)
Good capacity for shock absorption.	Embrittled at low temperature	Croll (2023)
Chemically inert and corrosion-resistant.	Deformed under minimal load.	Jacobson and Iroh (2021); Mallinson (2020)
Good thermal and electrical insulating properties due to low thermal expansion coefficient.	Low heat resistance and poor ductility.	Haque et al. (2021)
Good adhesiveness and water-resistance.	Combustible.	Mori (2023)

Biofilm/ Bioplastic – an alternative to commercial plastics

Recent researches focus on the development of new bio-based materials, primarily due to their crucial role in replacing synthetic and hazardous substances (Vinod et al., 2020). Biofilms, which are thin, flexible layers made from biopolymer molecules, are bonded together using natural binding agents such as glycerol, titanium dioxide, calcium carbonate, and vinegar. These biofilms can be produced from various biopolymers, including polylactide (PLA), polyhydroxyalkanoate (PHA), poly (3-hydroxybutyrate-co-3-hydroxyvalerate) (PHBV), starch, cellulose, proteins, gluten, and PEEK (Vinod et al., 2020). The integration of nanoparticles into biopolymeric films presents an exciting area of research, offering sustainable alternatives to petroleum-derived synthetic packaging materials. Chitosan and starch are considered the most promising biodegradable polymers for food preservation due to their availability, cost-effectiveness, and film-forming capabilities (De Menezes et al., 2021).

Biofilms can be engineered to act as physiological barriers that prevent oxygen from entering packaging, thereby slowing oxidative processes that contribute to food spoilage and degradation (Janjarasskul et al., 2018). These films can be crafted from proteins and polysaccharides like starch, cellulose, and chitin, making them suitable for use as edible coatings for fruits, vegetables, and other food products (Ju et al., 2019). Furthermore, biofilms can serve as "active packaging" systems, releasing preservatives or antioxidants to enhance food preservation (Sharma et al., 2020). This technology confers several benefits by extending the shelf life of baked goods, such as bread, cakes, and pastries, by preventing staleness and retaining moisture (Harnkarnsujarit et al., 2021).

Several biopolymers, including cellulose, polylactide (PLA), chitin, and chitosan, are widely

used in tissue engineering. These biodegradable materials are derived from natural sources and are free of harmful synthetic chemicals. Starch enables the production of environmentally friendly biofilms from agricultural raw materials, which can be produced in large quantities (Mangaraj et al., 2022). These starch-based biofilms are non-toxic and safe for use in various applications, including food packaging and medical products (Chhatariya et al., 2022). Biofilm coatings have also demonstrated the ability to reduce weight loss and support proper fruit ripening during a 15-day storage period in controlled-atmosphere conditions, underscoring their potential in food preservation (Mohamed et al., 2020).

Despite their biodegradability and lower toxicity, biopolymers often lack the mechanical strength and durability of conventional plastics, which can limit their large-scale applications (Rosentrater & Otieno, 2006). The hydrophilic nature of starch and cellulose biofilms also results in poor water vapor barrier properties, which can compromise their long-term stability (Szlek et al., 2022). Moreover, scaling up biofilm production is technically complex and often economically uncompetitive compared to conventional plastics, largely due to high production costs, specialized operating conditions, and lower material performance (Mohammad et al., 2019; Sessini et al., 2021). The production of biofilms often depends on specific feedstock materials, such as plant-based starches or proteins, which may not always be available in sufficient quantities to meet demand. It is, therefore, essential to consider these drawbacks when evaluating biofilms as a viable alternative to traditional plastics. Further research and development are essential to overcome current limitations and enhance both the scalability and functional performance of biofilms across a range of applications.

Table 2. Advantages and disadvantages of several types of bioplastics/biofilms

Types of bioplastics	Advantages	Disadvantages	References
Starch-based	Odorless, tasteless, good O ₂ and CO ₂ barrier properties.	Poor water vapor and tensile properties.	Jayarathna et al. (2022)
Cellulose-based	Tasteless, odorless, resistant to oil and fat, hydrophilic; also shows thermal and chemical stability.	Hardly dissolves or melts due to high crystallinity and shows reduced antimicrobial activity.	Hossain et al. (2024); Unni et al. (2023)
Protein-based	Excellent barrier properties to aroma compounds and oils.	Hydrophilic and less resistant to moisture.	Qazanfarzadeh and Kumaravel (2023)
Lipid-based	Excellent barriers against moisture transmission.	Damages the appearance and gloss of the coated food products.	Zubair et al. (2021)
Chitin-based	Good barrier properties and antimicrobial properties.	No significant antioxidant and antifungal activity and limited ability to impede oxygen and water.	Panariello et al. (2022)
PLA-based	Environmentally friendly, high transparency, and biological compatibility.	High hardness and brittleness, lower tensile strength, and thermal instability.	Rajeshkumar et al. (2021)
PHA-based	Suitable for processing, versatile structure- property relationship, and excellent elasticity.	Low water resistance and hardness.	Meereboer et al. (2020)

Edible biofilm and coating

Edible films are primary packaging materials made from safe, food-grade ingredients that can be consumed with the product and extend its shelf life. They also enhance the quality of items such as fruits

and vegetables by shielding them from physical, chemical, and microbiological alterations, including moisture loss, enzymatic browning, and fat oxidation (Kocira et al., 2021).

Table 3. List of plant sources and their application

Plant source	Type of polymer	Application	Reference
Foot yam (<i>Amorphophallus paeoniifolius</i>)	Starch	Food packaging	Nagar et al. (2020)
Potato peel (<i>Solanum tuberosum</i>)	Cellulose	Food packaging	Xie et al. (2020)
Apple pomace (<i>Malus pumila</i>)	Pectin	Food industry	Naqash et al. (2022)
Cassava (<i>Manihot esculenta</i>)	Starch	Food packaging	Silva et al. (2019)
Psyllium seeds (<i>Plantago ovata</i>)	Non-starch polysaccharide	Pharmaceutical and food industries	Ahmadi et al. (2012)
Black soybean seed (<i>Glycine max</i>)	Chitosan	Food packaging	Kong et al. (2023)

The term "edible biofilm" specifically refers to a thin, protective layer composed of edible materials, primarily used in the food industry (Dehghani et al., 2018). Below are some common sources of materials used to prepare edible biofilms Table 3.

Edible films provide an additional protective layer against contaminants and microbial growth, thereby reducing the risk of foodborne illnesses. A notable benefit of antimicrobial edible films is their ability to target and inhibit microbial contaminants that may settle on the food surface after processing. The diffusion rate of antimicrobial agents into food can be modulated by incorporating specific substances into the film matrix (Cagri et al., 2004). Such films are commonly used to minimize the rate of oxidative reactions in both fresh and processed fruits and vegetables, which are particularly susceptible to rapid spoilage, especially after cutting. Cutting increases the surface area of produce, exposing internal tissues to oxygen and microbial contamination. Edible films confer an effective solution to extend the shelf life of fresh-cut produce (Yousuf et al., 2018). Additionally, edible films can encapsulate flavours, nutrients, or functional ingredients, enhancing both the sensory attributes and nutritional quality of food products (Ribeiro et al., 2021).

Although edible films and coatings share similarities in their function, they differ in preparation and application. Edible films are typically produced separately and then applied to the food surface, while coatings are formed directly on the food (de Azeredo, 2012). Edible coatings are thin layers of edible material applied directly in liquid form onto the surface of food items, serving multiple functions, including protection against mechanical damage, chemical reactions, and moisture loss, thereby extending the shelf life of fruits and vegetables (Embuscado and Huber, 2009). These coatings can create a partial barrier to water movement, reducing moisture loss, and can also modify the surrounding atmosphere, delaying respiration, ripening, and

senescence. This action also helps inhibit fungal growth and improves the sensory attributes and nutritional quality of the fruits (Dhall, 2013; Mahajan et al., 2014).

The food industry has increasingly turned to edible coatings to improve the preservation, quality, and safety of perishable products such as fruits, vegetables, and meats (Dhall, 2013). Edible coatings can be applied to both whole and fresh-cut fruits, including apples, oranges, peaches, avocados, cucumbers, bell peppers, melons, and tomatoes, and are expected to replace synthetic packaging in the future due to their antimicrobial, chemical, and physical properties (Dubey and Dubey, 2020). The combined incorporation of essential oils, nanoparticles, and agricultural by-products into edible coatings often generates synergistic effects, significantly enhancing the antimicrobial, antioxidant, and barrier properties of food packaging (Dubey and Dubey, 2020). The choice of base materials, along with plasticizers such as sorbitol and gelatin, influences the mechanical and physicochemical properties critical to edible films and coatings (Hassan et al., 2018). In addition, edible coatings provide a natural and eco-friendly alternative to chemical treatments and synthetic fungicides, helping to promote food safety, reduce postharvest decay, and support sustainable agricultural practices (Andrade et al., 2017; Hajji et al., 2018). These coatings can also incorporate active antimicrobial agents, such as essential oils, GRAS (Generally Recognized as Safe) compounds, and microbial antagonists, which help extend shelf life and reduce pathogen growth on food surfaces (Blancas-Benitez et al., 2022). Commercial edible coatings are already being used on fresh and fresh-cut produce in the market to reduce weight loss, prevent physiological disorders, and maintain product quality (Dhall, 2013). Lipid-based edible coatings, derived from natural or synthetic waxes, are particularly effective in reducing water vapor permeability due to their hydrophobic characteristics

(Yousuf et al., 2022). Application of edible coatings also enhances the visual appeal of fruits and vegetables by providing a glossy finish (Dhall, 2013). The benefits of edible coatings for fresh

produce are clearly illustrated in Figure 7, which highlights their potential to reduce spoilage and enhance overall food quality.

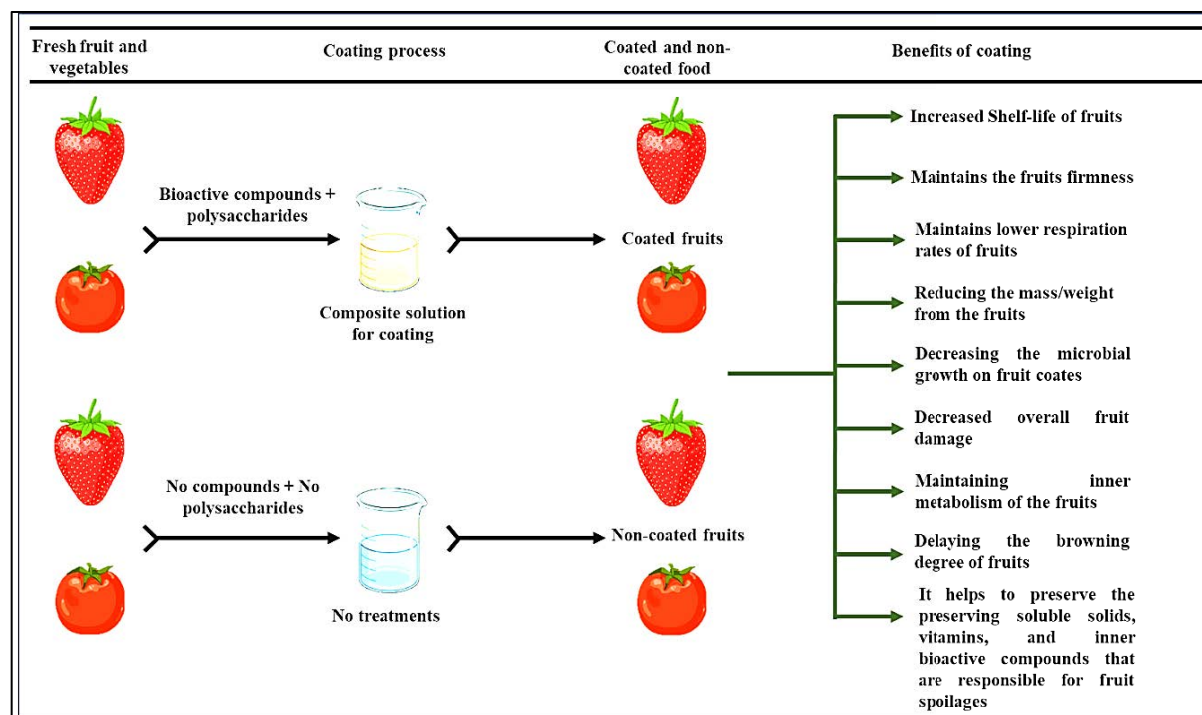


Figure 7. Benefits of edible coatings for the preservation of fresh fruits and vegetables

Conclusion

The main concerns of this study are the production of biodegradable biofilms, edible coatings, and edible films. The global trends in industry research and development are towards using renewable biomass and environmentally friendly materials, i.e., less-pollutant, eco-friendly materials. Starch is one of the most abundant and cheapest materials for producing biofilms/edible coatings and films. As the uses of starch in various industries, especially in the food packaging and starch production industries, increase, starch production and use will grow as essential raw materials across different industrial sectors. Apart from its uses, starch is one of the most promising sources for novel research on the application of biodegradable biofilms. Due to technological advances, we face many problems, including increased constraints on food packaging, environmental issues, consumer health concerns, and economic restrictions. Hence, food scientists

and technologists are more focused on developing biopolymer packages. Starch satisfies all the principal aspects, making it a promising raw material for edible coatings/films. Modified starch has attracted considerable attention at both academic and industrial levels because these films exhibit dramatic improvements in film properties without incurring any significant increase in production cost.

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