Article

Efficacy of alginate and pectin-based edible coatings in extending the shelf life of potato tubers

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Abstract

Hydrocolloids are macromolecular food ingredients with high water-absorption capacities, playing a vital role in modulating texture and enhancing product stability. This review critically examines the potential of alginate and pectin as foundational materials for edible coatings designed to extend the postharvest shelf life of potato (Solanum tuberosum) tubers. This review was conducted using scholarly databases, including Google Scholar and ScienceDirect, to synthesize current research findings. The consolidated evidence indicates that edible coatings formulated from alginate and pectin significantly prolong potato shelf life. The primary mechanisms of action include: (1) suppressing tuber respiration rate, thereby decelerating metabolic degradation; (2) forming a semi-permeable barrier that markedly reduces water loss, maintaining turgor and weight; and (3) providing a physical shield against microbial invasion. Furthermore, alginate-pectin matrices effectively inhibit the activity of polyphenol oxidase, mitigating enzymatic browning and preserving the tuber's visual appeal. Consequently, these coatings help maintain the potato's textural firmness and nutritional content throughout extended storage periods. In conclusion, alginate-pectin based edible coatings represent a promising, sustainable technology for postharvest potato management. By concurrently modulating respiration, minimizing moisture loss, and offering a platform for active compounds, these biopolymer coatings effectively preserve critical quality attributes and extend commercial shelf life.

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1. Introduction

Hydrocolloids are macromolecules with strong water-absorbing properties and widely used in the food industry (1). These compounds play an important role in imparting texture to food products. Hydrocolloids commonly applied in food processing include alginates and pectins (2). One of the major applications of alginates and pectins in the food industry is supporting food preservation processes.

Food preservation aims to extend shelf life, inhibit microbial growth that causes spoilage, and maintain nutritional value and sensory quality (3). Preservation methods are continually evolving with technological progress. However, consumer concerns about chemical preservatives have driven demand for natural alternatives. Among these, edible coating technology has become a prominent natural preservation method.

Edible coating is one of the thin films made from natural materials such as proteins, carbohydrates, or edible lipids. It is applied to the surface of food to form an effective barrier against the transfer of water vapor, oxygen, and other gases (4). In addition, edible coatings can also function as carriers of additives such as antioxidants, antimicrobials, and vitamins (5). The use of edible coatings has several advantages over conventional packaging,

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namely that it is more environmentally friendly, can increase the shelf life of food, and provides additional protection against physical and chemical damage. The basic ingredients of edible coatings are often hydrocolloid, so the utilization of hydrocolloids in the development of edible coatings is very important. Therefore, this study was conducted to determine the potential of alginate and pectin hydrocolloid as raw materials for making edible coatings to extend the shelf life of potato.

2. Materials and Methods

This review was conducted using the method of collecting and reviewing data and information sourced from the Google, Google Scholar, dan Sciencedirect site. The main keywords used were: "alginate edible coating"; "pectin edible coating"; "alginate pectin coating"; "edible coating potato"; "potato tuber shelf life" and "hydrocolloid-based edible films" among others. All the included references were manually selected and reviewed by the authors.

3. Results and Discussion

3.1. Hydrocolloid

Hydrocolloids are polymers derived from animals, plants, or microbial sources that form gels or increase solution viscosity upon contact with water. These polymers are widely used to improve product texture, stability, and shelf life (1). The physical properties of hydrocolloids include viscosity enhancement, gel formation, and water absorption. These properties allow them to modify food texture, create stable gel structures, and retain moisture to maintain product hydration and extend shelf life (2). Chemically, hydrocolloids consist of polysaccharides or proteins with polymeric structures that enable interactions with other food components, such as fats, proteins, and carbohydrates, enhancing emulsion and suspension stability. Hydrocolloids are also capable of undergoing chemical modifications under certain conditions, further tailoring their functional performance in various applications (2).

Hydrocolloids encompass a diverse range of polymers, including glucomannan, chitosan, and xanthan gum. Glucomannan is a water-soluble polysaccharide extracted from konjac tubers (*Amorphophallus konjac*). Due to its high water-absorbing capacity and ability to mimic gluten-like texture, it is widely used in the food industry to produce gluten-free bread, providing essential structure, elasticity, and desirable crumb characteristics (6). Chitosan is a polysaccharide obtained from chitin, a structural component found in the crustacean shells such as shrimp, crabs, and lobsters. Due to its antimicrobial properties, chitosan is commonly applied in the pharmaceutical field, particularly in the development of ointments and creams for treating infections (7,8). Xanthan gum is an extracellular polysaccharide produced through the fermentation of dextrose by Xanthomonas campestris (9). In the petroleum industry, xanthan gum is used as a lubricating agent in oil well drilling due to the thickening and salt-binding properties that help lubricate wells and separate solids from crude oil (10).

3.1.1. Alginate

Alginate is a hydrophilic, water-soluble polysaccharide derived from the marine sources, such as brown algae like Laminaria, Ascophyllum, dan Macrocystis (11). It exhibits several notable physical properties, including a soft and elastic texture, high water absorption capacity leading to swelling and gel formation, and significant viscosity. Alginate is a linear copolymer composed of alternating monomeric units of β-D-mannuronic acid (M) and α-L-guluronic acid (G). Its molecular weight varies, and generally shows good stability under neutral to alkaline pH conditions. Additionally, alginate can undergo ionotropic gelation by reacting with various polyvalent metal ions (11). Alginate structure can be seen in Figure 1.

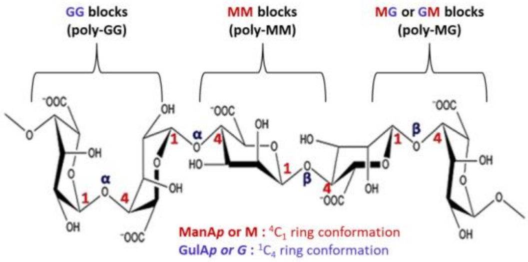
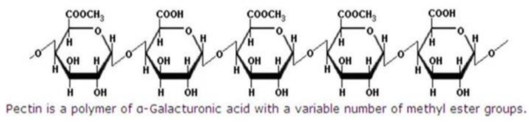


Figure 1. Alginate Structure (12)

Alginate is composed of D-mannuronate (M) and L-guluronate (G) acid units, which form its characteristic copolymer structure. It exhibiting excellent chemical stability allowing it to perform under diverse environmental conditions without significant degradation, and it readily interacts with various ions and molecules (12). Alginate is widely applied in the pharmaceutical industry as a raw material in drug formulation due to its gel-forming capacity and its function as a binding agent in tablets (13). In the rubber industry, alginate is utilized to enhance the quality of latex products by improving their durability and physical properties (14). In the food industry, alginate serves as a thickener and texture improver, contributes to emulsion stability in products such as sauces, prevents precipitation, maintains product quality, and extends shelf life (15).

3.1.2. Pectin

Pectin is a water-soluble polysaccharide composed of galacturonic acid units linked through α-(1-4) glycosidic and carboxyl groups esterified with methanol bonds within plant cell walls (16,17). It is made naturally in the cell walls of higher plants and is especially common in fruits like dragon fruit, bananas, pineapples, and mangoes (18). Physically, pectin appears as a fine powder, with its color varying according to the extraction method and processing conditions (19). Pectin consists of galacturonic acid units, exhibits strong gel-forming properties, and can undergo derivatization reactions that influence its gelling behavior. It also demonstrates pH sensitivity that affects gel stability and formation and is capable of reacting with various chemical agents (20). The structure of pectin can be seen in Figure 2.



Picture 2. Pectin Structure (20)

The food industry commonly uses pectin in the production of jams and jellies due to its strong gel-forming ability in solution (21). In the cosmetics industry, pectin is incorporated into skincare and haircare formulations to improve emulsion stability and enhance product texture. Meanwhile, the pharmaceutical industry utilizes pectin in drug development because of its potential to lower blood sugar and cholesterol levels, as well as its therapeutic effects against various diseases (22).

3.2. Edible Coating

Edible coatings are thin layers made from natural materials that provides physical protection, enhances quality, and extend the shelf life of food products (4). Common materials used in edible coatings include polysaccharides (e.g., agar, chitosan, alginate, pectin), proteins (gluten, casein, soy protein), and lipids (waxes, vegetable fats, and oils) (5). In addition to extending shelf life, edible coatings can enrich foods with bioactive components and function as natural preservatives, offering both nutritional enhancement and functional preservation. Furthermore, these natural, biodegradable coatings represent a sustainable alternative to conventional synthetic packaging (4). A distinction exists between edible coatings and edible films: coatings are thin layers applied directly to food surfaces, while films are thicker, self-supporting sheets used as separate packaging materials (4).

3.3. Potato

Potatos are significant carbohydrates source, which contribute to enhanced energy levels and support metabolic functions (23). Morphologically, potatoes typically exhibit round, oval, or egg-shaped forms with brown skin and variable sizes. The potato chemical composition includes carbohydrates, proteins, vitamins, minerals, water, and starch (24). The nutritional composition per 100 grams of potato includes 347 kcal of energy, 0.3 g protein, 0.1 g fat, 85.6 g carbohydrates, 20 mg calcium (Ca), 30 mg phosphorus (P), 0.5 mg iron (Fe), and 0.04 mg vitamin B (25). A notable biochemical characteristic is enzymatic browning, driven by polyphenol oxidase activity. When potato cells are damaged, this enzyme catalyzes the oxidation of endogenous phenolic compounds, resulting in the formation of brown pigments (26).

In the food industry, potatoes serve as a major raw ingredient in various processed products, function as thickeners, and are used in alcohol production (27). In the pharmaceutical field, potatoes are utilized in drug development due to their bioactive components (28). Additionally, the livestock sector frequently employs potatoes as animal feed because their nutrient content supports healthy growth and productivity (29).

3.4. Mechanism of Alginate-Pectin Based Edible Coatings for Potato

Alginate and pectin extend the shelf life of potatoes through multiple mechanisms as edible coatings, including reducing respiration rate, inhibiting moisture and weight loss, enhancing microbial resistance, minimizing enzymatic browning, and preserving texture and nutritional quality. These biopolymers form a semipermeable layer that regulates gas exchange, particularly oxygen (O_2) and carbon dioxide (CO_2) (30). By modulating gas diffusion, the coatings lower the respiration rate, thereby slowing metabolic processes that lead to deterioration during storage. This reduction in respiration also decreases ethylene production, which otherwise accelerates potato senescence (31,32). Furthermore, the alginate-pectin coating acts as a barrier against water loss through evaporation, helping to maintain potato texture and mass (33). This aligns with the research of Sarengaowa, who reported that potatoes treated with edible coatings exhibited up to four times less weight loss compared to uncoated potatoes (34).

Pectin and alginate will function as a physical protective layer against microbial contamination of potato (35). When combined with antimicrobial agents such as essential oils, these coatings will reduce the growth of microorganisms such as Li*steria monocytogenes* and mold on potatoes. Previous research found that alginate combined with essential oils can reduce bacterial growth to 3.63 log cfu/g during storage. In addition, edible coating produced from alginate and pectin will inhibit oxygen contact with potato which will reduce the activity of the enzyme polyphenol oxidase (PPO) so that the color of potato will remain brighter during storage which will also increase consumer appeal (34). Edible coatings produced from alginate and pectin also have the ability to maintain the texture and nutritional quality of potatoes. Parameter such as total phenolic content (TPC) and antioxidant activity can be maintained better in coated potatoes than those not coated with edible coatings (33).

4. Conclusions

The application of alginate-pectin based edible coatings offers significant potential for extending the shelf life of potatoes. By reducing respiration rates, minimizing moisture loss, and providing a barrier against microbial contamination, these coatings effectively preserve the physical, sensory, and nutritional quality of the tubers. Overall, hydrocolloid-based edible coatings represent an effective and environmentally friendly approach in the food industry for prolonging product shelf life.

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Author Contributions

Conceptualization, F.A.M.F.; methodology, F.A.M.F.; validation, F.A.M.F.; formal analysis, F.A.M.F.; resources, F.A.M.F.; data curation, F.A.M.F.; and writing F.A.M.F.

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Data Availability Statement

Available data are presented in the manuscript.

Conflicts of Interest

The author declares no conflict of interest.

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