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The effects of nano-edible coating on shelf life, physicochemical, microbial and sensory properties in food preservation and horticulture: A mini review

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Abstract. Packaging with a nano-edible coating is a relatively new food preservation technique. Previous research has shown that nano-edible coating has the potential to maintain quality attributes and could extend the shelf life of food. The nano-edible coating was proven to have better capabilities than the edible coating. The structure of nanoparticles in the coating material can increase the ability of antioxidants, antibacterial, surface area, and mechanical properties to maintain the color and weight of the product. The materials used in making nano-edible coating are the safest potential and have been widely studied, namely starch-based, pectin, essential oils, honey, and chitosan. This review comprehensively describes the latest studies of functional additives and their mechanisms. In addition, this article provides insight into the potential application of the nano-edible coating in food preservation and horticulture.

1 Introduction

The development of packaging types in recent years has increased throughout the world. This phenomenon occurs due to changes in consumer lifestyles, including changes in purchasing behavior and consumption behavior. Consumers today tend to need food that is healthy, safe, and environmentally friendly. This behavior change creates opportunities for the application of food preservation technology. During storage, food will experience a process of decreased quality, physicochemical changes, and spoilage [1, 2]. This process is the main problem faced by the food and horticultural producers, which contributes significantly to food waste. Therefore, it is necessary to use edible packaging, which can add an extra layer of protection by inhibiting microbial spoilage, acting as a moisture and gas barrier, and increasing shelf life.

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Food and horticultural packaging have a lot of potential for improving packaging material properties. The nano-edible coating is typically a liquid that contains chemical and biological nanoparticles. Until now, the nano-edible coating has been reported to have the ability to increase the capacity of antioxidant, antibacterial, surface area, and mechanical properties, and maintain the color and weight of the product. The nano-edible coating acts as a barrier between moisture, oxygen, taste, odors, and oils. In addition, this coating can inhibit polyphenol oxidation activity that can cause fruit browning, inhibit microbial growth that causes damage, and increase antioxidant activity that can prevent food lipid oxidation and extend shelf life [3-11]. Several types of nano-edible coating materials have been reported to be capable of preserving food quality and extending the shelf life of horticulture.

Progress in the preparation of nanosystems that combines acceptable materials for food products has enabled researchers to investigate edible functional modification of the coatings by integrating nanoemulsion, polymer nanoparticles, nanofibers, lipid nanoparticles, and polymer nanocomposites [12]. The materials used in making nano-edible coatings that have the most potential and have been widely studied are starch [3], [13–15], chitosan [4, 5], [7, 16], pectin [6, 11], [15, 16], essential oils [10, 11], [17, 18], and honey [8], [20, 21]. The addition of functional additives to nano-edible coatings such as soluble soybean polysaccharide [3], nano-ZnO [9, 4], cinnamon essential oil [3, 11], cumin essential oil [10], grape seed extract [17, 22], ferulic acid [7], eugenol [23], and cress seed gum [5] as antioxidant agents, antimicrobials, and good coating.

This study examines recent trends in the use of nano-edible coating technology to extend the shelf life of food and horticulture, focusing on technological aspects such as coating materials, application methods, and their effects on quality and nutrition, as well as functional additives in the nano-edible coating.

2 Methodology

A literature review was conducted in July 2022. This study is a descriptive literature review that discusses and analyzes the results of previous studies. The data source used is secondary data obtained from the search for international literature indexed by Scopus and other refereed journals. The literature review is identified by the research focus on information and innovation, with some steps of the process below (Table 1).

Table 1. 3 Phases the research was conducted.

Number of Phases	Phase	Description
Phase 1	Identification of research papers through Scopus and other refereed journal	The identification of research papers that inquire about the questions was expressed and the guidelines were created for collecting the literature
Phase 2	Research data analysis	The data were analyzed descriptively using the literature review method
Phase 3	Drafting and final manuscript	After the analysis carried out in the previous phase, the next step was to make the outline, draft the manuscript, and follow it with the preparation of the final manuscript

3 Result and discussion

3.1 Starch-based nano-edible coatings

One of the polymer materials that is widely used in making nano-edible coatings is starch and its derivatives. Starch is a natural polymer that can be degraded and renewable that has been used because the source is widely available and low cost. Starch consists of two types of glucose polymers: straight chains referred to as amylose and branched chains called amylopectin [24]. There are numerous advantages to using starch-based nano-edible coatings, including cost-effectiveness, transparency, tastelessness, and colorlessness. However, several weaknesses limit the application, namely the hydrophilic properties that make the resistance low to the water and have a low barrier to water vapor [25]. This problem has been solved by the addition of various chemical and biological agents such as nanoemulsions, polymer nanoparticles, and polymer nanocomposites.

Mung bean starch composite coatings enriched with nano-emulsion essential oils to improve the quality and shelf life of the buns were developed and characterized. Antimicrobial agents include a nano-emulsion of cinnamon and clove essential oils. The results showed that the addition of essential oil nano-emulsion has proven to have a positive effect and can increase antimicrobial efficiency. The essential oil nano-emulsion treatment combined with green bean starch coating materials can suppress bacterial contamination to the last storage (10 days), reducing 1 log CFU/g on fungal and mold parameters. In addition, the coating can delay the loss of moisture or product water content and is proven to maintain the original taste of the buns without reducing sensory quality during the storage period [3].

Dai et al. [13] reported that the addition of 6% cross-linked starch has no effect on coating color and transparency. This significantly increases the tensile strength, modulus of elasticity, and water vapor permeability. In addition, coatings can maintain color, firmness, total phenolic, soluble solids, and titratable acid content and inhibit the activity of peroxidase enzyme (POD) and polyphenol oxidase enzyme (PPO). Wang et al. [14] the hierarchical micro and nanostructure formed by the HER-SNP aggregates combined with the low surface energy of PDMS, the superhydrophobic coating has good water resistance. The EHR_SNP@PDMS composite coating reduced the residues of all tested liquid foods, showing the potential of biodegradable packaging to reduce environmental pollution due to food waste. Other results showed that this composite coating can be used to monitor freshness during food storage and transportation. Dash et al. [15] A thorough evaluation of sweet potato starch and lemon-waste pectin base-edible films with nano-titania inclusions was conducted. It improves mechanical properties, moisture barriers, and nearly all visible light spectrum and UV are perfectly absorbed or squatted, allowing it to be used as a UV filter packaging material to protect food from damage. These findings indicate that the higher the concentration of nano-titania, the tensile strength and modulus of the young film increase.

3.2 Pectin-based nano-edible coatings

Polysaccharides as coatings have been widely used in recent years, mainly because of their availability and cheap prices, solubility, stability, safety, non-toxic, tasteless, odorless, and ability to form a transparent layer [26]. Among the existing types of polysaccharides, pectin is one of the compounds used for edible coating applications. Pectin is a complex anionic polysaccharide consisting of b-1, 4-linked d-galacturonic acid residues where carboxyl uronic acid is esterified completely or partially [27]. Gorrasi et al. [6] developed and studied edible bio-nano-hybrid Coatings for food protection. The significant ability to extend the shelf life of fresh apricots was demonstrated by nano-hybrid coating pectin and layered double hydroxide (LDH) modified with salicylate anions.

Naqash et al. [11] The effect of pectin nanoemulsion derived from apple pulp combined with cinnamon essential oil on the safety and quality of fresh-cut apples was investigated. During storage, nanoemulsion pectin significantly reduced E.Coli bacteria contamination by 3.44 log CFU/g and L.monocytogenes bacteria contamination by 6 log CFU/g. There is no significant difference resulting from pH analysis, acidity, and TSS. Coatings using pectin nanoemulsion can prevent the formation of polyphenol oxidases, hydrolysis enzyme activity, and microflora activity that can reduce the quality of fresh-cut apples, so as to maintain the color and hardness of fresh-cut apples well during storage.

3.3 Essential oils-based nano-edible coatings

Essential oils have excellent hydrophobic properties as a barrier to moisture loss. The incorporation of essential oils into the nano-edible coating enhances its functionality as an antimicrobial and anti-browning. Essential oil-based coatings have demonstrated their effectiveness in extending shelf life and improving food and horticulture appearance [28]. El-Sayed et al. [10] developed and studied white soft cheese preservation using a nanoemulsion solution containing cumin essential oil (CEO). The nanoemulsion CEO showed the antimicrobial activity of all pathogenic strains tested, especially against the most sensitive S.aureus bacteria, which has a diameter of inhibition zones ranging from 8,6 to 18,3 mm, so that it can maintain the quality of white soft cheese from bacterial contamination for more than 45 days.

Kazemeini et al. [18] reported that alginate edible coating with 1% Trachyspermum ammi essential oil nano-emulsion decreased the highest Listeria monocytogenes bacteria during storage. On the other hand, the structure of nanoparticles in essential oils can increase the antibacterial activity. The alginate edible coating with cumin essential oil nano-emulsion significantly increases the shelf life of turkey fillets stored in the refrigerator. Wu et al. [19] chitosan-based nanoemulsion affects the size of drops, stability, and rheological properties, which directly affect the physiochemical properties of fish. The nanoemulsion coating is effective in inhibiting microorganisms growth and biochemical changes in fish during refrigerator storage. The use of chitosan-based nanoemulsions can extend the shelf life of fish from 12 to 16 days. Sharifimehr et al. [23] studied the influence of Aloe vera and eugenol nano-emulsion on the physiochemical properties of shrimp. The nano-emulsion antioxidant activity increased rapidly with the increase in the added concentration of eugenol. Shrimp coated with nanoemulsion showed the lowest droplet loss of 2.89% after 7 days of storage. Weight loss was reduced from 61.52% to 27.7% in samples coated with nano-emulsi. The coating also inhibits water loss, weight loss, softening of the texture, and lipid oxidation.

3.4 Honey-based nano-edible coatings

The edible coating is typically applied to the surface of food and horticulture by dipping or spraying a coating solution on the surface, so it must be natural and safe for consumption. Stingless bee honey has natural antimicrobial activity, containing antioxidants and high secondary metabolic compounds [29]. Maringgal et al. [20] reported that CaO nanoparticle biosynthesis using Trigona SP honey has a significant effect on the decline in the growth of the mycelia Colletotrichum brevisporuum. Using CaO nanoparticles coated in 15% concentration, they showed the strongest protective effect against symptoms of anthracnose disease. Maringgal et al. [8] studied the effect of coating Kelulut honey nanoparticles on papaya during cold storage. Nanocomposite coating can reduce the amount of O_2 gas for respiration and limit CO_2 diffusion from fruit tissue, significantly reducing the rate of respiration and ethylene production. The layer of papaya surface showed closed stomata of the papaya skin, which causes delays in the ripening process. The coated papaya retains more of its total phenolic content than the control treatment.

3.5 Chitosan-based nano-edible coatings

Chitosan is a non-toxic polycationic heteropolysaccharide derived from the deacetylation of chitin bases that can be extracted from hard-shelled animals (crustaceans). Chitosan's antibacterial properties are due to its polymer structure, which contains a positively charged amine group, whereas other polysaccharides are neutral or negatively charged. Li et al. [4] reported that the preservation of cherry tomatoes using chitosan-nano-ZnO composite films effectively inhibits respiration and hydrolysis of carbohydrates into sugar. Composite films are also effective in reducing discoloration, slowing the ripening process, and inhibiting the synthesis of ascorbic acid. The addition of nano-ZnO to the film was effective in increasing mechanical properties and antimicrobial activity.

Esmaeili et al. [5] reported that the coating of chitosan nanocomposite and Lepidium sativum seed gum increases antioxidant activity, thereby reducing the oxidation reaction of beef. Nanocomposite coating can increase antibacterial activity and reduce the value of TVB-N beef. Noshirvani et al. [9] developed nanocomposite packaging with carboxymethyl cellulose-chitosan-ZnO-NPs to increase the shelf life of bread. The presence of an active layer can help increase the water content of bread by limiting water vapor migration to the environment. The addition of 2% nanocomposite coating CM-CH-OL-ZnO-NPs increased antimicrobial activity, effectively inhibiting fungal growth and increasing bread shelf life from 5 to 28 days at 25°C storage temperatures. Sami et al. [16] the effect of nisin, nanosilica, and chitosan coating on the oxidation process of button mushrooms was investigated. The combination coating significantly influences peroxidase activity and avoids melanin synthesis in the fungus. This is because a combination coating can inhibit the rate of mushroom's respiration and increase antioxidant activity. The coating also effectively reduces microbial contamination and damage, improves post-harvest quality, and extends button mushroom shelf life.

4 Conclusion

Over the past few years, several types of edible coating materials have been investigated for food preservation and horticulture. Several modifications of edible functional additives by integrating nanoemulsions, nano polymers, nanofibers, lipid nanoparticles, and polymer nanocomposites have also been extensively developed for coating formation. However, most of the coating systems are still on a laboratory scale. Further research is needed that focuses on a commercial scale so that the information received is more realistic and can be carried out to commercialize food and horticulture coated with a nano-edible coating. The use of nanotechnology in developing nano-edible coating is the hope of extending shelf life, maintaining quality, and preventing food and horticultural spoilage.

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