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Laras Putri Wigati
Faculty of Agriculture, Kyushu University

Tanaka, Fumina
Faculty of Agriculture, Kyushu University

Tanaka, Fumihiko
Faculty of Agriculture, Kyushu University

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Essential Oils in Starch-based Edible Coatings for Fruit-storage Applications: A Mini Review

Laras Putri Wigati^{1,2}, Fumina Tanaka¹, Fumihiko Tanaka¹

¹ Faculty of Agriculture, Kyushu University, 744, Motoooka, Nishi-ku, Fukuoka-shi, Fukuoka 819-0395, Japan

² International Research Fellow of Japan Society for Promotion of Science (JSPS), Postdoctoral Fellowship for Research in Japan (Standard)

Corresponding author email: wigati.putri.laras.820@m.kyushu-u.ac.jp

Abstract:

Plastic food packaging, including fruit packaging, is difficult to recycle and takes time to decompose. Moreover, plastic pollution is challenging to eliminate and poses a long-term threat to soil and water. Consuming plastic contaminated food can have detrimental effects on human health. Many studies have attempted to develop a surface-contact packing known as an edible coating. The edible coating can protect fruit from contaminants and microorganisms that reduce quality and quantity. This review investigates technological challenges, including the choice of coating materials, application methods, and factors affecting quality, quantity, and nutrition. Current improvements in coating technology, especially the use of essential oils (EOs) and starches to extend fresh fruit storage life, are also investigated.

Keywords: Edible Coating; Essential Oil; Starch; Storage; Quality

1. INTRODUCTION

Food packaging, including for fresh produce such as fruits, has become a problem for the environment because plastic packaging is difficult to recycle and takes a long time to decompose. For example, persistent plastic pollution poses a significant and lasting risk to soil and water, as it can be difficult to eradicate completely [1]. In addition to environmental impacts, human health can be affected if food becomes contaminated with plastic and is consumed by humans [2]. Fifty percent of packaging produced worldwide is used for food products [3]. However, with time and greater public awareness, environmentally safe, biodegradable, and sustainable packaging is becoming more popular [4].

The packaging of food products, especially fresh fruit, is a critical issue because packaging protects features other than just the fruit peel. Indeed, packaging aims to prevent external environmental conditions, contamination, and microorganisms from reducing the quality and quantity of the whole fruit. The Food and Agriculture Organization (FAO) reports that approximately 45% of freshly harvested fruit is lost owing to inadequate post-harvest processing, including incorrect packaging. Food loss constitutes a reduction in the quantity of consumable food at many stages of the supply chain, including production, post-harvest, and consumption [5].

Recently, packaging that makes direct contact with the surface has been developed, and many studies have attempted to develop this technology. We can refer to this packaging as an ‘edible coating,’ a thin layer that is both edible and environmentally friendly. The coating primarily consists of consumable substances derived from plants, grains, and marine-derived materials and provides a barrier against gases, microbes, and moisture in food products [6,7].

This study focuses on technological issues, including coating materials and application techniques, as well as their impact on quality, quantity, and nutrition. It also examines current advances in the use of essential oils (EOs) and starches in coating technology to extend the storage life of fresh fruits.

2. METHODOLOGY

This literature review was conducted in July 2024. The studies discussed in this article are reviews that discuss and analyze the results of previous research. The studies cited in this article are limited to those referring to edible coatings made with various types of starch and the use of EOs as additive ingredients to maintain the storage life of post-harvest fruits. The data used in this review were collected from secondary sources by searching for international articles in Scopus.

The steps for preparing the article review were as follows: Step 1: Search, collect, and identify research articles using the Scopus software. Step 2: Research and data analysis. Step 3: Draft and finalize the manuscript.

3. RESULTS AND DISCUSSION

3.1 Essential oils and their relationship with foods

Essential oils are blends of volatile compounds obtained from many plant sources, including flowers, fruits, seeds, roots, leaves, and bark [7], [8]. Essential oils are extracts derived from natural raw sources, such as plants. These materials are processed into EO using methods such as steam distillation, mechanical extraction from fruits, and dry distillation [8]. Important discoveries have been made regarding the various types of EOs. It has been shown that some EOs possess antioxidant, antimicrobial, and anesthetic properties. This is due to the presence of physiologically active and beneficial components in the oils. Furthermore, some EOs are employed for their antibacterial, fungicidal, insecticidal, herbicidal, nematocidal, anti-inflammatory, and

antioxidant properties [9]. Many of them have been commercially exploited and used as taste enhancers in foods and beverages, condiments, and cosmetics. Thus, EOs may be found in food preservatives, fragrances, and aromatherapy products [10].

As mentioned above, EOs are used in food handling and processing. Even when crops are in the ground, EOs can be used to control a wide variety of pests. These pesticides are natural substances and proven to be as effective as chemical-based or synthetic alternatives. Essential oils are mostly used as pesticides in organic cultivation [11–13]. They serve as substitutes for well-known synthetic preservatives. Food preservatives made from EOs can enhance food storage life and the original physical, biochemical, and microbiological characteristics of the product. Notably, EOs are widely used for fruits, vegetables, and seafood [14–17].

3.2 Edible coating for fresh fruits

After harvesting, fruits continue to undergo metabolic processes, including respiration. Their quality, including nutritional value, taste, and visual appeal, declines during storage and transportation due to factors such as dehydration, discoloration, and decomposition [18–20]. Fruit is a perishable agricultural product; hence, there is a need for protection from unwanted negative environmental effects and factors that can accelerate fruit damage [21] post-harvest or until the fruit reaches consumers. Various packaging technologies can protect the fruits from damage, and one option is edible coating. This method can maintain the storage life of post-harvest products, including fruits; thus, in addition to preserving the quality of the product, it can extend its marketing period and prevent further losses [22]. To maintain the quality and freshness of fruit products, respiration must be controlled [23].

An edible film or coating refers to any material used to enrobe (cover or wrap) food to prolong its storage life. This material can be removed or consumed along with the product. Edible films serve as substitutes or enhancements to prevent moisture loss and control the interchange of vital gases, including carbon dioxide, ethylene, and oxygen, which play a role in respiration processes using natural layers (see Fig. 1). Films or coatings also offer surface sterility and prevent the loss of other crucial components. Typically, the film thickness is below 0.3 mm [24].

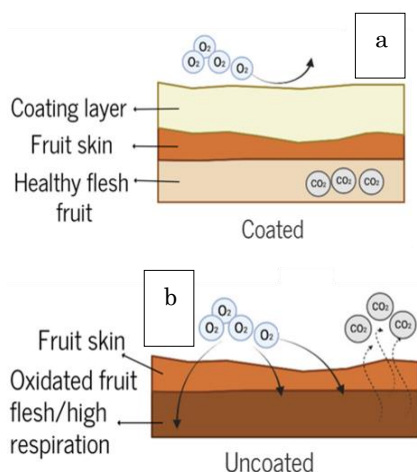


Fig. 1. Illustration fruit surface with coating (a) and without coating (b).

Edible coatings are usually applied to products by dipping, spraying, brushing, extrusion, panning, or solvent casting techniques (see Fig. 2). The most frequently used application methods are dipping and spraying, due to their exceptional convenience. Dipping is a coating method that has been employed since the 12th century. The process is simple and efficient. The product is immersed in the coating solution for a designated time, drained, and allowed to dry prior to storage [25].

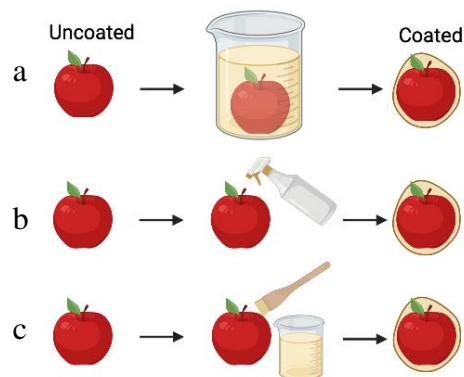


Fig. 2. Illustration edible coating application methods: dipping (a), spraying (b), brushing (c).

3.3 Starch for main material edible coating

Edible coatings require vital components derived from biopolymers. Biopolymers can function either as the sole material or in conjunction with other biopolymer materials. The physical and chemical properties of the biopolymers significantly influence the coating and film. In addition, these materials may possess hydrophobic or hydrophilic properties. Water and ethanol are the only liquids allowed in the production of edible coatings [26,27].

The main categories of materials used in the production of edible coating films are listed in Table 1 [27].

Table 1. Edible coatings and films material sources

Materials	Derivatives
Proteins	Corn zein, collagen, rice bran, peanut protein, gelatin, casein, whey protein, wheat gluten, soy protein, keratin, protein, cottonseed protein.
Polysaccharides	Regular and modified starch.
Modified cellulose	Alginate, pullulan, carboxy methylcellulose (CMC), methylcellulose (MC), hydroxypropyl (HPC), hydroxypropyl methylcellulose (HPMC), xanthan gum, pectin, chitosan, gellan gum.
Lipids	Paraffin, beeswax, rice bran wax, carnauba wax.
Resins	Terpenes, acetoglycerides, shellac.
Plasticizers	Water, glycerin, corn syrup, sucrose, propylene glycol, sorbitol, polyethylene glycol.

Materials	Derivatives
Functional additions	Flavors, antimicrobials, medicines, antioxidants, nutrition, and colors.
Additional substances	Tweens, Spans, Lecithin, lipid emulsions e.g. fatty acids, edible waxes.

Edible coatings are often made from starch and its derivatives. Starch is cost-effective compared with other materials that typically have a high tensile strength. Using cornstarch with a high amylose concentration enhances the properties of the resulting film. Combining chemicals and acid hydrolysis with amylose-containing starch enhances the transparency and flexibility of edible films. Additionally, glycerin and polyhydric alcohols can be used as plasticizing agents to enhance the characteristics of edible films and their ability to provide protective barriers [28].

3.4 Application of essential oil and starch edible coating to preserve fresh fruit and extend storage

3.4.1 Preserving strawberries using jicama starch and agarwood edible coating made with *Aetoxylon bouya* essential oil

An investigation was conducted to examine the impact of four edible coatings composed of different combinations of three ingredients: 1) jicama starch (SJ); 2) agarwood *bouya* essential oil (AB); and 3) calcium propionate (CP) on the preservation of strawberries over a 16-day cold storage period. The coating combinations were SJ, SJ-AB, SJ-CP, and SJ-AB-CP, which were applied by dipping. Strawberries covered in a layer of coating and fruits without coating were simultaneously placed in airtight containers and stored in an incubator at a temperature of 4°C and 85% relative humidity (RH). Antifungal assessment of the coating solutions was performed using membrane permeability and germination of *Botrytis cinerea*. Atomic force microscopy was used to analyze the surface characteristics of the edible films. Additionally, fresh fruits were tested at 4-day intervals to evaluate surface color, weight loss, firmness, and surface characteristics using scanning electron microscopy (SEM) and antifungal activity. Furthermore, the physicochemical properties of strawberry juice, that is, titratable acidity, total soluble solids, citric acid, and pH, were analyzed.

Subsequently, each outcome was evaluated using TOPSIS-Shannon entropy analysis. Based on this analysis, the edible coating with ST-ES yielded the most favorable results. A consistency index (Ci) score of 0.839 was achieved, which was higher than that of the untreated and treated samples. Furthermore, the score surpassed that of the fruit without any coating, indicating that the coating effectively preserved the quality of strawberries during storage. On the last day of storage, the ST-ES samples had the following measurements: L^* value of 30.9, a^* value of 26.65, b^* value of 16.36, and a total soluble solids content of 3.98 °Bx [29].

3.4.2 Pre-gelatinized corn starch/basil essential oil application to prevent loss of quality in oranges

Edible coating solutions were developed using the Pickering emulsion method and included pre-gelatinized

corn starch (PS), basil essential oil (BO), and cellulose nanofibers (CN). Solution characteristics such as emulsion stability, pH, viscosity, and oil droplets were measured. Additionally, the surface microscopy, contact angle, moisture content, and thermal properties of the resulting edible films were analyzed.

The dipping method was used to coat orange fruits with the various solutions, and the quality criteria (citric acid, weight loss, pH, surface color, and ascorbic acid) were tested throughout a 12-day storage period at room temperature. The pregelatinized maize starch was formulated at concentrations of 4% and 5%, BO at concentrations of 2% and 3%, and CN at a concentration of 0.5%.

The study findings indicate that a blend of PS and BO could be suitable for the development of a coating to preserve the overall quality of oranges. Specifically, the BO3PS4 and BO3PS5 samples showed the potential to maintain the storage life of oranges. The coated fruits in these treatments experienced a weight loss of 19.81% for BO3PS4 and 20.11% for BO3PS5, compared with the control samples, which had a weight loss of 24.41%. In terms of quality preservation, the L^* (lightness) value of the fruit surface, particularly on the 12th day, was 54.78% (BO3PS4), while BO3PS5 was 56.73%, which was greater than the control value of 53.01% [30].

3.4.3 Edible coating application made from modified sweet potato starch/cumin essential oil for maintain the storage life of pears

An edible solution was prepared using modified sweet potato starch (PS) and cumin essential oil (CO). The effect of the coating on the physicochemical-sensory characteristics of pear fruit (early crisp) was assessed using the dipping method. The fruit was stored at a setting temperature of 25°C for 28 days. The results showed that the addition of 0.2~0.4% (v/v) CO to edible coatings with modified sweet potato starch resulted in a significant ($p < 0.05$) reduction in pear damage due to infection, especially the rot disease caused by *Alternaria alternata*. The coating delayed changes in fruit quality, i.e., firmness, color, and chlorophyll degradation.

Application of the coating greatly reduced the occurrence of increases in respiration and limited the amount of weight lost by the pear samples. The stomatal density in the coated pear was effectively maintained. In general, edible coatings with antifungal properties enhance the quality of pears during storage and preserve their market value as well as their superior sensory characteristics compared to the uncoated samples. Incorporating 0.2–0.4% (v/v) CO into modified PS could serve as an effective preservation technique to mitigate losses in post-harvest pears and promote sustainability in future agricultural [31].

3.4.4 Cassava starch as a coating material and the encapsulation of essential oil for mango

This study aimed to assess the effectiveness of cassava starch coatings containing *Salvia sclarea* L. essential oil (encapsulated), in preserving 'Palmer' mangoes after harvest. The coatings were applied using a dipping method. The experiment was conducted at three different oil concentrations (0.30%, 0.60%, and 0.90% m/m) mixed with 4% cassava starch (m/v). The coated fruits were dipped in a mixture of canola oil and 4%

cassava starch (m/v), and the control groups had no coating (SR).

The quality of post-harvest fruits was assessed by measuring firmness, weight loss, soluble solids, fruit color, titratable acidity, pH, carotenoid content, and chlorophyll levels of vitamin C. The coating acted as a barrier to the exchange of gases, resulting in a reduction in titratable acidity, peel firmness, weight loss, soluble solids, chroma (both in the peel and pulp), total chlorophylls, and carotenoids. The 0.30% m/m coating formulation showed the most favorable outcome. The growth of harmful bacteria was effectively suppressed on all coated fruits, but not on the uncoated controls, demonstrating antifungal activity at all concentrations. Therefore, the application of an edible coating containing *S. sclarea* essential oil was found to slow the ripening process of mango (Palmer) fruits. This coating presents a viable replacement for chemical agents used post-harvest to maintain quality and is likely to be well received by consumers [32].

3.4.5 Guava fruit coated with an edible starch made from mango kernel seeds and lemongrass essential oil

A novel edible coating was created using seed starch from mango kernels (SS) mixed with varying amounts of lemongrass essential oil (LO). This study examined the effects of different formulations of edible coating solutions on the microbiological, physicochemical, and physiological characteristics of fresh guava fruit during storage. The tested formulations were T-1 (2% SS), T-2 (2% SS and 0.25% LO), T-3 (2% SS and 0.5% LO), and T-4 (2% SS and 1% LO). Guava fruits were stored at 23 ± 2 °C with RH of $85 \pm 5\%$ for a maximum of nine days. The guava fruits were coated using a dipping method. This study indicates that the use of coatings made from SS and LO successfully extended the storage life of guava fruits while preserving their quality parameters. The application of LO 0.5% (T-3) with SS was the most promising treatment for reducing both the oxidation rate and weight loss of the stored guava fruit samples. This treatment also maintained physicochemical properties, including total soluble solids, acidity, physical properties, sensory profiles, and phenolic content. The T-4 treatment showed a similar but slightly less significant effect. The T-3 and T-4 treatments also reduced yeast and mold growth. All coating treatments effectively increased the storage period of guava fruits by maintaining post-harvest quality features for nine days of storage. In addition, the T-3 treatment improves fruit quality [33].

3.4.6 Incorporating apricot oil into a tamarind starch/gelatin-based edible covering to extend grape storage life

Edible coatings containing tamarind seed starch (TS), gelatin (GL), and 1% apricot essential oil (AO) were used to coat freshly harvested grapes. This study investigated the influence of coatings on the physicochemical characteristics at room temperature throughout 20 days' storage period in a refrigerator. A range of films with different TS/GL ratios (1:5, 1:4, 1:3, 1:1, 3:1, 4:1, and 5:1) were prepared. Among all the mixtures evaluated, the 1:1 TS:GL formulation was determined to be the most suitable for future studies.

It has a low water vapor permeability, high tensile strength, low solubility, and low moisture content.

The physicochemical parameters of the coated grapes, including total acidity, total soluble solids, weight loss, and color, were assessed. During a 20-day period of refrigerated storage, coated grapes demonstrated a superior storage period and quality of physicochemical alterations compared to uncoated grapes. After 20 days of storage in a refrigerated environment, the weight losses of the coated and uncoated grapes were 7.17% and 18.61%, respectively. At room temperature, the weight losses of the coated and uncoated grapes were 41.55% and 56.59%, respectively. The hardness of the coated samples decreased by 31.42% and 38.06%, whereas the firmness of the uncoated samples decreased by 62.78% and 62.84%, respectively, after 20 days of storage at ambient and refrigeration temperatures.

Tamarind seed starch exhibited antibacterial properties that were further enhanced by the addition of 1% AO. The presence of apricot oil increased the inhibition zone of the film to 2.4 cm, compared with 2.0 cm for the blank sample, thereby improving its antimicrobial effectiveness. In addition, the inclusion of apricot oil extended the storage life of the film. The use of 1% apricot oil in TR/GE-coated grape samples resulted in accelerated degradation when stored at room temperature [34].

4 CONCLUSION

Various edible coating materials have been investigated for their potential use in fruit protection. The process of coating development has been studied extensively by combining different types of starch and EOs to improve the functionality. Nevertheless, most coating techniques are limited to laboratory settings. Additional investigations are required to concentrate on large-scale operations to obtain more accurate data and facilitate the commercialization of fruits coated with starch and EOs. The utilization of cost-effective and readily available materials, such as starches and many other components, has the potential to prolong the period of product storage, preserve quality and quantity, and minimize fruit loss and waste.

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