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Effect of alginate and propolis-based edible coating on moisture loss and microbial status of raspberries, cherries, and blueberries during storage

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Abstract. Raspberries, strawberries, and cherries are among the most perishable fruits in terms of moisture loss and microbial spoilage during storage, especially at room temperature. The present study aims to evaluate the effect of an edible sodium alginate-based coating, applied alone or in combination with a glycerol extract of propolis, on moisture retention and microbial stability in these three fruit types. For each fruit group, three samples were prepared: a control (without coating), a sample with alginate coating, and a sample with alginate and propolis extract. The fruits were stored at room temperature for a period of 168 h. Moisture loss was monitored daily, and at the end of the storage period, the total count of aerobic mesophilic microorganisms was determined. Soft fruits such as raspberries, strawberries, and cherries are highly valued by consumers for their fresh taste, rich content of bioactive compounds, and beneficial health properties. However, these fruits are extremely susceptible to mechanical damage, moisture loss, and microbial contamination, which significantly limit their postharvest shelf life. When stored at room temperature, moisture loss leads to fruit shrinkage, loss of freshness and texture, while microbial growth accelerates spoilage and decay processes.

1 Introduction

The issue of post-harvest losses in fruits and vegetables has emerged as a significant global challenge, affecting both industrialized and developing nations. Due to their inherently perishable nature—attributable to specific morphological and physiological characteristics—these products can experience losses amounting to approximately 40%–44% of the total yield [1]. The economic impact of such losses is substantial, with estimated annual costs reaching USD 750 billion, posing a serious threat to global food security, particularly in low- and middle-income countries [2].

In an effort to reduce postharvest losses, recent years have seen growing interest in the use of edible coatings as a natural alternative to synthetic preservatives. Alginate, a naturally occurring polysaccharide derived from brown seaweed, is characterized by its excellent film-

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forming ability and moisture retention properties, making it well-suited for application on fresh fruits. Moreover, the incorporation of natural additives such as propolis—a bee-derived substance with well-documented antimicrobial and antioxidant properties—can further enhance the protective function of the coating.

Owing to their remarkable characteristics—such as renewability, biocompatibility, biodegradability, antimicrobial properties, gelation ability, and ease of processing—alginates have garnered extensive attention and application across a variety of scientific and industrial domains, including tissue engineering, drug delivery systems, wound healing, textiles, cosmetics, and food science [3].

Within industrial contexts, alginates are frequently utilized as stabilizing and thickening agents, as well as antimicrobial coating materials in food processing technologies. Their inherent biodegradability renders them particularly suitable for developing active packaging films in both the food and pharmaceutical industries. Additionally, recent investigations have explored the potential of alginate-based materials in various non-food applications such as electrode surface modification, environmental pollutant removal, and immobilized cell fermentation systems [4].

In the field of food preservation, alginate-based coatings have been successfully employed to maintain quality and extend the shelf life of perishable items, particularly by enabling the controlled release of embedded bioactive substances. These coatings have been shown to reduce spoilage, limit food waste, and contribute to the prevention of foodborne illnesses and product recalls. In line with this, recent research has turned toward the use of polysaccharides enriched with functional compounds for improving the postharvest stability of fruits and vegetables [5].

The growing environmental concerns related to plastic pollution have intensified the search for sustainable packaging alternatives, positioning edible coatings and films as environmentally friendly and multifunctional solutions. A recent systematic review indexed in Scopus highlights significant advancements in edible packaging technologies, with a focus on novel biopolymer-based systems, nanotechnology integration, and the development of active packaging strategies. Particular attention is given to natural polymers such as chitosan, starch, alginate, and various proteins, which are frequently blended or chemically modified to enhance their mechanical strength, barrier efficacy, and biodegradability. Moreover, the inclusion of bioactive agents – such as antioxidants, antimicrobials, and nutraceuticals—further enhances the preservation capabilities, microbial safety, and shelf-life of packaged foods [6].

Among the natural polymers, alginate and gelatin are among the most widely used biopolymers for edible coatings in food products. Alginate-based films are recognized for their excellent oxygen barrier properties and optical transparency; however, their hydrophilic nature limits their resistance to moisture. Nevertheless, alginate's versatility allows for blending with other biopolymers to improve water resistance and barrier characteristics, and it serves as an effective matrix for incorporating bioactive compounds, thereby advancing its functionality in packaging applications [4].

Empirical studies have demonstrated the successful application of edible alginate-based coatings in preserving the freshness and quality of a wide range of fruits, including bananas, litchis, strawberries, blackberries, peaches, and mandarins [5]. The effectiveness of these coatings has been substantiated through evaluations of various functional properties, including mechanical properties, antifungal activity, antimicrobial action, and antioxidant capacity [3].

According to Sambou et al. [7], propolis is a resinous substance produced by bees through the combination of plant resins – collected from leaves, flower buds, stems, and bark fissures – with their saliva and beeswax. This complex mixture serves as a structural and defensive material within the hive and has attracted considerable scientific interest due to its diverse bioactive properties.

Propolis is widely acknowledged for its broad spectrum of therapeutic effects, including antibacterial, antioxidant, antifungal, anti-obesity, and anticancer activities, among others [8, 9]. These multifunctional properties have positioned propolis as a promising natural additive for use in food preservation and biomedical applications.

As of July 2025, the scientific literature reflects growing interest in the integration of propolis into edible coatings for food applications, with more than four peer-reviewed articles indexed in the Scopus database focusing specifically on this topic [10, 11]. This growing body of research underscores the potential of propolis as a bioactive component in sustainable food packaging technologies. The effectiveness of biological activities exhibited by propolis varied in different countries due to varying geographical areas, seasonality, vegetation sources, bee species, and collecting seasons [12,13].

A comprehensive study was conducted between 2020 and 2022, examining eighty propolis samples collected from all twenty-eight districts of Bulgaria to assess their physicochemical composition as well as antioxidant and antimicrobial potential [14]. The total phenolic content (TPC) of the samples ranged from 63.14 mg GAE/g to 737.27 mg GAE/g, while the total flavonoid content varied from 29.22 mg QE/g to 234.17 mg QE/g. The samples exhibited notable antioxidant activity, and antimicrobial screening revealed that methanolic extracts at a concentration of 20 mg/mL were particularly effective against Gram-positive bacteria, demonstrating strong inhibitory effects.

The present study aims to evaluate the effect of an alginate-based edible coating, as well as its combined application with a glycerol extract of propolis, on moisture retention and microbial stability in raspberries, strawberries, and cherries stored at room temperature (26.4 – 27.4°C) over a period of 168 h.

This study seeks to assess the efficacy of natural composite coatings as a potentially sustainable approach for extending the shelf life of highly perishable fruits under suboptimal storage conditions.

2 Materials and methods

The study utilized fresh soft fruits – cherries (*Prunus avium* L.), blueberries (*Vaccinium corymbosum* L.), and raspberries (*Rubus idaeus* L.) – all classified as Class I and sourced from the Bulgarian commercial market. Fruits were purchased in polyethylene terephthalate (PET) containers. Sodium alginate (plant-derived, E401, batch No 0253, France) was used as the base material for the edible coatings. A local Bulgarian manufacturer supplied Glycerol (99% purity).

The propolis used in the present study for the preparation of the glycerine extract was sourced from central Bulgaria and underwent chemical characterization to determine its antioxidant and antimicrobial properties. Microbiological assessment of the raw propolis indicated the presence of mesophilic bacteria, while yeasts and moulds were not detected. Phytochemical analysis identified a diverse range of compounds, with flavanones and flavones being predominant, followed by hydrocinnamic acids and esters, monosaccharides, benzoic acids, alcohols, fatty acids, and various organic acids. The corresponding tincture prepared from this sample was found to contain 18.48 mg GAE/g of total phenolic compounds, confirming its functional potential for incorporation into edible coatings [15].

2.1 Preparation of Propolis Extract

Two concentrations of glycerol-based propolis extract were prepared. A 70:30 (v/v) glycerol-to-distilled water mixture served as the solvent, chosen to enhance the solubility and extraction of a broad spectrum of polar and semi-polar compounds.

The first extract was prepared using a 1:10 (w/v) ratio of propolis to solvent, while the second followed a 1:5 (w/v) ratio. In both cases, the mixtures were sealed in amber glass flasks and stored at 40°C in a thermostatic chamber for 7 days, with intermittent agitation to facilitate extraction. The resulting extracts were filtered and stored under refrigeration until further use.

2.2 Preparation of Sodium Alginate and Coating Solutions

A 0.5% (w/v) sodium alginate solution was prepared by dissolving 0.5 g of sodium alginate in 99.5 mL of distilled water at 40°C. The solution was stirred continuously with a glass rod until homogeneous and subsequently refrigerated at 6°C for 4 h to allow air bubbles to dissipate. Two additional formulations were developed by incorporating propolis extract into the alginate solution: Alginate + 5% 1:10 propolis extract**, and Alginate + 5% 1:5 propolis extract. For each, 1 mL of the appropriate extract was mixed into 19 mL of the sodium alginate solution, yielding a final 5% (v/v) concentration of propolis extract in the coating matrix.

2.3 Organoleptic Evaluation of Coating Films

To assess sensory and physical properties, 10 mL of each solution (alginate only and the two alginate-propolis mixtures) was poured into glass Petri dishes and dried at room temperature (26–27 °C) for 7 days. The resulting films were subjected to an organoleptic evaluation based on the following parameters: color, odor, surface texture, presence of defects (e.g., air bubbles, cracks), and degree of dryness. Each criterion was scored on a 3-point scale: 1 - Unsatisfactory; 2 - Satisfactory but improvable; 3 - Fully satisfactory. The results are presented in Fig. 1.

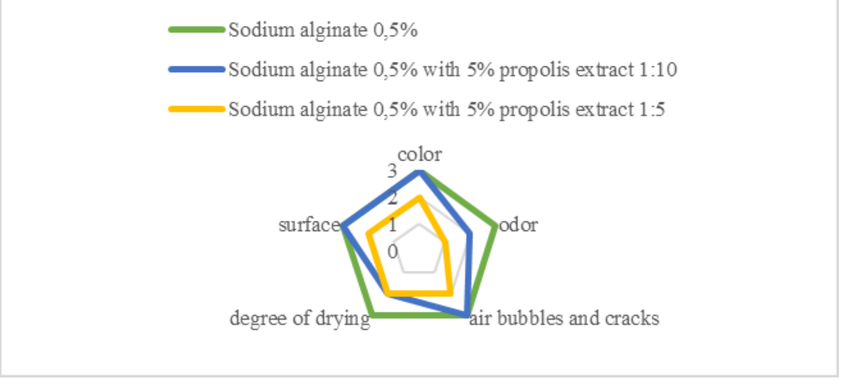

Fig. 1. Sensory analysis of edible food coatings

The coating prepared with the 1:5 propolis extract exhibited a dark brown color and strong odor, and showed incomplete drying and a tacky surface. Based on these findings, this formulation was excluded from further application. The 0.5% alginate coating and the 5% 1:10 propolis extract–enriched alginate coating were selected for subsequent experiments.

2.4 Sample Preparation

Nine experimental groups were prepared (three per fruit type) as follows: untreated (control); coated with 0.5% sodium alginate; coated with alginate + 5% 1:10 propolis extract.

Fruits were dipped into their respective coating solutions for 30 s, allowed to drain for 1 h on a grid at room temperature (26–27°C), and then weighed to determine coating mass retention.

Moisture loss was monitored at 24-h intervals over 168 h. After the storage period, all samples were subjected to microbiological analysis to determine the total viable count (TVC), following ISO 4833-1, targeting aerobic mesophilic and facultative anaerobic microorganisms incubated at 30°C.

3 Results and discussion

Coating application resulted in a measurable weight increase: Raspberries: +1.9% (alginate), +3.89% (alginate + propolis extract); Blueberries: +1.19% (alginate), +3.01% (alginate + propolis extract); Cherries: +0.41% (alginate), +0.26% (alginate + propolis extract).

Moisture loss measurements were taken every 24 h over a period of 7 days. The results are presented in Fig. 2, 3, and 4.

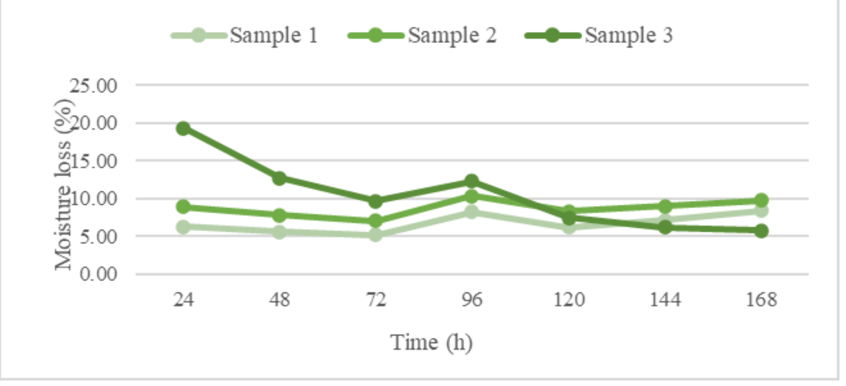

Fig.2. Moisture loss of raspberries during storage

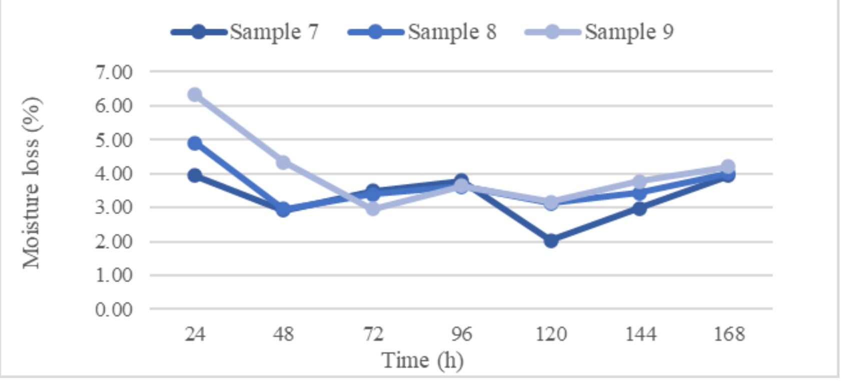

Fig. 3. Moisture loss of blueberries during storage

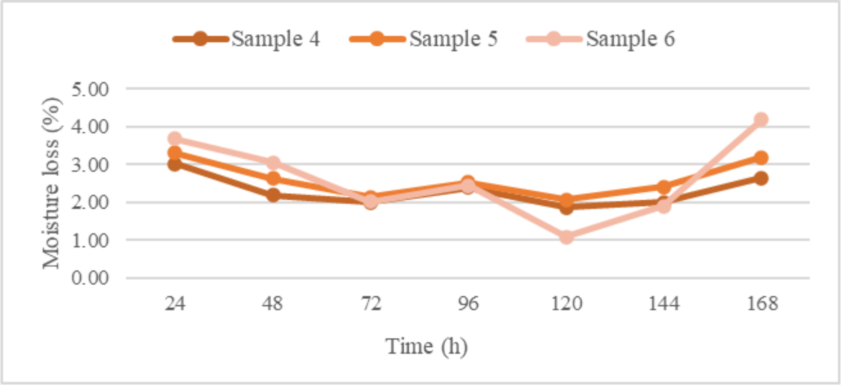

Fig. 4. Moisture loss of cherries during storage

Results showed that samples with propolis extract lost moisture faster than untreated or alginate-only samples, especially within the first 48 h. A sharp drop occurred at 72 h, followed by increases at 96 h. For raspberries, moisture loss stabilized after 96 h, while blueberries and cherries showed a dip at 120 h and another peak at 144–168 h. The highest losses were seen in coated raspberries with propolis; the lowest in untreated fruits. Raspberries exhibited the highest cumulative moisture loss (up to 73.64%), while cherries showed the least (16.33–18.4%).

After 168 h, all samples underwent microbiological analysis. Results presented in Table 1 revealed significant variation in total viable counts. The coating enriched with propolis extract exhibited potential antimicrobial effects, particularly in raspberries and blueberries.

Table 1. Results from laboratory investigation for TCM in CFU/g

	Natural fruit	**Fruit with alginate coating**	**Fruit with alginate coating with propolis extract**
Raspberries	$5.1x10^7$	$6.1x10^6$	$9.6x10^6$
Cherries	10	$1.x10^3$	$21.8x10^3$
Blueberries	$3.3x10^2$	$5x10^3$	9

4 Conclusion

The use of sodium alginate-based edible coatings did not significantly reduce moisture loss in soft fruits stored at room temperature. Moreover, the incorporation of glycerin-based propolis extract appeared to accelerate the rate of moisture evaporation. While propolis extract may enhance the antimicrobial efficacy of the coating, higher concentrations adversely affected the sensory properties of the film. It is also important to consider the method of coating application and the structural characteristics of the fruit, as excessive coating accumulation can lead to increased surface moisture retention.

Despite these limitations, biopolymer-based edible coatings remain a promising and sustainable strategy for extending the shelf life of perishable fruits under ambient storage conditions.

Future studies will optimize coating application methods and alginate concentrations across different fruit types to account for surface characteristics and enhance preservation efficiency.

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