Review Article

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Possibilities to Extend the Shelf Life of Citrus Fruits with Natural Rosin Coating, Benefiting from Forest By-Products Review

Orman Yan Ürünlerinden Yararlanarak Doğal Rosin Kaplama ile Narenciye Meyvelerinin Raf Ömrünü Uzatma Olanakları İncelemesi

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ABSTRACT:
The current study examines using a biodegradable rosin coating derived from forest products to extend the shelf life of lemon fruits. Recent research findings show that rosin-coated lemons exhibit significantly lower moisture loss and maintain higher water activity levels compared to uncoated control samples. This suggests that the rosin coating effectively acts as a moisture barrier, reducing dehydration. Additionally, the Brix levels in coated lemons remain stable throughout the storage period, while the control group experiences a notable decline. The pH levels also indicate that the rosin coating helps preserve the acidity of lemons, which is crucial for their preservation. The coated samples retain firmness better and exhibit significantly lower weight loss compared to the control group. The effectiveness of the rosin coating in reducing physiological and biochemical degradation is highlighted. Sensory evaluations reveal that rosin-coated lemons possess superior visual appeal, texture, and overall acceptability compared to uncoated control samples. Due to the extended shelf life and improved quality, potential consumer preferences for rosin-coated lemons are indicated. Overall, the application of rosin coatings significantly extends the shelf life of lemons by preserving quality attributes under various storage conditions. This study demonstrates the potential of biodegradable rosin coatings as an effective method for preserving citrus fruits, reducing postharvest losses, and enhancing marketability.

KEYWORDS: *Citrus fruits, coating, rosin*

ÖZ:

Mevcut çalışma, limon meyvelerinin raf ömrünü uzatmak amacıyla orman ürünlerinden elde edilen biyolojik olarak parçalanabilen bir reçine kaplamanın kullanımını incelemektedir. Son araştırmaların sonuçları incelendiğinde; reçine kaplı limonların, kaplanmamış kontrol numunelerine göre önemli ölçüde daha düşük nem kaybı sergilediği ve daha yüksek su aktivitesi seviyelerini koruduğu gösterilmektedir. Bu durum, reçine kaplamanın etkili bir şekilde nem bariyeri görevi görerek dehidrasyonu azalttığını

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öne sürmektedir. Ayrıca kaplamalı limonlardaki brix seviyelerinin depolama süresi boyunca sabit kaldığı, kontrol grubunda ise kayda değer bir düşüş yaşandığı belirtilmektedir. Ph seviyeleri de reçine kaplamanın limonların asitliğini korumaya yardımcı olduğunu ve bunun da limonların korunması için çok önemli olduğunu göstermektedir. Kaplanmış numunelerde limonların sertliğinin daha iyi korunduğu ve kontrol grubuna göre önemli ölçüde daha düşük ağırlık kaybı sergilediği vurgulanmaktadır. Reçine kaplamanın fizyolojik ve biyokimyasal bozulmayı azaltmadaki etkinliği belirtilmektedir. Duyusal değerlendirmeler; reçine kaplı limonların, kaplanmamış kontrol numunelerine kıyasla üstün görsel çekiciliğe, dokuya ve genel kabul edilebilirliğe sahip olduğunu ortaya koymaktadır. Artırılmış raf ömrü ve kalitesi nedeniyle reçine kaplı limonlara yönelik potansiyel tüketici tercihleri öne çıkmaktadır. Genel olarak reçine kaplamanın uygulanmasının, farklı depolama koşullarında kalite özelliklerini koruyarak limonların raf ömrünü önemli ölçüde uzattığı gösterilmektedir. Bu çalışma; narenciye meyvelerinin korunması, hasat sonrası kayıpların azaltılması ve pazarlanabilirliğin artırılması için biyolojik olarak parçalanabilen reçine kaplamaların etkili bir yöntem olarak kullanılma potansiyelini göstermektedir.

Anahtar Kelimeler: *Turunçgiller, kaplama, reçine*

INTRODUCTION:

Citrus fruits, belonging to the Aurantoideae subfamily of the Rutaceae family, represent some of the most economically and nutritionally significant crops cultivated globally. Key species within this group include *Citrus limon* (lemon), *Citrus sinensis* (orange), *Citrus reticulata* (mandarin), and *Citrus paradisi* (grapefruit). These fruits are renowned for their rich nutritional profiles, containing high levels of essential vitamins, particularly vitamin C, minerals, dietary fiber, and a range of bioactive compounds such as flavonoids, carotenoids, and essential oils. These components contribute to numerous health benefits, including antioxidant, anti-inflammatory, and cardiovascular protective effects (Viuda-Martos et al., 2008).

The global citrus industry plays a pivotal role in the agricultural economies of many countries. In 2013, the worldwide production of citrus fruits surpassed 123 million tons, with China, Brazil, the United States, India, Mexico, and Spain emerging as the top producers (Palou et al., 2015). Citrus fruits are not only consumed fresh but are also processed into juices, oils, and various other value-added products, enhancing their economic importance. In Turkey, a significant player in the global citrus market, the production of lemons alone reached 750,550 tons in 2015, underscoring the crop's substantial contribution to the region's agricultural economy (Gemici, 2024).

Despite their high economic value and considerable health benefits, citrus fruits are highly perishable due to their elevated moisture content and delicate structure. This perishability leads to substantial postharvest losses, which can occur at various stages, including harvesting, transportation, and storage. Such losses present significant challenges to producers, distributors, and retailers, affecting not only economic returns but also food security and environmental sustainability. The high perishability of citrus fruits necessitates advanced postharvest handling techniques that focus on preserving the fruits' quality, extending their shelf life, and minimizing losses (Marmur et al., 2012).

Traditional postharvest methods such as refrigeration, chemical treatments, and synthetic coatings have been widely used to mitigate these losses. However, growing concerns over the environmental and health impacts of chemical residues, coupled with increasing consumer demand for natural and sustainable products, have driven the search for innovative alternatives. Among these, biodegradable and edible coatings derived from natural resources are gaining traction as a promising solution to extend the shelf life of citrus fruits while maintaining their quality.

The current study explores the potential of natural, biodegradable resin coatings, specifically derived from forest products, in enhancing the shelf life and marketability of citrus fruits, with a particular focus on lemons. By addressing the challenges of citrus perishability, the research aims to contribute to more sustainable practices in the postharvest management of these valuable crops.

1. Postharvest Challenges and Traditional Solutions

Postharvest losses in citrus fruits can be of physical, physiological, or pathological origin. Physical losses are often due to rind wounds or bruises caused during harvest, transportation, or handling. These injuries cause direct losses and serve as infection sites for fungal pathogens like Penicillium digitatum and Penicillium italicum, which cause green and blue molds, respectively(Palou, et al., 2015). Traditional methods to reduce these losses include cold storage and treatments with conventional chemical fungicides and synthetic waxes. However, the continuous application of these treatments has raised concerns about health and environmental issues associated with chemical residues and the proliferation of resistant pathogenic strains (Demirci, 2011).

2. Edible Coatings: An Innovative Solution

Edible coatings have emerged as a promising alternative to traditional postharvest treatments. These coatings act as barriers to moisture and gas exchange, slowing down respiration and senescence processes, and can be enhanced with active ingredients like antioxidants and antimicrobial agents further to improve fruit preservation (Ayana, et al., 2010).Research indicates that edible coatings can significantly improve various fruits' shelf life and quality by reducing moisture loss, maintaining firmness, and preserving nutritional and sensory attributes Coma, et al., 2002).

3. Types of Edible Coatings

Polysaccharide-Based Coatings: These coatings are made from materials such as alginate, chitosan, and starch. They are known for their ability to form films that reduce water loss and gas exchange, which are crucial for extending the shelf life of fruits (Kocira, et al., 2021).

Protein-Based Coatings: Proteins such as casein, soy protein, and gelatin are used to create these coatings. They provide good mechanical properties and can incorporate active compounds that enhance the preservation of fruits(Bhaskar, et al., 2023).

Lipid-Based Coatings: These include materials like waxes and oils. Lipid-based coatings are effective at reducing moisture loss due to their hydrophobic nature but may not always provide a good barrier to gas exchange (Demircan and Ocak, 2021).

Rosin-Based Coatings: Natural rosins, such as colophony (rosin), offer a sustainable alternative to petroleum-based paraffin coatings. Derived from pine trees, colophony provides a natural, biodegradable barrier that can help extend the shelf life of fruits by reducing moisture loss and protecting against microbial contamination (Peres,et al., 2015).

4. Active Ingredients in Edible Coatings

Edible coatings, which act as protective barriers on the surface of fruits, can be further enhanced by incorporating various active ingredients. These additions not only improve the physical properties of the coatings but also provide additional functional benefits, such as extending shelf life, preserving nutritional quality, and enhancing the overall health benefits of the coated fruits. The inclusion of active ingredients transforms these coatings from mere physical barriers into multifunctional systems that actively contribute to the preservation and improvement of the fruit's quality. Below are some of the key active ingredients that can be incorporated into edible coatings:

Antimicrobials:
The addition of antimicrobial agents is one of the most effective ways to reduce microbial spoilage, a leading cause of postharvest fruit losses. These agents work by inhibiting the growth of harmful bacteria, fungi, and yeasts that can cause decay and deterioration of the fruit. Common antimicrobials used in edible coatings include natural extracts such as essential oils (e.g., thyme, oregano, and clove oil), organic acids (e.g., citric acid, lactic acid), and bacteriocins like nisin. The incorporation of these compounds into edible coatings not only extends the shelf life of the fruit but also reduces the need for synthetic chemical preservatives, aligning with the growing consumer demand for natural and clean-label products. Furthermore, the use of natural antimicrobials can help in combating the rise of antimicrobial resistance, making them a safer and more sustainable option.

Antioxidants:
Oxidative degradation is a common issue in postharvest fruits, leading to the loss of essential nutrients, color changes, and the development of off-flavors. Antioxidants play a crucial role in preventing these oxidative processes by neutralizing free radicals and inhibiting enzymatic reactions that cause spoilage. Common antioxidants incorporated into edible coatings include ascorbic acid (vitamin C), tocopherols (vitamin E), polyphenols, and flavonoids. By adding these antioxidants to the coatings, the nutritional quality of the fruit is better preserved, ensuring that essential vitamins and bioactive compounds remain intact throughout storage. This not only maintains the fruit's health benefits but also enhances its visual and sensory appeal, making it more attractive to consumers (Tomás et al., 2001; Şen Arslan and Yerlikaya, 2023).

Nutritional Enhancements:

In addition to preserving the fruit's natural nutrients, edible coatings can also be fortified with additional nutrients, further enhancing the health benefits of the coated fruits. For example, coatings can be enriched with vitamins (e.g., vitamin D, B-complex vitamins), minerals (e.g., calcium, iron), and dietary fibers. This fortification can be particularly beneficial for fruits that are often consumed by health-conscious consumers, as it adds extra value to the product. Moreover, the incorporation of bioactive compounds, such as probiotics, prebiotics, and omega-3 fatty acids, can turn ordinary fruits into functional foods that offer additional health benefits beyond basic nutrition. These nutritionally enhanced coatings cater to the growing demand for fortified foods and functional products, making the fruits more appealing in the market (Aayush et al., 2022; Şen Arslan, 2023).

5. Application of Natural Rosin Coatings to Citrus Fruits

The current review highlights the application of biodegradable rosin coatings, specifically colophony derived from forest products, as an innovative solution to extend the shelf life of citrus fruits, with a particular focus on lemons. Rosin, a natural resin, has garnered attention for its ability to form a protective barrier on the surface of fruits, effectively reducing moisture loss and preserving essential quality attributes such as texture, flavor, and nutritional value. By creating a semi-permeable layer, rosin coatings slow down the respiration rate of the fruit, minimizing the physiological processes that lead to spoilage and decay (Tzia et al., 2016).

The efficacy of rosin coatings in extending the shelf life of citrus fruits is particularly significant given the high perishability of these products. The ability of rosin to act as a moisture barrier is crucial in preventing dehydration, which is one of the primary causes of postharvest quality degradation in citrus fruits. Additionally, rosin's natural antimicrobial properties help to reduce microbial contamination on the fruit surface, further enhancing its preservation potential.

This research specifically evaluates the effectiveness of rosin coatings in prolonging the shelf life of lemons stored under various temperature conditions, from ambient to refrigerated environments. By examining how rosin coatings interact with the physiological and biochemical parameters of lemons, the study provides a comprehensive assessment of their impact on key quality indicators, including firmness, acidity, and sugar content. The ability of rosin coatings to maintain optimal pH levels, reduce weight loss, and preserve the overall sensory appeal of lemons over extended storage periods underscores their potential as a natural and sustainable alternative to conventional synthetic coatings.

Furthermore, the application of rosin coatings aligns with the growing demand for environmentally friendly and biodegradable packaging solutions in the food industry. As consumers increasingly seek out natural and organic products, the use of rosin coatings derived from renewable forest resources offers a promising approach to meet these preferences while also addressing the challenges of postharvest fruit preservation.

In conclusion, the utilization of natural rosin coatings represents a significant advancement in the postharvest management of citrus fruits. By enhancing shelf life, reducing spoilage, and maintaining quality, rosin coatings not only contribute to the sustainability of citrus production but also offer economic benefits by minimizing waste and extending the marketability of fresh produce. Continued research and development in this area are essential to optimize the formulation and application of rosin coatings, ensuring their effectiveness across a wide range of citrus varieties and storage conditions.

6. Methods of Application

Edible coatings can be applied using various techniques, including dipping, spraying, and brushing. The choice of application method depends on the type of coating material and the specific requirements of the fruit being treated. Dipping is commonly used due to its simplicity and effectiveness in ensuring uniform coating coverage (Patil, et al., 2023; Yerlikaya and Şen Arslan, 2021).

7. Temperature and Storage Conditions

The storage temperature significantly affects the efficacy of edible coatings. Citrus fruits stored at lower temperatures generally show better preservation outcomes due to reduced metabolic activities. However, it is essential to avoid temperatures that may cause chilling injury to the fruits. The combination of appropriate storage temperatures and edible coatings can significantly enhance the shelf life of citrus fruits(Prasad, et al., 2018).

8. Case Studies and Recent Advances

Recent studies have demonstrated the effectiveness of various edible coatings in extending the shelf life of citrus fruits. For example, plant-based edible active coatings have been shown to preserve sweet cherry fruits' quality and bioactive compounds during storage (Hazarika, et al., 2023). Similarly, carnauba wax and wood rosin coatings have effectively reduced weight loss and maintained the sensory quality of oranges during cold storage(Carvalho, et al., 2023).

Nanotechnology has also been increasingly applied in the development of edible coatings. Nanoemulsion-based coatings, which incorporate nanoparticles such as zinc oxide and silver, offer enhanced antimicrobial properties and improved barrier functions. These advanced coatings can further extend the shelf life of fruits by providing a more effective barrier against microbial contamination and physical damage(Odetayo, 2022).

9. Results and discussion

Extending the shelf life of citrus fruits using edible coatings, particularly natural rosin-based coatings like colophony, presents a sustainable and practical approach to reducing postharvest losses. The high perishability of citrus fruits due to their moisture content necessitates innovative preservation methods to maintain their nutritional and sensory quality during storage. Edible coatings act as barriers to moisture and gas exchange, slowing down the respiration and senescence processes, and can be enhanced with active ingredients like antioxidants and antimicrobials to improve further fruit preservation(Abd-Allah, et al., 1996).

9.1. Benefits and Effectiveness

Natural rosin-based coatings, such as those derived from colophony, offer a biodegradable and environmentally friendly alternative to petroleum-based paraffin coatings. Studies have shown that these coatings effectively reduce weight loss, maintain firmness, and preserve citrus fruits' color and sensory attributes during storage. For example, using carnauba wax and wood rosin coatings on sweet oranges significantly reduced weight loss. It maintained the sensory quality of the fruits during cold storage for up to 60 days (El-Ghazawy, et al., 2015). Similarly, plant-based edible coatings have been demonstrated to preserve various citrus fruits' quality and bioactive compounds, enhancing their shelf life and marketability (Ncama, et al., 2018).

9.2. Technological Advancements

Recent advancements in nanotechnology have further improved the efficacy of edible coatings. Nanoemulsion-based coatings, incorporating nanoparticles such as zinc oxide and silver, enhance antimicrobial properties and improve barrier functions. These coatings offer a more effective defense against microbial contamination and physical damage, thus extending the shelf life of citrus fruits even further(Khezerlou, et al., 2021).

9.3. Environmental and Economic Impacts

Adopting natural rosin-based coatings addresses the environmental concerns associated with synthetic chemicals and aligns with the increasing consumer demand for natural and organic produce. These coatings contribute to food security and economic sustainability by reducing postharvest losses. They help decrease food waste, enhance the availability of nutritious food, and minimize the environmental impact of fruit production and distribution(Tyagi, et al., 2021

9.4. Future Directions

Future research should focus on optimizing the formulations and application methods of natural rosin-based edible coatings to maximize their benefits for different types of fruits. Developing cost-effective and environmentally friendly coating materials will be crucial for the widespread adoption of these technologies in the fruit industry. Additionally, exploring the synergistic effects of combining various natural ingredients and advanced technologies can lead to developing even more effective preservation solutions (Yüksel, et al., 2020).

CONCLUSİON:

The application of natural rosin-based coatings offers a transformative and sustainable approach to the postharvest management of citrus fruits. By creating an effective barrier against moisture loss and microbial spoilage, these biodegradable coatings significantly extend the shelf life of citrus fruits, thereby reducing postharvest losses that have long plagued the industry. In addition to preserving the fruits' essential quality attributes, such as texture, flavor, and nutritional content, rosin-based coatings also align with the growing consumer demand for natural, high-quality, and organic produce.

As the global emphasis on environmental sustainability intensifies, the use of renewable, forest-derived materials like rosin presents a valuable alternative to synthetic coatings, minimizing the ecological footprint associated with conventional preservation methods. Moreover, the economic benefits of extending the marketability and shelf life of citrus fruits cannot be understated, as this approach contributes to both reducing food waste and increasing profitability for producers and retailers.

Continued innovation and rigorous research in this field are crucial to unlocking the full potential of rosin-based coatings. Future studies should focus on optimizing coating formulations, refining application techniques, and exploring the synergistic effects of combining rosin with other natural ingredients. Additionally, expanding the scope of research to include a broader range of citrus varieties and storage conditions will ensure that these coatings can be effectively applied across the industry.

In summary, natural rosin-based edible coatings represent not only a practical solution to the challenges of citrus preservation but also a forward-looking strategy that supports the sustainability of the food supply chain. By bridging the gap between environmental responsibility and commercial viability, these coatings hold great promise in shaping the future of postharvest fruit management.

ETİK STANDARTLAR:

Çıkar Çatışması: Yazarlar herhangi bir çıkar çatışması olmadığını beyan eder.

Etik Kurul İzni: Bu makalede etik kurul iznine gerek yoktur, buna ilişkin ıslak imzalı etik kurul kararı gerekmediğine ilişkin onam formu sistem üzerindeki makale süreci dosyalarına eklenmiştir

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