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Development of eco-friendly edible coating for extending the shelf life of fruits and vegetables

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Abstract
The perishability of fruits and vegetables poses a critical challenge to global food security, particularly during crises such as the COVID-19 pandemic, which disrupted supply chains and led to significant post-harvest losses This study aims to evaluate the effectiveness of a chitosan-based edible coating in extending the shelf life of perishable crops, specifically tomatoes and mustard greens. The research assesses the weight changes of treated produce over a 10-day storage period, comparing the chitosan-based coating with synthetic and natural waxes, as well as an untreated control group. A controlled trial was conducted, and statistical analyses, including descriptive statistics, ANOVA, and post hoc Tukey's test, were used to evaluate the results. The findings suggest that while the chitosan-based edible coating was more effective than the control group in preserving tomatoes, it did not show a significant advantage over commercial waxes. For mustard greens, the performance of the edible coating was less effective, with no significant differences observed between the treatment groups. This research highlights the potential of chitosan-based coatings as a sustainable alternative for preserving fresh produce but also emphasizes the need for further optimization of the coating formulation and application methods for broader agricultural use.

Keywords: Edible coating, chitosan, post-harvest loss, shrimp shell

Introduction

The COVID-19 pandemic, declared by the World Health Organization (WHO) as a global health emergency, has significantly disrupted food supply chains worldwide, particularly in agricultural sectors. Malaysia, like many other countries, faced substantial challenges in maintaining food supply during the pandemic. The restrictions imposed by the government, including the Movement Control Order (MCO), led to disruptions in the transportation and distribution of fresh produce, affecting farmers' ability to market their crops [1]. This resulted in considerable losses, particularly for vegetables and fruits that have short shelf lives. During this period, many farmers in Malaysia and globally were unable to market their produce in time, leading to wastage, which further compounded the economic challenges faced by the agricultural sector [2]. Additionally, with the global demand for fresh produce decreasing, the agricultural sector has been under pressure to find ways to extend the shelf life of fruits and vegetables to mitigate such losses. In response to this, research into natural preservatives, such as chitosan, has gained significant interest. Chitosan, derived from shrimp shells, is known for its natural preservative properties, which could be particularly useful in extending the shelf life of perishable agricultural products [3]. Edible coating, an environmentally friendly edible coating derived from chitosan, has emerged as a promising solution to enhance the freshness and shelf life of fruits and vegetables. The primary issue addressed in this research is the rapid spoilage of fruits and vegetables, which leads to significant post-harvest losses, especially during global crises such as the COVID-19 pandemic. Farmers in Malaysia have faced challenges in maintaining the freshness of their produce due to the short shelf life of perishable crops like tomatoes and mustard greens. This problem has been exacerbated by restrictions on movement and labor shortages, leading to financial losses for farmers [1]. Moreover, the use of synthetic preservatives may not be sustainable, and the need for more environmentally friendly alternatives has become urgent. The main objectives of this study are to develop and assess the efficacy of a chitosan-based edible coating for extending the shelf life of tomatoes and mustard greens, to analyse the weight changes in the tomatoes and mustard greens after being treated with edible coating over a 10-day storage period and to compare the effectiveness of edible coating with other commonly used edible coatings, such as commercial synthetic waxes and natural waxes, in preserving the freshness of perishable produce. This study is significant for both local and global agricultural sectors, particularly in the context of food security during crises like the COVID-19 pandemic. By developing a natural, eco-friendly solution to prolong the shelf life of fruits and vegetables, this research offers a sustainable alternative to synthetic preservatives, which may pose health and environmental risks. The potential impact of this research is far-reaching. By extending the shelf life of fresh produce, farmers can reduce post-harvest losses and improve the economic viability of their crops. Additionally, this solution could help mitigate food security concerns in Malaysia, ensuring a more stable and continuous food supply. The application of Edible coating could also open export opportunities for Malaysian agricultural products, boosting the economy. Furthermore, this study contributes to the broader body of knowledge in the fields of food science, agriculture, and sustainable development. It provides valuable insights into the use of natural preservatives and their application in the agricultural industry, supporting the shift toward more sustainable agricultural practices.

Materials and Methods

1. Study Design / Experimental Setup

This study evaluates the effectiveness of an edible coating, a chitosan-based edible coating, in extending the shelf life of two perishable crops: tomatoes (*Lycopersicum esculentum*) and mustard greens (*Brassica juncea*). The experimental design involved a controlled trial with four treatment groups: chitosan-based edible coating, commercial synthetic wax, commercial natural wax, and a control group with no coating. Each treatment was applied to the crops, and the samples were stored at room temperature (approximately 25°C) for 10 days. Regular observations were made every two days to monitor its weight.

2. Materials, Chemicals, and Instruments Used

The materials, chemicals, and instruments used in this study included various items for the preparation and application of Edible coating. Fresh, ripe tomatoes (*Lycopersicum esculentum*) were sourced from local suppliers in Sandakan, Sabah, and fresh mustard greens (*Brassica juncea*) were obtained from local farms. Shrimp shells, used for the extraction of chitosan, were sourced from local seafood processors in Sandakan. The chemicals involved included chitosan, derived from shrimp shells using standard extraction procedures, acetic acid for dissolving the chitosan, sodium hydroxide (NaOH) for deproteinization and deacetylation of chitosan, and hydrochloric acid (HCl) for the demineralization of shrimp shells. Instruments used included a pH meter for measuring the pH of the solutions during Edible coating preparation, a weighing balance for accurate measurement of chemicals and materials, a hot plate stirrer to maintain temperature during chitosan preparation, spray bottles for applying the Edible coating Solution and a digital camera for documenting changes in color and appearance.

3. Procedures/Protocol Preparation of Edible coating

3.1 Preparation of Edible coating

This method was adopted by several scholars [4] and [5]. To prepare the chitosan-based edible coating, shrimp shells were thoroughly washed to remove impurities, dried, and ground into a fine powder. This powder underwent deproteinization with sodium hydroxide to remove proteins, followed by demineralization using hydrochloric acid to eliminate minerals. Finally, the chitosan was deacetylated with sodium hydroxide to produce chitosan-based edible coating. For the preparation of the chitosan-based edible coating solution, 1 gram of chitosan was dissolved in 50 mL of 1% acetic acid solution, and distilled water was added to bring the total volume to 100 mL. The mixture was stirred continuously to ensure complete dissolution of the chitosan. The chitosan-based edible coating solution was then applied evenly to the surface of tomatoes and mustard greens using spray bottles to ensure uniform coating.

3.2 Application of Coatings

The control group consisted of untreated samples, with no coating applied, treated sample chitosan-based edible coating. For the commercial synthetic wax treatment, tomatoes and mustard greens were coated using a commercially available synthetic wax, following the manufacturer's instructions. Similarly, the commercial natural wax was applied to the produce in the same manner as the synthetic wax.

3.3 Storage and Observation

After the coatings were applied, all samples were stored in separate containers at room temperature (approximately 25°C) for a period of 10 days. Observations were made every two days (on Days 0, 2, 4, 6, 8, and 10) to monitor weight loss, which was measured using a digital scale. Additionally, the overall condition of the samples was evaluated for signs of spoilage, such as wilting, rot, and discoloration.

3.4 Statistical Analysis Methods and Tools Used

The statistical analysis of the results was conducted using several methods and tools. Descriptive statistics were employed to summarize the data for each treatment group, including means, standard deviations, and ranges for observed weight parameter. A one-way Analysis of Variance (ANOVA) was performed to compare the means of the different treatment groups (chitosan-based edible coating, synthetic wax, natural wax, and control) at each time point, allowing the identification of significant differences between the groups. To further explore the differences, post-hoc Tukey's test was used. All statistical analyses were carried out using SPSS version 26, with a significance level set at $p < 0.05$.

Results and Discussion

This study aimed to evaluate the effectiveness of Edible coating, a chitosan-based edible coating, in preserving the shelf life of tomatoes (*Lycopersicum esculentum*) and mustard greens (*Brassica juncea*), compared to synthetic and natural commercial waxes and a control group. The results (Table 1) indicated that chitosan-based edible coating was more effective than the control in preserving the weight of tomatoes, with a weight loss of 6.5% compared to the control's 15% after 10 days of storage. Despite this, statistical analysis (One-Way ANOVA) revealed no significant difference between the treatment groups for tomatoes ($p = 0.333$). In contrast, for mustard greens (Table 2), chitosan-based edible coating showed only marginally better performance compared to other treatments, with a weight loss of 11% versus 15.5% in the control. However, as with tomatoes, no significant differences were found between the treatments ($p = 0.746$).

Table 1: The statistical analysis of tomatoes

Treatment	Mean (%)	Standard Deviation (%)	Range (%)	ANOVA p-value
Edible coating	3.35	2.41	6.50	0.333
Natural Wax	3.88	2.83	7.80	0.333
Synthetic Wax	6.03	4.53	12.50	0.333
Control	7.17	5.47	15.00	0.333

Table 2: The statistical analysis of green mustard

Treatment	Mean (%)	Standard Deviation (%)	Range (%)	ANOVA p-value
Edible coating	6.45	4.00	11.00	0.746
Natural Wax	8.63	5.53	15.50	0.746
Synthetic Wax	9.88	6.42	18.00	0.746
Control	8.43	5.42	15.00	0.746

The lack of statistical significance in both crops suggests that while chitosan-based edible coating appears to have some potential, its effectiveness in preserving perishable crops may be limited under the tested conditions. The finding that chitosan-based edible coating performed better than the control group in tomatoes aligns with previous studies on chitosan-based coatings, which have been shown to reduce weight loss, maintain firmness, and improve the overall shelf life of fruits and vegetables [6]. However, the differences between chitosan-based edible coating and other treatments, including commercial waxes, were not significant, which implies that factors such as the composition of the coating, its application method, and the type of produce may all influence its effectiveness.

Several studies have demonstrated the effectiveness of chitosan as a natural preservative. For example, a study by Rayees Sheikh and co-author [6] found that chitosan coatings significantly reduced weight loss in tomatoes compared to untreated controls. Similarly, other research has indicated that chitosan-based coatings can extend the shelf life of tomatoes and other fruits by reducing water loss, controlling respiration rates, and acting as a barrier to microbial contamination [7]. In our study, while chitosan-based edible coating exhibited these benefits for tomatoes, it failed to outperform synthetic and natural waxes in terms of statistical significance, suggesting that either the coating concentration or application method may need optimization to achieve more pronounced results.

The performance of chitosan-based edible coating with mustard greens was notably less impressive. Mustard greens, being leafy vegetables with high water content and a delicate structure, may require different preservation treatments compared to firmer produce like tomatoes. Leafy vegetables are known to be more prone to dehydration and microbial growth, making it harder to preserve using simple coatings [8]. This aligns with our findings that all treatments, including chitosan-based edible coating, showed significant weight loss and deterioration in mustard greens, with no treatment significantly outperforming others.

The failure of chitosan-based edible coating to significantly preserve mustard greens may be attributed to the unique nature of leafy vegetables. According to research by Momin *et al*. [9], edible coatings can be effective in reducing moisture loss and extending the shelf life of fruits, but their application to leafy vegetables often results in minimal improvement. This is likely due to the high transpiration rate of leafy greens, which makes them more difficult to preserve through coatings alone. Other methods, such as modified atmosphere packaging or refrigeration, may be required to extend the shelf life of such produce [10].

Furthermore, while synthetic waxes are often favored in the food industry for their ability to create a strong barrier against moisture loss, their use is increasingly scrutinized due to environmental and health concerns. Natural alternatives like chitosan-based coatings offer a more sustainable option, but their performance varies depending on the type of crop and coating formulation [9]. Our study indicates that while chitosan-based edible coating showed promise in preserving tomatoes, it was not significantly better than commercial waxes, indicating that further refinement in the formulation or application methods might be necessary.

A study by Vaishali *et al*. [7] highlighted that chitosan-based coatings significantly reduced microbial load and weight loss in fruits such as tomatoes, cucumbers, and apples. This was consistent with our findings for tomatoes, where chitosan-based edible coating showed a reduction in weight loss compared to the control. However, in our study, the lack of significant differences with other coatings indicates that further adjustments, such as varying the concentration of chitosan or applying multiple layers of coating, could improve effectiveness.

In contrast, other studies have reported challenges in preserving leafy vegetables like mustard greens. For example, Prasad *et al*. [8] found that coatings made from chitosan and other polysaccharides showed limited success in leafy vegetables due to high water content and rapid dehydration. This supports our observation that chitosan-based edible coating was not effective in preserving mustard greens in this study.

To improve the performance of chitosan-based edible coating, future studies could explore the optimization of chitosan-based edible coating formulation by adjusting the concentration of chitosan or incorporating additional components such as essential oils or antioxidants may improve its effectiveness in preserving produce. Besides, the use of multiple coatings or different application techniques (e.g., dipping, spraying) could be investigated to determine the effectiveness for better preservation. Apart from that, the combination of other preservation techniques could be done by exploring the synergy between edible coating and other preservation methods, such as refrigeration or modified atmosphere packaging.

Conclusion

While chitosan-based edible coating showed potential in preserving the shelf life of tomatoes, its effectiveness was not significantly different from other commercially available coatings, such as natural and synthetic waxes. Moreover, chitosan-based edible coating did not significantly improve the preservation of mustard greens, indicating that further optimization is required for specific types of produce. This study highlights the promise of chitosan-based edible coating as a natural preservative but underscores the need for further research to optimize its formulation and application for broader agricultural use.

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