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# The Effect of Cinnamon Extract on the Prevention of Fruit Spoilage via Delay in Microbial Growth

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## ABSTRACT

Background: Approximately 30% of fresh produce spoils in its packaging before consumption, impacting the economy and straining environmental resources. The goal of this project is to elucidate a safe and effective solution for extending the post-harvest life of fruit. The benefits of cinnamon extract have been studied in numerous applications, including antimicrobial ones. This study investigates whether infusing an extract of 0.1% cinnamon bark essential oil into pulp fiber produce containers would reduce microbial growth and volume loss associated with fruit spoilage. Methods: Three fresh strawberries were placed in individual pulp fiber containers infused with cinnamon bark extract, and 3 were placed in similar containers without the extract. Strawberries were selected for uniformity in size, color, and state of freshness and were stored in identical environmental conditions. Each strawberry was swabbed for microbes and plated on DRBC agar. Colony counts, photographs, and strawberry weights were recorded daily for 7 days. Results: There was a 57.9% reduction in microbial colony counts in the strawberries stored in containers treated with extract compared to the control group. A greater reduction in weight was seen in the treatment group, likely explained by the added weight of mold growth noted in the control group. Conclusion: This research holds the promise of enhancing food preservation methods safely and effectively, thereby mitigating food waste and ensuring the availability of fresh produce.

## Introduction

Extending the shelf life and ensuring the freshness of food is a vital concern in today's world. Populations who are food insecure are particularly at risk of not being able to receive fresh fruits and vegetables, and facilities serving these communities are often forced to discard produce due to spoilage. The rate at which produce spoils in its packaging is staggering, with approximately 20% of post-harvest produce being lost annually due to spoilage (Barth), with considerable economic impact, environmental strain, and adverse health consequences for vulnerable individuals. To meet the growing demand for sustainable practices, it is critical to develop safe, efficacious, and readily accessible methods for prolonging the post-harvest decay of fresh produce.

Food spoilage caused by microbial growth or activity is the most prevalent cause of food degradation. The need for improving shelf life by protecting against foodborne pathogens, coupled with consumer preference for minimally processed foods without synthetic preservatives, have fostered the development of antimicrobial packaging, which is a form of active packaging that allows for the release of substances to suppress the activity of specific microorganisms (Fadiji et al, Gonzalez et al). Essential oils, which are secondary metabolites produced by aromatic plants, have been studied over a wide range of applications within the culinary, cosmetic, and food processing industries. Essential oils of lemon, ginger, peppermint, rosemary, thyme, clove, mustard, and cinnamon have all been investigated (Serag et al). Cinnamaldehyde is the primary active chemical constituent derived from the bark of cinnamon cassia. It exerts its antimicrobial effects via inhibition of cell division as well as via degradation of cell membranes (Nabavi et al).

Like all produce, strawberries are subject to spoilage. Several molds account for approximately two-thirds of the cases of strawberry post-harvest decay (KLU). The primary pathogen involved in *Botrytis cinerea*, which causes gray mold growth on strawberries (Feliziani et al). *Rhizopus* and *Mucor* spp. are other common pathogens causing spoilage of this fruit. Dichloran rose bengal chloramphenicol (DRBC) agar was chosen for this study because it selectively allows the growth of only these common fruit spoilage pathogens. Prior studies have shown that a 0.1% concentration of cinnamon cassia, when integrated into standard packaging material, effectively reduced the rate of pathogen growth on strawberries, helping to prolong and preserve their freshness.

## Methods

### Study Design

In this prospective observational cohort study, we investigated whether the addition of a 0.1% concentration of cinnamon bark essential oil to conventional pulp fiber produce packaging material would prolong the shelf life of fresh strawberries. The quantitative parameters measured were microbial growth and strawberry weight.

### Study Population

Six fresh strawberries, purchased at the same vendor, and selected based on uniformity of size, shape, color, and absence of obvious physical damage or visible mold, were included in the study.

### Study Procedure

Generation of produce containers: Two pulp fiber produce containers were cut into small pieces and added to 1.5 cups of boiling water. The mixture was boiled 2 minutes to soften. The mixture was then placed in a blender and shredded until it was uniform in appearance. The shredded pulp fiber was drained of any remaining water and divided into 2 equal halves. One half was labeled “CONTROL” and was set aside. Three drops of cinnamon bark essential oil (need manufacturer) were added to one half cup of the remaining pulp fiber to achieve a final cinnamon essential oil concentration of 0.1%; this was labeled “EXTRACT.” The EXTRACT shredded pulp was blended again for 1 minute to evenly distribute the essential oil throughout the mixture. The CONTROL and EXTRACT pulp fibers were then each shaped into 3 small cup-like containers designed to hold 1 strawberry each, and the containers were labeled appropriately. All 6 containers (3 CONTROL and 3 EXTRACT) were then placed on a drying rack inside a sealed plastic container at room temperature (72 degrees Fahrenheit) for 48 hours to dry. Preparation of strawberries: Six fresh strawberries were selected based on the criteria listed above. Each strawberry was photographed and weighed on a digital scale. Each was washed separately under continuously running cold tap water for 10 seconds and then patted dry, taking care to not bruise or deform the berry. Each strawberry was placed in a shaped pulp fiber container, labeled CONTROL or EXTRACT, and assigned a number from 1 to 3. Three strawberries in the CONTROL group and 3 in the EXTRACT group were used for the study. Strawberries were kept in their respective shaped pulp fiber containers and stored in a plastic egg carton for the duration of the study. Microbial analysis: Each strawberry was swabbed with a sterile cotton tip applicator on 5 different sides. The swab was then plated on DRBC (dichloran rose bengal chloramphenicol) agar using 10 strokes of the applicator over the agar. Data collection: The number if mold/yeast colonies was counted and recorded at the same time every day for 7 consecutive days. Photographs were taken daily during the study period.

### Data Analysis

The number of mold/yeast colonies were counted and recorded each day of the 7-day study period for the 3 CONTROL and 3 EXTRACT strawberries. The percent reduction in microbial growth between test and control subjects was calculated. In an attempt to reduce outlier or anomalous data, this calculation was repeated after excluding colony counts seen in CONTROL strawberry 2. The calculations and date were presented separately. Additionally, the weight decrease in strawberries for each group during the study period were calculated, and subsequently compared.

## Results

The number of mold/yeast colonies observed and counted each day of the 7-day study period for the 3 CONTROL and the 3 EXTRACT strawberries is displayed in Figures 1 and 2, respectively.

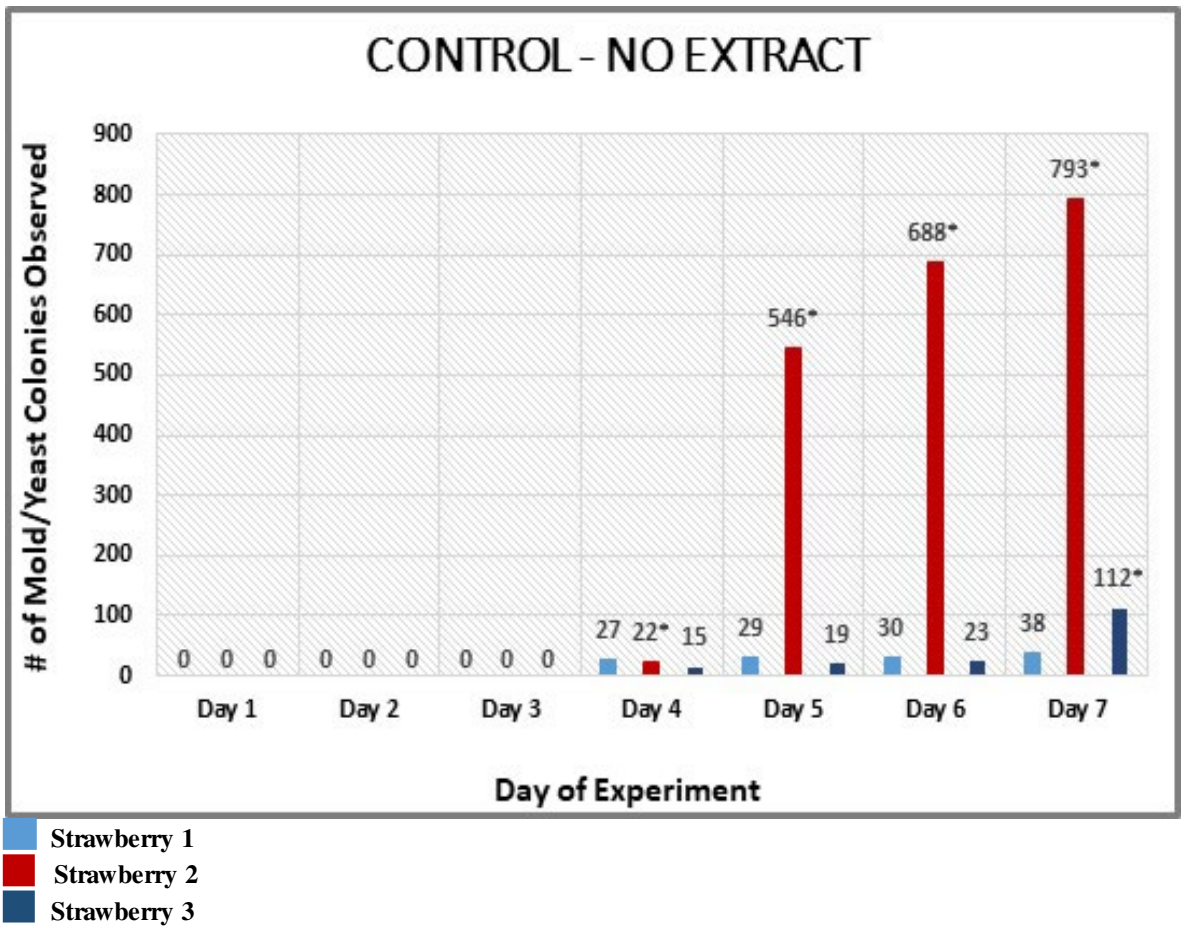



**Figure 1.** Number of mold/yeast colonies in CONTROL group over 7-day period.

* Indicates best estimate as some colonies were contiguous and ill-defined; therefore, they could not be precisely counted.

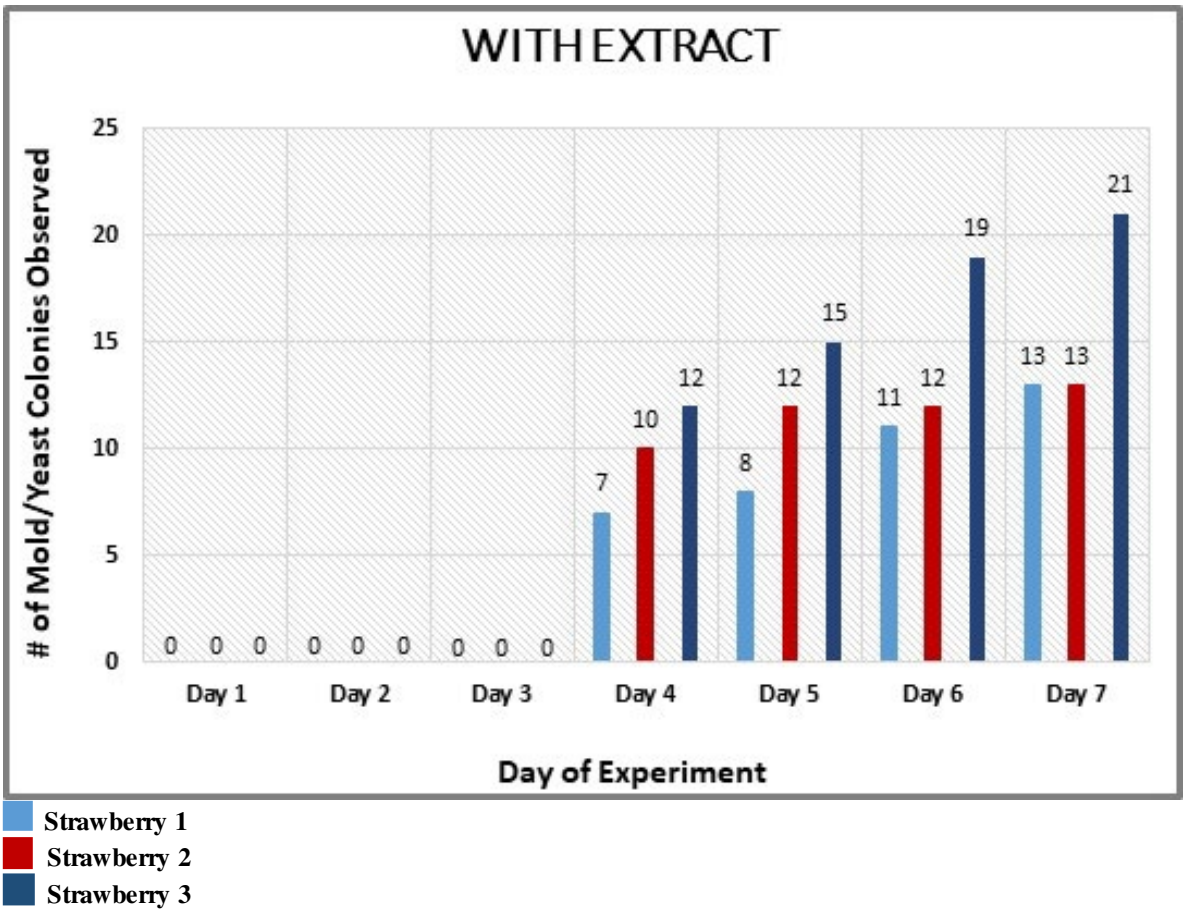



**Figure 2.** Number of mold/yeast colonies in EXTRACT group over 7-day period.

The table in Figure 3 documents the percent reduction in microbial growth seen in the EXTRACT group when compared to the CONTROL strawberries; In an attempt to avoid the influence of outlier data, the reduction percentage was re-calculated after excluding the likely anomalous growth observed on CONTROL strawberry 2; this data is presented in a separate column in the table of Figure 3.

| | **Percent Reduction of Mold/Yeast Colonies Observed** | |
|---|---|---|
| | **Control vs. With Extract** | **Control vs. With Extract (excluding Control Strawberry 2)** |
| **Day 1** | 0% | 0% |
| **Day 2** | 0% | 0% |
| **Day 3** | 0% | 0% |
| **Day 4** | 54.66% | 53.95% |
| **Day 5** | 94.11% | 51.38% |
| **Day 6** | 94.33% | 47.17% |

| | | |
|---|---|---|
| **Day 7** | 95.02% | 79.11% |
| **Average of Days 4 - 7** | 84.53% | 57.90% |

**Figure 3.** Percent reduction of pathogen colonies in CONTROL vs. EXTRACT groups, with and without CONTROL strawberry 2 data.

Figure 4 displays the average number of mold/yeast colonies observed in the CONTROL group, the CONTROL excluding data from strawberry 2, and the EXTRACT group. Even after excluding CONTROL strawberry 2 from the data set, there was a clear and significant reduction in pathogen growth of 57.9% in the strawberries whose containers were treated with cinnamon extract (the EXTRACT group) compared to those that were not (CONTROL group).

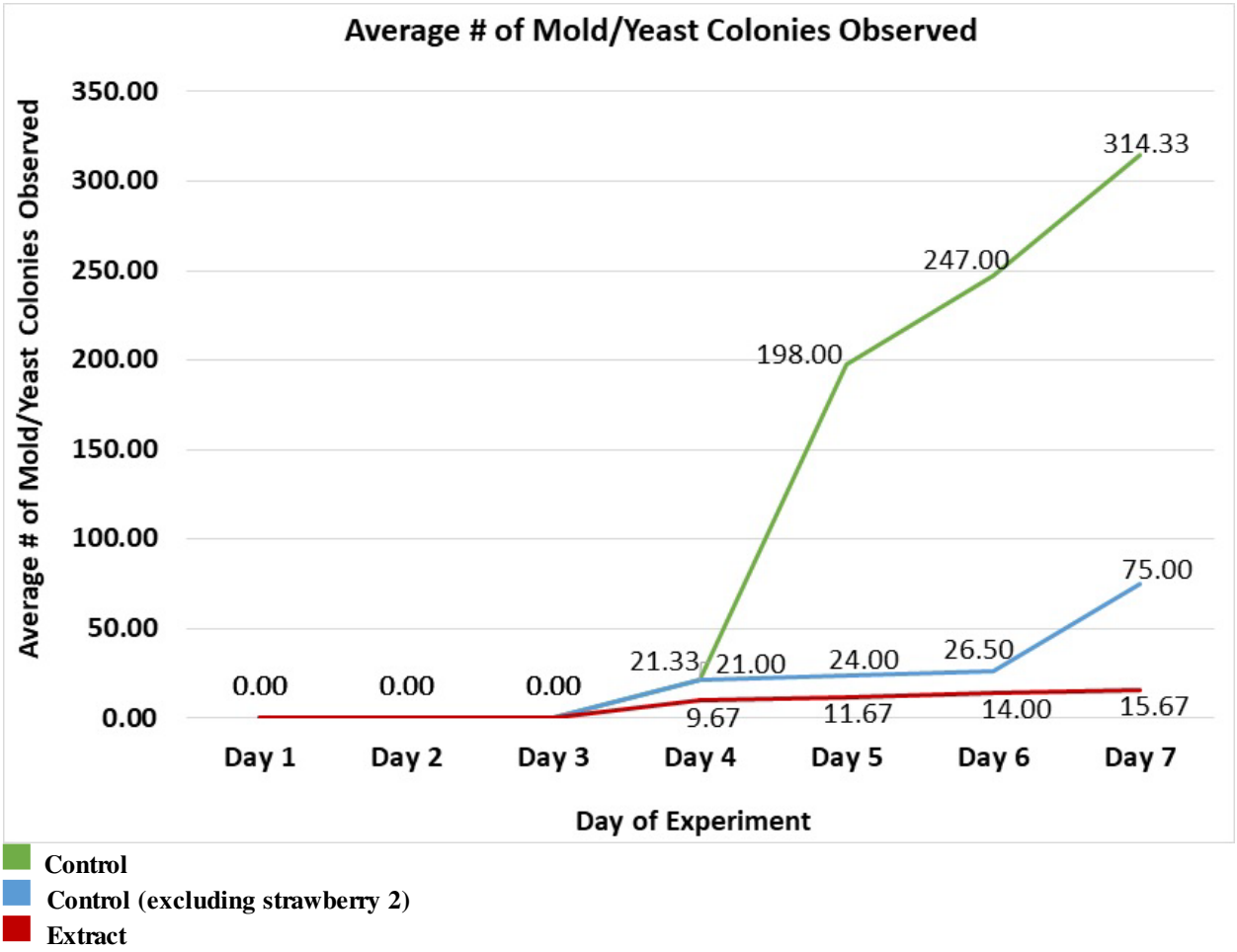
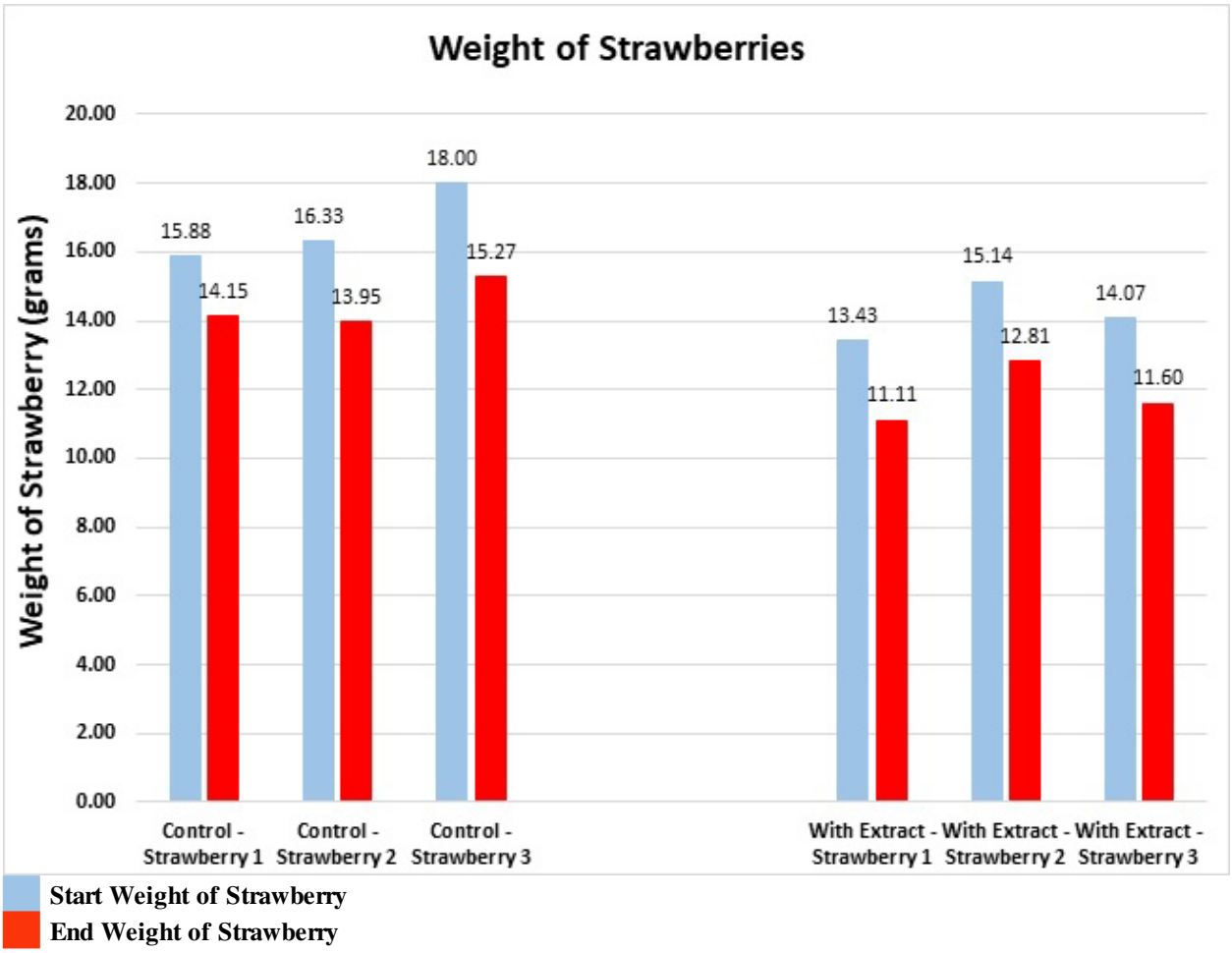



**Figure 4.** Graphical representation of mold/yeast colonies observed in all groups over a 7-day period.

Figure 5 displays the measured weights of each of the 6 strawberries at the start of the experiment and then at the end of the 7-day study period. The cinnamon extract treated group had an average decrease in weight of 16.70% compared to a 13.62% reduction in the CONTROL group.




**Control**

Average % Change in Weight = 13.62%

**With Extract**

Average % Change in Weight = 16.70%

**Figure 5.** Weight reduction of all strawberries over a 7-day period.

## Discussion

The purpose of this study was to determine whether a 0.1% solution of essential cinnamon oil, when infused with standard produce packaging materials, could reduce microbial growth and improve the post-harvest shelf life of produce. To that end, we developed a prospective observational cohort study, analyzing the effect of cinnamon essential oil added to strawberry packaging and compared the results to a control group of identical strawberries without the addition of cinnamon to packaging, Consistent with the results of prior studies (Zaveleta et al, Pizato et al), we were able to conclude that a 0.1% concentration of cinnamon essential oil, when integrated into standard packaging materials, is effective in reducing the rate of pathogen growth on strawberries (as observed on DRBC agar plates), helping to prolong and preserve their freshness. Even after reducing outlier data from CONTROL strawberry 2, our study demonstrated a 57.90% reduction in colony growth in the EXTRACT group compared to CONTROL, across all days observed in the study period.

Water and volume loss are associated with fruit spoilage (Ref?), so we would have expected a greater relative reduction in weight in the strawberries not treated with cinnamon extract (i.e. CONTROL group). However, this was not seen in the experiment as the EXTRACT group lost a greater volume in our study: 16.70% weight reduction compared to 13.62% seen in the CONTROL arm. One possible explanation for this theoretical incongruity is the compensatory effect in weight by the increased mold growth seen in the CONTROL strawberries.

In conclusion, this study aimed to determine whether infusing cinnamon extract into standard produce packaging materials would be effective in prolonging the post-harvest shelf life of strawberries via reduction of microbial pathogen growth. The findings reveal that, even with our most conservative calculations, packaging material containing a 0.1% solution of cinnamon essential oil showed a 57.90% reduction of pathogen growth compared to packaging material without extract.

## Limitations and Areas of Further Research

Our study was limited by a small sample size. Further studies, with sample sizes large enough to be adequately powered to determine statistical significance, should be done in the future. Additionally, despite all attempts to standardize strawberries prior to dividing them into experimental and control arms for our study, it was impossible to know how long the produce was handled and under what conditions prior to purchasing it; this could introduce an additional variable affecting spoilage rates. Finally, though effective at reducing microbial growth, cinnamon extract imparted a scent, and likely flavor, to the strawberries, which may impact consumer preference. Further areas of research may focus on different delivery systems within the packaging, such as a delayed release, or aerosolized mechanism that may hopefully minimize this issue.

## Acknowledgments

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## References

1. Barth M, Hankinson TR, Zhuang H, Breidt F. 2009. Microbiological spoilage of fruits and vegetables. In: Compendium of the microbiological spoilage of fruits and vegetables. 135-83.
2. Fadiji T, Rashvand M, Daramola M, Iwarere S. A review on antimicrobial packaging for extending shelf life of food. Processes 11 (2023) 590.
3. Gonzalez R, Yilmaz B, Khaneghah A, Hano C, Shariati M, Bangar S, Goksen G, Dhama K, Lorenzo J. Cinnamon: An antimicrobial ingredient for active packaging. Food Packaging and Shelf Life 35 (2023) 1-9.
4. Serag M, Elfayoumy R, Mohesien M. Essential oils as antimicrobial and food preservatives. DOI: http://dx.doi.org/10.5772/intechopen.10300.
5. Nabavi S, Lorenzo A, Izadi M, Sobarzo-Sanchez E, Daglia M, Nabavi S. Antibacterial effects of cinnamon: From farm to food, cosmetic, and pharmaceutical industries. Nutrients 7 (2015) 7729-48.
6. Strawberries: Nutritional content, spoilage, and preservation methods. https://medium.com/@Klusch.
7. Feliziani E., Romanazzi G. Postharvest decay of strawberry fruit: Etiology, epidemiology, and disease management. Journal of Berry Research 6 (2016) 47-63.
8. Zavaleta M, Echeverria C, Leon-Vargas J, Lescano L, Sanchez-Gonzalez J, Linares G, Rojas M. Coverage of chitosan and essential cinnamon oil for strawberry conservation (Fragaria ananassa) var. Aroma, minimally processed. 18th International Multi-Conference for Engineering, Education, and Technology. July 27-31, 2020, Virtual Ed.

9. Pizato S, Vega-Herrera S, Chevalier R, Pinedo R, Cortez-Vega W. Impact of chitosan coatings enriched with clove essential oil on quality of minimally processed strawberries. Vol. 65, e22210278, 2022. https://doi.org/10.1590/1678-4324-2022210278.