Enhancing the Shelf Life of Tomatoes Using Lemongrass and Chili Pepper Oils

By

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December 2024

Contents

1. Introduction

Tomato (*Solanum lycopersicum L.*) is a highly valued horticultural crop, widely consumed for its nutritional benefits, versatility, and culinary applications. Rich in vitamin C, lycopene, and essential minerals, tomatoes are used in various forms such as vegetables, table fruits, juices, and processed foods. Originating in South America, tomato cultivation has become a global phenomenon, with numerous varieties adapted to diverse climates, including greenhouse production in cooler regions. In Georgia (U.S.), tomatoes hold a pivotal role in the diet and food security programs, being a staple ingredient in households across the state. Classified as climacteric fruits, tomatoes experience a respiratory peak during ripening, which accelerates their perishability. Typically, their shelf life ranges from 2 to 3 weeks, contingent on harvest maturity and storage conditions. The "farm-to-fork" postharvest system, encompassing all activities from harvesting to consumer delivery, underscores the challenges of maintaining tomato quality. Water content, accounting for approximately 90% of the fresh weight of tomatoes, makes them particularly susceptible to postharvest deterioration. Factors such as water loss, temperature, and relative humidity significantly influence the quality and shelf life of tomatoes during storage. High water activity in tomatoes predisposes them to rapid quality degradation, reducing their market acceptability. Storage in sealed packages, which creates an environment with high carbon dioxide and low oxygen levels, has been shown to preserve firmness, maintain acidity and soluble solids concentration, and delay ripening. However, physical, physiological, mechanical, and microbiological damages remain significant contributors to postharvest losses. These losses not only affect economic returns but also challenge efforts to ensure consistent supply and food security.

To mitigate these challenges and enhance the postharvest longevity of tomatoes, several techniques have been developed. These include heat treatments, synthetic pesticides, surface coatings, and controlled atmospheric storage. Among these, the application of surface coating films stands out for its effectiveness and practicality. Edible coatings, in particular, offer an eco-friendly and consumer-acceptable solution, providing a protective barrier to reduce water loss, delay ripening, and minimize microbial spoilage. Their adaptability across different stages of the supply chain makes them a valuable tool in maintaining the quality of tomatoes from producers to consumers.

1.1 Aim and Objectives of the Study

1.1.1 Aim. The aim of this research is to enhance the shelf life of tomatoes by using lemongrass and chili pepper oils as surface coatings.

1.1.2 Objectives.

- To evaluate the impact of surface coating tomato fruits at the pink ripening stage with varying concentrations of hot pepper extract (*Capsicum annuum*) on shelf life, physicochemical properties, and disease severity during storage.
- To assess the effects of coating tomato fruits at the pink ripening stage with different

concentration combinations of lemongrass extract (*Cymbopogon citratus*) on shelf life, physico-chemical changes, and disease severity during storage.

1.2 Literature Review

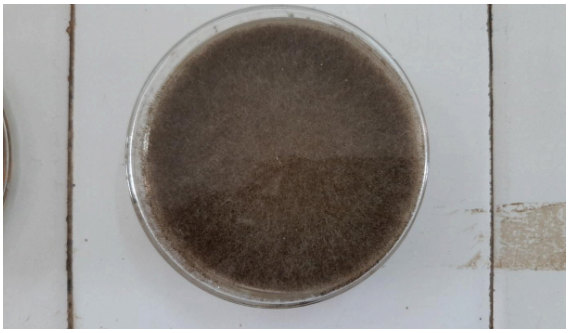
1.2.1 History of Tomato. Tomatoes (*Solanum lycopersicon L.*) are climbing, annual fruit vegetable crops that hold significant economic and nutritional importance worldwide. They originated in South America and were introduced to Europe in the 16th century, eventually reaching East Africa through colonial settlers in the early 1900s[3]. Tomatoes are now integral to diets globally, providing essential nutrients and vitamins. In Nigeria, tomatoes are among the most widely consumed vegetables, cultivated primarily during the hot rainy season in the southwestern region[1]. Nigeria is a key producer of fresh tomatoes in Africa, contributing 10.8% of the continent's production. Over the past decade, tomato production in Nigeria has increased significantly, growing by 25% from 1.8 million tonnes to an estimated 2.3 million tonnes annually. In Kenya, tomato production is equally important, accounting for 14% of the total vegetable output and 6.72% of overall horticultural crops[2]. The cultivation methods in Kenya vary, with open-field farming being the dominant approach, representing 95% of the total production, while greenhouse technology contributes the remaining 5% [4]. This dual approach to farming highlights the adaptability of tomatoes to various growing conditions, underscoring their global importance as a versatile and valuable crop.

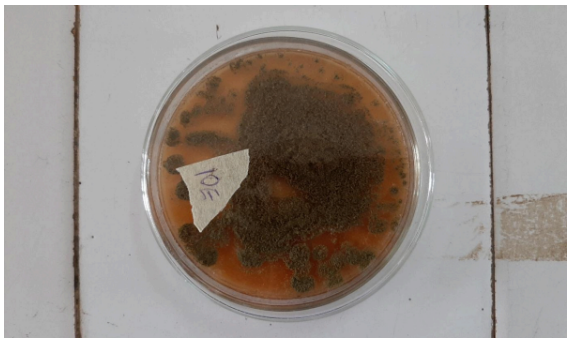
2. Methodology

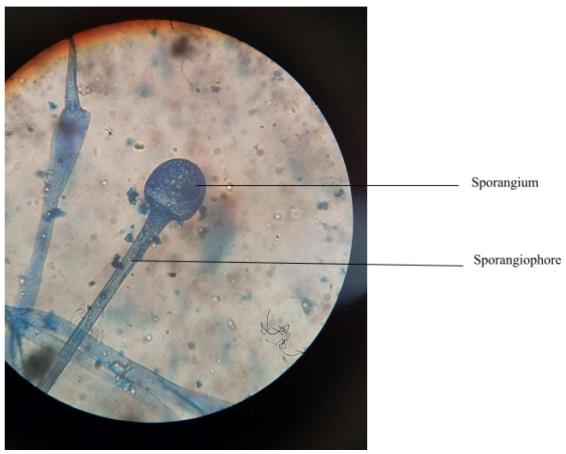
2.1 Identification of Fungi Responsible for Spoilage of Surface-Coated Tomato Fruits Stored at 28°C ± 2°C

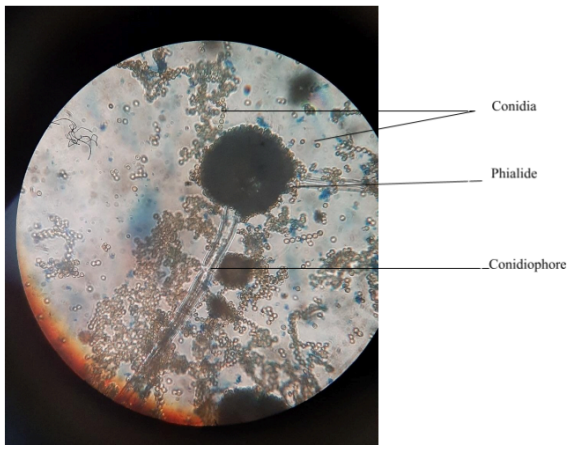
Two fungal species were isolated from diseased tomato fruits during the study. These fungi exhibited distinct physical characteristics, appearing as green and dirty white colonies, shown in Plate 1 and Plate 2, respectively. The dirty white mycelial growth featured hyphae with branched structures and unbranched sporangiophores capped with sporangia, enclosing numerous spherical or subglobose sporangiospores. The hyphal protoplasm was continuous, lacking cross walls, and the fungus was identified as *Rhizopus* sp., as per the criteria established by Barnett and Hunter (1960).

The green mycelial growth displayed filamentous structures with upright, simple conidiophores terminating in globose, cleaved swellings bearing phialides. The conidia were exposed to the external environment, and the protoplasm exhibited some interruption by cross walls. This fungus was identified as *Aspergillus* sp. (Plate 3 and Plate 4). These findings underscore the role of these fungal species in the spoilage of tomato fruits during storage.









2.2 Sample Collection & Testing

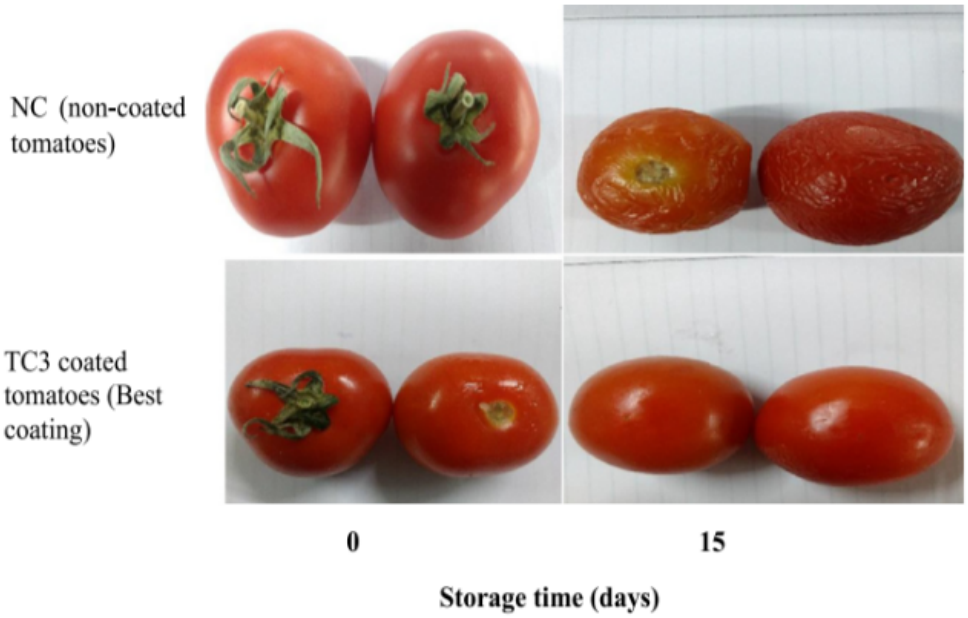
The study focused on the postharvest quality and shelf life of tomatoes, with all experimental procedures conducted at the Georgia State University Biology Laboratory. To ensure consistency and reliability of the results, tomatoes were meticulously selected based on uniformity in size, color, and ripeness. Only fruits free from visible defects, disease, or blemishes were chosen, as these factors can significantly influence the outcomes of postharvest treatments. The sampling process adhered to stringent criteria to reduce variability and ensure representative testing conditions.

Following collection, the tomatoes were carefully packed and transported to the laboratory within an hour to minimize exposure to environmental factors that could compromise their freshness and quality. This prompt transportation helped preserve the inherent characteristics of the fruit, maintaining their physiological and biochemical integrity for subsequent testing. The samples were then subjected to controlled experimental conditions designed to evaluate the effectiveness of various postharvest treatments.

2.2.1 Testing Procedure. The testing procedure involved the following steps:

1. **Cleaning and Sanitizing:** Tomatoes were rinsed with tap water to remove any soil or debris and then disinfected by immersion in a 0.1% sodium hypochlorite solution for 10 minutes.
2. **Drying:** The tomatoes were air-dried at room temperature.
3. **Coating Application:** Using the dipping method, tomatoes were coated with different formulations of whey protein isolate, xanthan gum, and clove oil in varying ratios. The application involved dipping each tomato twice, allowing a 10-minute drying interval between each coat.
4. **Storage Conditions:** Both coated and non-coated tomatoes were stored in an environmental chamber set at 20°C and 85% relative humidity for up to 15 days. Assessments were conducted at intervals (days 0, 3, 6, 9, 12, and 15) to monitor changes in quality attributes.

Figure 2.1: Effect of edible coatings on the decay rate of tomato during storage



2.3 Selection of a Response Variable

The selection of response variables in this study was guided by the objective of evaluating the effectiveness of lemongrass and chili pepper oil coatings in extending the shelf life of tomatoes while maintaining their quality. Key parameters were identified to comprehensively assess postharvest quality and storage performance.**Weight loss**, calculated as a percentage of the initial weight, was chosen to monitor moisture retention and freshness. **Firmness**, measured in Newtons using a Texture Profile Analyzer, provided insights into the structural integrity of the fruit over time. Changes in **color** were assessed using a colorimeter to measure the L value (lightness), a value (red-green balance), and b value (yellow-blue balance), all of which are critical indicators of visual quality during storage. Chemical properties also played a central role in the study. **Total Soluble Solids** (TSS), measured in Brix using a refractometer, provided an indicator of sugar content and ripening progression. **Titratable Acidity** (TA) and **pH** were used to track acidity changes, reflecting ripening and flavor alterations. **Ascorbic acid content**, determined through titration, served as a measure of vitamin C retention, while the measurement of **total and reducing sugars** offered additional insights into ripening dynamics. Additionally, **total phenolic and flavonoid content**, analyzed spectrophotometrically, helped evaluate the antioxidant capacity, which is crucial for both nutritional value and shelf-life extension.

Further response variables included **microbial analysis**, using total plate count to evaluate microbial growth, a significant determinant of spoilage rates. **Decay percentage** was calculated to quantify the proportion of spoiled tomatoes during the storage period, offering a direct measure of shelf life. Finally, **sensory evaluation** was conducted at the beginning and end of storage to assess consumer acceptability based on color, texture, taste, and overall appearance. These response variables collectively provided a robust framework for assessing the coatings' ability to

preserve quality and extend the shelf life of tomatoes under different storage conditions.

Choice of Experimental Design

These experiments involve studying the effects of multiple factors, making a factorial experimental design highly suitable. A factorial design refers to an experimental approach that incorporates two or more factors, each with multiple levels, allowing for the investigation of main effects and interactions among the factors. In this study, a **Randomized Complete Block Design (RCBD)** was employed with two factors:

- **Lemongrass Oil Concentration:** 0%(L_0) (control), 1%(L_1), and 2%(L_2).
- **Chili Pepper Oil Concentration:** 0%(P_0) (control), 1%(P_1), and 2%(P_2).

Six treatment combinations were tested, including a control group, $(L_1P_0, L_2P_1, L_1P_1, L_1P_2, L_0P_1)$ and a control group (L_0P_0) with each treatment replicated three times, resulting in a total of 72 tomato samples. This design allowed for the systematic evaluation of the effects of different oil concentrations as well as their potential interactions on the shelf life and quality of tomatoes. The RCBD was chosen because it minimizes variability within blocks, improves precision, and ensures that the conclusions drawn are reliable across varying experimental conditions. Furthermore, this design is cost-effective and adaptable, enabling a thorough examination of both main effects and interactions without requiring excessive additional resources.

2.4 Treatment of Tomato Fruits

Twelve tomato samples of each experimental design were randomly selected and treated by dipping each fruit into the described emulsions of L_1P_0, L_2P_1, L_1P_1, L_1P_2, and L_0P_1, respectively, while the control (L_0P_0) was not surface-coated in any emulsion. Their surfaces were brushed instantaneously to allow thorough circulation of the extract over the surface of the tomato fruits. The fruits were then labeled accordingly.

2.5 Effect of Surface Coating and Storage on the Physicochemical Parameters of Tomato

Weight loss, total soluble solids, pH, texture (hardness), total titratable acidity, and disease severity of the tomato fruits were monitored throughout the 12 days of storage.

2.6 Assessment of Weight Loss of Tomato Fruits Coated with Lemongrass Oil and Chili Pepper Oil During Storage at $28°\text{C} \pm 2°\text{C}$

After treatment of the tomato samples with the extracts, the weight was recorded using an electric weighing balance and likewise recorded at 3-day intervals. The final weights after each respective day of storage were subtracted from the initial weights of the tomatoes. This was achieved using the following equation:

$$W_2 = W_0 - W_1$$

where:

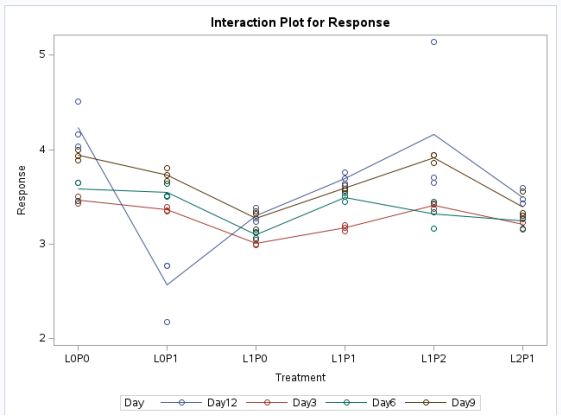
$W_2 =$ Weight loss of the tomato
$W_0 =$ Initial weight immediately after coating
$W_1 =$ Final weight during data collection

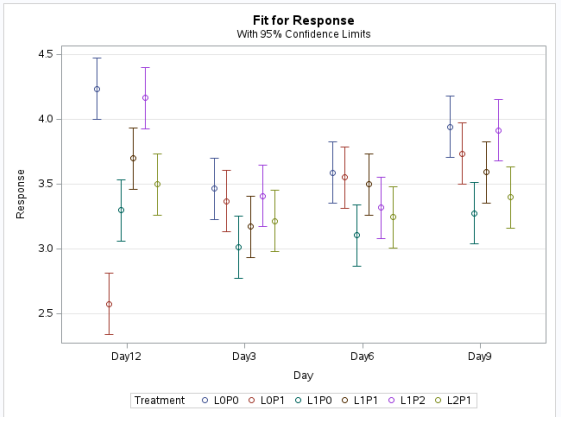
3. Analysis and Result

Factor estimation of main effects and interaction effects was conducted to assess the influence of lemongrass oil and chili pepper oil concentrations on the selected response variables. The significance of the effects was determined using ANOVA, and significant effects were identified for further analysis. The interaction effects and main effects that were statistically significant included **lemongrass oil concentration (L_1)**, **chili pepper oil concentration (P_1)**, and their interaction **(L_1P_1)**.

Post-hoc tests were performed to determine the specific levels of the factors that contributed to the significant effects. The findings suggest that higher concentrations of lemongrass oil and chili pepper oil, as well as their combined application, contributed to improved shelf life and quality retention of tomatoes.

The results are supported by the effect plots below, which clearly identify significant effects as the red square points in the plot. These visualizations highlight the critical role of lemongrass and chili pepper oil concentrations, both individually and in combination, in preserving postharvest quality attributes.





The plot shows how the response changes across different treatments (combinations of lemon and chili oil) over the different days. From the plot, we can observe the varying responses for each treatment on different days.

The GLM Procedure

Class Level Information		
Class	Levels	Values
Treatment	6	L0P0 L0P1 L1P0 L1P1 L1P2 L2P1
Day	4	Day12 Day3 Day6 Day9

Number of Observations Read	72
Number of Observations Used	72

The GLM Procedure

Dependent Variable: Response

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	23	9.32086111	0.40525483	9.65	<.0001
Error	48	2.01546667	0.04198889		
Corrected Total	71	11.33632778			

R-Square	Coeff Var	Root MSE	Response Mean
0.822212	5.908553	0.204912	3.468056

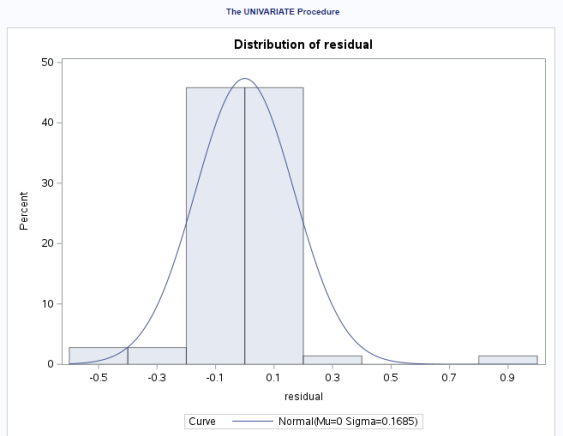
Source	DF	Type I SS	Mean Square	F Value	Pr > F
Treatment	5	3.60006111	0.72001222	17.15	<.0001
Day	3	1.57653889	0.52551296	12.52	<.0001
Treatment*Day	15	4.14426111	0.27628407	6.58	<.0001

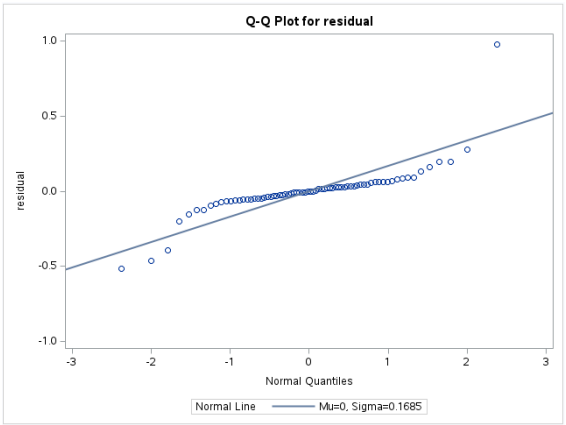
Source	DF	Type III SS	Mean Square	F Value	Pr > F
Treatment	5	3.60006111	0.72001222	17.15	<.0001
Day	3	1.57653889	0.52551296	12.52	<.0001
Treatment*Day	15	4.14426111	0.27628407	6.58	<.0001

An R-Squared value of 0.822212 indicates that the model explains about 82% of the variance in the response variable.

The F-values for **Treatment**, **Day**, and the interaction (**Treatment*Day**) are significant (all $p < 0.05$), which suggests that both treatment and day, as well as their interaction, have significant effects on the response.

Parameter	Estimate		Standard Error	t Value	Pr > |t|
Intercept	3.396666667	B	0.11830594	28.71	<.0001
Treatment L0P0	0.543333333	B	0.16730987	3.25	0.0021
Treatment L0P1	0.336666667	B	0.16730987	2.01	0.0498
Treatment L1P0	-0.123333333	B	0.16730987	-0.74	0.4646
Treatment L1P1	0.193333333	B	0.16730987	1.16	0.2536
Treatment L1P2	0.516666667	B	0.16730987	3.09	0.0033
Treatment L2P1	0.000000000	B	.	.	.
Day Day12	0.100000000	B	0.16730987	0.60	0.5529
Day Day3	-0.183333333	B	0.16730987	-1.10	0.2786
Day Day6	-0.153333333	B	0.16730987	-0.92	0.3640
Day Day9	0.000000000	B	.	.	.
Treatment*Day L0P0 Day12	0.193333333	B	0.23661189	0.82	0.4179
Treatment*Day L0P0 Day3	-0.293333333	B	0.23661189	-1.24	0.2211
Treatment*Day L0P0 Day6	-0.200000000	B	0.23661189	-0.85	0.4022
Treatment*Day L0P0 Day9	0.000000000	B	.	.	.
Treatment*Day L0P1 Day12	-1.260000000	B	0.23661189	-5.33	<.0001
Treatment*Day L0P1 Day3	-0.183333333	B	0.23661189	-0.77	0.4422
Treatment*Day L0P1 Day6	-0.030000000	B	0.23661189	-0.13	0.8996
Treatment*Day L0P1 Day9	0.000000000	B	.	.	.
Treatment*Day L1P0 Day12	-0.076666667	B	0.23661189	-0.32	0.7473
Treatment*Day L1P0 Day3	-0.080000000	B	0.23661189	-0.34	0.7368
Treatment*Day L1P0 Day6	-0.016666667	B	0.23661189	-0.07	0.9441
Treatment*Day L1P0 Day9	0.000000000	B	.	.	.
Treatment*Day L1P1 Day12	0.006666667	B	0.23661189	0.03	0.9776
Treatment*Day L1P1 Day3	-0.236666667	B	0.23661189	-1.00	0.3222
Treatment*Day L1P1 Day6	0.060000000	B	0.23661189	0.25	0.8009
Treatment*Day L1P1 Day9	0.000000000	B	.	.	.
Treatment*Day L1P2 Day12	0.150000000	B	0.23661189	0.63	0.5291
Treatment*Day L1P2 Day3	-0.323333333	B	0.23661189	-1.37	0.1781
Treatment*Day L1P2 Day6	-0.443333333	B	0.23661189	-1.87	0.0671
Treatment*Day L1P2 Day9	0.000000000	B	.	.	.
Treatment*Day L2P1 Day12	0.000000000	B	.	.	.
Treatment*Day L2P1 Day3	0.000000000	B	.	.	.
Treatment*Day L2P1 Day6	0.000000000	B	.	.	.
Treatment*Day L2P1 Day9	0.000000000	B	.	.	.


The UNIVARIATE Procedure
Distribution of residual
Percent
50
40
30
20
10
0
-0.5
-0.3
-0.1
0.1
0.3
0.5
0.7
0.9
residual
Curve
Normal(Mu=0 Sigma=0.1685)


Q-Q Plot for residual
residual
1.0
0.5
0.0
-0.5
-1.0
-3
-2
-1
0
1
2
3
Normal Quantiles
Normal Line
Mu=0, Sigma=0.1685

4. Conclusion and Recommendation

Edible coating is a safer and more effective way of preserving the overall quality of tomato fruits from physiological stresses and post-harvest decay. Unlike fungicides and other synthetic microbicidal, natural products leave no harmful environmental and food residue. The results of the research revealed that treatment with lemongrass oil (*Cybopogon citratus*) alone (L_1P_0) preserved the overall quality of pink tomato fruits throughout the 12 days of storage in this study, followed by L_2P_1. However, treatment with chili pepper oil alone (L_0P_1) and the treatment with a high concentration of chili pepper oil (L_1P_2) showed poor preservative quality compared to the control (L_0P_0). In conclusion, lemongrass (*C. citratus*) oil (L_1P_0) may be a good alternative for preserving the quality and extending the shelf life of fresh tomato fruits under ambient tropical conditions.

Regarding the efficacy of L_1P_0 and L_2P_1 for effective control of decay and the overall quality of fruits as demonstrated in this research, the use of lemongrass oil (L_1P_0) and the concentration of lemongrass to chili pepper of 2g:1g (L_2P_1) are hereby recommended. Lemongrass oil is easy to prepare compared to the use of fungicides, which leave residues that may be toxic to human health after consumption and are likewise detrimental to aquatic settings due to drift. Further studies are needed to extend the storage duration achieved by this experimental design, which may be accomplished through the combination of lemongrass oil with other plant oils or by combining heat treatment with effective surface coating.

References

[1] Sunday O Akintoye, Caroline Chebli, Susan Booher, Penelope Feuillan, Harvey Kushner, Derek Leroith, Natasha Cherman, Paolo Bianco, Shlomo Wientroub, Pamela Gehron Robey, et al. Characterization of gsp-mediated growth hormone excess in the context of mccune-albright syndrome. *The Journal of Clinical Endocrinology & Metabolism*, 87(11):5104–5112, 2002.

[2] İsmail Gök, OO Askın, Cem Okan Özer, and Birol Kılıç. Effect of textured soy protein and tomato pulp on chemical, physical and sensory properties of ground chicken döner kebab. *African Journal of Biotechnology*, 11(25):6730–6738, 2012.

[3] Kenneth O Tembe, George N Chemining'wa, Jane Ambuko, and Willis Owino. Effect of water stress on yield and physiological traits among selected african tomato (solanum lycopersicum) land races. 2017.

[4] Shreya Rini Titus, A Kerketta, and V Bahadur. Genetic variability, heritability and genetic advance studies for different characters of tomato (solanum lycopersicum l.). *International Journal of Current Microbial and Applied Science*, 9(12):1647–1653, 2020.

APPENDICES

4.1 Dataset

pH (Buffer 7)				
Treatment	DAY 3	DAY 6	Day 9	Day 12
L0P0	3.46	3.65	4	4.51
L0P0	3.5	3.65	3.89	4.16
L0P0	3.43	3.46	3.93	4.03
L1P0	3.04	3.13	3.32	3.38
L1P0	3	3.12	3.35	3.27
L1P0	2.99	3.06	3.15	3.24
L2P1	3.26	3.3	3.56	3.59
L2P1	3.15	3.16	3.3	3.47
L2P1	3.23	3.27	3.33	3.43
L1P1	3.2	3.5	3.62	3.76
L1P1	3.14	3.54	3.58	3.69
L1P1	3.17	3.45	3.57	3.64
L1P2	3.43	3.45	3.94	5.14
L1P2	3.42	3.34	3.94	3.7
L1P2	3.37	3.16	3.86	3.65
L0P1	3.39	3.51	3.8	2.77
L0P1	3.35	3.64	3.67	2.18
L0P1	3.36	3.5	3.73	2.77

4.2 SAS Code

```
    data tomato_data;
    input Treatment $ Day $ Replicate Response;
    datalines;
L0P0 Day3 1 3.46
L0P0 Day3 2 3.5
L0P0 Day3 3 3.43
L0P0 Day6 1 3.65
L0P0 Day6 2 3.65
L0P0 Day6 3 3.46
L0P0 Day9 1 4
L0P0 Day9 2 3.89
L0P0 Day9 3 3.93
L0P0 Day12 1 4.51
L0P0 Day12 2 4.16
L0P0 Day12 3 4.03
L1P0 Day3 1 3.04
L1P0 Day3 2 3
L1P0 Day3 3 2.99
```

```
L1P0 Day6 1 3.13
L1P0 Day6 2 3.12
L1P0 Day6 3 3.06
L1P0 Day9 1 3.32
L1P0 Day9 2 3.35
L1P0 Day9 3 3.15
L1P0 Day12 1 3.38
L1P0 Day12 2 3.27
L1P0 Day12 3 3.24
L2P1 Day3 1 3.26
L2P1 Day3 2 3.15
L2P1 Day3 3 3.23
L2P1 Day6 1 3.3
L2P1 Day6 2 3.16
L2P1 Day6 3 3.27
L2P1 Day9 1 3.56
L2P1 Day9 2 3.3
L2P1 Day9 3 3.33
L2P1 Day12 1 3.59
L2P1 Day12 2 3.47
L2P1 Day12 3 3.43
L1P1 Day3 1 3.2
L1P1 Day3 2 3.14
L1P1 Day3 3 3.17
L1P1 Day6 1 3.5
L1P1 Day6 2 3.54
L1P1 Day6 3 3.45
L1P1 Day9 1 3.62
L1P1 Day9 2 3.58
L1P1 Day9 3 3.57
L1P1 Day12 1 3.76
L1P1 Day12 2 3.69
L1P1 Day12 3 3.64
L1P2 Day3 1 3.43
L1P2 Day3 2 3.42
L1P2 Day3 3 3.37
L1P2 Day6 1 3.45
L1P2 Day6 2 3.34
L1P2 Day6 3 3.16
L1P2 Day9 1 3.94
L1P2 Day9 2 3.94
L1P2 Day9 3 3.86
L1P2 Day12 1 5.14
L1P2 Day12 2 3.7
L1P2 Day12 3 3.65
```

```
L0P1 Day3 1 3.39
L0P1 Day3 2 3.35
L0P1 Day3 3 3.36
L0P1 Day6 1 3.51
L0P1 Day6 2 3.64
L0P1 Day6 3 3.5
L0P1 Day9 1 3.8
L0P1 Day9 2 3.67
L0P1 Day9 3 3.73
L0P1 Day12 1 2.77
L0P1 Day12 2 2.18
L0P1 Day12 3 2.77
;
run;

* Running the General Linear Model for RCBD;
proc glm data=tomato_data;
    class Treatment Day;
    model Response = Treatment Day Treatment*Day;
    output out=glm_output p=Predicted r=Residual;
run;

* Checking residuals for normality and homoscedasticity;

* 1. Normality check: Shapiro-Wilk test and QQ plot;
proc univariate data=glm_output normal;
    var Residual;
    histogram / normal;
    qqplot / normal(mu=est sigma=est);
run;

* 2. Residual vs Predicted Plot;
proc sgplot data=glm_output;
    scatter x=Predicted y=Residual;
    refline 0 / axis=y lineattrs=(color=red);
    title "Residual vs Predicted Plot";
run;

* 3. Additional diagnostics for model fit;
proc glm data=tomato_data;
    class Treatment Day;
    model Response = Treatment Day Treatment*Day / solution;
    lsmeans Treatment / pdiff=all;
    lsmeans Day / pdiff=all;
run;
```