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Research Article

Shelf-Life Extension of Tomatoes using Pectin-Based Edible Coatings Extracted via Ultrasound-Assisted Extraction (UAE)

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ABSTRACT

Widespread tomato consumption in Pakistan faces challenges due to significant losses from poor management and processing. These challenges by utilizing waste from abundant fruits, first time of extracting pectin from grapefruit peels through ultrasonic-assisted extraction (UAE), and applying it to tomatoes to extend their shelf life. The qualitative and quantitative analysis of the extracted pectin includes assessments of solubility, pH, color, methoxyl content, yield, and equivalent weight. Pectin yield could be enhanced by ultrasonication by 28% for 20 minutes. The dipping method with pectin concentrations (6, 9 and 12%) protects tomatoes against microbial contaminants. A 12% pectin coating (T_3) effectively delayed tomato softening and reduced microbial growth compared to untreated samples. Coated tomatoes also showed less weight loss and maintained greater firmness during storage. These results demonstrate that ultrasound-assisted extraction improved pectin yield, and that the pectin coating successfully slowed microbial deterioration, thereby extending the shelf life of tomatoes by several days.

Keywords: Tomato preservation, Grapefruit peels, UAE, pectin coating, fungal count

INTRODUCTION

Citrus fruit peels, including those of orange, lemon, lime, citron, and grapefruit, are rich sources of pectin. During juice processing, large quantities of peel waste are generated, which can be effectively repurposed for pectin extraction—a valuable biopolymer with diverse applications in the food and pharmaceutical industries (Pourhossein et al., 2019). Focusing on pectin recovery from these peels not only adds value to this agro-industrial waste but also supports sustainable resource utilization (Imran, 2022). While citrus peels contain other bioactive compounds, this study emphasizes the extraction and application of pectin, given its significant functional properties and industrial relevance (Santos, Dweck, Viotto, Rosa, & de Morais, 2015).

From grapefruit peel, a higher yield of pectin can be obtained. Pectin extraction is done by different thermal and non-thermal techniques i.e. microwave assisted extraction (MAE), solvent extraction, ultrasound assisted extraction (UAE)(Sengar, Rawson, Muthiah, & Kalakandan, 2020), dielectric barrier discharge plasma extraction (DBD) and enzymatic extraction. In pectin extraction, time and temperature are the main factors that affect the yield of pectin. Conventional methods are time-consuming and also affect both the yield and quality. Conventional methods of pectin extraction include acid extraction, enzymatic extraction, and microwave-assisted extraction. Among these, acid extraction, using mineral acids like hydrochloric or sulfuric acid at high temperatures, is the most widely used due to its ability to produce high-quality pectin with good yield. Enzymatic extraction offers specificity and milder conditions, while microwave-assisted extraction can reduce processing time and energy consumption. However, acid extraction involves long processing times, high energy and water usage, and risks pectin degradation under harsh conditions. Additionally, the use of strong acids poses environmental challenges, requiring careful wastewater management. Enzymatic methods, though gentler, can be costly and slower, while microwave techniques may require specialized equipment, limiting their widespread adoption. (H. Duguma, 2021). UAE is an innovative technique used for pectin extraction (Marić et al., 2018). It employs ultrasonic energy waves to extract target

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compounds from plants. The ultrasound technique utilizes mechanical waves with a frequency >20kHz- 10 MHz, which is higher than the audible frequency range for humans (20 Hz to 20 kHz). A recent study has demonstrated that sonication exhibits antifungal effects of up to 80% within a 40-minute duration (Faisal Manzoor et al., 2023). In a recent study, strawberry juice underwent treatment with high-temperature short-time (HTST) processing, and the results were compared to sonication at intervals ranging from 5 to 15 minutes. Sonication demonstrated promising outcomes in the preservation of strawberry juice and enhancement of its phytochemical properties (Yildiz & Aadil, 2020). A research study revealed that combining plasma-activated water (PAW) with sonication significantly reduced chlorothalonil fungicide residues on tomatoes, with the PAW-U10 treatment being particularly effective. This innovative approach not only ensured the quality and safety of the produce but also minimized agro-chemical waste and associated health risks (Ali et al., 2023). Ultrasound-assisted extraction boosts pectin yield and quality. Pectin obtained through UAE exhibits superior sensory properties compared to other extraction methods (Wang et al., 2016).

Tomato (*Solanum lycopersicum)* is renowned as a highly lucrative crop that generates profits for small-scale farmers. Its popularity stems from high consumer demand attributed to its affordability, rich nutritive value, appealing taste, and widespread accessibility(Rodriguez-Garcia et al., 2016). Certainly, attention should be directed towards the microorganisms associated with the spoilage of tomatoes. The isolation of microorganisms, coupled with unfavorable storage conditions and fungal attacks, adversely affects the quality of tomatoes, resulting in postharvest losses. Therefore, the application of edible coatings emerges as an effective method to counteract the impact of anaerobic bacteria on tomatoes, ultimately extending their shelf life (H. T. Duguma, 2022). Pectin coatings can be employed to preserve the texture of tomatoes, as highlighted by Rodriguez-Garcia et al. (2016). Grapefruit peel pectin coatings are especially appealing due to their edibility, biodegradability, antioxidant properties, and cost-effectiveness. (Guo et al., 2012).Grapefruit pectin coatings effectively extend the shelf life of tomatoes while preserving their appearance, firmness, and moisture content. These coatings exhibit robust barrier properties against microbial, particularly fungal spoilage, lipid oxidation, moisture and gas transmission, and enzymatic activities. Moreover, they not only delay the respiration rate but also reduce ethylene production, thereby minimizing physiological decay (Marić et al., 2018).

This research aimed to develop a sustainable and biodegradable coating for tomato preservation by utilizing pectin extracted from grapefruit peel—an underused food waste—through ultrasound-assisted extraction (UAE). The study sought to introduce a novel alternative to conventional coatings by combining waste valorization with an efficient green extraction technique, addressing the need for more effective and environmentally responsible postharvest preservation methods.

MATERIALS AND METHODS

Grapefruits were obtained from local fruit shop from Faisalabad, Pakistan. The grapefruits were washed, peeled and afterward the peels were cut into small pieces. The peels were dried in dehydrator (R-5A, Eugene, US) for 2-3 days at 50 °C. At that point, dried peel pieces were grounded and particles having size smaller than 0.6 mm in diameter were further used. Tomatoes of uniform shape and size were chosen at their turning stage.

Extraction of pectin from grapefruit peel using ultrasound assisted extraction (UAE): In a constant ratio of 1:30 g/mL, 1g of grapefruit rind powder was combined along citric acid. Under different extraction conditions, a probe ultrasonic processor (UCD-950, Jinan, China) was used with extreme power of 1000 Watt and a frequency of 20 kHz with 50 % pulse of (3 seconds on and 6 seconds off). The extracts were collected after the sonication treatment and centrifuged (MPW-352R, Dublin, Ireland) at 4500 rpm for 20 minutes. The supernatant was separated with muslin cloth, condensed with 95% ethanol (1:2 volume-by-volume), and stored at 4°C overnight. The pectin was collected and cleaned thrice through ethanol before drying in a dehydrator. Finally, using a grinder, the dry sample was grinded into powder (Panwar, Panesar, & Chopra, 2023).

Table 1. The pectin extraction treatment plan utilizing the UAE involves employing a frequency of 20 kHz with intervals of 5 minutes.

Treatments	Ultrasound (kHz)	Time (minutes)
T_1	20	5
T_2	20	10
T_3	20	15
T_4	20	20

Analysis and characterization of pectin

Solubility of dry pectin in cold and hot water: In a conical flask, 0.25 % pectin samples were taken, and subsequently, 50 mL of distilled water along with 10 mL of 95 % ethanol was added. The mixture was then shaken to form a suspension and heated for 15 minutes at 85-95 °C(Sundararaman, Gopakumaran, Sundari, Amarnath, & Thayyil, 2016).

Solubility of pectin solution in cold and hot alkali (NaOH): To prepare the sample, 5mL pectin solution was combined with 1 mL of 0.1 N NaOH solution. The solution was heated at 85-90 °C for 15 minutes (Sundararaman et al., 2016).

PH determination: The pH was determined using a pH meter (Ohaus Starter 5000, Shanghai, China). To assess the pH of the extracted pectin, a buffer solution with a pH of 7 was prepared. This buffer solution served to standardize the glass electrode, which was rinsed with distilled water before being inserted into the pectin solution (Yuliarti, Hoon, & Chong, 2017).

Quantitative tests

Yield of pectin: Yield of pectin was calculated through utilizing following equation (Kanmani, 2014).

$$\text{Yield (\%)} = \frac{\text{Wt.of dried extracted pectin (g)}}{\text{Wt.of grapefruit peel powder (g)}} \times 100$$

Equivalent weight: The few drops of phenol red indicator were mixed. Then, the mixture was titrated against 0.1M NaOH till pink shade was attained and lasted for at least 30 seconds(Ciriminna et al., 2017).

$$\text{Equivalent weight} = \frac{Wt.of\ sample \times 1000}{Vol.\ of\ alkali \times Normality\ of\ alkali}$$

Methoxyl content: The NaOH of 0.25 M and 25 mL was added to a neutral solution having 0.5 g of pectin material that was titrated for equivalent weight. It was shaken thoroughly and in a stoppered flask permitted to stand for half an hour at room temperature. To same end point, 25mL of 0.25M HCI was added and titrated with 0.1M NaOH as before in equivalent weight (Ciriminna et al., 2017).

$$\text{Methoxyl content (\%)} = \frac{\text{Vol.of alkali (mL) x Normality of alkali}}{\text{Wt.of sample (g)}} \times 100$$

Degree of esterification (DE): The determination of the DE value of pectin was conducted by blending the pectin sample into deionized water using a magnetic stirrer until complete dispersion of the pectin was achieved Ciriminna et al. (2017). Subsequently, 0.1 M NaOH was added, and the mixture was stirred for approximately 30 minutes. The excess NaOH was titrated with 0.1 M HCl, using phenolphthalein as the indicator. The end point was considered to reach, when a pale pink color was persisted for at least 30 seconds. The same steps were repeated for a blank sample (containing only water and NaOH). The degree of esterification in the sample was then calculated using the following formula:

$$\text{DE} = \frac{[(\text{V2}-\text{V1}) \times \text{M} \times \text{F} \times 176.14]}{W}$$

Where:
V1: volume of HCI used for titration
V2: volume of HCI used for titration of pectin sample (mL)
M: molarity of HCI (0.1 M)
F: correction factor for the HCI solution (101 for HCI solution)
W: weight of the pectin sample (g)
176.14: molecular weight of galacturonic acid

The DE value is expressed as a percentage of the degree of esterification of sample. Following a comprehensive evaluation of pectin extracts from four distinct treatments, the sample exhibiting the highest degree of esterification (DE) was selected for tomato coating applications.

Preparation of pectin coatings: At 90ºC, the pectin (3%) was dissipated in distilled water. Glycerol (2.5%), Polyvinyl-Alcohol (PVA) (1.25%), and citric acid (1 %) were added to this pectin solution and combined using the magnetic stirrer. The mixture was brought down to the room temperature, and to degas it took for 2-4 hours though stirring or agitation can reduce the time (Menezes & Athmaselvi, 2016).

Table 2. Treatment plan for pectin-based coatings containing different percentages of pectin, distilled water, polyvinyl-alcohol (PVA), glycerol, and citric acid on tomatoes.

Treatments	Concentration %
T_0	-
T_1	6
T_2	9
T_3	12

Application of pectin coatings on tomato: The tomatoes at the turning stage were immersed in a solution of 5 g sodium hypochlorite and 495 mL water for 15 minutes. After thorough air drying, the tomatoes were subsequently immersed in pectin solutions T_1, T_2, and T_3 for durations ranging from 30 seconds to a few minutes. The pectin-coated tomatoes were then stored at 4±2 °C and subjected to regular analyses at intervals of 13 days over a storage period of 39 days.

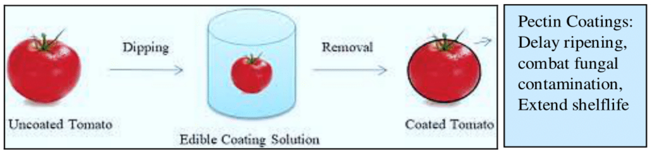


Figure 1. Application of pectin-based coatings on tomato by dipping method with varied pectin concentrations (6%, 9%, 12%)

Physicochemical analysis of pectin-coated tomatoes: Various quality parameters of the coated tomatoes were assessed to evaluate the impact of the applied coatings. The **pH** level was measured using a digital pH meter (Ohaus Starter 5000, Shanghai, China) after subjecting 20 g of tomato paste to a water bath at 50 °C, with calibration performed using buffer solutions (Aragüez, Colombo, Borneo, & Aguirre, 2020). **Firmness**, indicative of fruit hardness, was analyzed using a penetrometer (53205 SP, Forli, Italy), and three replicates of each sample were taken to ensure accuracy (Wu, Lu, and Wang (2016). **Total acidity** was determined through titration, with 10 g of tomato paste added to distilled water, and acidity expressed in grams of citric acid per 100 g of tomato weight (Tigist, Workneh, and Woldetsadik (2013)). **Color** characterization was conducted using a Colorimeter (D65, Beijing, China), measuring brightness (L*), color ranges (a* and b*), and overall color variation (ΔE).

$$\text{Color } (\Delta E) = [(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2]^{½}$$

The color variation in sample was measured using above formula by Won, Lee, Park, Song, and Min (2018). Finally, **weight loss** was calculated as the percentage difference between initial and final weights after specified time intervals. These comprehensive assessments provide a detailed understanding of the coated tomatoes' physicochemical characteristics throughout the storage period (Ghasemi and Chayjan (2019).

$$\text{Weight loss (\%)} = \frac{\text{Initial weight} - \text{final weight}}{\text{Initial weight}} \times 100$$

Microbial analysis: In this research, the microbial quality of tomatoes was assessed through Total Plate Count (TPC), representing the total colony forming units (CFU). Tomatoes were homogenized in Ringer's solution, and 1:9 dilutions were prepared. The pore plate method, utilizing plate count agar culture media (HiMedia, M001, Mumbai, India), was employed, and samples were incubated at 35 °C for 48 hours. Throughout the 30-day experiment at 2-day intervals, microbial counts were recorded in log CFU/g, following the methodology by Feldsine, Abeyta, and Andrews (2019). For the determination of Total Fungal Count (TFC), 20 g of tomato samples were precisely weighed and placed into sterilized stomacher bags with 180 mL of 0.1% peptone water. After homogenization using a blender stomacher for 2 minutes, serial dilutions were performed. Potato dextrose agar (PDA) medium was spread onto petri dishes, and the samples were inoculated in 100 mL of PDA. The petri dishes were then maintained at 25 °C for 5 days. The enumeration of total mold or yeast colony-forming units (CFU) was conducted following the method described by Duc et al. (2022).

Sensory analysis: Sensory analysis of coated tomatoes treated with different concentrations of grapefruit peel extracts were employed by hedonic test. Ten professional panelists evaluated the samples using a 9-point scale, ranging from 1 (very poor) to 9 (optimum quality). The analysis involved dividing samples into two halves, each assigned a unique 3-digit code, and presenting them to panelists for evaluation at room temperature. Palate cleansing with water was provided between sample assessments. The external attributes of the fruits were also considered in the sensory analysis. This evaluation was conducted using a nine-point hedonic scale, in accordance with the methodology described by Dehghani, Hosseini, and Rousta (2022).

Statistical analysis: The collected numerical data underwent appropriate statistical analysis to determine the most effective treatment. The analytical tests were run three times, and the outcomes were reported as mean average deviation. To evaluate results, ANOVA was built by means of the statistics program. Data was analyzed statistically to check its significance level referring to the method defined in Montgomery (2017).

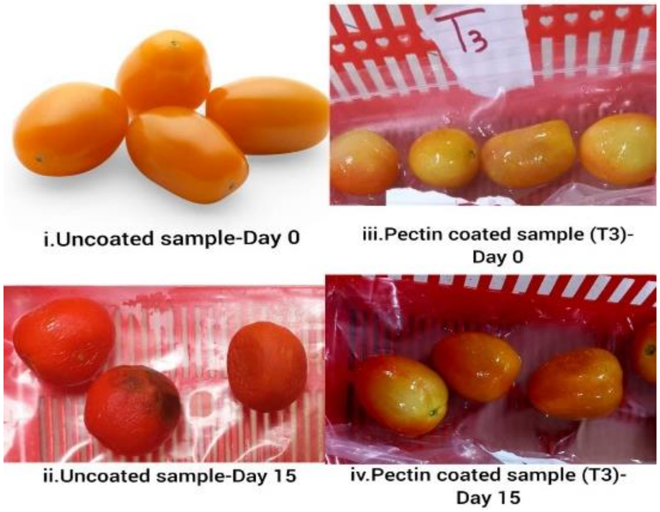
RESULTS AND DISCUSSION

Characterization of extracted pectin: The extracted pectin was characterized by its solubility, showing 90% solubility in hot alkali and 65% in cold alkali. Table 3 presents pH was measured at 3.5 and color analysis showed a light yellow color (L*=78.6). The methoxyl content was 6.5%, highest yield of pectin 28% and equivalent weight about 684g/mol. These parameters showed good efficiency of pectin obtained from grapefruit peel via ultrasound-assisted extraction.

Table 3. Characterization of extracted pectin

Parameter	**Value**
Solubility	90% in hot alkali, 65% in cold alkali
pH	3.5
Color	Light yellow (L*=78.6)
Methoxyl content	6.5%
Yield	28%
Equivalent weight	684g/mol

Weight loss: Table 4 presents the results pertaining to weight loss in tomatoes. The primary cause of weight loss in tomatoes is attributed to increased water transpiration, leading to a reduction in organoleptic properties and postharvest quality. The control sample (T_o) exhibited the maximum increase in weight loss from day 13 to day 39 of cold storage. In contrast, tomatoes coated with pectin demonstrated the least amount of weight loss. By the end of the 39th day of storage, the T_o treatment displayed the greatest weight loss value (6.22±0.09%), while T_3 (coated with 12% pectin) exhibited the least weight loss value (4.21±0.03%). This emphasizes the efficacy of pectin coatings in minimizing weight loss and preserving the overall quality of tomatoes during storage.



i.Uncoated sample-Day 0

iii.Pectin coated sample (T3)-Day 0

ii.Uncoated sample-Day 15

iv.Pectin coated sample (T3)-Day 15

Figure 2. (i) Uncoated Tomato sample at day 0; (ii) Uncoated sample at day 15; (iii) Pectin coated with best treatment (T_3) at day 0 ; (iv) Pectin coated sample at day 15 on 4±2 °C.

Comparing our results to prior studies, K. Das, Roychoudhury, and & Chakraborty (2013) reported weight reductions ranging from 2.5% to 11.5% with starch-based coatings. Our grapefruit peel pectin coating, on the other hand, resulted in less weight losses, specifically 93-94 g/kg for coated tomatoes compared to 175 g/kg for uncoated tomatoes. This reflects a notable 4.2% to 7.7% reduction in weight loss for coated tomatoes, highlighting the superior preservation ability of our coating (Araújo, Silva, Cunha, Fernandes, & & Pinho, 2018). These findings underscore the potential of grapefruit peel pectin coatings to effectively mitigate weight loss and uphold tomato firmness during storage, aligning with the conclusions drawn from previous studies.

Color: Color and visual appeal stand as pivotal quality criteria, profoundly influencing customers' perceptions of product quality, particularly in the case of tomatoes. Pectin coatings emerge as a crucial factor, playing a significant role in mitigating or delaying color changes in tomatoes during storage. Table 4 presents the results for L*, a*, and b*. The significant effect of days and treatment time was calculated for the L* values of tomatoes. With the advancement of the storage period, L* values were decreased, indicating a darkening or reduced brightness of the tomatoes over time. The initial L* values of both coated and uncoated samples ranged from 52.12±0.01 to 51.92±0.05 on the 0th day of storage. The control sample (T_o) exhibited the maximum decrease to 36.23±0.04, while the T_3 coated samples showed the minimum decrease in L* values at 43.56±0.01, 42.54±0.03, and 42.39±0.03 on the 13th, 26th, and 29th days of cold storage, respectively. Tomatoes coated with chitosan demonstrated the least reduction in L*, indicating a slowed ripening process with an increased storage period for tomatoes (Sucheta, Chaturvedi, Sharma, & Yadav, 2019). Control samples (T_o) exhibited the highest a* value (24.75±0.04), while pectin-coated samples (T_1, T_2, T_3) displayed a* values of 22.83±0.05, 23.06±0.05, and 24.07±0.04, respectively. When comparing pectin coatings with rice-based starch coatings containing antioxidant compounds in coated tomatoes, a modest increase in a* value was observed. This increase in a* value is indicative of a limited accumulation of lycopene components, effectively contributing to the delay in color changes during storage (Rohasmizah & Azizah, 2022). A comparison with the control sample revealed the maximum decrease in b* values (25.96±0.04 to 18.15±0.08), whereas pectin-coated samples exhibited the least decrease in b* values (25.62±0.06 to 20.5±0.04) during the 0th, 13th, 26th, and 39th days of cold storage. In a study by Yao and Adjouman (2018), focusing on tomatoes coated with cassava starch, a notable decrease in b* values from yellow to green was reported for coated tomatoes. Throughout the ripening process, chlorophyll, the green pigment, degraded, and carotenoids, particularly lycopene, accumulated, imparting the red color characteristic of ripe tomatoes. It was observed that grapefruit pectin coatings exert a significant influence in preserving the color of tomatoes.

Firmness: Firmness is a key quality attribute in tomatoes, indicating texture, freshness, and ripeness. It is largely influenced by cell wall structure, especially pectin content, and is critical for reducing postharvest losses and maintaining shelf life. The firmness of pectin-coated tomatoes shown in Table 4. The maximum firmness value was observed on the 39th day of storage (1.61±0.07), in contrast to the uncoated sample which displayed the lowest firmness value (1.50±0.06) at the same storage duration. This disparity signifies that the pectin-coated samples experienced less softening, attributed to the presence of a protective pectin layer on the fruit exterior. This coating minimized moisture loss and cellular degradation. In comparison, the control sample, lacking this coating, exhibited greater moisture loss during storage. Our findings suggested that the pectin coating effectively preserved tomato firmness, possibly by reducing enzymatic activity and acting as a moisture barrier. Coating thickness was approximately 50-70µm, which contributed to gas permeability. By comparing pectin-based coatings with Casariego et al. (2008) in which the research described the impact of chitosan-based edible coatings on carrot and tomato, showed the improved firmness retention in coated tomatoes, which was consistent with our observations. Pectin coatings better maintained the texture of tomatoes. It also prevented fruit softening and reduced moisture loss.

pH value: The outcome values for pH are shown in Table 4. The results showed the significant relation of treatment and storage on pH of tomatoes. The pH values were ranged from 4.2±0.04 to 1.89±0.09 in control sample (T_o) and 3.7±0.08 to 2.11±0.02 in pectin treated samples (T_1, T_2, T_3) during 0 day to 39th day of storage. During storage, untreated tomatoes showed a more significant decrease in pH, reaching 1.89 ± 0.09 by the 39th day, while pectin-coated tomatoes maintained a higher pH of 2.11 ± 0.02. This indicates that the pectin coating slowed down the acidification process. These findings highlight a substantial drop in pH for the uncoated samples, attributed to the delayed utilization of organic compounds and an elevated respiration rate. In contrast, the coated tomatoes exhibited a modest decrease in pH value. Salas-Méndez et al. (2019) determined the quality of tomatoes by extending the life of coated fruits, and this study revealed a slight increase in the pH range 4.17-4.59.

Total acidity: Results regarding mean values for total acidity are shown in Table 4. The total acidity in pectin-coated tomatoes remained higher throughout the storage period compared to untreated samples, with acidity gradually increasing over time in all cases. Together, these results suggest that the pectin coating helped preserve the tomatoes' acidity balance, thereby contributing to improved quality and extended shelf life. This rise in acidity was attributed to high respiration rates and phenolic oxidation, as described by T. Jiang, Feng, Zheng, and Li (2013). On the 13th day, control samples exhibited higher acidity of 1.44±0.05 than to treated tomatoes (1.32±0.05) indicating the coating's potential to effectively control acidity changes. By the 26th day, all tomatoes, regardless of treatment, exhibited slightly higher acidity than the initial value, with pectin-coated tomatoes showing the higher acidity results of 1.87±0.03, 2.14±0.03 and 2.42±0.03 in T_1, T_2, T_3, which was statistically significant compared to untreated samples. This increase in acidity could be attributed to the pectin coating, potentially increasing respiration rates according to T. Jiang, Feng, Zheng, and Li (2013) and the utilization of organic acids in treated tomatoes. Pectin coatings preserve the acidic characteristics of the fruit and create a barrier that limits the external influences on tomato acidity. According to Liu, Yuan, Chen, Li, and Liu (2014), who studied the combination effect of chitosan and ascorbic acid coating, coated plums had significantly lower total acidity than untreated plums after 20 days. The combined chitosan coating has a lesser acidity impact than the ascorbic acid-added coating. After postharvest, the acid level of fleshy fruits dropped, while alginate coating caused reduction in plum acidity.

Microbial assay

Total plate count: Results regarding the value of TPC are shown in Table 4. An overall decreasing trend was observed in different treatments of different concentration of grapefruit peel extracts. Uncoated samples have the most total viable count at the end of the storage compared to the coated sample. This may be due to antimicrobial activity of the protective barrier created by the coating, which hinders the ingress of gases and various substances. After 13 days of storage, the log (CFU)/g of mesophilic bacteria of uncoated tomatoes were higher than coated tomatoes. Control sample had the highest value (5.31±0.06 log CFU/g) than T_1 (4.92±0.05), T_2 (4.45±0.03) T_3 (4.81±0.02,) treated samples at 39th day of refrigerated storage. The highest observation of TPC was recorded in treatment T_o at 39th day in control sample. Stearic acid, a fatty acid in pectin prevents the penetration of moisture essential for microbial growth due to its hydrophobic nature. The uncoated sample showed the shelf life of approximately 21 days. Similar results were reported by D. K. Das, Dutta, and Mahanta (2013), who studied the effect of rice starch base coating on tomato, and the plate count of coated samples dropped during his 20-day storage trial. The coating consist a combination of starch, glycerol and lipids which gave the best results than the combination of starch, glycerol, lipid and antioxidant. The plate counts from 0 to 20 days were ranged from 1140 CFU/mL to 2640 CFU/mL for untreated samples and 940 CFU/mL for coated samples.

Total fungal count (TFC): The results regarding the value of TFC are shown in Table 4. Initially, the treated sample showed low TFC, indicating some protection against fungal growth due to the edible coating. However, as storage duration increased, TFC showed a slight increase in all treatments along the days, a common trend due to natural fruit deterioration. Notably, untreated tomatoes T_o exhibited the highest TFC 3.17±0.09 on the 39th day, while coated tomatoes T_1 (2.78±0.08), T_2 (2.25±0.09), T_3 (2.12±0.01) maintained the lower TFC levels, suggesting that the pectin-based coating helped to delay fungal contamination and extend microbial safety. These findings suggested that the pectin-based edible coating had the potential to enhance the microbial safety of tomatoes during storage. The computed values are similar to the findings of Davoodi and Naji (2018), who investigated the effect of pomegranate peel extract in sodium alginate coating. Mold and yeast counts were decreased when pomegranate peel pectin concentration increased to 2% to 10%. In coated samples, the reduction was from 3.59 to 2.29. Breda, Morgado, de Assis, and Duarte (2017) found that the antifungal impact of chitosan with pequifruit peel extract on tomato, yeast and mold count was lower than the estimated value of $1.5(10^3)$ CFU/mL. The protonated amino group of chitosan and cellular negative sites interaction cause the change and hindrance to nutrition of fungus and create barrier to fungal growth.

Sensory analysis

Color: Results regarding the value of color and overall acceptability are shown in Table 4. The obtained outcomes about the treatment as well as storage time exhibited the significant impact on color coated tomatoes. The highest color value was observed in T_3 by the 39th day as compared to the control sample. Treatments and days exhibited the increasing trend for color, and the maximum value of color was recorded in T_3 (4.11±0.01) at 39th day of cold storage. Mohamed, Muhammad, Sijam, and Siddiqui (2010) Used different concentrations (0.5, 1.0, 1.5and 2%) of chitosan coating on papaya fruit. The coating contained 0.5% concentration of chitosan showed the results as fruit began ripening within the three weeks of storage. Similarly, papaya fruit with the concentration of 1.5% chitosan started degradation during the four weeks of study due to complete ripening process. The 2% showed the lowest ripening of papaya and 1.5% concentration was given the maximum score by panelists.

Flavor: The obtained statistical results showed that storage days as well as treatment exhibited a highly significant effect for flavor. Coated samples showed the increasing trend from 4.20±0.06 to 5.60±0.09 from 0 day to 39th day during the storage. Control sample recorded the highest value 6.99±0.03 at the 39th day of storage. H. Jiang, Sun, Jia, Wang, and Huang (2016) treated blueberries with several amounts of chitosan, and the flavor outcomes for two chitosan concentrations were good. Ten panelists used a 9-point hedonic scale to generate the score, with 9 representing extraordinary quality, 7 representing very well, 5 representing good, 3 representing fair, and 1 representing spoilt, terrible outcomes. The size and quality of the control sample were reduced.

Overall acceptability: The calculated results indicated that both variables (days and treatment) had a significant impact on overall acceptability. A slight decreasing pattern was observed in the overall acceptability, decreasing from 4.80±0.05 to 3.41±0.08 for the pectin-treated samples from day 0 to day 39. The control sample exhibited the lowest value, reaching 2.91±0.05 on the 39th day of storage. Yousuf, Wu, and Siddiqui (2021) Reported that the coating of pectin on tomatoes resulted in the better overall acceptability.

Therefore, fruits coated with pectin were considered superior in quality and better suited to meet consumer requirements than other coating materials. Such high-value products could be used in industries for the manufacturing of various items.

Table 4. Effect of UAE pectin on weight loss, color, firmness, pH, total acidity, lycopene, TPC, TFC and sensory attributes of tomato fruits during storage

		0 Day	**13 Day**	**26 Day**	**39 Day**
Weight loss	T_o	3.40 ± 0.04^{b}	4.38 ± 0.07^{ab}	5.06 ± 0.08^{ab}	6.22 ± 0.09^{a}
	T_1	3.36 ± 0.01^{b}	3.56 ± 0.05^{b}	4.18 ± 0.07^{ab}	4.32 ± 0.06^{ab}
	T_2	3.32 ± 0.02^{b}	3.49 ± 0.04^{b}	4.15 ± 0.04^{ab}	4.25 ± 0.05^{ab}
	T_3	3.29 ± 0.05^{b}	3.45 ± 0.02^{b}	4.14 ± 0.04^{ab}	4.21 ± 0.03^{ab}
Color(L*)	T_o	52.12 ± 0.01^{ab}	46.44 ± 0.03^{ab}	44.98 ± 0.03^{ab}	36.23 ± 0.04^{e}
	T_1	52.08 ± 0.04^{bc}	45.89 ± 0.04^{bcd}	44.34 ± 0.07^{cd}	43.80 ± 0.05^{a}
	T_2	50.03 ± 0.03^{cd}	44.07 ± 0.03^{cde}	43.21 ± 0.03^{cde}	42.98 ± 0.06^{cde}
	T_3	51.92 ± 0.05^{cde}	43.56 ± 0.01^{cde}	42.54 ± 0.03^{de}	42.39 ± 0.03^{cd}
a*	T_o	21.46 ± 0.01^{cde}	22.70 ± 0.05^{bcd}	23.23 ± 0.05^{abc}	24.75 ± 0.04^{a}
	T_1	20.46 ± 0.02^{e}	$21.15\pm0.02^{b-e}$	21.99 ± 0.09^{cde}	22.83 ± 0.05^{abc}
	T_2	20.89 ± 0.02^{de}	21.98 ± 0.02^{cde}	$22.33\pm0.04^{b-e}$	23.06 ± 0.05^{abc}
	T_3	21.31 ± 0.04^{cde}	$22.65\ \pm0.03^{bcd}$	23.01 ± 0.07^{abc}	24.07 ± 0.04^{ab}
b*	T_o	25.96 ± 0.04^{a}	24.64 ± 0.03^{b}	22.28 ± 0.01^{fg}	18.15 ± 0.08^{l}
	T_1	25.62 ± 0.06^{b}	23.76 ± 0.02^{c}	21.92 ± 0.01^{g}	18.94 ± 0.09^{j}
	T_2	24.94 ± 0.07^{cd}	22.79 ± 0.02^{ef}	21.23 ± 0.02^{h}	19.57 ± 0.09^{k}
	T_3	24.55 ± 0.03^{de}	21.10 ± 0.01^{h}	20.89 ± 0.09^{i}	20.50 ± 0.04^{i}
Firmness	T_o	2.86 ± 0.01^{a}	2.01 ± 0.03^{a}	1.76 ± 0.05^{ab}	1.50 ± 0.06^{abc}
	T_1	2.63 ± 0.04^{abc}	1.98 ± 0.03^{abc}	1.82 ± 0.06^{abc}	1.77 ± 0.09^{abc}
	T_2	2.34 ± 0.09^{abc}	1.84 ± 0.04^{abc}	1.75 ± 0.08^{abc}	1.70 ± 0.08^{abc}
	T_3	2.04 ± 0.09^{c}	1.79 ± 0.07^{bc}	1.69 ± 0.05^{abc}	1.61 ± 0.07^{abc}
pH	T_o	4.20 ± 0.04^{a}	3.13 ± 0.02^{a}	2.04 ± 0.06^{a}	1.89 ± 0.09^{ab}
	T_1	3.70 ± 0.08^{ab}	3.50 ± 0.01^{ab}	3.30 ± 0.03^{ab}	3.10 ± 0.05^{ab}
	T_2	2.90 ± 0.07^{ab}	2.82 ± 0.09^{ab}	2.74 ± 0.07^{ab}	2.61 ± 0.01^{ab}
	T_3	2.51 ± 0.03^{ab}	2.44 ± 0.02^{ab}	2.30 ± 0.09^{b}	2.11 ± 0.02^{b}
Total acidity	T_o	1.10 ± 0.06^{g}	1.44 ± 0.05^{fg}	$2.67\pm0.03^{b-e}$	$2.98\pm0.03^{a-d}$
	T_1	1.29 ± 0.04^{efg}	1.32 ± 0.05^{fg}	$1.87\pm0.04^{a-d}$	$1.90\pm0.02^{a-d}$
	T_2	2.10 ± 0.05^{ab}	2.31 ± 0.03^{def}	$2.14\pm0.03^{b-e}$	$2.61\pm0.03^{a-d}$
	T_3	2.33 ± 0.03^{a}	2.39 ± 0.02^{cdef}	2.42 ± 0.03^{ab}	2.58 ± 0.02^{abc}
TPC	T_o	2.25 ± 0.02^{gh}	3.96 ± 0.04^{h}	4.38 ± 0.03^{h}	5.31 ± 0.06^{h}
	T_1	2.14 ± 0.02^{ef}	2.92 ± 0.03^{fg}	4.58 ± 0.04^{fgh}	4.92 ± 0.05^{fg}
	T_2	2.12 ± 0.04^{bc}	2.80 ± 0.02^{cd}	3.79 ± 0.04^{cde}	4.45 ± 0.03^{de}
	T_3	2.11 ± 0.02^{a}	2.71 ± 0.02^{a}	3.72 ± 0.03^{ab}	4.81 ± 0.02^{ab}
TFC	T_o	0.35 ± 0.01^{f}	1.89 ± 0.02^{f}	2.51 ± 0.05^{f}	3.17 ± 0.09^{f}
	T_1	0.32 ± 0.02^{cde}	1.70 ± 0.03^{de}	2.07 ± 0.03^{e}	2.78 ± 0.08^{e}
	T_2	0.27 ± 0.04^{bc}	1.62 ± 0.04^{cde}	1.85 ± 0.04^{de}	2.25 ± 0.09^{de}
	T_3	0.23 ± 0.03^{a}	1.57 ± 0.04^{ab}	1.77 ± 0.09^{bcd}	2.12 ± 0.01^{cde}
Sensory (color)	T_o	$3.78\pm0.09^{b-e}$	3.85 ± 0.08^{bc}	3.92 ± 0.07^{ab}	$3.99\ \pm0.03^{a}$
	T_1	3.29 ± 0.08^{cde}	3.37 ± 0.08^{cde}	3.50 ± 0.09^{bcd}	3.8 ± 0.09^{ab}
	T_2	3.63 ± 0.07^{e}	3.65 ± 0.01^{e}	$3.76\pm0.04^{b-e}$	$3.78\pm0.08^{b-e}$
	T_3	3.60 ± 0.040^{de}	3.62 ± 0.09^{de}	3.67 ± 0.04^{cde}	$4.11\pm0.01^{b-e}$
Flavor	T_0	$5.56\pm0.\ 03^{abc}$	5.80 ± 0.02^{ab}	5.93 ± 0.04^{cde}	6.99 ± 0.03^{cde}
	T_1	4.20 ± 0.06^{cde}	4.63 ± 0.07^{de}	4.86 ± 0.08^{bcd}	5.20 ± 0.09^{ab}
	T_2	$4.53\pm0.03^{b-e}$	4.73 ± 0.05^{c}	5.10 ± 0.04^{ab}	5.46 ± 0.02^{abc}
	T_3	4.96 ± 0.04^{cbd}	4.89 ± 0.03^{abc}	5.30 ± 0.09^{ac}	5.60 ± 0.09^{cd}
Overall acceptability	T_o	4.87 ± 0.03^{a}	4.50 ± 0.02^{ab}	4.17 ± 0.03^{abc}	2.91 ± 0.05^{c}
	T_1	4.80 ± 0.05^{a}	4.31 ± 0.01^{abc}	4.10 ± 0.01^{abc}	3.73 ± 0.02^{abc}
	T_2	4.75 ± 0.08^{ab}	4.21 ± 0.09^{abc}	3.91 ± 0.09^{abc}	3.61 ± 0.03^{abc}
	T_3	4.72 ± 0.06^{ab}	4.10 ± 0.06^{abc}	3.79 ± 0.05^{bc}	3.41 ± 0.08^{bc}

T_o: Tomatoes without coating; T_1: Pectin: 6 %, Dw: 200 mL, PVA: 2.5 g, Glycerol: 5 g, Citric acid: 2 g; T_2: Pectin: 9 %, Dw: 300 mL, PVA: 3.75 g, Glycerol: 7.5 g, Citric acid: 3 g; T_3: Pectin: 12 %, Dw: 400 mL, PVA: 7.5 g, Glycerol: 10 g, Citric acid: 4 g

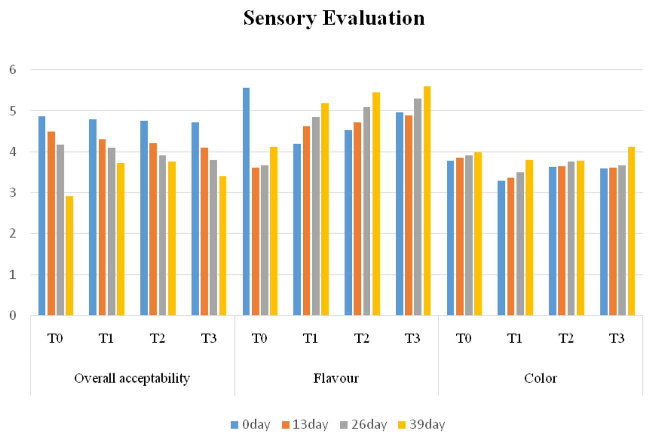


Figure 3. Effect of UAE pectin coatings on Color, Flavor, and Overall acceptability of tomato. Treatments followed by the storage days are significant according to Tuckey's test *p*=0.001.

Conclusions: In summary, the utilization of pectin coatings extracted from grapefruit peel was developed as a promising technique to significantly slow down the ripening of tomatoes, concurrently mitigating fungal contamination. These results showed the dual benefit of pectin coatings: prolonging the shelf life of tomatoes by up to 7 days and preserving their overall quality. The pectin-based edible coating significantly reduced tomato weight loss from 21.65% to 12.81%, preserved firmness from 0.53N to 1.28N, and increased lycopene and ascorbic acid retention by 18% and 35%, respectively. This study also showed the potential of grapefruit-derived pectin coatings as a natural and safe approach, offering a sustainable solution to enhance the storage and transportation of fresh tomatoes, thereby curbing food waste and enhancing consumer contentment. Looking ahead, future research could delve into optimizing the application process and dosage of grapefruit-based pectin coatings for different tomato varieties. Exploring the scalability and economic viability of implementing this technique on a larger scale in the agricultural and food industry would also be valuable. These endeavors will contribute to the continued development and practical application of grapefruit peel-extracted pectin coatings in the realm of post-harvest preservation and food sustainability.

Data availability statement: All the derived data supporting the findings of this study are used in this manuscript.

Ethical Statement: This study involved sensory evaluation conducted with human participants. According to National Institute of Food Science and Technology (NIFSAT) ethical approval was **not required** for this type of research. All participants were informed about the purpose and procedures of the study. Participation was entirely voluntary, and informed consent verbal was obtained from all individuals prior to their involvement. Participants were assured of the confidentiality of their data, the right to withdraw at any time without penalty. No personal or identifiable data were disclosed in the study.

Conflicts of interest: The authors declare that they have no conflict of interest.

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SDGs addressed: SDG 2: Zero Hunger; SDG 3: Good Health and Well-being;SDG 9 – Industry, Innovation, and Infrastructure .

Policy referred: Food Waste Reduction Policy Goals; Sustainability & Green Technology Policy; Food Security & Postharvest Loss Reduction Policies.

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REFERENCE

Ali, M., Cheng, J.-H., Tazeddinova, D., Aadil, R. M., Zeng, X.-A., Goksen, G., Lorenzo, J. M., Esua, O. J., Manzoor, M. F. 2023. Effect of plasma-activated water and buffer solution combined with ultrasound on fungicide degradation and quality of cherry tomato during storage. Ultrason. Sonochem., 97, 106461. https://doi.org/10.1016/j.ultsonch.2023.106461.

Aragüez, L., Colombo, A., Borneo, R., Aguirre, A. 2020. Active packaging from triticale flour films for prolonging storage life of cherry tomato. Food Packag. Shelf Life, 25, 1-7. https://doi.org/10.1016/j.fpsl.2020.100520.

Araújo, A. P., Silva, A., Cunha, S. C., Fernandes, J. O., Pinho, O. 2018. Application of pectin-based coatings to enhance the postharvest quality of tomatoes. Postharvest Bio. Technol., 136, 71-79.

Breda, C. A., Morgado, D. L., de Assis, O. B. G., and Duarte, M. C. T. 2017. Effect of chitosan coating enriched with pequi (Caryocar brasilienseCamb.) peel extract on quality and safety of tomatoes (Lycopersicon esculentumMill.) during storage. J. Food Process. Preserv., 41(6), e13268. https://doi.10.1111/jfpp.13268.

Casariego, A., Souza, B. W. S., Vicente, A. A., Teixeira, J. A., Cruz, L., Díaz, R. 2008. Chitosan coating surface properties as affected by plasticizer, surfactant and polymer concentrations in relation to the surface properties of tomato and carrot. Food Hydrocoll., 22(8), 1452-1459. https://doi.org/10.1016/j.foodhyd.2007.09.010.

Ciriminna, R., Fidalgo, A., Delisi, R., Tamburino, A., Carnaroglio, D., Cravotto, G., Ilharco, L. M., Pagliaro, M. 2017. Controlling the degree of esterification of citrus pectin for demanding applications by selection of the source. ACS Omega, 2(11), 7991-7995. https://doi.10.1021/acsomega.7b01109.

Das, D. K., Dutta, H., Mahanta, C. L. 2013. Development of a rice starch-based coating with antioxidant and microbe-barrier properties and study of its effect on tomatoes stored at room temperature. LWT - Food Sci. Technol., 50(1), 272-278. https://doi.org/10.1016/j.lwt.2012.05.018.

Das, K., Roychoudhury, A., Chakraborty, S. 2013. Tomato (solanum lycopersicum l.) responses to sodium chloride and sodium sulfate salinities. Sci. Hortic., 150, 86-94.

Davoodi, F., Naji, M. 2018. Study of the effect of sodium alginate coating containing pomegranate peel extract on chemical, sensory and microbial quality of walnut kernel. Environ. Health Eng. Manag., 5, 249-257. https://doi.10.15171/EHEM.2018.33.

Dehghani, S., Hosseini, E., Rousta, E. 2022. Shelf-life extension of tomato (Solanum lycopersicum L.) using an edible coating of bitter almond gum-fish gelatin conjugates. Prog. Org. Coat., 170, 1-10. https://doi.org/10.1016/j.porgcoat.2022.106980.

Duc, H., Nguyen, T., Linh, Chinh, N., Thi, N., Trang, N., Quoc, M., Linh, N., Thang, D., Anh, L., Nam, N., Nguyen, G., Quoc Trung, V. 2022. Preparation of preservative coating for tomatoes based on polyphenol modified chitosan and silver nanoparticles. Vietnam J. Chem., 86-95. https://doi.10.1002/vjch.202200087.

Duguma, H. 2021. Potential application and limitation of edible coatings for maintaining tomato quality and shelf life. Int. J. Food Sci. Technol., 57. https://doi.org/10.1111/ijfs.15407.

Duguma, H. T. 2022. Potential applications and limitations of edible coatings for maintaining tomato quality and shelf life. Int. J. Food Sci. Technol., 57(3), 1353-1366. https://doi.org/10.1111/ijfs.15407.

Feldsine, P., Abeyta, C., Andrews, W. H. 2019. AOAC international methods committee guidelines for validation of qualitative and quantitative food microbiological official methods of analysis. J. AOAC Int., 85(5), 1187-1200. https://doi.10.1093/jaoac/85.5.1187.

Ghasemi, A., Chayjan, R. A. 2019. Numerical simulation of vitamin c degradation during dehydration process of fresh tomatoes. J. Food Process Eng., 42(6), e13189. https://doi.org/10.1111/jfpe.13189.

Guo, X., Han, D., Xi, H., Rao, L., Liao, X., Hu, X., Wu, J. 2012. Extraction of pectin from navel orange peel assisted by ultra-high pressure, microwave or traditional heating: A. comparison. Carbohydr. Polym., 88(2), 441-448. https://doi.org/10.1016/j.carbpol.2011.12.026.

Imran, A. 2022. Anticoccidial efficacy of citrus sinensis essential oil in broiler chicken. Pak. Vet. J., 42(04), 461-466. https://doi.10.29261/pakvetj/2022.082.

Jiang, H., Sun, Z., Jia, R., Wang, X., Huang, J. 2016. Effect of chitosan as an antifungal and preservative agent on postharvest blueberry. J. Food Qual., 39(5), 516-523. https://doi.10.1111/jfq.12211.

Jiang, T., Feng, L., Zheng, X., Li, J. 2013. Physicochemical responses and microbial characteristics of shiitake mushroom (Lentinus edodes) to gum arabic coating enriched with natamycin during storage. Food Chem., 138(2), 1992-1997. https://doi.org/10.1016/j.foodchem.2012.11.043.

Kanmani, P. (2014). Extraction and analysis of pectin from citrus peels: Augmenting the yield from citrus limon using statistical experimental design. Iran. J. energy environ., 5(3). https://doi.10.5829/idosi.ijee.2014.05.03.10.

Liu, K., Yuan, C., Chen, Y., Li, H., Liu, J. 2014. Combined effects of ascorbic acid and chitosan on the quality maintenance and shelf life of plums. Sci. Hortic., 176, 45-53. https://doi.org/10.1016/j.scienta.2014.06.027.

Manzoor, F., M., Ali, M., Aadil, M., R., Ali, A., Goksen, G., Li, J., Zeng, X.-A., Proestos, C. 2023. Sustainable emerging sonication processing: Impact on fungicide reduction and the overall quality characteristics of tomato juice. Ultrason. Sonochem., 94, 106313. https://doi.org/10.1016/j.ultsonch.2023.106313.

Marić, M., Grassino, A. N., Zhu, Z., Barba, F. J., Brnčić, M., Rimac Brnčić, S. 2018. An overview of the traditional and innovative approaches for pectin extraction from plant food wastes and by-products: Ultrasound-, microwaves-, and enzyme-assisted extraction. Trends Food Sci. Technol., 76, 28-37. https://doi.org/10.1016/j.tifs.2018.03.022.

Menezes, J., Athmaselvi, K. A. 2016. Study on effect of pectin based edible coating on the shelf life of sapota fruits. Biosci. Biotechnol. Res. Asia, 13(2), 1195-1199. https://doi.10.13005/bbra/2152.

Mohamed, M., Muhammad, M., Sijam, K., Siddiqui, Y. 2010. Effect of chitosan coating on the physicochemical characteristics of Eksotika II papaya (Carica papaya L.) fruit during cold storage. Food Chem., 124. https://doi.10.1016/j.foodchem.2010.06.085.

Montgomery, D. C. 2017. Design and analysis of experiments.

Panwar, D., Panesar, P. S., Chopra, H. K. 2023. Ultrasound-assisted extraction of pectin from citrus limetta peels: Optimization, characterization, and its comparison with commercial pectin. Food Biosci., 51, 102231. https://doi.org/10.1016/j.fbio.2022.102231.

Pourhossein, Z., Qotbi, A., Seidavi, A., Laudadio, V., Mazzei, D., Tufarelli, V. 2019. Feeding of dried sweet orange (Citrus sinensis) peel on humoral immune response of broiler chickens. Int. J. Recycl. Org. Waste Agric., 8. https://doi.10.1007/s40093-019-0272-8.

Rodriguez-Garcia, I., Cruz-Valenzuela, M. R., Silva-Espinoza, B. A., Gonzalez-Aguilar, G. A., Moctezuma, E., Gutierrez-Pacheco, M. M., Tapia-Rodriguez, M. R., Ortega-Ramirez, L. A., Ayala-Zavala, J. F. 2016. Oregano (Lippia graveolens) essential oil added within pectin edible coatings prevents fungal decay and increases the antioxidant capacity of treated tomatoes. J. Sci. Food Agric., 96(11), 3772-3778. https://doi.org/10.1002/jsfa.7568.

Rohasmizah, H., Azizah, M. 2022. Pectin-based edible coatings and nanoemulsion for the preservation of fruits and vegetables: A review. Appl. Food Resear., 2(2), 100221. https://doi.org/10.1016/j.afres.2022.100221.

Salas-Méndez, E. d. J., Vicente, A., Pinheiro, A. C., Ballesteros, L. F., Silva, P., Rodríguez-García, R., Hernández-Castillo, F. D., Díaz-Jiménez, M. D. L. V., Flores-López, M. L., Villarreal-Quintanilla, J. Á., Peña-Ramos, F. M., Carrillo-Lomelí, D. A., Jasso de Rodríguez, D. 2019. Application of edible nanolaminate coatings with antimicrobial extract of Flourensia cernua to extend the shelf-life of tomato (Solanum lycopersicum L.) fruit. Postharvest Bio. Technol., 150, 19-27. https://doi.10.1016/j.postharvbio.2018.12.008.

Santos, C. M., Dweck, J., Viotto, R. S., Rosa, A. H., de Morais, L. C. 2015. Application of orange peel waste in the production of solid biofuels and biosorbents. Bioresour. Technol., 196, 469-479. https://doi.org/10.1016/j.biortech.2015.07.114.

Sengar, A. S., Rawson, A., Muthiah, M., Kalakandan, S. K. 2020. Comparison of different ultrasound assisted extraction techniques for pectin from tomato processing waste. Ultrason. Sonochem., 61, 104812. https://doi.org/10.1016/j.ultsonch.2019.104812.

Sucheta, Chaturvedi, K., Sharma, N., Yadav, S. K. 2019. Composite edible coatings from commercial pectin, corn flour and beetroot powder minimize post-harvest decay, reduces ripening and improves sensory liking of tomatoes. Intl. J. Biol. Macromol., 133, 284-293. https://doi.org/10.1016/j.ijbiomac.2019.04.132.

Sundararaman, S., Gopakumaran, N., Sundari, N., Amarnath, M., Thayyil, P. 2016. Extraction of pectin from used citrus limon and optimization of process parameters using response surface methodology. Res. J. Pharma. Technol., 9, 2246-2251. https://doi.10.5958/0974-360X.2016.00453.4

Tigist, M., Workneh, T. S., Woldetsadik, K. 2013. Effects of variety on the quality of tomato stored under ambient conditions. J. Food Sci. Technol., 50(3), 477-486. https://doi:10.1007/s13197-011-0378-0.

Wang, W., Ma, X., Jiang, P., Hu, L., Zhi, Z., Chen, J., Ding, T., Ye, X., Liu, D. 2016. Characterization of pectin from grapefruit peel: A comparison of ultrasound-assisted and conventional heating extractions. Food Hydrocoll., 61, 730-739. https://doi.org/10.1016/j.foodhyd.2016.06.019.

Won, J. S., Lee, S. J., Park, H. H., Song, K. B., Min, S. C. 2018. Edible coating using a chitosan-based colloid incorporating grapefruit seed extract for cherry tomato safety and preservation. J. Food Sci., 83(1), 138-146. https://doi.org/10.1111/1750-3841.14002.

Wu, S., Lu, M., Wang, S. 2016. Effect of oligosaccharides derived from laminaria japonica-incorporated pullulan coatings on preservation of cherry tomatoes. Food Chem., 199, 296-300. https://doi.org/10.1016/j.foodchem.2015.12.029.

Yao, D., & Adjouman, D. 2018. Effect of edible coating based on improved cassava starch on post-harvest quality of fresh tomatoes (solanum lycopersicum l.). Int. J. Food Sci. Technol. Nutr., 4, 1-10.

Yildiz, G., Aadil, R. M. 2020. Comparison of high temperature-short time and sonication on selected parameters of strawberry juice during room temperature storage. J. Food Sci. Technol., 57(4), 1462-1468. https://doi:10.1007/s13197-019-04181-y.

Yousuf, B., Wu, S., Siddiqui, M. W. 2021. Incorporating essential oils or compounds derived thereof into edible coatings: Effect on quality and shelf life of fresh/fresh-cut produce. Trends Food Sci. Technol., 108, 245-257. https://doi.org/10.1016/j.tifs.2021.01.016.

Yuliarti, O., Hoon, A. L. S., Chong, S. Y. 2017. Influence of pH, pectin and Ca concentration on gelation properties of low-methoxyl pectin extracted from Cyclea barbata Miers. Food Struct., 11, 16-23. https://doi.org/10.1016/j.foostr.2016.10.005.