Effects of Pectin-Lemon Essential Oil Coatings on the Visual Shelf Life of Tomatoes and Apples: A Preliminary Study

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Abstract: ***Postharvest deterioration is an important cause of quality loss in climacteric fruits. This preliminary study investigated pectin-based edible coatings containing 0.0%, 0.5%, or 1.0% lemon essential oil for maintaining the visual quality of tomatoes and apples during room-temperature storage. Pectin extracted from orange peel was incorporated into coating formulations containing constant amounts of pectin and glycerol with different essential oil concentrations. One tomato and one apple were assigned to each treatment, double-dipped in the respective coating, and visually monitored during storage. Acceptability was assessed from visible changes including browning, leakage, splitting, softening, collapse, and apparent decay. Among the tomato samples, the 1.0% essential oil treatment retained acceptable visual appearance for the longest period. In contrast, the pectin-only apple showed better visual preservation than the essential-oil-treated apples. These preliminary observations suggest that the performance of pectin-essential oil coatings may depend on fruit type and formulation. Replicated experiments incorporating quantitative quality and microbial measurements are required to confirm these observations.***

Keywords: postharvest shelf life; edible coating; pectin; lemon essential oil; tomato; apple

1. Introduction

Pectin is a structural fiber found in fruits such as oranges, lemons, and apples [1]. Pectin is extracted from citrus peel, which is otherwise discarded as waste, and the coating made from it is used to extend the shelf life of fruits. Postharvest losses in fruits and vegetables represent one of the most important challenges in global food supply chains. Approximately 20% to 50% of the produce lost globally is due to decay, poor handling, and inadequate infrastructure for storage. These losses aren't just confined to food wastage but also reduced farmer income, food insecurity, and increased environmental burden, as decaying organic matter emits methane [2]. Post-harvest deterioration of fruits contributes substantially to food loss, particularly in climacteric fruits that continue to ripen after harvest.

2. Literature Survey

Tomatoes [3] and apples [4] are both classified as climacteric fruits, and their quality during storage is greatly influenced by respiration, transpiration, and ethylene production. The plant hormone ethylene stimulates the ripening and eventual spoilage of fruits [5]. Since ethylene production is an autocatalytic process [6], once it's synthesized, it amplifies production, which accelerates ripening. Therefore, during transportation and storage, respiration and ethylene activity continue to soften the fruit; simultaneously, transpiration causes moisture loss, further accelerating spoilage because the fruit becomes more susceptible to microbial activity. The current preservation methods include storage in refrigerated conditions, coating, waxing, or treating with chemical compounds [7]. However, these treatments have prominent disadvantages. Firstly, they can change the taste of the fruit due to internal alterations. Secondly, using chemical fungicides pose health and environmental risks because of the residues produced by these compounds. Consequently, edible films are regarded as a safer and more suitable preservation method. Amongst the available polysaccharides used in the formulation of films, pectin is mostly favoured for its ability to form films and be compatible with fruit surfaces. However, when used alone, pectin has limitations. Pectin is hydrophilic; this means it soaks up and retains water instead of blocking it [8]. So, it doesn't limit water absorption and makes the fruit vulnerable to microbial deterioration. Essential oils help in covering these gaps; since they are rich in phenolic compounds, they show antifungal, antioxidant, and antimicrobial properties [9]. As a consequence, mixing pectin with essential oils helps create a holistic prevention technique for fruits that addresses both moisture retention and microbial spoilage in a single coating. While numerous studies explore the benefits of edible coatings made of pectin and essential oils, most of them don't carry out the procedure at varying essential oil concentrations. Higher essential oil concentrations are said to improve antimicrobial potency. However, the strong aroma of the essential oils can suppress the fruit's natural flavour profile and lead to lower consumer acceptability. Contrastingly, lower concentrations act synergistically with other coating compounds and don't compromise on sensory quality either [10]. In this study, we evaluated the effectiveness of pectin-based edible coatings with essential oil (EO) at varying concentrations (0.0%, 0.5%, and 1.0%) in delaying microbial spoilage and preserving the sensory and visual quality of tomatoes (Solanum lycopersicum) and apples (Malus domestica) under normal storage conditions.

3. Materials and Methodology

3.1. Materials

3.1.1. Chemical Reagents

All chemicals used in this experiment were analytical reagent grade. Citric acid (99.5% purity) was used for extracting pectin by isolating it from the citrus peel. Absolute ethanol (99.5% purity) was used for the precipitation of pectin. Glycerol (100% purity) was used as a plasticizer to ensure the pectin coating was pliable. Lemon essential oil (100% purity) was incorporated for its antimicrobial and antioxidant properties. Tween 80 (polysorbate 80) was used as a surfactant for emulsification and uniform dispersion of the essential oil in the pectin solution. Xanthan gum was used for thickening the coating. Distilled water was used throughout the experiment.

3.1.2. Plant Material

Fresh oranges (Citrus x sinensis), apples (Malus domestica), and tomatoes (Solanum lycopersicum), free from damage or fungal infection, were acquired from local stores in Mumbai, Maharashtra.

3.1.3. Laboratory Equipment

The equipment used for extraction, coating preparation, and physical characterization included an analytical balance (0.001 g precision) and a top-pan balance (0.1 g precision) for fruit weighing. Pectin extraction was carried out using a hot plate with a magnetic stirrer and a water bath (up to �similar 90 °C), with solution pH monitored using a pH meter and temperature monitored using a thermometer/temperature probe. Dried orange peel was powdered using a mixer/grinder and passed through a sieve to obtain a uniform particle size.

3.2. Methodology

3.2.1. Acid Extraction

For extraction, 46g of orange peel powder was weighed after grinding into a fine powder. 13.8g of citric acid was added to a liquid-to-solid ratio of 20:1 (920mL of distilled water for 46g of peel powder) and was mixed until completely dissolved. To create a homogeneous suspension, the weighed peel powder was later added to the acid solution and thoroughly stirred. The suspension was heated for 75 minutes with intermittent to constant stirring in a water bath kept at 85°C (limited to the range of 80-90°C).

To obtain a clear pectin extract, the liquid was cooled to 50°C to 60°C and then filtered twice, first through a muslin cloth and then through filter paper.

3.2.2. Pectin Precipitation

Pectin was precipitated from its extract using cold ethanol at a modified extract-to-ethanol ratio of 1:2 (250mL of extract was mixed with 500mL of ethanol), while stirring continuously. The mixture was gently covered and cooled at 4°C for 12-24 hours to allow precipitation. The produced pectin precipitate was filtered and washed with 150-200mL of ethanol to eliminate any remaining contaminants. This precipitate was allowed to dry and later crushed into a fine powder. This pectin powder was kept cool and dry in an airtight container.

3.2.3. Preparation of Pectin-Essential Oil Coating

Three coating formulations were created by altering the proportion of lemon essential oil, while maintaining the pectin and glycerol contents, as shown in Table 1. To create a uniform base solution, pectin and glycerol were dissolved in distilled water while being continuously stirred. The lemon essential oil was emulsified with Tween 80 before being added to the pectin-glycerol solution and then stirred further to ensure uniform dispersion of the oil phase within the aqueous matrix. Xanthan gum was then added to glycerol until a homogeneous mixture formed and then added to the coating solution. Each formulation was made up to 100mL using distilled water.

Table 1: Composition of pectin-based coatings

Components	Sample 1 (0.0% EO)	Sample 2 (Pectin + 0.5% EO)	Sample 3 (Pectin + 1.0% EO)
Pectin	1.00g	1.00g	1.00g
Glycerol	1.75g	1.75g	1.75g
Lemon Essential Oil	0.0mL	0.50mL	1.00mL
Tween 80	0.0mL	0.10mL	0.20mL
Xanthan Gum	0.5g	0.5g	0.5g
Distilled Water	Made up to 100mL	Made up to 100mL	Made up to 100mL

3.2.4. Fruit Sample Preparation and Coating Application

Before applying the coating, fresh tomatoes (Solanum lycopersicum) and apples (Malus domestica) of uniform size and maturity were washed with distilled water and air-dried. The fruits were divided into three groups: sample 1 (pectin only), sample 2 (pectin + 0.5% EO), and sample 3 (pectin + 1.0% EO). One tomato and one apple were assigned to each treatment group. Each treatment group therefore consisted of a single fruit (n = 1); this single-replicate, exploratory design does not support statistical inference, and the results should be interpreted as preliminary observations.

The coating was applied using a dipping method; each fruit was completely submerged in the coating solution to ensure a uniform and unbroken coating. A double-dip strategy was used, where the fruit was dipped again only after the first coating layer had completely air-dried at room temperature. Following the second dip, the fruits were allowed to air-dry at room temperature.

3.2.5. Storage Conditions

Throughout the trial, all fruit samples were kept at room temperature (approximately 25°C). Fruits were placed on a clean tray. The samples were weighed and photographed to document visual differences across treatment groups over a period of time.

3.3. Quality Parameters Evaluated

Fruit quality was evaluated every day for a total storage period of 21 days (3 weeks). During each observation, the following parameters were assessed:

3.3.1. Visual Microbial Assessment

Microbial growth was examined visually for each of the tomatoes and apples, through surface mold, discoloration, or decay.

3.3.2. Sensory and Visual Evaluation

Sensory and visual quality of the fruits was assessed at each observation based on changes in appearance, texture, colour, and overall freshness. Qualities such as surface wrinkling, softening, colour change, and onset of decay were recorded and compared across the three treatment groups.

4. Results

Tomatoes (Solanum lycopersicum)

0.0% EO (pectin only)
The pectin-coated tomatoes (0.0% EO) showed the clearest signs of microbial decay first. By day 5 (29th June), it started to turn translucent, and its fluid began leaking out. By day 9 and 10 (3rd and 4th July), the fruit was completely spoiled and began splitting open.

0.5% EO
The 0.5% EO tomatoes remained intact till day 7 (1st July). From day 8 (2nd July), the tomatoes began leaking fluid and became soft and slightly wrinkled. By day 11 (5th July), it was completely spoiled and turned brown with a more wrinkled surface.

1.0% EO
The 1.0% EO tomatoes remained intact till day 10 (4th July), but by day 11 (5th July) they started turning brown and soft in certain areas. On day 15 (10th July), they turned black in some places, though they never leaked any fluid, unlike the 0.0% EO and 0.5% EO. Overall, as the concentration of essential oil increased, the shelf life of the tomatoes also increased.

Apples (Malus domestica)

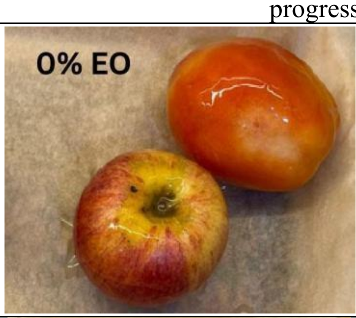
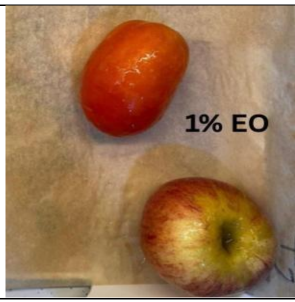
0.0% EO
The pectin-coated apples (0.0% EO) remained intact until day 15 (10th July), and from that point onwards it starts to turn brown on top, with a little growth of visible fungus taking place.

0.5% EO
The 0.5% EO apples were found to be intact till day 10 (4th July); however, on day 11 (5th July) browning was observed near the stem end of the apples. The affected area was dark brown and visibly softened/sunken by day 13 (7th July). This patch grew until day 21 (15th July), at which point it became black-brown and covered most of the area, and the skin looked shriveled over the rotten area.

1.0% EO
The 1.0% EO apples were able to withstand the treatment until approximately day 10 (4th July), when they started to display some localized browning towards the stem end, and by day 11 (5th July) they began to rot. On day 13 (7th July), the affected area was slightly darkened and softened in a patch. This patch grew more and on day 21 (15th July) became brown-black, but generally remained more contained than the 0.5% treatment, whilst the rest of the fruit remained firm and a uniform color. Overall, as the concentration of essential oil increased, the shelf life of apples decreased.

Visual Scoring and Final Acceptability
Visual quality was assessed by daily observation. Fruits were considered visually acceptable while they remained intact, with minimal browning and no severe leakage or collapse. Once a fruit displayed extensive browning, softening, splitting, or obvious microbial decay, it was considered no longer acceptable. In tomatoes, the pectin-only sample was judged unacceptable earliest due to rapid onset of translucency and fluid leakage followed by splitting; the 0.5% EO tomato remained acceptable for a longer period before developing leakage, wrinkling, and full spoilage, and the 1.0% EO tomato retained acceptable appearance for the longest time, with delayed browning and softening and no obvious leakage before blackening appeared. In apples, the pectin-only treatment maintained acceptable visual quality until the end of storage, with comparatively limited browning and decay, whereas both EO-containing treatments lost acceptability sooner, as they showed larger brown-black areas, pronounced softening, shrinkage, and tissue collapse as shown in Table 3. Overall, visual scoring indicated that 1.0% EO provided the highest final acceptability in tomatoes, while pectin-only coating provided the highest final acceptability in apples, highlighting the fruit-specific nature of the coating response.

Table 2: Time-series images of tomatoes and apples under different pectin–essential oil coatings showing visual shelf-life progression and final spoilage

25th June 2026			
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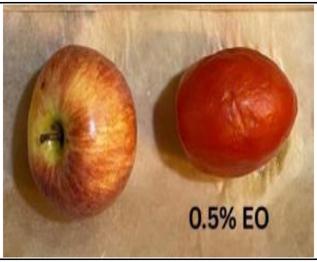
27th June 2026			
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29th June 2026			
30th June 2026			
1st July 2026			
2nd July 2026			
3rd July 2026			
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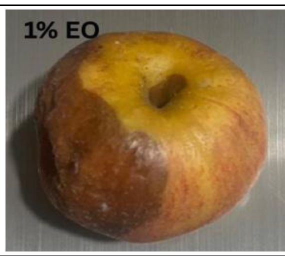
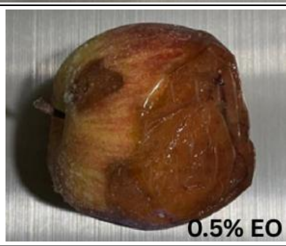
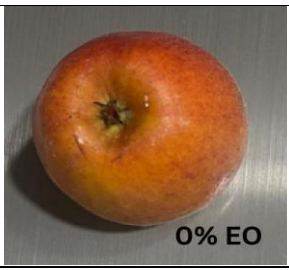
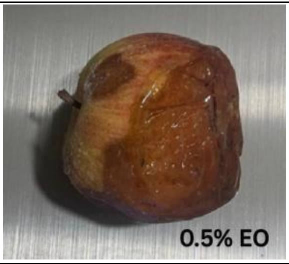
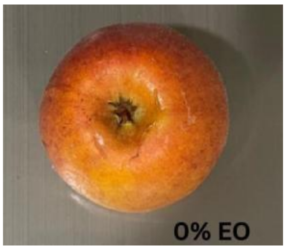
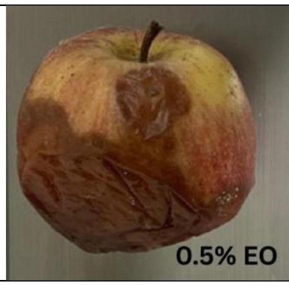
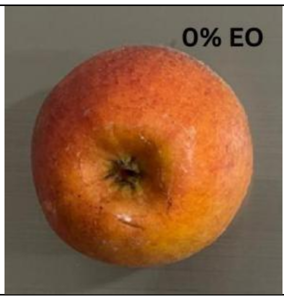
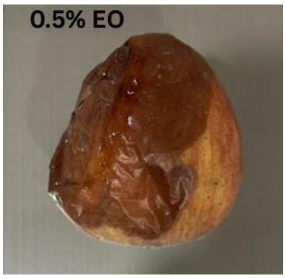
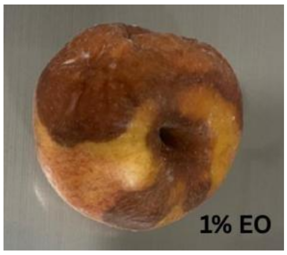
11th July 2026			
12th July 2026			

13th July 2026			
14th July 2026			
15th July 2026			
16th July 2026			

5. Discussion

Table 3: Summary of qualitative visual changes

Observation window	Tomato pectin only	Tomato 0.5% EO	Tomato 1.0% EO	Apple pectin only	Apple 0.5% EO	Apple 1.0% EO
Day 1 to 4	Fresh appearance was maintained, with no major visible spoilage.	Fresh appearance was maintained, with no major visible spoilage.	Fresh appearance was maintained, with no major visible spoilage.	Fresh appearance was maintained, with no major visible spoilage.	Fresh appearance was maintained, with no major visible spoilage.	Fresh appearance was maintained, with no major visible spoilage.
Day 5 to 8	Early spoilage developed, with translucency and leakage becoming apparent.	Deterioration was delayed relative to the pectin-only treatment.	The best surface retention among tomato treatments was observed in this interval.	No appreciable additional visual deterioration was observed during this interval.	No appreciable additional visual deterioration was observed during this interval.	No appreciable additional visual deterioration was observed during this interval.
Day 9 to 12	Advanced spoilage was present at this stage.	Spoilage was present, but later than in the pectin-only treatment.	This remained the best-preserved tomato treatment during this interval.	This remained the least decayed apple treatment.	Clear browning and tissue damage were present.	Clear browning and tissue damage were present.
Day 13 to 15	Complete spoilage was observed.	Complete spoilage was observed, but later than in the pectin-only treatment.	Delayed blackening and softening were observed relative to the other tomato treatments.	This remained the most intact apple treatment at the end of storage.	Extensive darkening, softening, and shrinkage were observed.	Severe browning and tissue collapse were observed.
Day 16 to 21	No additional meaningful change occurred after complete spoilage.	No additional meaningful change occurred after complete spoilage.	Blackening and softening persisted without obvious leakage.	This remained the least decayed apple treatment overall.	Deterioration remained greater than in the pectin-only treatment.	Deterioration remained greater than in the pectin-only treatment.

Most literature values indicate that an increase in essential oil concentration increases the shelf life of coated fruit. In our study, this relationship was found to be fruit-dependent. The pectin coating with a higher essential oil concentration was effective in extending the shelf life of tomatoes, as expected. However, our results for apples varied: as the essential oil concentration increased, the shelf life decreased.

Our optimisation potential was limited because we were unable to prepare coatings at varying pectin concentrations; consequently, viscosity changed during application, and the optimum coating thickness was not achieved for apples. Differences in the natural waxy coating of tomatoes and apples further compounded the adhesion problem: the apple's waxy coating was incompatible with the applied coating's thickness, whereas the tomato's surface properties allowed better adhesion between the coating and its outer layer. The stability of the coating matrix during storage was also a concern for the structural integrity and durability of the coating on apples.

A further limitation of this study is that, while physiological weight loss was recorded throughout the storage period, the dataset was not fully quantified and analysed alongside the visual and microbial observations. A complete day-by-day PWL analysis would strengthen future comparisons between treatments and fruit types. Additionally, since only one fruit per treatment group was used, the results reflect single-replicate observations rather than statistically validated trends, and should be interpreted as an initial, exploratory comparison. Future studies should conduct optimisation trials at different concentrations of both pectin and essential oil, include replicate samples and full quantitative PWL analysis, and take fruit-specific surface characteristics into account to establish the ideal coating for each fruit type.

6. Conclusion

This preliminary study examined orange-peel-derived pectin coatings containing different concentrations of lemon essential oil for preserving the visual quality of tomatoes and apples. Under the conditions tested, the tomato treated with 1.0% essential oil retained acceptable visual appearance longer than the other tomato treatments, whereas the pectin-only apple showed better visual preservation than the essential-oil-treated apples. These observations indicate that coating performance may vary with fruit type and formulation. Differences in fruit surface characteristics and coating behavior may contribute to the contrasting responses, but these mechanisms require direct investigation. Future studies should include replicated samples, an uncoated control, quantitative quality measurements, and optimization of both pectin and essential oil concentrations to determine whether the observed treatment effects are reproducible.

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