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Synthesis of Poly-Edible coating to Extend the Shelf Life of Fruits and Vegetables

[1]Muthu Kumara Pandian A, [2]Harshini S K, [3]Mounika K P, [4]Sangeetha M
Vivekanandha College of Engineering for Women, Tiruchengode,Namakkal.

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ABSTRACT
Fruits and vegetables are highly perishable, with approximately 30% suffering damage from insects, microorganisms, and environmental factors. Edible coatings have emerged as a promising solution to extend shelf life and maintain quality. Recent advancements in bio-based and active edible packaging have shown potential in ensuring food safety and quality while reducing post-harvest losses.This study aimed to develop a novel poly-edible coating incorporating onion peel extract (OPE), green tea extract (GTE), and Aloe vera extract (AVE) to extend the shelf life of fruits and vegetables. The coating was synthesized using a combination of natural polymers and waxes. The physical, chemical, and mechanical properties of the coating were characterized. The coating's effectiveness in extending shelf life was evaluated on selected fruits and vegetables. Results showed that the OPE-GTE-AVE coating significantly reduced weight loss, maintained firmness, and inhibited microbial growth. Sensory evaluation and nutritional analysis revealed that the coating preserved the quality and nutritional value of the coated produce. This study demonstrates the potential of using OPE, GTE, and AVE in developing a sustainable and effective poly-edible coating for extending the shelf life of fruits and vegetables.
KEYWORDS: Poly-edible coating, shelf life extension, antimicrobial, antioxidant.

I. INTRODUCTION

Currently, there is a high demand for fruits and vegetables in the market due to their nutritional benefits. Their perishable nature results in a short shelf life. Approximately 30% of fruits and vegetables suffer damage from insects, microorganisms, and both pre and post-harvesting conditions during transport and storage. Preserving fruits and vegetables presents a significant challenge worldwide. An effective solution to this issue is the use of edible coatings, which provide a protective layer to fruits and vegetables.

Over the last ten years, there has been significant advancement in the creation of bio-based and active edible packaging aimed at ensuring the safety and quality of food while decreasing postharvest losses in fruits and vegetables (Wang et al., 2022). Edible coatings provide an environmentally friendly and sustainable method for preserving the quality characteristics of fruits and vegetables during storage by reducing lipid peroxidation,modifying the respiration rate,minimizing weight loss, andsustaining other quality characteristics (Suhag et al., 2020). Additionally, edible coatings enhance the microbiological safety of fruit and shield them from external environmental impacts, thereby prolonging their shelf life (Al-Ali et al., 2021). Furthermore, incorporating functional agents or compounds like antioxidants, antimicrobials, and nutraceuticals into edible coatings enhances the quality traits and postharvest features of fruits and vegetables (Kumar et al., 2021). There is a growing consumer preference for reduced chemical usage on minimally processed fruits and vegetables, leading to increased focus on finding naturally occurring substances that can serve as alternative antimicrobials and antioxidants. The utilization of natural products, particularly extracts, has emerged as a viable alternative strategy for minimizing spoilage and extending the shelf life of harvested fruits and vegetables (Khaliq et al., 2016). The extract obtained from onion peel, a significant byproduct of processing, is abundant in antioxidant compounds like quercetin, ferulic acid, kaempferol, and gallic acid, which demonstrate substantial antioxidative properties (Kumar et al., 2022). The application of onion peel powder and its extract has been utilized in various food products as a source of dietary fiber and antioxidants. Similarly, Aloe vera (Aloe barbadensis Miller) gel has been recently identified as a viable edible coating for food preservation and packaging (Maan et al., 2021; Kaur et al., 2024). The transparent jelly material mainly comprises water carbohydrates, proteins, organic acids, vitamins, minerals, and bioactive compounds. Historically, Aloe vera gel (AV) has been known to have many therapeutic benefits and is used to treat several diseases (George et al.,2023). A.Vera gel has expanded at a wider scale, and it has been employed as a coating material to extend the shelf life of many horticulture products (Farooq et al., 2023). Similarly, green tea (Camellia sinensis) is a good source of polyphenolic compounds with strong antioxidant properties. The beneficial effects of phenolic compounds result from their ability to eliminate reactive oxygen species. Research clearly demonstrates that green tea effectively delays lipid oxidation in a range of food products, such as marine oil, soybean oil, and fermented sausage oil (Bortolini et al., 2021; Harte, 2010). As a powerful source of polyphenols, green tea extract is an excellent active ingredient for incorporation into food packaging films, offering significant antioxidant properties that can substantially extend the shelf life of these products.

II. MATERIALS AND METHOD

2.1. Preparation of onion peels extract (OPE)

Onion peels were gathered and cleaned to eliminate any dirt and debris, then dried at 45ºC in a hot air oven. The dried onion peels were subsequently ground to create an extract. A 20% (w/v) aqueous extract of onion peels was formulated in a conical flask. This mixture was then placed in a shaking water bath at 70°C for 2 hrs, followed by filtration. The resulting filtrate was identified as onion peel extract (OPE) (Siddiqui et al., 2024).

2.2. Preparation of Aloe vera extract

The A. vera rind was cleaned to eliminate impurities. Following that, it was cut, and the thick outer layer was removed. Subsequently, the gel portion was rinsed with warm water to wash away the yellow sap. The gel was then blended to a crushed consistency and filtered through 80 µm mesh sieves to separate the gel from the solid components. The gel was heated in an iron cast pot on a stove at a temperature of 80ºC for 5 mins. Once heated, the A. vera gel was left to cool down to room temperature (Jati et al., 2022).

2.3. Preparation of green tea extract

The dried green tea leaves were blended in a commercial blender for 5 mins. A stainless steel sieve with a 100 µm mesh was then used to separate the ground leaves in order to obtain a uniform particle size. The extraction parameters were set at 80°C for 30 mins, utilizing a water-to-tea ratio of 20:1 (mg L^{-1}), with the extractions performed under magnetic stirring at a speed of 120 rpm. Following this, the extract was centrifuged using a Beckman CoulterTM centrifuge at 8000 rpm for 20 mins, and the supernatant was filtered through Whatman filter paper No. 1 (Jayamali et al., 2022).

2.4. Preparation of chitosan solution

20 g of chitosan powder was dissolved in 100 mL of a 1% (v/v) acetic acid solution. The blend was stirred for 30 mins to guarantee thorough dissolution. Subsequently, distilled water was added to bring the total volume to 100 mL (Singh et al., 2015).

2.5. Coating solution preparation

Prior to the coating process, tomatoes were sanitized using chlorinated water (200 ppm) and allowed to dry for 30 mins in ambient conditions. A coating solution containing 100% poly herbal extracts was formulated by combining 1% (v/v) onion peel extract (OPE), 1% (v/v) green tea extract (GTE), and 2% (v/v) Aloe vera extract (AVE) with a 20% (v/v) chitosan solution and then diluting the mixture with 75% (v/v) distilled water to achieve a uniform and effective coating. The resulting coating solution was maintained in a water bath at 90℃ for 30 mins while being vigorously shaken to induce gelatinization. After 30 mins, the coating solution was removed from the water bath and allowed to cool until the temperature dropped to 50℃. When the temperature reached 50℃, add 1% (v/v) glycerol and mix the solution for another 20 mins in the water bath (Menezes &Athmaselvi 2016).

2.6. Tomato and Brinjal coating and storage

The tomatoes and brinjals were rinsed to eliminate any impurities and then allowed to dry. The dried tomatoes and brinjals were separated into two groups (control and coated), with each group containing 10 tomatoes. One group was immersed in the coating solution for 2 mins and then air-dried for 2 hrs. The other group (the control) was submerged in deionized water. Both groups (control and coated) were kept at room temperature (37℃) for 15 days. Physiochemical and sensory evaluations of the tomatoes were conducted on days 0, 2, 4, 6, 8, 10, 12, and 14 of storage andthe brinjal were conducted on 0, 3,6, 9, 12, and 15 of storage.

2.7. Preparation of extract for analysis

10 g of control and coated tomatoes and brinjals were homogenized with 50 mL of distilled water. The obtained slurry was then filtered through filter paper to remove insoluble and finally centrifuged at 5000 RPM. The supernatant was then used as an extract of tomato and brinjal for chemical analysis such as percent titratable acidity, flavonoid content, phenolic content, and antioxidant activity (Nair et al., 2018b).

2.8. The pH

A pH meter was used to measure the pH of the coated and uncoated tomatoes and brinjals. After immersing the electrode in the sample solution and measuring the pH, 15 mL of filtrate were placed in a beaker for the analysis. Before taking readings, pH meter was calibrated against standard buffer solutions of 4.0, 7.0, and 10.0 pH.

2.9. Weight loss

Throughout the storage periods, the tomato's and brinjal's weight decreased. At the start of the experiment (day 0), the weight of the coated and uncoated tomatoes and brinjals was determined using analytical balance. After that, the samples were weighed every three days until day fifteen. The following formula was used to determine the weight loss:

$$\text{Weight loss \%} = \frac{\text{initial weight} - \text{final weight}}{\text{initial weight}} \times 100$$

2.10. Moisture content

The sample's moisture content was ascertained using the hot air oven method. In short, 5–10g of the material was sliced and placed in an aluminum dish that had been previously weighed and dried. Dry the sample for 2 to 3hrs, or until the weight remains consistent, in a hot air oven set to 105ºC. After taking the dish out of the oven and allowing it to cool in desiccators, the dish and sample were weighed once more. A formula was used to determine the sample's moisture content.

$$\text{Moisture content \%} = \frac{\text{initial weight} - \text{final weight}}{\text{initial weight}} \times 100$$

2.11. Lycopene content

The fresh tomatoes were blended, and 5 g of tomato puree was added to a glass beaker covered with aluminum foil. Next, 50 mL of a hexane: acetone: ethanol (2:1:1) solvent mixture was introduced. The resulting mixture was homogenized with a magnetic stirrer. Subsequently, the mixture was transferred to a separating funnel, and 10 mL of distilled water was added. The mixture was then shaken vigorously for 15 mins. The upper layer was extracted, transferred to a 50 mL volumetric flask, and brought to volume with the same solvent. After that, the mixture was homogenized again, and the absorbance was measured at 513 nm. The lycopene concentration was reported as mg/kg of the sample(Anthon &Barrett 2007).

2.12. Total Phenolic content

A test tube was filled with 0.5 mL of extract and 1 mL of Folin-Ciocalteau reagent. After adding 4 mL of distilled water and 2 mL of 2.5% Na_2Co_3, the liquid was vortexed once more and left for 5 mins. The solution was kept for 30 mins in a dark place. A measurement of the mixture's absorbance was made at 720 nm. The results that were collected were plotted (Jati et al., 2014).

2.13. Total Flavonoid content

0.5 mL of extract was combined in a 10 mL volumetric flask with 0.3, 0.3, and 2 mL of 5% $NaNO_2$, 10% $AlCl_3$, and 1 M NaOH, respectively. The distilled water was then added to the volume. Next, the mixture was made homogeneous. The mixture's absorbance was measured at 510 nm. Using distilled water as the blank and catechin as the standard, respectively, the result was reported as mg catechin equivalent/g sample (Huang et al., 2018).

2.14. Antioxidant activity

DPPH Method

The mixture of 1 mL of extract, 2 mL of 0.2 M DPPH, and 2 mL of methanol was homogenized and stored for 1hr in a dark room. After that, the absorbance was determined using a spectrophotometer at 517 nm (Astadi et al., 2009). The result of the scavenging capacity of the extract was expressed as follows:

$$\text{\% Radical scavenging capacity} = \frac{\text{Control} - \text{Sample}}{\text{Control}} \times 100$$

III. RESULT AND DISCUSSION

3.1.pH

The pH values of coated and uncoated tomatoes and brinjals were monitored. The results showed that the pH of both coated and uncoated tomatoes and brinjals decreased over time. However, the pH of coated tomatoes and brinjals decreased at a slower rate compared to uncoated ones.

The pH of coated tomatoes increased by 3.5%, from 4.3 to 4.45, over 14 days. In contrast, the pH of uncoated tomatoes increased by 16.3%, from 4.3 to 5.0, over the same period. In uncoated tomatoes, the polyphenol oxidase increases pH by forming alkaline quinones. In contrast, the poly-edible coating in coated tomatoes inhibits the enzyme, reducing the pH increase.

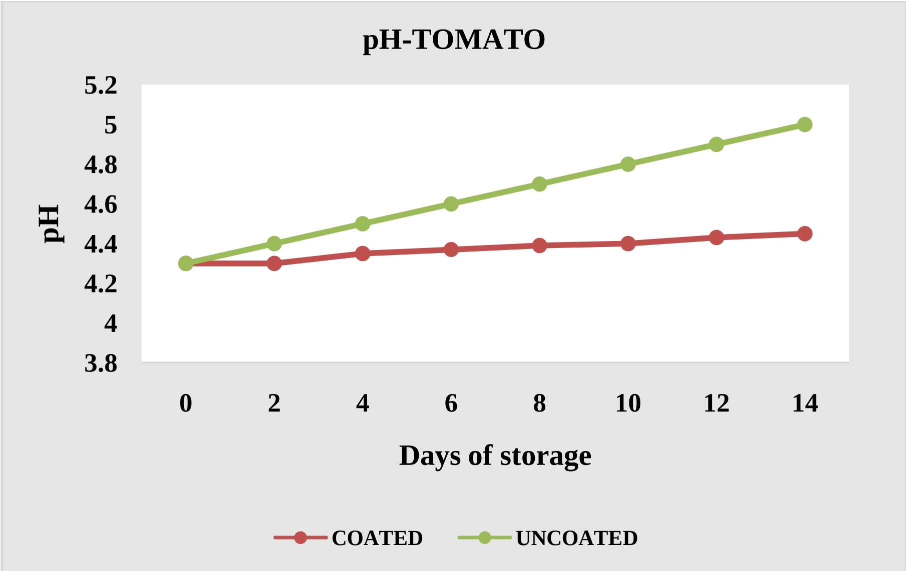

Fig 1: Effect of edible coating on pH of tomato

The pH of coated brinjal increased from 5.5 to 5.7 over 15 days, a 3.6% increase. In contrast, the pH of uncoated tomatoes increased from 5.5 to 6.8 over the same period, a 23.6% increase. In uncoated brinjals, ethylene production stimulates enzymatic reactions, leading to pH increases. In contrast, the poly-edible coating of the coated brinjal reduces the stimulation of enzymatic reactions.

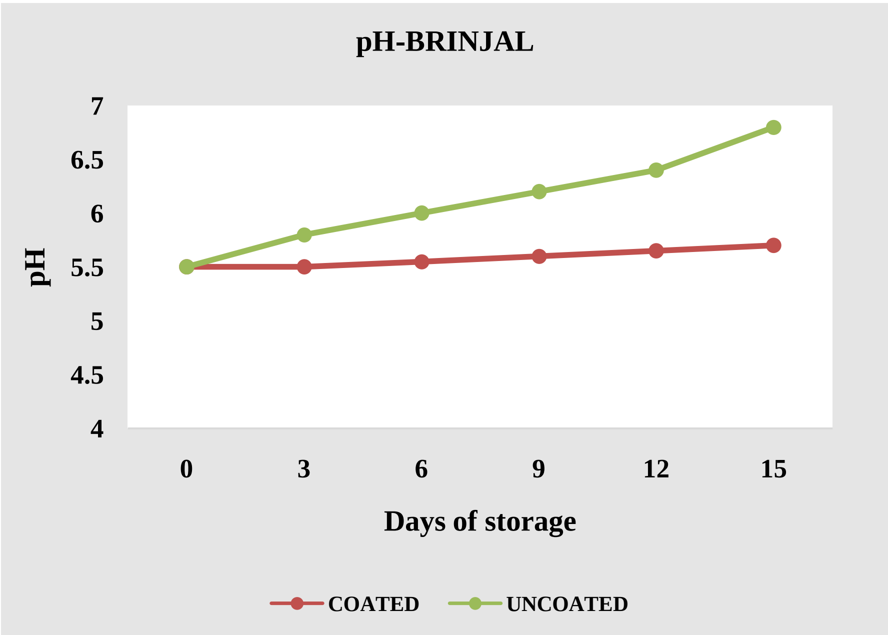

Fig 2: Effect of edible coating on pH of brinjal

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3.2.Weight loss

Weight loss in uncoated samples increased rapidly over time, reaching 18% on day 14, whereas coated samples showed significantly lower weight loss, reaching only 3.6% on day 14. Weight loss in tomatoes is mainly due to transpiration. The coating reduces transpiration, weight loss, and ethylene production, leading to extended shelf life.

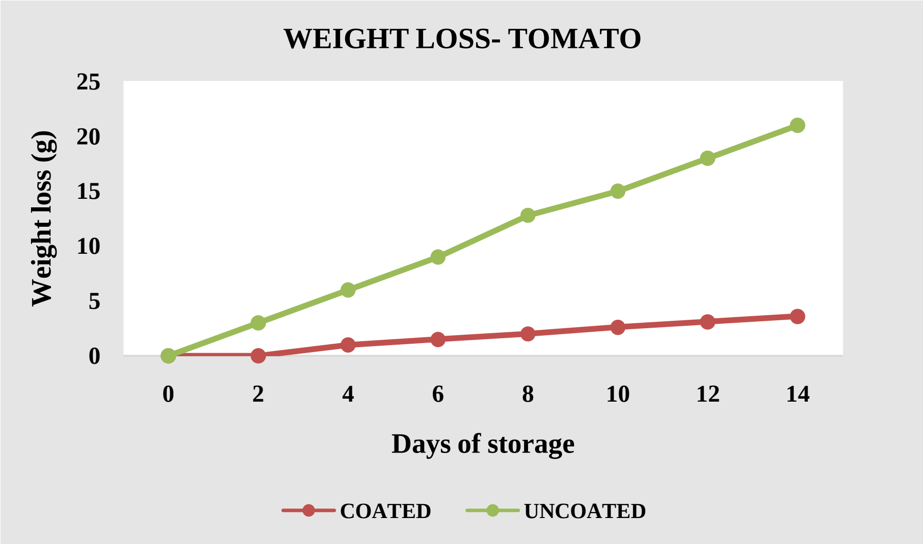

Fig 3: Effect of edible coating on weight loss (%) of tomato

Coated brinjals lost 2% of their weight over 15 days, while uncoated tomatoes lost 4.9% of their weight over 15 days. Coating brinjals reduces weight loss by minimizing water loss and regulating ethylene production, preserving freshness, and extending shelf life.

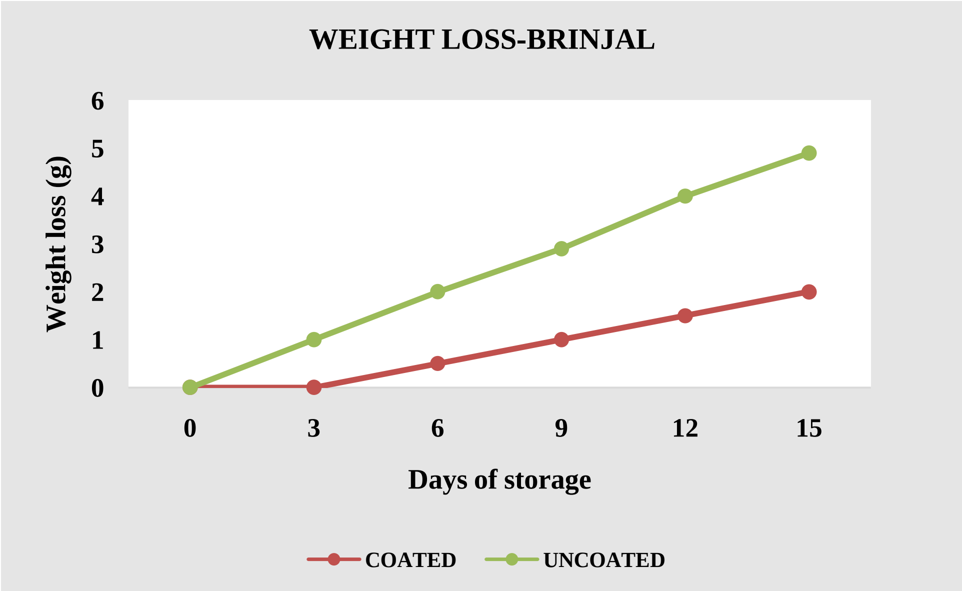

Fig 4: Effect of edible coating on weight loss (%) of brinjal

3.3.Moisture content

Coated tomatoes retained a higher moisture content of 96.2% than uncoated tomatoes of 80% after 14 days. In uncoated tomatoes, the water is lost through the skin, especially through the stem scar and natural openings.

This indicates that the edible coating helped to retain moisture in tomatoes, resulting in a

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lower moisture loss compared to uncoated tomatoes. The coating's ability to reduce moisture loss can potentially extend the shelf life of tomatoes.

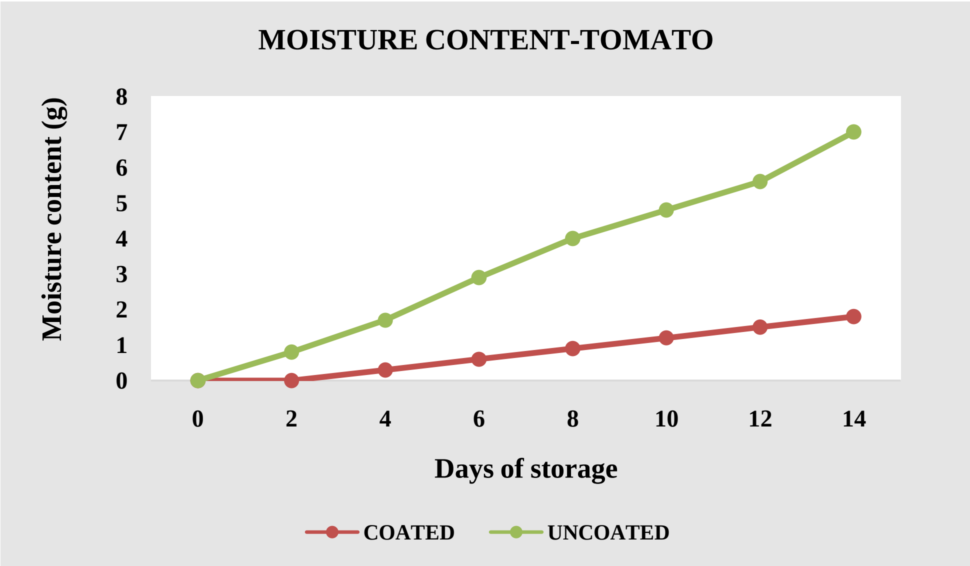

Fig 5: Effect of edible coating on moisture content of tomato

Coated brinjals retained a higher moisture content of 95% compared to uncoated brinjals of 75% after 15 days. Moisture loss in brinjals occurs due to transpiration, respiration, evaporation, and ethylene production, affecting their freshness and shelf life**.**

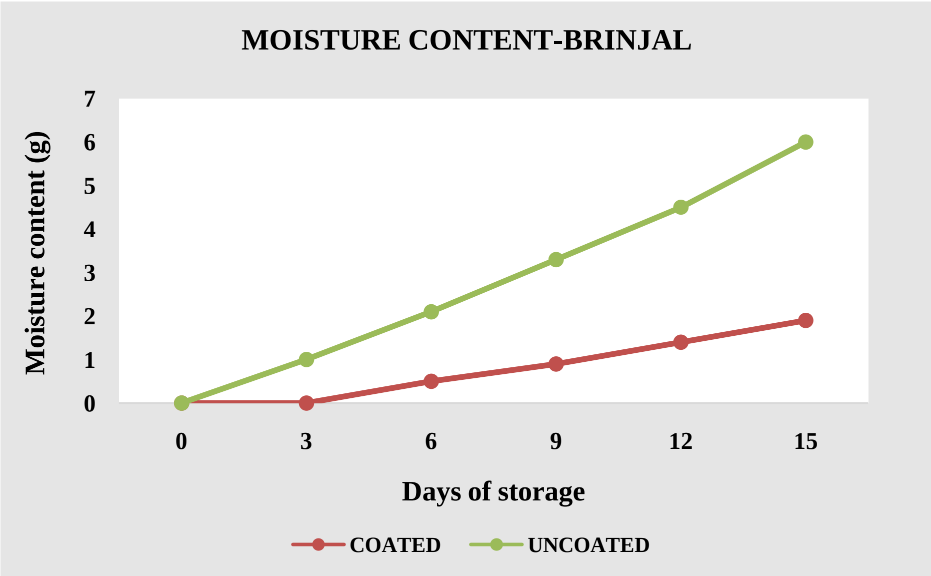

Fig 6: Effect of edible coating on moisture content of brinjal

3.4. Lycopene content

Lycopene content in coated tomatoes increased from 15.67 to 21 mg/100g over 14 days, whereas uncoated tomatoes increased from 15.67 to 32 mg/100g over 14 days. Uncoated tomatoes showed a higher increase in lycopene content than coated tomatoes, suggesting that the coating may have influenced the ripening process and the synthesis of lycopene.

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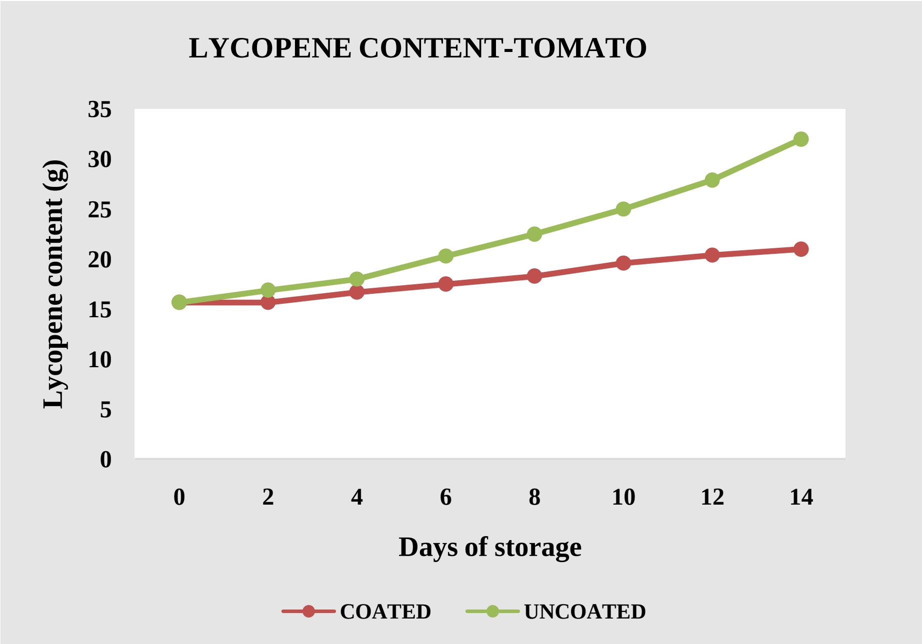

Fig 7: Effect of edible coating on lycopene content of tomato

3.5. Total Phenolic content

The total phenolic content (TPC) in coated tomatoes remained relatively stable, with a retention of 90.9% after 14 days. In contrast, the TPC in uncoated tomatoes decreased significantly, with a retention of 79.4% after 14 days.

The increase in TPC can be attributed to the potential antioxidant properties of the coating, which may have helped preserve the phenolic compounds in the tomatoes. These findings are consistent with the idea that edible coatings can enhance the nutritional value and shelf life of fruits and vegetables.

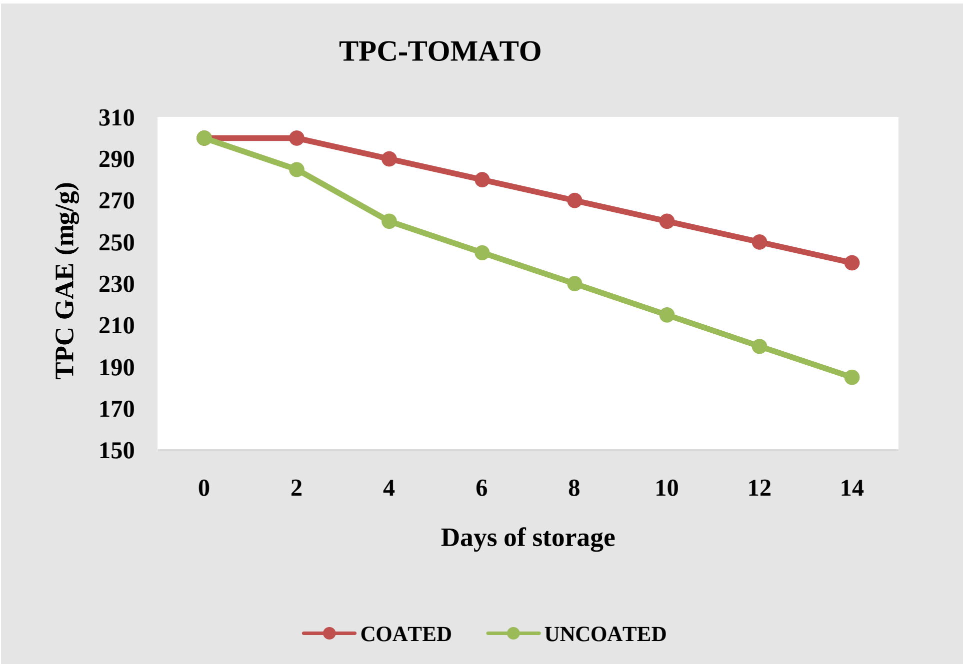

Fig 8: Effect of edible coating on total phenolic content of tomato

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After 15 days, coated brinjals retained 95.7% of their initial TPC, whereas uncoated brinjals retained only 80.5% of their initial TPC. The loss of total phenolic content (TPC) in brinjals is due to a combination of enzymatic degradation, oxidation, moisture loss, ethylene production, microbial spoilage, physical damage, and temperature.

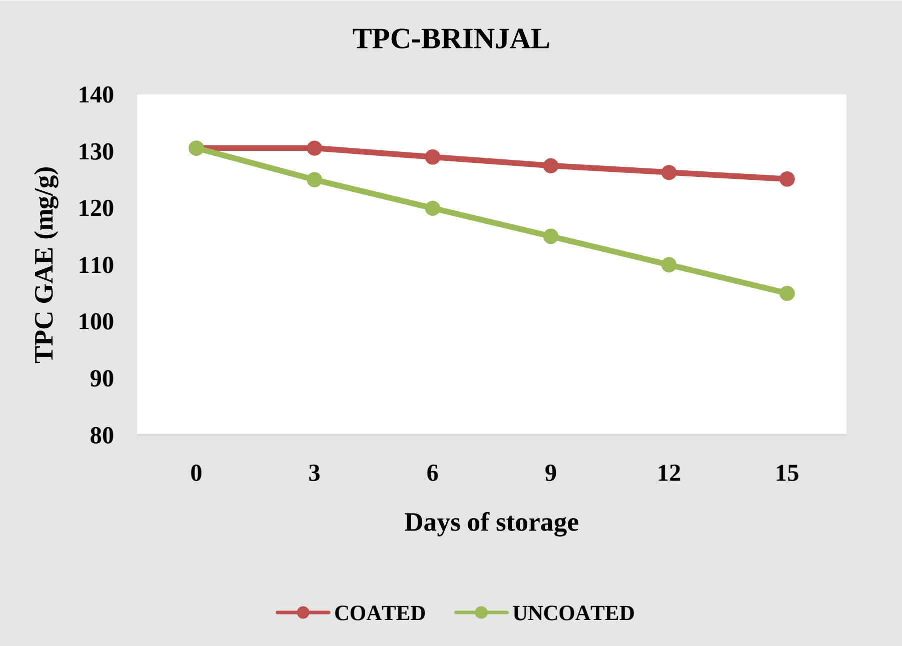

Fig 9: Effect of edible coating on total phenolic content of brinjal

3.6. Total Flavonoid Content

The total flavonoid content (TFC) in coated tomatoes remained relatively stable, with a retention of 93.6% of the initial TFC after 14 days. In contrast, the TFC in uncoated tomatoes decreased significantly, with a retention of 81.4% of the initial TFC after 14 days. The coating preserved flavonoids by reducing moisture loss, limiting oxygen exposure, and preventing physical damage.

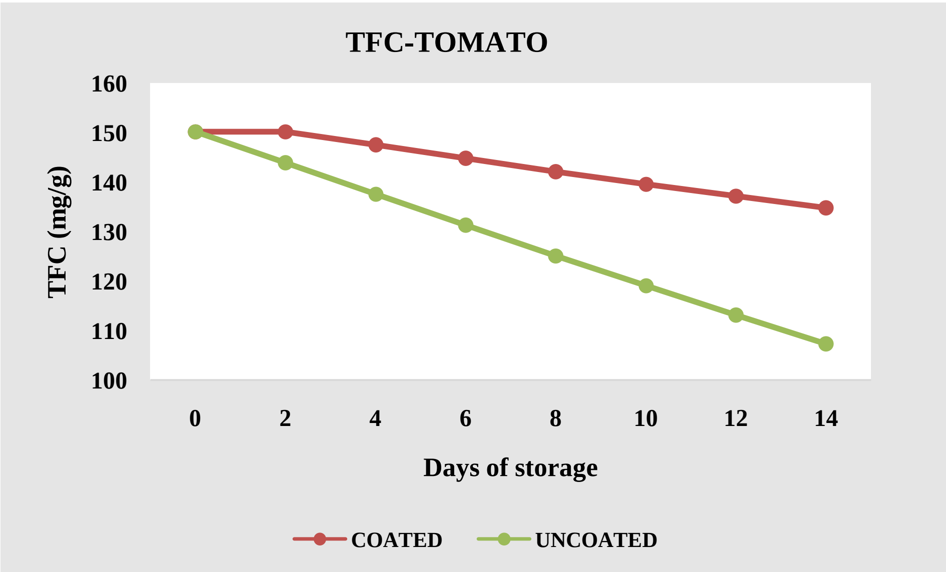

Fig 10: Effect of edible coating on total flavonoid content of tomato

The total flavonoid content (TFC) in coated brinjals remained relatively stable, with a retention of 94.6% of the initial TFC after 15 days. In contrast, the TFC in uncoated brinjals decreased significantly, with a retention of 83.7% of the initial TFC after 15 days. The coating preserved flavonoids by reducing moisture loss, limiting oxygen exposure, and preventing physical damage.

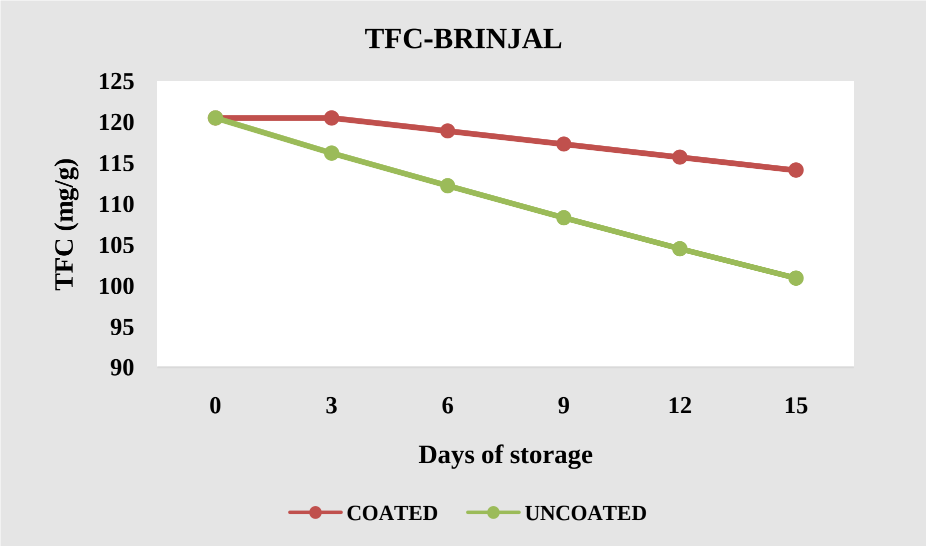

Fig 11: Effect of edible coating on total flavonoid content of brinjal

3.7. Antioxidant activity

The antioxidant activity in coated tomatoes remained relatively stable, with a retention of 85.9% of the initial antioxidant activity after 14 days. In contrast, the antioxidant activity in uncoated tomatoes decreased significantly, with a retention of 56.6% of the initial antioxidant activity after 14 days. The coating preserved antioxidant activity in tomatoes by reducing moisture loss, limiting oxygen exposure, and preventing physical damage.

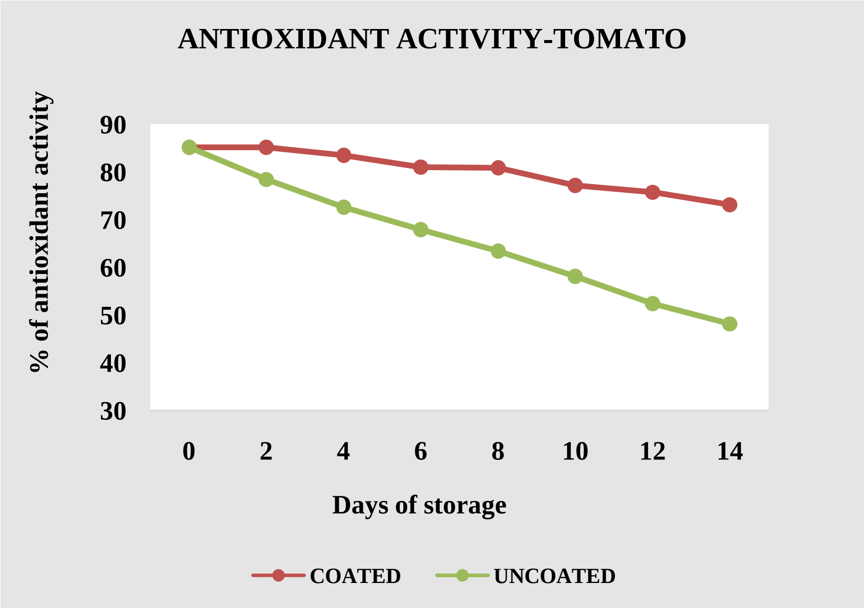

Fig 12: Effect of edible coating on antioxidant activity of tomato

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The antioxidant activity in coated brinjals remained relatively stable, with a retention of 88.9% of the initial antioxidant activity after 15 days. In contrast, the antioxidant activity in uncoated brinjals decreased significantly, with a retention of 70.1% of the initial antioxidant activity after 15 days. The coating preserves antioxidant activity in brinjal by reducing moisture loss, limiting oxygen exposure, and preventing physical damage.

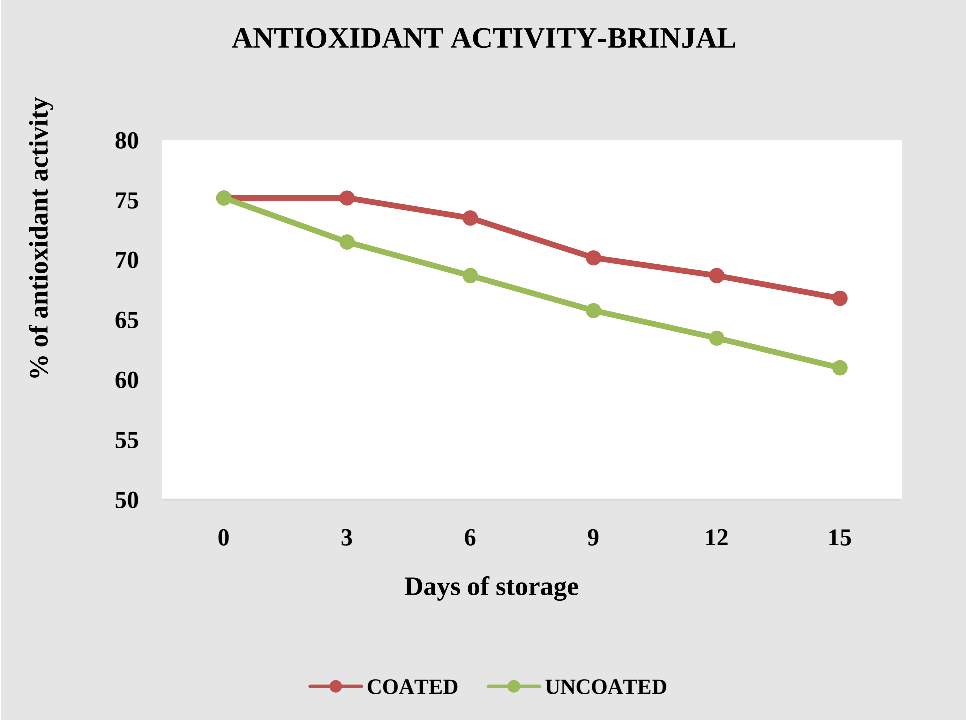

Fig 13: Effect of edible coating on antioxidant activity of brinjal

3.8. Sensory Evaluation

The images show a comparative evaluation of tomatoes, with one set untreated (UC - Uncoated) and the other coated with a polyedible coating, observed over a period of 14 days. Sensory attributes such as texture, firmness, color, and overall appearance were visually assessed.

- **Firmness:** The uncoated (UC) tomatoes started showing visible signs of softening as early as Day 6, with noticeable wrinkling and shrinkage. The coated tomatoes maintained firmness for a longer duration, showing no shrinkage
- **Color:** The coated tomatoes retained a fresher and more uniform red color, while the uncoated ones began developing dull and wrinkled surfaces earlier in the storage period
- **Surface Quality:** By Day 8, the uncoated tomatoes exhibited clear wrinkling and textural degradation, while the coated ones remained smoother and more intact
- **Shelf-Life Extension:** The uncoated tomatoes showed significant spoilage by Day 10, whereas the coated ones maintained an acceptable appearance until at least Day 14

The polyedible coating effectively preserved tomato freshness by retaining moisture and firmness, reducing weight loss and microbial attack, and minimizing color and texture degradation. This led to an enhanced shelf life, with sensory evaluation confirming the coating's efficacy and aligning with physicochemical parameters.

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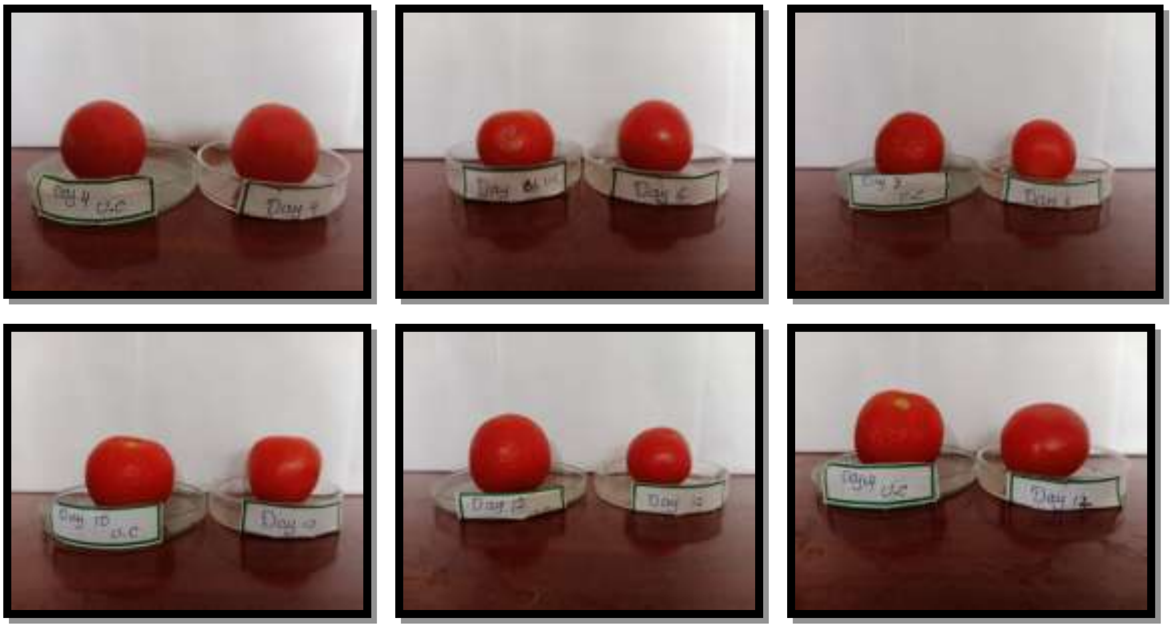

Fig 14: Sensory evaluation of tomato

The images show a comparative sensory evaluation of brinjal (eggplant) samples, with one set left untreated (uncoated) and the other treated with a polyedible coating, observed over 15 days. The assessment is based on visual parameters like texture, color, shriveling, and overall appearance.

- **Texture and Firmness:**
  - ➢ The uncoated brinjals began showing signs of shriveling and softness as early as Day 6.
  - ➢ By Day 12, the uncoated brinjals exhibited significant wrinkles and loss of firmness, while the coated ones maintained a firmer texture.
  - ➢ On Day 15, the uncoated brinjals were severely shriveled, whereas the coated brinjals retained a better shape and texture.
- **Color Retention:**
  - ➢ The coated brinjals maintained their vibrant purple color longer compared to the uncoated ones.
  - ➢ The uncoated samples began turning dull and wrinkled earlier, whereas the coated samples still had a relatively fresh appearance even by Day 15.
- **Overall Appearance and Shelf Life:**
  - ➢ The uncoated brinjals showed significant deterioration by Day 12, while the coated samples remained acceptable for consumption up to Day 15.
  - ➢ The edible coating helped in reducing moisture loss, delaying softening, and preserving visual freshness.

The sensory evaluation confirms that the polyedible coating effectively delayed the spoilage of brinjal by reducing moisture loss and oxidative damage. The coated brinjals exhibited better firmness, less shriveling, and superior color retention throughout the storage period. The visual and textural differences indicate that the coating played a role in minimizing microbial growth and weight loss, thus extending the shelf life of brinjal.

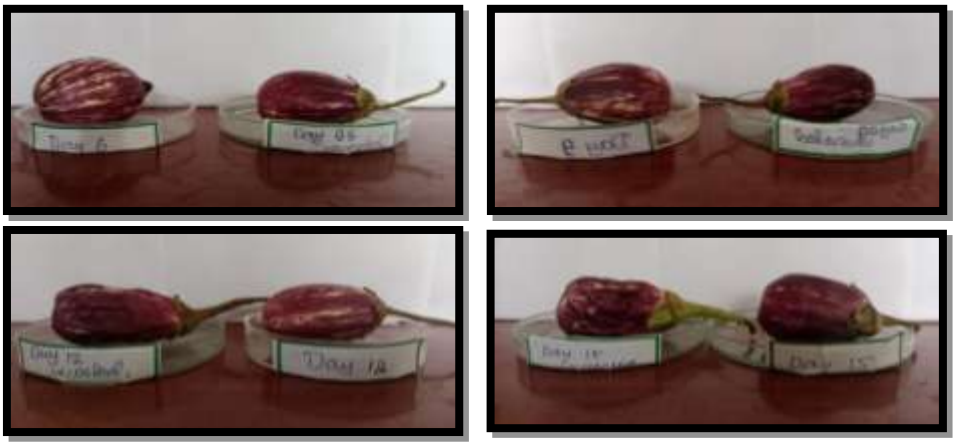

Fig 15: Sensory evaluation of brinjal

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