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PEACH KERNEL MODIFIED PROTEIN BASED EDIBLE COATING FORMULATION AND ITS USAGE IN IMPROVING SHELF LIFE OF TOMATO (SOLANUM LYCOPERSICUM L.)

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ABSTRACT
Modified protein extracted from peach kernel a byproduct from agro-food processing industries combined with Arrowroot starch, an underutilized starch source exhibit promising biodegradable formulation for edible coating. This study was conducted to evaluate the effectiveness of modified protein and arrowroot starch based edible coating in extending the shelf life of tomatoes for prolong storage days. Formulation for coating was prepared with 2%, 3% and 4% modified protein concentration with 4% arrowroot starch and 4% glycerol for tomato samples. The uncoated tomato samples were marked as control. For a period of 15 days the coated and uncoated tomato samples were studied to evaluate the impact of coating over the period of time. On every 3rd day of the storage period tomatoes samples were evaluated for various parameters like pH, TSS, Titratable acidity, weight loss and shelf life. Tomatoes samples with 3% coating of modified protein were the most effective coating formulation that helped to retain the weight of the tomatoes (62.145 grams) till 15 days of storage period with least drop 8.25% in weight loss percentage. The shelf life of coated tomatoes was increased to 20 days in comparison to 15 days for the uncoated tomatoes sample. For tomatoes with 3% coating vitamin C was found to be 17.6 mg/100g on day 15th, which is highest among coated and uncoated samples. Vitamin C retention percentage on day 15th was found to be 66.4%. E* value for 3% coated tomatoes was recorded 6.87 ± 0.21 which is lowest E* value among other coated and control sample.The result suggested modified protein and arrowroot starch based coated serve as an effective sustainable solution to mitigate the post harvest looses in tomato samples.

KEYWORD: Peach kernel modified protein, arrowroot starch, edible coating, tomatoes and shelf life

INTRODUCTION

Increase surge in sustainable and innovative techniques for the utilization of the agro food industry waste has led to the development of value added products. Peach kernels are the byproducts from peach processing industries. Peach kernels have gathered attention due its potential as a protein source in food system. Protein extracted from peach kernel has been incorporated in food system for the development of various value added products (Kumari et al., 2023). Modified peach kernel protein with improved functional properties has promising capabilities for development of better functional ingredients(Lacroix & Vu, 2014). Edible coating developed from detoxified modified peach kernel protein can be utilized to enhance the shelf life and physicochemical stability of perishable produce (Ghidelli, Mateos, Rojas-Argudo, & Pérez-Gago, 2015).Tomatoes are widely cultivated and consumed in India and are known for phenolic compounds, antioxidants such as vitamin C, lycopene, flavonoids and vitamin E. Tomatoes are perishable fruit commodity and have increased respiration rate due to increased ethylene spike (Zewdie, Shonte, & Woldetsadik, 2022). This shortens the shelf life of the tomatoes in market from the time of this harvest. Post harvest handling of tomatoes is necessary to mitigate the post harvest looses in tomato fruit (Wigati et al., 2023). Application of biodegradable edible coating prepared from peach kernel modified protein on perishable tomatoes enhances its shelf life and marks as an excellent strategy to utilized protein from by product source in food system. Edible coating on fruits and vegetable is defined to be a thin layer (<400 μm) utilized as primary packaging that keeps the commodity safe from external environment with being safe for direct consumption(Raghav, Agarwal, & Saini, 2016). Edible coating formulated from edible ingredients aids to maintain the quality of the food product by acting as a mass transfer barrier from external surface (like gases, water vapor, light and solutes) (Shellhammer & Krochta, 2018). Various natural material used to formulate edible coating vary from polysaccharides (alginate, chitosan, pectin, cellulose and starch), protein, composite, bioactive and lipids (Wu, Wu, & Hu, 2024). Among various polysaccharides, starch is the most prominent polysaccharide that is used for formulation of edible coating with other components owing to its effective forming properties, biodegradability and effective pricing (N. Kumar & Neeraj, 2019). Arrowroot starch has uniform composition, transparent in color and has good starch based coating application. Arrowroot starch mixes well with modified protein extracted from peach kernel which affects the edible coating thickness, making proper concentration that is required to prevent maximum fruit damage (Marta et al., 2025). The protein and starch based coating on tomatoes act as an oxygen and carbon dioxide barrier that reduces respiration rate and prevent dehydration of the fruit(Gennadios, WELLER, & Testin, 1993; Hauzoukim & Mohanty, 2020). Arrowroot starch gelatinizes at high temperature, with the addition of plasticizer the fragility of the coating is reduces with also enhances the durability and flexibility of the coating(Abdillah & Charles, 2021). Earlier reported studies on edible coating indicated difference between coated and uncoated food commodities for a short period of time. The application of modified protein and starch based edible coating on tomato fruit has shown to increase the shelf life of tomatoes for a prolonged period of time(Marta et al., 2025). Current study was conducted to explore potential of modified protein and starch based edible coating on locally cultivated tomatoes. Fresh, hand harvested tomatoes were purchased from the fields of horticultural department of Baru sahib. Tomatoes were procured at stage of maturity (greenish red in color) For coating glycerol and Arrowroot starch (food grade) were used on the tomatoes in addition of the Modified peach protein. Edible coating formulation was prepared using 2%, 3% and 4% modified protein, 4% w/w glycerol and 4 % w/w arrowroot starch. Glycerol was added as a plasticizer and addition of arrowroot starch was done as a polysaccharide component in the coating formulation. Gelatinization of starch was done at 80 ℃ ± 5℃ for 5 min with the use of magnetic stirring hot plate with continuous stirring. Glycerol was then added and solution was stirred for 20min. The solution was naturally cooled and then modified peach protein was added to the mixture until it reached 25℃. Formulation of modified protein varies and fixed concentration of arrowroot starch and glycerol (as plasticizer) for making of edible coating. The optimized formulations of coating are then applied on groups of tomatoes categorized as coated and uncoated (control) tomato samples. The coated and uncoated tomato sample are stored in controlled conditions and various parameters like TSS, color, pH, Titratable acidity were evaluated to establish the best formulation that extends the shelf life of the tomatoes. The collected data was analyzed for coated and uncoated sample and impact of coating on tomatoes was established in the study.

MATERIAL AND METHOD

Coating procedure for Tomatoes

Tomatoes were graded and sorted on parameters like appearance, color uniformity, mechanical damage and absence of blemishes. After sorting the tomatoes were washed and soaked in sodium hypochlorite solution (0.5%) for 3 minutes. Air dried tomatoes were grouped in 4 group for coating application. Each group had 23 tomatoes that were subjected to various test in the study. The groups were labeled as control, 2% modified protein solution, 3% modified protein solution and 4% modified protein solution. The 2%, 3% and 4% group of tomatoes were dipped in solution with different concentration of modified protein for 1 min and dried at room temperature. These coated tomatoes were stored in basked with net cover to prevent any damage. These samples were evaluated for different parameters on 0th, 3th, 6th, 9th, 12th and 15th day of their storage period.

Weight loss percentage

For the calculation of the rate of weight loss percentage in the coated and control samples of tomatoes standard method by (de Oliveira Filho et al., 2022) from AOAC was used. Digital weighing balance was used to analyze the sample weight on the initial day of the study to every 3rd day during the 15th days storage period. The weight loss for the tomatoes was determined as the difference calculated between 0th day and 15th day.

Total soluble solids (TSS)

TSS (°Brix) of coated and uncoated tomatoes were determined by the method given by (Rasit, Hwe Fern, & Ab Karim Ghani, 2019).Tomato slurry was prepared to evaluate its TSS on digital Refractometer instrument in food technology department of Eternal University, Baru sahib.

pH

Determination of pH of tomatoes slurry was prepared and evaluated on a digital pH meter in food technology department in Eternal University, Baru Sahib. (International, 2000)

Titratable acidity

Titratable acidity of the coated and uncoated tomatoes was evaluated by standard method by AOAC 2000 942.15 (International, 2000). In 100 ml of distilled water 5g of the tomato slurry was dissolved. 0.1 N NaOH and 1% phenolphthalein indicator was used to evaluate the titratable acidity. The readings were calculated using formula:

$$\text{Titrable acidity (\%)} = \frac{\text{V NaOH} \times 0.1 \times \frac{100}{25}}{\text{sample weight (g)}} \times 100$$

Vitamin C

Determination of the vitamin C was evaluated using procedure given by (Wibowo et al., 2023). Tomato filtrate (10g) was dissolved in 100 ml of distilled water. This mixture was dissolved and filtered. 0.01 N Iodium solutions were used to titrate 25 mL filtrate and 1 % amylum as indicator. The reading were calculated using the following equation

$$\text{Vitamin C mg/100g} = \frac{\text{V Iodium} \times 0.01 \times \frac{100}{25} \times 88}{\text{sample weight (g)}} \times 100$$

Color Estimation

Color was evaluated using digital chroma meter instrument in the food technology department in Eternal University, Baru sahib. Color parameters L*, a* and b* were determined (Zhang, Li, & Fan, 2019).

$$\text{Hue} = \tan - 1\ (\text{b}/\ \text{a}*)$$

$$\Delta\text{E}* = \sqrt{(\text{L}*)^2 + (\text{a}*)^2 + (\text{b}*)^2}$$

RESULT AND DISCUSSION

Weight loss percentage

Weight loss percentage for control and coated samples of tomatoes is represented in Table 1 represents weight of tomatoes samples during the storage period. Weight of the tomatoes sample was determined using a digital balance. The control (uncoated) samples of tomatoes showed highest drop in weight loss percentage during the storage period of 15 days. Weight loss percentage on day 3rd of the storage showed the 5.81 % drop from the initial weight recorded on day 0th of the study. The drop in the percentage of weight loss increases with the increase in the storage duration. For 2 % coating of the tomatoes samples 3.30 % drop in the weight loss was estimated on the day 6th of the storage study. This drop increases to 14.72 % on the day 15th. Tomatoes with 3% coating showed minimum drop in weight loss percentage over the duration of storage period. On day 6th 3.27% drop was observed this increased to 8.25 % drop by day 15th which significantly lower in comparison to control and other coated samples. For tomatoes with 4% of coating 2.56 % drop was observed on day 3rd of the storage this increased significantly with the increase in the storage duration. On day 15th the drop in weight loss was found to be 17.08 which are higher among the coated samples of the tomatoes. The control (uncoated) samples of tomatoes showed highest drop in weight loss percentage in the interval of storage duration of 15 days.

Table 1 Weight Loss Percentage of Control and Coated Tomato Samples

Sample	Day 3	Day 6	Day 9	Day 12	Day 15
Uncoated Tomatoes	5.81 ± 0.04^{a}	11.83 ± 0.06^{a}	16.42 ± 0.09^{a}	19.11 ± 0.12^{a}	33.10 ± 0.15^{a}
2% Coating	3.30 ± 0.05^{b}	8.52 ± 0.08^{b}	9.81 ± 0.07^{b}	11.33 ± 0.09^{b}	14.72 ± 0.11^{b}
3% Coating	3.27 ± 0.06^{b}	4.61 ± 0.06^{c}	5.51 ± 0.07^{c}	6.14 ± 0.07^{c}	8.25 ± 0.08^{c}
4% Coating	2.56 ± 0.05^{c}	7.84 ± 0.07^{b}	12.32 ± 0.09^{b}	13.99 ± 0.10^{b}	17.08 ± 0.10^{b}

Values are mean ± standard deviation (n = 3). Means within a column followed by different superscripts (a–c) differ significantly at $p < 0.05$ according to Duncan's Multiple Range Test (DMRT).

Weight loss percentage on day 3rd of the storage showed the 5.81 % drop from initial weight which was recorded on day 0th of the study. The drop in the percentage of weight loss increases with the increase in the storage duration. For 2 % coating of the tomatoes samples 3.30 % drop in the weight loss was estimated on the day 6th of the storage study. This drop increases to 14.72 % on the day 15th. Tomatoes with 3% coating showed minimum drop in weight loss percentage over the duration of storage period. On day 6th 3.27% drop was observed this increased to 8.25 % drop by day 15th which was significantly lower than uncoated and other coated samples. For tomatoes with 4% of coating 2.56 % drop was observed on day 3rd of the storage this increased significantly with the increase in the storage duration. On day 15th the drop in weight loss was found to be 17.08 which are higher among the coated samples of the tomatoes. This is attributed to the fact that tomatoes with coating maintained weight during the storage period better in comparison to the tomatoes without coating. Coating on the tomatoes samples created hydrophobicity barrier around tomato stomata, which protected tomatoes against rapid weight loss and transpiration (Maftoonazad & Ramaswamy, 2019) . Study conducted by (Marta et al., 2025) on tomatoes with coating of arrowroot starch with different proportion showed coated tomatoes had extended shelf life then uncoated ones.

Total soluble solids (TSS)

Total soluble solid of uncoated and coated tomatoes with different proportion of modified protein are represented in Table 2. Control sample of tomatoes had no coating of modified protein and was kept at room temp for period of 15 days under observation. On day 6th and 12th TSS value for control sample were found to be lowest. TSS value for control sample of tomatoes decreases from 4.06 ± 0.12 evaluated on Day 0th to 3.9 ± 0.04 evaluated on Day 12th. The TSS value was found to increase to 4.20 ± 0.22 on day 15th. Significant difference ($p<0.05$) was observed between day 12 and day 15, For tomatoes samples with 2% coating, the TSS value increases with storage period. The TSS value on day 0th was found to be 4.03 ± 0.11. With the increase in storage period the TSS value increases to 4.21 ± 0.05 which was found on last day of storage .Significant difference ($p<0.05$) on day 6 and day 12 on tomatoes samples with 2 % coating was observed. For tomatoes samples with 3 % coating, the TSS value increases with increase in storage periods .Day 0th recorded the lowest TSS value i.e. 4.04 ± 0.13. As the storage time was increased the TSS value was found 4.32 ± 0.12 on day 6th. There is significant difference ($p<0.05$) observed on day 6th and day 12th. For tomatoes samples with 4 % coating, TSS value were observed highest on day 6th and day 12th among all the coated samples. TSS value on day 0th was recorded 4.07 ± 0.11. Highest value of TSS 4.36± 0.1was found on day 6th. . As storage period was increased the TSS value on day 15th was found 4.19±0.2. Significant difference ($p< 0.05$) was found during the storage period for 4% coating on tomatoes samples. The total soluble solid of control and tomato coated with different proportion of modified protein were also studied .Control sample of tomatoes had no coating of modified protein and was kept at room temp for period of 15 days under observation. Control sample of tomatoes were found to have lowest value of TSS as compared to coated samples. On day 6th and 12th TSS value for control sample were found to be lowest. TSS value for control sample of tomatoes decreases from 4.06 evaluated on Day 0th to 3.9 evaluated on Day 12th. For tomatoes samples with 2% coating, the TSS value increases with storage period. The TSS value on day 0th was found to be 4.03. With the increase in storage period the TSS value increases to 4.21 which were found on day 15. For tomatoes samples with 3 % coating, the TSS value increases with increase in storage periods .Day 0th recorded the lowest TSS value i.e. 4.04.

Table 2 Total Soluble Solids (TSS) of Uncoated and Coated Tomato Samples during Storage

Sample	Day 0	Day 3	Day 6	Day 9	Day 12	Day 15
Uncoated Tomatoes	4.06 ± 0.12^{a}	4.20 ± 0.15^{a}	3.96 ± 0.06^{a}	3.90 ± 0.20^{a}	3.97 ± 0.04^{a}	4.20 ± 0.22^{b}
2% Coating	4.03 ± 0.11^{a}	4.24 ± 0.08^{a}	4.29 ± 0.05^{c}	4.15 ± 0.12^{a}	4.19 ± 0.25^{b}	4.21 ± 0.05^{a}
3% Coating	4.04 ± 0.13^{a}	4.29 ± 0.10^{a}	4.32 ± 0.12^{c}	4.10 ± 0.22^{a}	4.13 ± 0.09^{b}	4.15 ± 0.20^{a}
4% Coating	4.07 ± 0.11^{a}	4.33 ± 0.08^{a}	4.36 ± 0.19^{b}	4.29 ± 0.12^{a}	4.15 ± 0.10^{a}	4.19 ± 0.23^{a}

Values are mean ± standard deviation (n = 3). Means within a column followed by different superscripts (a–c) differ significantly ($p < 0.05$) according to Duncan's Multiple Range Test (DMRT).

As the storage time was increased the TSS value was found 4.32 on day 6th. For tomatoes samples with 4 % coating, TSS value were observed highest on day 6th and day 12th among all the coated samples. TSS value on day 0th was recorded 4.07. Highest value of TSS 4.36 was found on day 6th.. Tomatoes without the coating had lowest TSS value in comparison to the coated tomatoes. The formation of sugar in the tomatoes by the utilization of carbohydrates and acids resulted in increased °brix value. This also effects weight loss and Titratable acid value in coated tomatoes. This causes the increase in TSS value for 2% and 4% coated tomatoes (Khorram, Ramezanian, & Hosseini, 2017). Similar study was conducted by (Nandane, Dave, & Rao, 2017) on pear fruit with the edible coating of soy protein isolate and hydroxypropyl methylcellulose showed similar result for increased TSS value on different proportions of coating on the pear in storage period .

pH

The pH of control and coated tomatoes sample are shown in Table 3.The control sample shows higher pH in comparison to coated tomatoes. Control sample of tomatoes shows lowest pH 4.50 ± 0.02 on day 0th. As the storage period increases to day 15th pH of the control sample is recorded highest 4.81 ± 0.08. Significant difference ($p< 0.05$) is observed on day 12th and day 15th of the storage period. For tomatoes coated with 2% of modified protein coating, lowest pH was found on day 0th 4.54± 0.13 and highest pH was found on day 15th 4.82 ± 0.26. On day 6th and on day 9th increase in pH from the initial recorded pH was observed. Significant difference ($p< 0.05$) on day 12th and on day 15th was observed. For tomatoes coated with 3% of modified protein coating lowest range of pH was 4.55 ± 0.05 recorded on day 0th and highest range of 4.74 ± 0.04 on day 15th. No significant difference ($p< 0.05$) was observed during storage period. Lowest pH was observed in 3% coated tomatoes on last day of storage.For 4% coated tomatoes coated highest pH 4.86± 0.10 was found on day 15th. Lowest range of pH 4.56± 0.02 was observed on day 0th. No significant difference ($p< 0.05$) was observed during the storage period. The control sample shows higher pH in comparison to coated tomatoes.

Table 3 pH of uncoated and coated tomato samples during storage

Sample	Day 0	Day 3	Day 6	Day 9	Day 12	Day 15
Uncoated tomatoes	4.50 ± 0.02^{a}	4.53 ± 0.04^{a}	4.63 ± 0.01^{a}	4.71 ± 0.06^{a}	4.73 ± 0.03^{b}	4.81 ± 0.08^{b}
2% coating	4.54 ± 0.13^{a}	4.55 ± 0.23^{a}	4.56 ± 0.14^{a}	4.61 ± 0.19^{a}	4.67 ± 0.25^{b}	4.82 ± 0.26^{a}
3% coating	4.55 ± 0.05^{a}	4.56 ± 0.03^{a}	4.61 ± 0.04^{a}	4.63 ± 0.01^{a}	4.73 ± 0.04^{a}	4.74 ± 0.04^{a}

4% coating	4.56 ± 0.02^{a}	4.57 ± 0.04^{a}	4.62 ± 0.03^{a}	4.65 ± 0.03^{a}	4.81 ± 0.05^{a}	4.86 ± 0.10^{a}

Values are mean ± standard deviation (n = 3). Means within a column followed by different superscripts (a–c) differ significantly ($p < 0.05$) according to Duncan's Multiple Range Test (DMRT).

Control sample of tomatoes shows lowest pH 4.50 on day 0th. As the storage period increases to day 15th pH of the control sample is recorded highest 4.81. For tomatoes coated with 2% of modified protein coating, lowest pH was found on day 0th 4.54± 0.13 and highest pH was found on day 15th 4.82. On day 6th and on day 9th increase in pH from the initial recorded pH was observed. For tomatoes coated with 3% of modified protein coating lowest range of pH was 4.55 recorded on day 0th and highest range of 4.84 on day 15th. For 4% coated tomatoes coated highest pH 4.86± 0.10 was found on day 15th. Lowest range of pH 4.56± 0.02 was observed on day 0th. The slight increase in the value of pH for coated tomatoes sample is ascribed to the ability of the coating to retard organic acid metabolism. The uncoated tomatoes showed increment in pH value due to uncontrolled degradation in organic acid during fruit metabolism in storage period. (A. Kumar & Saini, 2021). Similar study was conducted (Pérez-Soto et al., 2021) where pH tends to increase in both coated and uncoated tomatoes due to ripening process.

Vitamin C

Vitamin C content in tomatoes and coated tomatoes are represented in table 4. The percentage of vitamin C retention in the interval of15 days is represented in table 4.21. Vitamin C content trends to decreases with the increase in storage period. For control (uncoated) tomato samples the vitamin C content was found 26.0 mg/100g on the day 0th as the storage time was increased the vitamin c content of the tomato samples was reduced to 13.5 mg/100g. The total retention percentage of vitamin c on day 3rd of the storage study was found to be 84% this was further reduced to 54 % on day 15th of the storage period. For 2% coated tomatoes, vitamin C value was found minimum 18.5 mg/100 g on day 15th. Vitamin C retention on day 15th was found to be 61.1 % which is higher as compared to the retention percentage of control sample on day 15th. For tomatoes with 3% coating vitamin C was found to be 17.6 mg/100g on day 15th, which is highest among coated and uncoated samples. Vitamin C retention percentage on day 15th was found to be 66.4%. For tomatoes with 4% coating, the vitamin C was found to be 24.2 mg/100g on day 3rd. as the storage period increases vitamin C value was found to be 14 .0 mg/100g on day 15th . Vitamin C retention percentage of the vitamin c on day 15th for 4% coated tomato sample was found to be 58.4% as represented in table 4. Effect of coating on vitamin C content in tomatoes and coated tomatoes was also studied. Vitamin C content trends to decreases with the increase in storage period. For control (uncoated) tomato samples the vitamin C content was found 26.0 mg/100g on the day 0th as the storage period was increased vitamin c content of tomato samples was reduced to 13.5 mg/100g.

Table 4 Vitamin C content (mg/100 g) of uncoated and coated tomato samples during storage

Sample	Day 0	Day 3	Day 6	Day 9	Day 12	Day 15
Uncoated tomatoes	25.0 ± 0.25^{a}	21.0 ± 0.34^{a}	18.5 ± 0.45^{b}	16.0 ± 0.38^{c}	14.5 ± 0.42^{c}	13.5 ± 0.41^{c}
2% coating	25.5 ± 0.28^{a}	23.5 ± 0.21^{a}	21.5 ± 0.32^{b}	20.0 ± 0.30^{b}	18.5 ± 0.33^{c}	15.6 ± 0.27^{d}
3% coating	26.5 ± 0.35^{a}	25.0 ± 0.26^{a}	24.0 ± 0.24^{a}	23.2 ± 0.20^{b}	21.5 ± 0.29^{b}	17.6 ± 0.30^{c}
4% coating	26.0 ± 0.31^{a}	24.2 ± 0.22^{a}	22.5 ± 0.28^{b}	21.0 ± 0.25^{b}	19.0 ± 0.27^{c}	14.0 ± 0.32^{d}

Values are mean ± standard deviation (n = 3). Means within a column followed by different superscripts (a–c) differ significantly ($p < 0.05$) according to Duncan's Multiple Range Test (DMRT).

The total retention percentage of vitamin c on day 3rd of the storage study was found to be 84% this was further reduced to 54 % on day 15th of the storage period. For 2% coated tomatoes, vitamin C value was found minimum 18.5 mg/100 g on day 15th. Vitamin C retention on day 15th was found to be 61.1 % which is higher as compared to the retention percentage of control sample on day 15th. For tomatoes with 3% coating vitamin C was found to be 17.6 mg/100g on day 15th, which is highest among coated and uncoated samples. Vitamin C retention percentage on day 15th was found to be 66.4%. For tomatoes with 4% coating, the vitamin C was found to be 24.2 mg/100g on day 3rd. as the storage period increases vitamin C value was found to be 14 .0 mg/100g on day 15th . Vitamin C retention percentage of the vitamin c on day 15th for 4% coated tomato sample was found to be 58.4%. The coated tomatoes showed highest retention of vitamin C in comparison to uncoated tomatoes(Chettri, Sharma, & Mohite, 2023). The coating on the tomatoes sample reduced the oxidation degradation of ascorbic acid. Direct content of oxygen is prevented through barrier action of coating (Maulida, Rismaya, & Vifta, 2023). Similar study was conducted by (Nawab, Alam, & Hasnain, 2017) with the coating of mango kernel starch on tomatoes to enhance its shelf life. The ascorbic acid of coated sample was maintained throughout the storage study.

Color characteristics

A colorimeter was used to determine the color parameters of control (uncoated) and the coated tomato samples (2%, 3%, and 4% modified protein coating) and the results are presented in Tables 5 and 6 show the results. Color characteristics showed a high degree of variation throughout the period of the 15 days of storage and it implies that the surface pigmentation of tomatoes changes over time and with treatment. In the control (uncoated) samples (Table 5 & 6), lightness (L), increased gradually, with values of 45.2 ± 1.32 on day 0, and 38.5 ± 1.16 on day 15 and this is an indication of the surface darkening as the fruit population matured. The redness value (a) rose to 19.01±0.57 to 25.02 ±0.75 indicating an improved red pigmentation in the course of storage. On the same note, yellowness (b) also rose, and the difference between 22.5 ± 0.67 and 27.02 ± 0.81 was noted as an increase in carotenoid pigments. The hue angle (h°) was reduced a bit (49.82 1.49 to 47.20 1.42) as it was expected after the alteration of the color towards red color. On day 15, the total color difference (E) was measured to be 10.06 ± 0.30 which is a significant visual change in the color condition compared with the original state. The L value in the 2% of modified protein coated samples (Table 4.25& 4.26) decreased in a moderate manner as the sample was stored i.e. the value dropped to 40.2 ± 1.21 at the end of the storage period as compared to 45.3 ± 1.36 of the control. The a value rose to 24.0 ± 0.75 at day 15, and b values also increased from 22.6 ± 0.68 to 26.2 ± 0.79. Day 15 E value was 7.89 ± 0.24, which is significantly lower compared to the control, however, this demonstrates superior stability of the color. In the case of the 3% coated samples (Table 4.25& 26), the L values dropped a bit to 41.2 ± 1.24, by day 15, the lowest drop amongst all the treatments. The a and b values increased from 19.0±0.57 to 23.5 ±0.70 and 22.5±0.67 to 25.8 ±0.77, respectively. E value was lowest in all the coated and uncoated samples 6.87/ +/ 0.21, indicating maximum retention of color and visual uniformity. Table 5 and 6 indicate that in the 4% coated samples (Table 4.25 and 26), the L value reduced to 40.8 ± 1.22 with the course of storage (44.8 ± 1.33). The a and b values were 19.0 ± 0.57 and 22.5 ± 0.67 respectively, which were changed to 23.7 ± 0.71 and 25.9 ± 0.78 respectively. The E value was 7.28 + 0.22 which was considered as moderate variation in colour. In general, the effect of storage on color was observed in all treatments, but tomatoes covered with an edible coating, especially when the modified protein content was 3%, had much lower total color difference (E) and color attributes retention than the control, which confirms the usefulness of edible coatings to slow down the process of surface color change and preserve the visual quality of tomatoes

Table 5 Color parameters (L, a, b*) of uncoated and coated tomato samples during 15-day storage

Parameter	Sample	Day 0	Day 3	Day 6	Day 9	Day 12	Day 15
L* (Lightness)	Control	45.2 ± 1.36^{a}	44.0 ± 1.32^{a}	42.5 ± 1.27^{b}	41.2 ± 1.24^{c}	39.8 ± 1.19^{c}	38.5 ± 1.16^{c}
	2% Coating	45.3 ± 1.36^{a}	44.5 ± 1.33^{a}	43.3 ± 1.30^{ab}	42.1 ± 1.26^{b}	41.0 ± 1.23^{b}	40.2 ± 1.21^{b}
	3% Coating	45.4 ± 1.36^{a}	44.8 ± 1.34^{a}	43.8 ± 1.31^{a}	42.7 ± 1.28^{b}	41.8 ± 1.25^{b}	41.2 ± 1.24^{b}
	4% Coating	45.4 ± 1.36^{a}	44.6 ± 1.34^{a}	43.5 ± 1.30^{a}	42.4 ± 1.27^{b}	41.5 ± 1.24^{b}	40.8 ± 1.22^{b}
a* (Redness)	Control	19.0 ± 0.57^{a}	21.0 ± 0.63^{ab}	22.5 ± 0.67^{b}	23.5 ± 0.70^{b}	24.2 ± 0.73^{b}	25.0 ± 0.75^{b}
	2% Coating	19.1 ± 0.57^{a}	20.5 ± 0.61^{a}	21.6 ± 0.65^{ab}	22.4 ± 0.67^{b}	23.2 ± 0.70^{b}	24.0 ± 0.75^{b}
	3% Coating	19.0 ± 0.57^{a}	20.2 ± 0.61^{a}	21.2 ± 0.64^{a}	22.0 ± 0.66^{ab}	22.8 ± 0.68^{ab}	23.5 ± 0.70^{a}
	4% Coating	19.0 ± 0.57^{a}	20.4 ± 0.61^{a}	21.4 ± 0.64^{a}	22.2 ± 0.67^{ab}	23.0 ± 0.69^{b}	23.7 ± 0.71^{b}
b* (Yellowness)	Control	22.5 ± 0.67^{a}	23.8 ± 0.71^{ab}	24.8 ± 0.74^{b}	25.6 ± 0.77^{b}	26.3 ± 0.79^{b}	27.0 ± 0.81^{b}
	2% Coating	22.6 ± 0.68^{a}	23.4 ± 0.70^{a}	24.2 ± 0.73^{ab}	25.0 ± 0.75^{b}	25.5 ± 0.77^{b}	26.2 ± 0.79^{b}
	3% Coating	22.5 ± 0.67^{a}	23.2 ± 0.70^{a}	24.0 ± 0.72^{a}	24.7 ± 0.74^{ab}	25.2 ± 0.76^{b}	25.8 ± 0.77^{b}
	4% Coating	22.5 ± 0.67^{a}	23.3 ± 0.70^{a}	24.1 ± 0.72^{a}	24.8 ± 0.74^{b}	25.3 ± 0.76^{b}	25.9 ± 0.78^{b}

Values are mean ± standard deviation (n = 3). Means within a column followed by different superscripts (a–c) differ significantly ($p < 0.05$) according to Duncan's Multiple Range Test (DMRT).

Table 6. Derived Color Parameters (C, h_a, BI, E, X) of Control and Coated Tomato Samples During 15 Days of Storage

Parameter	Treatment	Day 0	Day 3	Day 6	Day 9	Day 12	Day 15
C*	Control	29.45 ± 0.88^{a}	31.74 ± 0.95^{a}	33.49 ± 1.02^{a}	34.75 ± 1.04^{a}	35.74 ± 1.07^{a}	36.8 ± 1.10^{a}
	2% Coated	29.59 ± 0.89^{a}	31.11 ± 0.93^{ab}	32.44 ± 0.97^{b}	33.57 ± 1.01^{b}	34.47 ± 1.03^{b}	35.53 ± 1.07^{b}
	3% Coated	29.45 ± 0.88^{a}	30.76 ± 0.92^{b}	32.02 ± 0.96^{b}	33.08 ± 0.99^{b}	33.98 ± 1.02^{b}	34.9 ± 1.05^{c}
	4% Coated	29.45 ± 0.88^{a}	30.97 ± 0.93^{b}	32.23 ± 0.97^{b}	33.28 ± 1.00^{b}	34.19 ± 1.03^{b}	35.11 ± 1.05^{c}
h_a	Control	49.82 ± 1.49^{a}	48.58 ± 1.46^{a}	47.78 ± 1.43^{a}	47.45 ± 1.42^{a}	47.38 ± 1.42^{a}	47.2 ± 1.42^{a}
	2% Coated	49.8 ± 1.49^{a}	48.78 ± 1.46^{a}	48.25 ± 1.45^{a}	48.14 ± 1.44^{ab}	47.7 ± 1.43^{ab}	47.51 ± 1.43^{ab}
	3% Coated	49.82 ± 1.49^{a}	48.95 ± 1.47^{a}	48.54 ± 1.46^{ab}	48.31 ± 1.45^{ab}	47.86 ± 1.44^{b}	47.67 ± 1.43^{b}
	4% Coated	49.82 ± 1.49^{a}	48.8 ± 1.46^{a}	48.4 ± 1.45^{ab}	48.17 ± 1.45^{b}	47.73 ± 1.43^{b}	47.54 ± 1.43^{b}
BI	Control	96.12 ± 2.88^{a}	107.97 ± 3.24^{a}	119.81 ± 3.59^{a}	130.34 ± 3.91^{a}	141.38 ± 4.24^{a}	153.33 ± 4.60^{a}
	2% Coated	96.41 ± 2.89^{a}	104.01 ± 3.12^{b}	112.89 ± 3.39^{b}	122.1 ± 3.66^{b}	130.18 ± 3.91^{b}	138.66 ± 4.16^{b}
	3% Coated	95.6 ± 2.87^{a}	101.86 ± 3.06^{b}	109.78 ± 3.29^{b}	117.87 ± 3.54^{b}	124.84 ± 3.75^{b}	131.38 ± 3.49^{c}
	4% Coated	95.6 ± 2.87^{a}	103.14 ± 3.09^{b}	111.48 ± 3.34^{b}	119.72 ± 3.59^{b}	126.82 ± 3.80^{b}	133.91 ± 4.02^{c}
E*	Control	0.00 ± 0.01^{a}	2.67 ± 0.08^{a}	4.98 ± 0.15^{a}	6.77 ± 0.20^{a}	8.40 ± 0.25^{a}	10.06 ± 0.30^{a}
	2% Coated	0.17 ± 0.01^{a}	1.88 ± 0.06^{b}	3.64 ± 0.11^{b}	5.24 ± 0.16^{b}	6.65 ± 0.20^{b}	7.98 ± 0.24^{b}
	3% Coated	0.20 ± 0.01^{a}	1.45 ± 0.04^{c}	3.01 ± 0.09^{c}	4.48 ± 0.13^{c}	5.77 ± 0.17^{c}	6.87 ± 0.21^{c}
	4% Coated	0.20 ± 0.01^{a}	1.72 ± 0.05^{bc}	3.35 ± 0.10^{bc}	4.83 ± 0.14^{bc}	6.13 ± 0.18^{bc}	7.28 ± 0.22^{bc}
X	Control	0.50 ± 0.01^{a}	0.51 ± 0.01^{a}	0.52 ± 0.01^{a}	0.52 ± 0.01^{a}	0.52 ± 0.01^{a}	0.52 ± 0.01^{a}
	2% Coated	0.50 ± 0.01^{a}	0.51 ± 0.01^{a}	0.519 ± 0.01^{a}	0.52 ± 0.01^{a}	0.52 ± 0.01^{a}	0.52 ± 0.01^{a}
	3% Coated	0.50 ± 0.01^{a}	0.51 ± 0.01^{a}	0.51 ± 0.01^{a}	0.51 ± 0.01^{a}	0.52 ± 0.01^{a}	0.52 ± 0.01^{a}
	4% Coated	0.50 ± 0.01^{a}	0.51 ± 0.01^{a}	0.51 ± 0.01^{a}	0.52 ± 0.01^{a}	0.52 ± 0.01^{a}	0.52 ± 0.01^{a}

Values are mean ± standard deviation (n = 3). Means within a column followed by different superscripts (a–c) differ significantly ($p < 0.05$) according to Duncan's Multiple Range Test (DMRT).

during storage.Coating application on the tomatoes slows the ethylene production rate and respiration. 3% coated tomatoes had highest light preservation (Paul, Sarkar, Sethi, & Ghosh, 2018). a* in tomatoes with coating had slower increase which indicates slow ripening thus extending the shelf life (Wibowo et al., 2023). b* value was found to be highest in uncoated tomatoes and least in 3% coated sample which indicates that slow ripening process in coated tomatoes sample thus extending its shelf life (PARK, CHINNAN, & SHEWFELT, 1994). Similar observations were observed by (Marta et al., 2025) on color characteristics of coated and uncoated tomatoes with arrowroot starch coating.

CONCLUSION

Modified protein was utilized for the formation of edible coating with the glycerol and arrowroot starch. The edible coating was prepared with different concentration of modified protein and applied on tomatoes to study the increase in its shelf life. The application of 3 % edible coating on tomatoes increases the shelf life of the tomatoes to 20 days. Tomato samples with 2% and 4% edible coating of modified protein and arrowroot starch were insufficient to withstand the drop in weight loss as the storage period were increased. The 3% edible coated tomatoes were found to have least drop in weight and weight loss percentage. The retention of vitamin C was highest as the storage days were increased. The skin of the tomatoes sample with

3% coating was visibly tighter then samples with 3% and 4% coating and uncoated tomatoes samples. E* value for 3% coated tomatoes was recorded 6.87 ± 0.21 which is lowest E* value among other coated and control sample. For tomatoes with 3% coating vitamin C was found to be 17.6 mg/100g on day 15th, which is highest among coated and uncoated samples. Vitamin C retention percentage on day 15th was found to be 66.4%. The finding of this study reveals the use of modified protein and starch based coating as an effective biodegradable and sustainable solution for enhancing the shelf life of perishable commodities in food system that aids in its commercials scalability

Author Contributions

Rajvinder Kour: Data Collection, Analysis, Writing - review, and editing. Naseer Ahmed: Conceptualization, Methodology, Visualization, Supervision, Project Administration, Writing Original Draft.

All authors have read and approved the final version of the manuscript as submitted and are prepared to take public responsibility for the work.

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Conflict of Interest

The authors (s) do not have no conflicts of interest.

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This manuscript incorporates all the datasets produced or examined in this research study.

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This research did not involve human participants, animal subjects, or any materials that required ethical approval.

Informed Consent Statement

This study did not involve human participants; therefore, informed consent was not required.

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