



Influence of pullulan-based edible coatings to enhance post-harvest storage life of tomatoes under ambient conditions

VS Ramakrishna Ganduri

Department of Biotechnology, Acharya Nagarjuna University, Nagarjuna Nagar, Guntur, Andhra Pradesh, India

Abstract

Pullulan, fungal derived edible biopolymer possesses an excellent protective coating ability was tested on fresh tomato produce to extend their shelf-life. Two new edible composite coatings T2 (10% pullulan + 5% sorbitol) and T3 (10% pullulan + 5% Polyethylene glycol), along with T1 (only 10% pullulan) were coated on fresh tomatoes and compared to uncoated (C) tomato fruits. Lowest physiological weight loss % was found in T1 (8.14%) compared to C (12.32%) group tomato fruits. The color parameters, L , a^* , and b^* were quite different ($p < 0.05$) among treatments (T1, T2, and T3) during 18 days of testing and found that uncoated tomatoes have displayed higher values than all coated groups. Tomato fruit's flesh firmness was also remained high for all coated samples (4.2 - 4.8 kg_f/cm²) than uncoated fruits (3.5 kg_f/cm²). During the storage period, total sugars content was increased in both coated and uncoated tomatoes. Titratable acidity % was more decreased in uncoated tomatoes (0.11%) compared to coated fruits. pH of tomato juice was sharply increased in uncoated fruit samples indicated that these fruits were quickly ripened. It was concluded that these pullulan-based coatings have affected favorably the shelf-life parameters and therefore could be advantageous in delaying fresh tomatoes ripening at 25±1 °C and 65-70% relative humidity, up to 18 days of storage.

Keywords: pullulan, quality, physico-chemical, shelf-life, tomatoes

1. Introduction

Postharvest losses in fresh fruit vegetables are facing major problems because of enhanced susceptibility to damage by fungal damage, physiological disorders, physical injuries, increased ripening and senescence. Many alternative methods such as modified atmosphere, petroleum-based chemical coatings, plastic film wrappings were in application to extend their shelf-life [1, 2, 3]. Artificial and synthetic (chemical) preservatives like sodium benzoate, benzoic acid, sodium nitrite, and sodium, potassium sorbate have shown severe health disorders (high blood pressure, increased cholesterol level, and kidney, liver malfunction) in humans [4, 5]. To combat these difficulties in postharvest losses, exploration of suitable and effective edible coating formulation as safer alternative to synthetic chemicals, is necessary in perishable fresh produce.

Tomato (*Solanum lycopersicum L.*), an herbaceous, solanaceous, climacteric and popular fruit vegetable comes in over thousand varieties present in most of cuisines (in many countries) and are highly consumed for possessing many vitamins, essential amino acids and healthy organic acids [6]. Marketability of these fruits were limited by high moisture content, lack of appropriate preservation and processing systems [7]. One way to control tomato ripening is by manipulating ambient temperature, gas and humidity [8]. In general, low temperature conservation limits the respiration rate and thermal decomposition which increases the shelf-life of tomatoes and prolonged low temperature storage causes cooling lesions with skin contraction which may reduce fruit's taste [9]. An ideal coating is defined as one that can extend storage life of fresh fruit without causing anaerobiosis, and that reduces decay without affecting the quality of the fruit [10].

Edible coatings have exhibited the improved food quality, prolonged shelf-life of fresh produce through regulation of oxygen, carbon dioxide transfer, aroma and taste compounds [11]. Usually, fresh produce is coated by methods such as dipping, brushing, spraying, as film wrapping on the food surface, that would function like semi-permeable membrane that will control the moisture loss and/or suppress the gas transfer [12]. So, a desirable coating method should be attempted to extend the storage life of fresh tomato produce without causing anaerobiosis with reduced fruit decay. In addition, edible coatings act like functional ingredients carriers like antimicrobial and antioxidant agents, nutraceuticals and color and flavor ingredients [13]. Recently, many researchers have attempted use of distinctive coating substances, such as chitosan [14], aloe vera [15], starch [16], Guar gum [8], cassava starch [17], tragacanth gum [18], gelatin [19], seaweed [20]. Pullulan, an exopolysaccharide derived from *Aureobasidium pullulans*, has been used as an edible coating on many fruits and vegetables to improve postharvest shelf-life [21,22,23,24,25,26]. Hence, the aim of present study was to evaluate the potential of pullulan-based edible coatings on the change in physicochemical parameters to prolong tomatoes shelf-life during 18-day storage period at ambient conditions.

2. Materials and methods

2.1 Tomato fresh produce

Freshly harvested tomato (*Solanum lycopersicum L. vc Round*) fruits at light yellow stage of ripening were selected from a local farm garden at Tadepalli village of Andhra Pradesh, India. The fruits having similar weight were visually graded for uniformity in size, color, absence of blemishes, and fungal infection. Tomato fresh produce were

brought to the laboratory within 1 h of harvest and were sterilized with sodium hypochlorite (0.1 g/l) for 3 min., rinsed and dried (25 ± 1 °C and 65-70% relative humidity), per the WHO guidelines [26]. Four batches, with 6 tomatoes each were considered to observe each of four coating formulations (3 coatings and 1 control).

2.2 Coating formulation

Coating material, Pullulan (*Kopulan*) biopolymer from M/s. Kumar Organic Products Ltd. (Bengaluru, India), Sorbitol and Polyethylene glycol (PEG) - 4000 from M/s. Merck (Germany), were purchased. Coating formulations, T1: 10% (w/v) Pullulan (10 g of pullulan in 100 ml distilled water), T2: 10% (w/v) Pullulan + 5% (v/v) Sorbitol (10 g of pullulan and 5 ml of sorbitol into distilled water of 100 ml final volume), T3: 10% (w/v) Pullulan + 5% (v/v) PEG-4000 (10 g of pullulan and 5 ml of PEG into distilled water of 100 ml final volume) were prepared and stirred at 600 rpm at 60 °C for 30 minutes on a magnetic stirrer with hot plate.

2.3 Peel color appearance

Ripening of tomato fruits were visually assessed by skin color and scored by experienced sensory panelists, based on specific cultivar color, using a 1 to 6 scale which represent six ripening stages. These stages were represented as 1 = totally green; 2 = yellowish green; 3 = light yellow; 4 = light Red; 5 = moderate red; and 6 = complete red. A color chart was used to support the visual or sensory observation.

2.4 Physiological Loss in Weight % (PWL%)

Tomato fruit's physiological loss in weight % was calculated for the samples (C, T1, T2, and T3) were weighed at 0, 4, 7, 10, 14 and 18 days of storage period and from the difference of fruit's initial and final weight (in terms of loss) occurred was expressed in percentage on the fresh weight basis. The average of three measurements was done and PWL % was calculated (Ganduri, 2020).

2.5 Color characteristics

Each tomato fruit's image was captured using a photographic camera (Canon PowerShot SX620 Digital Camera w/25x Optical Zoom) by placing tomato in a standard box with a light background and the color parameters of tomatoes were assessed with the help of RGB image program. Measurements were recorded at least five different locations of tomato's peel surface and the average of *L* (lightness or brightness), *a** (redness or greenness) and *b** (yellowness or blueness) values were obtained [27]. The Hue angle, Chroma (color saturation) and the total color difference (ΔE) was calculated from *L*, *a** and *b** values of coated and uncoated tomato samples on day 18 and day 0, thus representing the time related changes [26].

2.6 Flesh Firmness

Firmness (in kgf/cm^2) of the tomato fruit flesh was recorded with hand-held fruit hardness tester (Bary C, GY-3) equipped with 8 mm cylindrical stainless probes. Both the coated and uncoated tomato samples' firmness was measured by removing 1 cm thick transverse sections at the equator of tomato peel and average of three measurements were made on each fruit at different equator locations [8].

2.7 Total Soluble Solids (TSS)

The degree brix, as a measure of total soluble solids for tomato juice extracted was measured using hand-held refractometer (0 – 32 °Brix Wort Specific Gravity Refractometer, Simon Cheng). The homogenate (1 mL) of pulp, apportioned prior to pH check, was centrifuged at 3000Xg for 5 min, and a drop of the clear supernatant was used to measure TSS and reported in °Brix [26].

2.8 Titratable Acidity % (TA%)

Ten grams of tomato pulp from each sample group was ground with 100 ml of boiled, distilled water. This solution was titrated with 0.10 N NaOH (pH at 8.0) in the presence of phenolphthalein as an indicator (with sudden pink color as end point). The citric acid (as TA%) was calculated per sampled day and the average of three measurements was recorded [8].

2.9 Juice pH

The pH of ground tomato pulp solution, after TSS and TA% measurements was determined using pH meter (Sartorius, PB-11, Germany).

3. Results & Discussion

3.1 Peel color appearance

Shelf-life of any fresh produce was defined as “the recommended maximum time for which products or fresh (harvested) produce can be stored, during which the defined quality of a specified proportion of the goods remains acceptable under expected (or specified) conditions of distribution, storage and display” [28]. In the present study, pullulan-based formulations were coated on fresh tomato fruits to monitor the shelf-life parameters. The change in peel color was recorded (photographed) individually for uncoated (C) and coated (T1, T2, and T3) tomato fruits.

Fig 1. shows that the tomatoes coated with pullulan and stabilizers (sorbitol and PEG) were glossy in appearance when compared to uncoated tomatoes. Among the coated tomatoes, only pullulan coated (T1) ones were found to have a longer shelf life compared to pullulan blended with stabilizers (T2 and T3). Uncoated (C) group showed moderate signs of ripening and decay by 4th day. Half of the control have shown wrinkles, skin loss and dark spots (bacterial contamination) and tomatoes became very soft with shape alteration. By 14th day, the black-brown spots spread to larger portions and found with white patches (fungal infection) on sunken areas.

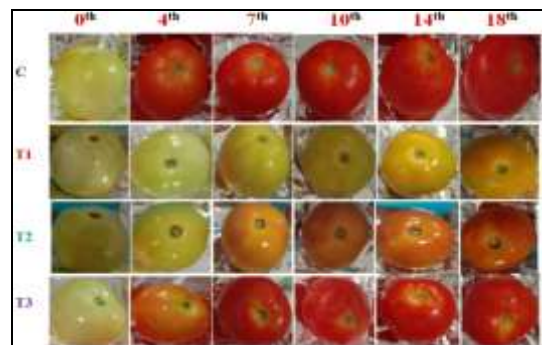


Fig 1: Effect of edible coatings in the physical appearance of Tomato fruits uncoated (C) and coated with T1: 10% pullulan, T2: 10% pullulan + 5% sorbitol, and T3: 10% pullulan + 5% PEG upon storage at 25 ± 1 °C and 70% RH up to 18 days.

Tomatoes coated with T1 formulation exhibited very slow signs of ripening (upto 10th day) and shown light reddish color in peel with delayed ripening (by the end of 18th day). Similar results were also seen in T2 formulated tomatoes with no sign of complete ripening. Whereas tomatoes coated with T3 (pullulan and PEG) coated tomato fruits exhibited few signs of damage by 10th day and yellow-whitish patches were observed on wrinkled regions. T3 coated have shown similar (to uncoated) stages of ripening by maintain glossiness on the surface for ready consumption by end user. All tomato fruits mildly shrank during 18-day storage period and uncoated fruits shrank more rapidly than coated ones. The similar peel color appearance findings were also reported by Ruelas-Chacon ^[8] in Roma tomatoes and Vignesh and Bindu ^[19] in Indian tomatoes.

3.2 Physiological Loss in Weight % (PWL%)

Tomato fruits in all the four treatment groups have started showing loss in weight from the 4th day and continued weight loss during the entire evaluation period. Physiological loss in weight (in %) was less apparent in coated fruits than in uncoated (C) tomatoes (Fig. 2). All the groups have shown steady PWL % increase over all the evaluation days. Low values of physiological weight loss % (PWL%) in coated fruits can be inferred that pullulan coatings formed semipermeable layer, which only allow movement of certain small molecules and acted as barrier to reduce respiration and transpiration on fruit surface ^[29,8]. Our results are also in good agreement with observations of made by El-Ghaouth ^[14] with chitosan coatings, Ali ^[30] with gum Arabic coatings, Cipolatti ^[29] with protein-phenolic based coatings, Das ^[13] with rice starch coatings, Ahmed ^[31] with delactosed whey coatings, Ruelas-Chacon ^[8] with guar gum.

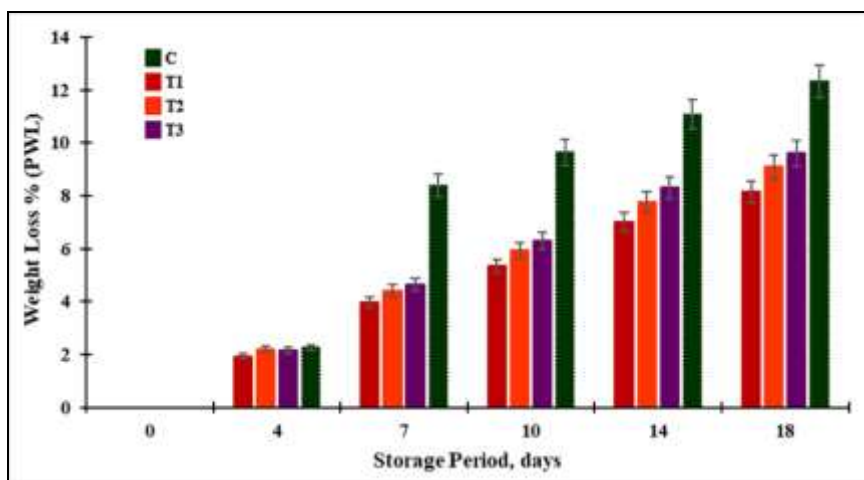


Fig 2: Effect of edible coatings on weight loss % of Tomato fruits uncoated (C) and coated with T1: 10% pullulan, T2: 10% pullulan + 5% sorbitol, and T3: 10% pullulan + 5% PEG upon storage at 25 ± 1 °C and 70% RH up to 18 days.

3.3 Color characteristics

The changes in CIE LAB parameters of coated and uncoated tomatoes during the storage time at ambient conditions (at 25 ± 1 °C and 70% RH) were tabulated in Table 1. It was observed that a significant difference in L values when compared to coated and uncoated fruits. All coated (T1, T2 and T3) tomato groups presented a higher visual brightness compared to uncoated (C) samples and significant differences in L values were observed between all the fruits during storage period. The parameter, a* (red color) was quite different (p < 0.05) among treatments for 18 days

testing and the a* values for uncoated tomatoes were higher than for all coated groups. The other parameter, b*, also displayed similar trend in the values. These values attributed the fact that modified atmosphere on the fruit coated by pullulan formulations which influenced respiration rate prolongs the color development (in ripening) between coated ones more than on the storage time itself. The higher chroma values were in uncoated (C) samples indicated that higher saturation related to the redness stage of ripening was appeared in comparison to coated fruits.

Table 1: Changes in color characteristics of uncoated and coated tomato samples at different storage time intervals.

Color characteristics	Storage Time, days	C	T1	T2	T3
L	0	64.94 ± 0.02 [§]	38.89 ± 0.11 [§]	64.93 ± 0.04 [§]	51.32 ± 0.07 [§]
	4	31.91 ± 0.06	59.07 ± 0.12	44.43 ± 0.32	65.43 ± 0.23
	7	33.76 ± 0.34	49.33 ± 0.23	30.03 ± 0.23	56.75 ± 0.26
	10	30.05 ± 0.23	30.19 ± 0.27	35.28 ± 0.43	44.15 ± 0.32
	14	61.27 ± 0.07	48.46 ± 0.55	37.88 ± 0.23	61.27 ± 0.41
	18	33.03 ± 0.24	36.48 ± 0.24	32.88 ± 0.11	44.83 ± 0.15
a*	0	-7.39 ± 0.04	-2.69 ± 0.05	-5.14 ± 0.02	-5.31 ± 0.07
	4	45.80 ± 0.23	-5.89 ± 0.03	32.02 ± 0.73	-12.53 ± 0.12
	7	53.30 ± 0.07	22.93 ± 0.11	46.73 ± 0.23	-3.22 ± 0.01
	10	48.30 ± 0.26	27.68 ± 0.23	52.35 ± 0.07	0.27 ± 0.01
	14	4.15 ± 0.12	31.74 ± 0.02	52.93 ± 0.13	4.15 ± 0.03
	18	49.60 ± 0.32	36.88 ± 0.92	51.07 ± 0.42	19.32 ± 0.11
b*	0	45.70 ± 0.11	37.09 ± 0.78	38.42 ± 0.23	34.44 ± 0.07

	4	40.30 ± 0.23	53.59 ± 0.23	48.07 ± 0.38	44.90 ± 0.53
	7	10.10 ± 0.74	49.18 ± 0.65	35.85 ± 0.02	52.93 ± 0.32
	10	36.50 ± 0.27	32.32 ± 0.07	40.26 ± 0.72	44.15 ± 0.04
	14	63.70 ± 0.37	49.84 ± 0.72	46.34 ± 0.35	63.68 ± 0.32
	18	38.20 ± 0.38	44.12 ± 0.56	40.51 ± 0.11	51.13 ± 0.42
<i>Hue Angle</i>	0	-80.81 ± 0.28	-85.85 ± 0.28	-82.38 ± 0.29	-81.24 ± 0.43
	4	41.34 ± 0.29	-83.73 ± 0.29	56.33 ± 0.23	-74.41 ± 0.02
	7	10.72 ± 0.03	65.00 ± 0.04	37.49 ± 0.68	-86.52 ± 0.73
	10	37.12 ± 0.23	49.42 ± 0.28	37.56 ± 0.32	89.65 ± 0.83
	14	86.27 ± 0.13	57.51 ± 0.72	41.20 ± 0.02	86.27 ± 0.39
<i>Saturation (or) Chroma</i>	0	46.26 ± 0.07	37.19 ± 0.23	38.76 ± 0.54	34.85 ± 0.97
	4	60.96 ± 0.47	53.91 ± 0.04	57.76 ± 0.23	46.62 ± 0.23
	7	54.20 ± 0.37	54.26 ± 0.12	58.90 ± 0.07	53.03 ± 0.25
	10	60.53 ± 0.11	42.55 ± 0.92	66.04 ± 0.02	44.15 ± 0.93
	14	63.82 ± 0.42	59.09 ± 0.38	70.35 ± 0.34	63.82 ± 0.83
<i>ΔE</i>	18	62.59 ± 0.27	57.50 ± 0.34	65.19 ± 0.84	54.66 ± 0.11
	--	65.74 ± 0.43	40.26 ± 0.78	64.74 ± 0.38	30.45 ± 0.35

[§]mean ± standard deviation of three experiments ($p < 0.05$);

C- Uncoated; T1- 10% pullulan; T2- 10% pullulan + 5% sorbitol; T3- 10% pullulan + 5% PEG

Color is an important quality and acceptability criterion by the tomato consumers [32]. Our study reports that there was a decrease in color index L happened when the red pigments begin to be synthesized with the index a^* changing from negative (green) to positive (red) [33, 15]. The value ΔE depends on the values a^* and b^* and it indicated that the color intensity (saturation) of the sample [15]. In this study, the pullulan coatings delayed a change in color of coated tomatoes (T1, T2 and T3) and similar results were reported by many researchers [30, 13, 17, 18]. The a^* values have shown change color from green through red (negative to positive), sharply indicated that the pullulan coatings had reduced synthesis of carotenoid compounds in tomatoes which retarded color change during storage time [13, 8, 17].

The color characteristic, *Saturation* or *Chroma* (depends on a^* and b^*) values were also estimated and observed high significant values in uncoated compared to coated tomato fruits, during storage time. These higher saturation values indicated to the redness stage of ripening. The total color difference (ΔE) values calculated from a^* and b^* , between 18th and 0th days were also higher for uncoated fruits (65.74 ± 0.43) than coated ones. During ripening, the green chlorophyll pigment degrades, and carotenoids were synthesized from colorless phytoene to pale yellow carotene, red lycopene, orange β -carotene, xanthophylls and yellow hydroxylated carotenoids, were the reasons for variations in the values of color characteristics.

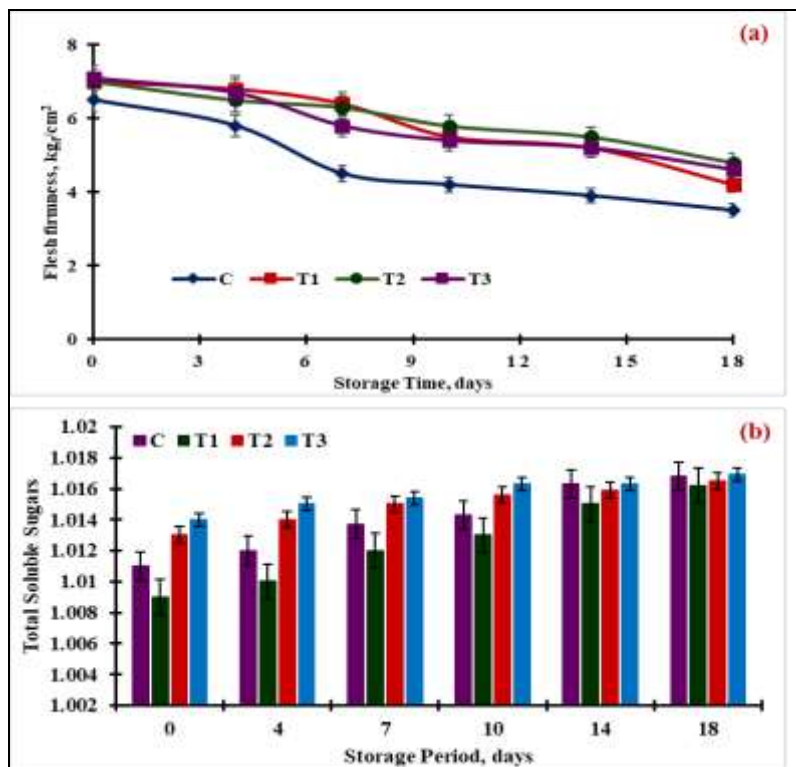


Fig 3: Effect of pullulan coatings on (a) flesh firmness (in kg/cm^2) and (b) Total soluble sugars of tomato fruits uncoated (C) and coated with T1: 10% pullulan, T2: 10% pullulan + 5% sorbitol, and T3: 10% pullulan + 5% PEG upon storage at 25 ± 1 °C and 70% RH up to 18 days.

3.4 Flesh Firmness

Tomato's flesh firmness (in kg/cm^2) of decreased continuously with storage time in both coated and uncoated fruits and firmness of uncoated (C) tomatoes decreased more rapidly than coated (T1, T2 and T3) fruits. There was a substantial reduction in the firmness in uncoated compared to coated ones (Fig. 3 (a)). Softening of fruit's flesh was due to deterioration in the cell wall composition and it is a biochemical process involves pectin and starch hydrolysis by enzymes. Further, increased CO_2 levels propitiated due to coating on the fruit, reduced the enzymes activity that allows maintenance of flesh firmness during storage time. Fruit's flesh firmness is an important measure for maturation degree determination and greater maturity means less firmness and less resistance when force is applied [34]. Further, the decrease in firmness of uncoated when compared to coated tomatoes has also been observed in several studies [30, 15, 34, 17].

3.5 Total Soluble Sugars (TSS)

Figure 3 (b) depicts the observations of both uncoated and coated tomato fruit's juice total soluble sugars (TSS) have shown that the increased TSS content (in °Brix) up to 18th day of storage time at ambient conditions. On the 18th day, TSS value of T1 coated fruit was significantly lower than C, T2, and T3 tomatoes. Decreased respiration rates also slowed down the metabolite synthesis and use, which reduced TSS values in T1 coated fruits [35]. Whereas an increased TSS (°Brix) values were due to insoluble polysaccharide hydrolysis into simple sugars and when conversion is lower than utilization, a reduction in TSS was observed in T1 [18]. Malic acid and citric acid were found to be major organic acids in tomato fruits and the interaction of TSS and acid contents affects the sweetness, sourness and flavor intensities in tomatoes [36]. Stabilizers such as sorbitol and PEG were also effectively retarded the metabolic processes that accounted for change in TA%.

3.6 Titratable Acidity % (TA%)

In the present study, the trend of titratable acidity % (TA%) values over storage time were shown in Fig. 4(a). The TA% values of uncoated (C) tomatoes were decreased with storage period because the citric acid content increases with maturity and ripening stage. After 18 days of storage, the acidity % content was also found maximum (0.3%) in T1 followed by T2 (0.273%) and was minimum (0.11%) in uncoated (C). Tomato's acidity was considered to be important in taste aspect of fruit and edible coatings affect internal quality parameters which depends on coating type, fruit cultivar, and storage conditions. The low ($p < 0.05$) level of TA% in control fruit compared to coated fruits suggest that the pullulan-based coating formulations delayed the ripening process because of transparent coating around the fruit. As organic acids like malic or citric acid act as primary substrates for respiration, resulted lower acidity % in highly ripening fruits [37, 18]. Similar observations were also reported by using different coating materials such as Guar gum [8], Cassava starch [17], Tragacanth+stearic acid+paraffin wax + CaCl_2 [18], seaweed [20].

3.7 pH of juice

As TA% decreases with storage time, the tomato fruit's juice pH increases, and it was observed that the pH variation trend was reverse to that of variation in TA% (Fig. 4(b)). By

the end of 18th day, T1 coated tomatoes have shown high juice pH due to delay in the ripening of fruits. The pullulan-based coatings and addition of sorbitol (T2) and PEG (T3) caused reduction in pH over the storage period.

4. Conclusions

The present study highlights that pullulan-based coatings delayed the ripening activity of fresh tomato fruits upon storage at ambient conditions, by inhibiting the respiration rate because of thin film coating on the fruit. These coatings with stabilizers not only maintained flesh firmness, but also increased postharvest quality of tomatoes. Pullulan coatings are edible and biodegradable, easily coated and cheap in price that prolong shelf-life of fresh tomato produce. This study may be extended to improve water vapor barrier properties by blending lipid components and to study the wrap-ups of edible films made from pullulan for post harvesting tomatoes under cold storage conditions.

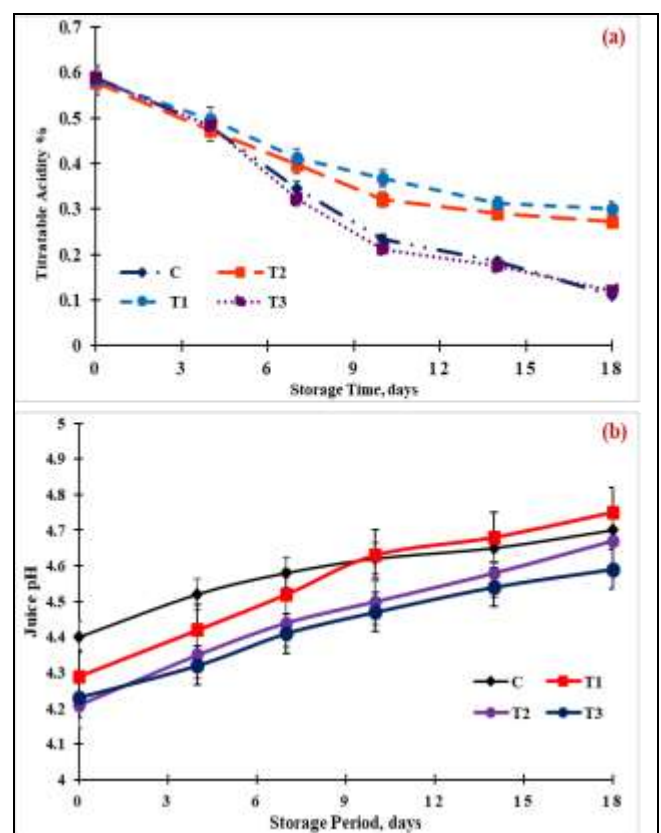


Fig 4: Effect of pullulan coatings on (a) titratable acidity % and (b) juice pH of tomato fruits uncoated (C) and coated with T1: 10% pullulan, T2: 10% pullulan + 5% sorbitol, and T3: 10% pullulan + 5% PEG upon storage at 25 ± 1 °C and 70% RH up to 18 days.

5. Acknowledgments

The author is thankful to SYST-SEED, Department of Science & Technology, Government of India for providing financial support under the Research Grant No.: SP/YO/026/2016(G)

6. References

1. Meheriuk M, Lau OL. Effect of two polymeric coatings on fruit quality of «Bartlett» and «d'Anjou» pears. *Journal of the American Society for Horticultural Science*. 1988; 113(2):222-6.
2. Kader AA, Zagory D, Kerbel EL, Wang CY. Modified atmosphere packaging of fruits and vegetables. *Critical*

- Reviews in Food Science & Nutrition. 1989; 28(1):1-30.
3. Thirupathi V, Sasikala S, Kennedy JZ. Preservation of fruits and vegetables by wax coating. *Sci. Tech. Entrepreneur*, 2006; 22:19-24.
 4. Srilakshmi, B. Food Science, seventh ed., New Age International Publisher, New Delhi, 2015.
 5. Zanetti M, Carniel TK, Dalcanton F, dos Anjos RS, Riella HG, de Araujo PH, de Oliveira D, Fiori MA. Use of encapsulated natural compounds as antimicrobial additives in food packaging: A brief review. *Trends in Food Science & Technology*, 2018; 81:51-60.
 6. Gopalakrishnan, T.R. Vegetable crops. Horticulture Science Series. New India Publishing Agency, New Delhi, India, 2007, 87-97.
 7. Ameyapoh Y, de Souza C, Traore AS. Hygienic quality of traditional processing and stability of tomato (*Lycopersicon esculentum*) puree in Togo. *Bioresource technology*. 2008; 99(13):5798-803.
 8. Ruelas-Chacon X, Contreras-Esquivel JC, Montañez J, Aguilera-Carbo AF, Reyes-Vega ML, Peralta-Rodriguez RD, *et al.* Guar gum as an edible coating for enhancing shelf-life and improving postharvest quality of roma tomato (*Solanum lycopersicum L.*). *Journal of Food Quality*, 2017, 2017.
 9. Zapata PJ, Guillén F, Martínez-Romero D, Castillo S, Valero D, Serrano M, *et al.* Use of alginate or zein as edible coatings to delay postharvest ripening process and to maintain tomato (*Solanum lycopersicon Mill*) quality. *Journal of the Science of Food and Agriculture*. 2008; 88(7):1287-93.
 10. Tharanathan RN. Biodegradable films and composite coatings: past, present and future. *Trends in food science & technology*. 2003; 14(3):71-8.
 11. Valverde JM, Valero D, Martínez-Romero D, Guillén F, Castillo S, Serrano M. Novel edible coating based on *Aloe vera* gel to maintain table grape quality and safety. *Journal of agricultural and food chemistry*. 2005; 53(20):7807-13.
 12. Lin D, Zhao Y. Innovations in the development and application of edible coatings for fresh and minimally processed fruits and vegetables. *Comprehensive reviews in food science and food safety*. 2007; 6(3):60-75.
 13. Das DK, Dutta H, Mahanta CL. 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 Science and Technology*. 2013; 50(1):272-8.
 14. El Ghaouth A, Ponnampalam R, Castaigne F, Arul J. Chitosan coating to extend the storage life of tomatoes. *HortScience*. 1992; 27(9):1016-8.
 15. Athmaselvi KA, Sumitha P, Revathy B. Development of *Aloe vera* based edible coating for tomato. *International Agrophysics*, 2013, 27(4).
 16. Begum N, Paul SK, Prasanna Kumar GV, Sahu JK, Husain SA. Development of tulsi impregnated starch-based edible coating to extend the shelf-life of tomatoes. *The Pharma Innovation Journal*. 2017; 6(9):249-55.
 17. Adjouman YD, Nindjin C, Kouassi KN, Tetchi FA, N'Guessan GA, Sindic M, *et al.* Effect of Edible Coating based on improved Cassava Starch on Post-Harvest quality of fresh Tomatoes (*solanum lycopersicum l.*). *International Journal of Nutritional Science and Food Technology*. 2018; 4(1):1-0.
 18. Ravi K, Paul PK, Sarad, G. Effect of edible coatings for enhancing shelf-life and quality in tomato (*Solanum lycopersicum L.*) fruits at ambient condition. *International Journal of Chemical Studies*. 2019; 7(3):3666-3671.
 19. Vignesh RM, Nair BR. Improvement of shelf life quality of tomatoes using a novel edible coating formulation. *Plant Science Today*. 2019; 6(2):84-90.
 20. Ramani S, Aswini M. Effect of seaweed coating on quality characteristics and shelf life of tomato (*Lycopersicon esculentum mill*). *Food Science and Human Wellness*, 2020.
 21. Chlebowska-Śmigiel A, Gniewosz M, Świńczak E. An attempt to apply a pullulan and pullulan-protein coatings to prolong apples shelf-life stability. *Acta Scientiarum Polonorum Technologia Alimentaria*. 2007; 6(1):49-56.
 22. Viškelis P, Rubinskienė M, Sasnauskas A, Bobinas Č, Kviklienė N. Changes in apple fruit quality during a modified atmosphere storage. *Journal of Fruit and Ornamental Plant Research*. 2011; 19(1):155-65.
 23. Gniewosz M, Kraśniewska K, Woreta M, Kosakowska O. Antimicrobial activity of a pullulan-caraway essential oil coating on reduction of food microorganisms and quality in fresh baby carrot. *Journal of food science*, 2013; 78(8):M1242-8.
 24. Kraśniewska K, Gniewosz M, Synowiec A, Przybył JL, Bączek K, Węglarz Z, *et al.* The use of pullulan coating enriched with plant extracts from *Satureja hortensis L.* to maintain pepper and apple quality and safety. *Postharvest Biology and Technology*. 2014; 90:63-72.
 25. Kraśniewska K, Gniewosz M, Kosakowska O, Cis A. Preservation of brussels sprouts by pullulan coating containing oregano essential oil. *Journal of food protection*. 2016; 79(3):493-500.
 26. Ganduri VR. Evaluation of pullulan-based edible active coating methods on Rastali and Chakkarakeli bananas and their shelf-life extension parameters studies. *Journal of Food Processing and Preservation*. 2020; 44(4):e14378.
 27. Korley Kortei N, Tawia Odamtten G, Obodai M, Appiah V, Toah Akonor P. Determination of color parameters of gamma irradiated fresh and dried mushrooms during storage. *Hrvatski časopis za prehrambenu tehnologiju, biotehnologiju i nutricionizam*. 2015; 10(1-2):66-71.
 28. Omenetto F, Kaplan D, Marelli B, Brenckle M. US. Patent No. US 10271561, 2019.
 29. Cipelatti EP, Kupski L, Rocha MD, Oliveira MD, Buffon JG, Furlong EB, *et al.* Application of protein-phenolic based coating on tomatoes (*Lycopersicum esculentum*). *Food Science and Technology*. 2012; 32(3):594-8.
 30. Ali A, Maqbool M, Ramachandran S, Alderson PG. Gum arabic as a novel edible coating for enhancing shelf-life and improving postharvest quality of tomato (*Solanum lycopersicum L.*) fruit. *Postharvest biology and technology*. 2010; 58(1):42-7.
 31. Ahmed L, Martin-Diana AB, Rico D, Barry-Ryan C. Effect of delactosed whey permeate treatment on physico-chemical, sensorial, nutritional and microbial properties of whole tomatoes during postharvest

- storage. LWT-Food Science and Technology. 2013; 51(1):367-74.
32. Aked J. Fruits and vegetables. In: Kilcast, D., Subramaniam, P. (Eds.), The Stability and Shelf-life of Food. Woodhead Publish. Ltd, 2000, 249-278.
 33. López Camelo AF, Gómez PA. Comparison of color indexes for tomato ripening. Horticultura Brasileira. 2004; 22(3):534-7.
 34. Solís Jimenez DA, Pineda Salazar LN, Mosquera Sánchez SA, Hoyos Concha JL, Villada Castillo HS. Coating effect of Modified cassava starch in Hass avocado. Producción+ Limpia. 2015; 10(2):31-7.
 35. Yaman Ö, Bayındırlı L. Effects of an edible coating and cold storage on shelf-life and quality of cherries. LWT-Food science and Technology, 2002; 35(2):146-50.
 36. Helyes LD, Dimény J, Pék Z, Lugasi A. Effect of maturity stage on content, color and quality of tomato (*Lycopersicon lycopersicum* (L.) Karsten) fruit. International Journal of Horticultural Science. 2006; 12(1):41-4.
 37. El-Anany AM, Hassan GF, Ali FR. Effects of edible coatings on the shelf-life and quality of Anna apple (*Malus domestica* Borkh) during cold storage. Journal of Food Technology. 2009; 7(1):5-11.