Shelf Life Extension of Tomatoes (*Solanum lycopersicum L.*) Using Coating of Carnauba Wax

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Abstract-During ripening, tomato undergoes two most visible changes (i) color change due to chlorophyll degradation and synthesis of carotenoids (ii) alter in firmness due to action of enzymes like pectin methyl esterase. Postharvest constraints such as deficient preservation and handle techniques, coupled with short shelf life limit their long duration storage and transportation. In order to extend the shelf life of tomatoes, the parameters such as moisture loss, ripening, temperature and relative humidity are to be manipulated. Values of color parameters, L*, a*, b*, C* and h* were 65.32, 15.62, 48.98, 50.75 and 72.18 respectively. Firmness (N), pH, total soluble solids (◦ Brix), titratable acidity (% citric acid) were 27.17, 4.17, 3.75 and 0.738 respectively. The optimum composition of coating solution with 1:9ratios of carnauba wax and oleic acid gave stable emulsion with a thickness of 0.0411 ± 0.003 mm over the surface of tomatoes. Experimentation revealed that by dipping tomatoes on *Carnauba Wax* emulsion, the shelf life of the tomatoes were extended from 21days(untreated) up to 49 days at 25 ◦C and 80 % RH under similar storage condition.

Index Terms: ***Tomato, shelf life, postharvest, preservation, wax, Carnauba*.**

PRACTICAL APPLICATION

Coating of tomatoes using Carnauba Wax is an effective means of preserving and lengthening the shelf life of soft textured tomatoes. As tomatoes are seasonal fruits, so availability of tomatoes are very essential in most of the dishes, cuisines and pharmaceutical research of Indian and Asian mainland, therefore there is a need to inhibit the respiration process of tomatoes. Concerning the postharvest damages, the techniques adopted in preparing the emulsion will also repel the insects to attack and spoil the tomatoes during storage. Neem (*Azadirachta indica)* is taken as an herbal insect repellent and can be nutritionally ingested. In context of Indian farmers, a cost effective study was taken in relation to the shelf life and was found that the % increase in price of tomatoes treated-vs.- untreated is Rs.16.75/kg and the % increase in shelf life of tomatoes treated-vs.-untreated is 133.33%.

INTRODUCTION

Tomato (*Solanum lycopersicum L.*) is recognized globally as one of the most important commercial and dietary crop belonging to the family solanaceae (Oyemaechi et al., 2014). With an annual production of 18.7 MT during the year 2014, India ranks 2nd after China contributing about around 2.46 % in the total world production (170 MT) of tomato (FAOSTAT, 2014). Tomatoes play a vital role in reducing certain ailments (Nguyen and Schwartz, 1999) like prostate cancer, cardiovascular disease and diabetes (Oyemaechi et al., 2014; Amusa et al., 2007). During ripening, a tomato undergoes physical and biochemical changes. The two most visible changes are: (i) color change due to chlorophyll degradation and synthesis of carotenoids and (ii) change in texture (firmness) due to the action ofenzymes like pectin methyl esterase (PME) which solubilizes that pectin (that providesstrength) present in the cell wall of the plant cells.

Certain postharvest constraints such as inefficient postharvest preservation and handling techniques (Shanfeng, 2001; Lixin andZhiwei, 2004; Raji and Oriola, 2007; Li et al., 2010) coupled with short shelf life due to respiration, moisture loss, ripening and susceptibility to disease limit their long duration storage and transportation causing enormous losses to the nation. The existing post harvest loss of fruits and vegetables could be considerably reduced by adopting improved coating (Manolopoulou and Varzakas, 2015), handling and efficient system of transport. Edible coatings are composed of hydrocolloids [polysaccharides (Nussinovitch, 1998), or proteins (Gennadios and weller, 1990; Mchugh and Krochta, 1994; Torres et al., 1997; Cuq et al., 1998)], hydrophobic compounds [lipids (Baldwin et al., 1997; Shellhammer and Krochta, 1997) or waxes (Singh *et al*., 2016)] or a combination of both (composite coating) that may enhance its properties for optimal handling. Weekly foliar sprays of neem oil and fish emulsion reduced disease severity on the foliage of inoculated field grown tomato and pepper plants in both years of a two-year study. Also results suggest that disease-management programs for bacterial spot may be enhanced by including foliar sprays of these products (Abbasi et al., 2003). A commercial carnauba-shellac coating is reported to delay ripening in pears due to evolution of higher CO_2 concentrations than non waxed fruit thus resulting in retention of firmness and delayed color changes. So based on this, the following objectives of the study is to formulate stable composition of carnauba wax based emulsion, and to enhance shelf life of tomatoes with the help of edible coating of carnauba wax.

The research study was done in the food processing lab of IIT kharagpur. Tomatoes were procured from local market of IIT Kharagpur and PUSA RUBY variety of tomato was recognized by the color, shape and size for the experiment. Representative samples were taken from the lot and tested for color, firmness, TSS, pH and acidity, to ensure that the tomato fruits had attained maturity.

MATERIALS AND METHODS

Coating materials, chemicals and reagents

The materials chosen for edible coating were carnauba wax and the other chemicals and reagents are oleic acid, sodium hydroxide, methanol, sulphuric acid, sodium phosphate and ammonium molybdate etc.

Pre-treatment of tomatoes

Tomatos were washed with potable water and were subjected to a 3 min dip 100 mg/L sodium hypochlorite solution. After each dip treatment tomatoes were blow-dried under the fan for about 30 min.

The tomatoes with physico-chemical parameters like moisture content (MC, W_b) 93.5%, total soluble solids (TSS) 3.75 °Brix, titratable acidity 0.738%, color (L*, a*, b*) 65.32, 15.62, 48.98 and pH 4.17 were used in the experiments to ensure the same maturity levels.

Preparation of emulsion

The coating solution was prepared by melting carnauba wax (10.0 g) in water bath with continuous stirring on a magnetic stirrer at 90-95 °C. Oleic acid (90.0 g) was added as emulsifier into the melted carnauba wax with continuous stirring at temperature (90-95 °C). After adding oleic acid into the melted carnauba wax, 100 ml hot coconut oil was added to the whole mix to make up the volume. Finally, 4-5 drops of neem extract, which was prepared from the leaves of neem tree was added. The purpose of adding neem extract to the whole mixture was to prevent the tomatoes from the microbial attack.

Stability of emulsion

The stability of the wax emulsion was determined by visual appearance of the emulsion based on hardness, melt speed, stickiness and slipperiness of the emulsion.

Application of coating

Randomly chosen, washed, pretreated and dried (drying of external moisture only) tomatoes were dipped into the wax emulsion for different treatment time periods viz. 30, 90 and 150 sec.

Optimization of coating time

Various parameters such as coating thickness, moisture loss and other storage properties were studied to optimize the dipping time of tomatoes into the coating.

Measurement of coating thickness

The peel of tomatoes was dried and thickness of the tomato skin was measured at random positions using micrometer (Athmaselvi et al., 2013). The dried tomato skin was dipped into the wax emulsion for different time durations and allowed to dry. After this, the thickness of the skin was measured again and the difference in thickness was divided by two, as in this case the peel was getting coated from two sides unlike the whole tomatoes that will be coated only on the surface.

Assessment of quality parameters of tomatoes during storage

The different quality parameters such as physiological weight loss (PLw), color (L*, a*, b*), firmness, total soluble solids (TSS), pH, titratable acidity and total antioxidant activity (TAA) were determined during storage. Tomatoes were stored at 25 °C and 80% RH and also subjected to quality analysis at 7 days interval. Sensory attributes such as color, texture, taste, flavor and gloss were also evaluated after the storage of tomatoes.

Physiological weight loss

The physiological weight loss (PLw) in weight (Nawab et al., 2017) all coated and uncoated fruits were weighed at the beginning of the experiment and after 7 days up to 49 days. The difference the initial and final weights were calculated as the percentage weight loss as given by the following equation.

$$PLw = \frac{Wi - Wf}{Wi} \times 100$$

Where, Wi is the initial weight of tomatoes before coating.

Wf is the final weight of tomatoes

PLw is the physiological weight loss or moisture loss of tomatoes.

Texture analysis

A penetration test was performed on the whole tomatoes using a TA-XT2i texture analyzer using method described by Wu and Abbott (2002).

The principle of operation of the TA-XT2i texture analyzer is to subject a sample to control forces in compression using a probe or in tension using grips.

Samples were penetrated to a depth of 20 mm. The speed of probe was 1 mm s^{-1} during the pre-test and 1.5 mm s^{-1} during penetration. From the force vs. time curves, firmness was defined as the maximum force. The analyzer was linked with the computer aided software called Texture Pro CT software.

Color

Skin color values of stored tomato samples were measured using a Konica Minolta colorimeter. In Konica Minolta colorimeter, value quantifies the lightness and range from black (L*=0) to white (L*=100), a* value corresponds to the degree of redness ranging from negative value for green and positive value for red, whereas, the b* value represents yellowness ranging from negative value for blue and positive value for yellow on the chromaticity coordinates.

$$Hue\ angle\ (h*) = \tan^{-1}\frac{b*}{a*}$$

$$Chroma\ (C*) = \sqrt{\Delta a^{*2} + \Delta b^{*2}}$$

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

The hue angle and chroma values were calculated using equations given below.

Total soluble solids

The total soluble solid (TSS) in ° Brix of the product are often correlated to the degree of maturity and ripeness. The TSS of the tomato juice was determined using a handheld refracto-meter having range 0-32 %.

pH

The pH of the sample was determined using a pH meter according to the method described inRanganna (2007).

Titratable acidity

The titratable acidity of tomatoes juice, which was extracted from pulp and filtered through muslin cloth was determined (Ranganna (2007). The acidity of the tomato juice was expressed in % citric acid because this is the major acid present in the tomatoes.

Theequivalent of citric acid is 64. The titratable acidity (mg/100ml of juice) was calculated using the equation given as follows.

$$Acidity\ (\%\ citric\ acid) = [(Equivalent\ weight\ of\ acid \times Normality\ of\ NaOH \times Tirate\ value) / (Weight\ of\ sample \times 1000)]$$

Total antioxidant capacity

Total antioxidant capacity (TAC) was measured by α-Tocopherol Equivalent using extinction coefficient of $4 \times 10^3\ M^{-1}\ cm^{-1}$ as described by Pineda (1998) and was calculated using equation

$$C = \frac{A}{\varepsilon l}$$

Where, C corresponds to total antioxidant capacity, A is the absorbance at 695 nm, l is thepath length of 1 cm and **ε** is the extinction coefficient.

Sensory evaluation

The sensory evaluation of tomato samples for different period of dipping time viz. 30, 90 and150 sec was done by 9-point hedonic scale method described by Silva et al. (2013).

The score was evaluated on 9-point hedonic scale where, 9 represented an excellent quality,6-8 good quality, 3-5 fair quality and 0-2 represented dislike extremely.

Statistical analysis

Each experiment was setup with triplicates and the data were represented as mean ± standarderror. Data was analyzed by ANOVA ($p < 0.05$) followed by t-test using Microsoft Excel.

RESULTS AND DISCUSSION

Optimization of Stable coating emulsion

The stability of the wax emulsion was determined by visual appearance and 1:9 (Carnauba wax: Oleic Acid) was the best option for preparation of wax emulsion based on hardness, melt speed, stickiness and slipperiness of the emulsion as the similar result was reported by Singh et al., 2016. Table 1 represents the parameters for finding out the stable emulsion.

Ratio	Hardness	Melt speed	Stickiness	Slipperiness
1:1	Very	Slow	Yes	Terrible
1:2	Very	Slow	Yes	Terrible
1:3	Very	Slow	Yes	Poor
1:4	Very	Slow	No	Good
1:5	Yes	Moderate	No	Good
1:6	Yes	Moderate	No	Good
1:7	Yes	Moderate	No	Good
1:8	No	Fast	No	Great
1:9	No	Fast	No	Great
1:10	No	Fast	No	Great

Effect of dipping time on Coating thickness

An increase in coating thickness was observed with increase in dipping time of tomato peel. The coating thickness was found to be 0.0146 ± 0.004, .0317 ± 0.008 and .0411 ± 0.003 mm after 30, 90 and 150 sec of coating duration respectively.

Analysis of storage properties

This section includes the result of changes in quality parameters such as physiological weightloss (PLw), color (L*, a*, b*), firmness, total soluble solids (TSS), pH, titratable acidity and total antioxidant activity (TAA). The results of quality changes were obtained after 7 days of interval and discussed below.

Effect of coating on the physiological weight loss of tomato:

The physiological weight loss (PLw) of the coated tomatoes varied from 1.15 % to 1.7the coated tomatoes with different periods of dipping time at the end of the storage period of 49 days, whereas, the control showed 10.27 % weight loss after 21 days of storage.

Among the three different periods of dipping time, 30 sec had the maximum physiological weight loss of 1.79 % and 150 sec had the minimum physiological weight loss of 1.15 %. This could be happened due to presence of coconut oil in the wax emulsion and also the thickness of the coating which might be due to decrease in the transmission rate of water and vapour.

Effect on the firmness of tomato

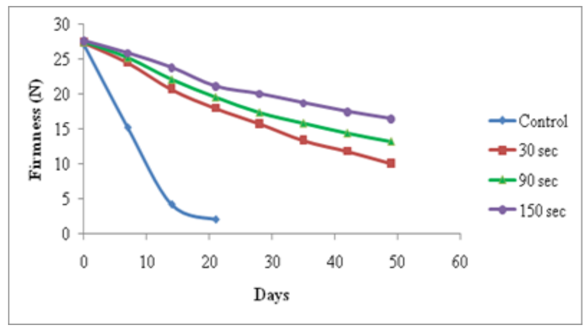

Fig: 1. Effect of the coating on the firmness of tomatoes during the storage period.

Firmness of coated tomatoes for different period of dipping time gradually decreased. Among the three different periods of dipping time, 30 sec was found to be the lowest firmness of 10.12 N and 150 sec was found to be the highest firmness of 16.49 N at the end of the storageperiod of 49 days, whereas, the control tomatoes showed firmness of 2.14 N at the end of storage of 21 days. Effect of the coating on the firmness of tomatoes during the storage period is depicted in the above fig.1.

Effect on total soluble solids of tomato

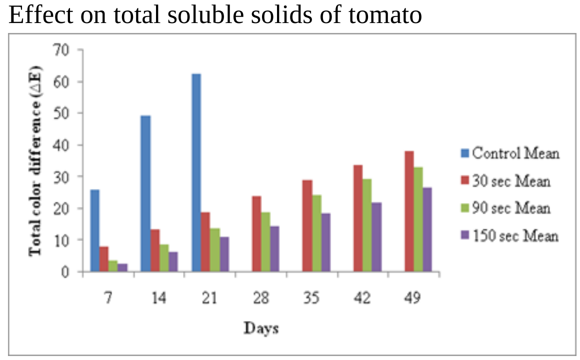

Fig.2. Effect of coating time on the TSS of tomatoes during the storage period

Total soluble solids (TSS) of the coated tomatoes varied from initial 3.77 ◦ Brix to as high as 4.63 ◦ Brix over the duration of storage period with change in dipping time. The TSS of control tomatoes initially increased after 7 days of storage and suddenly decreased after 21 days of storage. Effect of coating time on the TSS of tomatoes during the storage period is shown in fig. 2.

Effect on the pH of tomato

The pH of tomatoes did not vary significantly ($p < 0.05$) in the coated tomatoes for different periods of dipping time over the storage period of 49 days (table 2).

Table 2: Effect of coating on the pH of tomatoes during the storage period

Days interval	Treatment			
	Control	30 sec	90 sec	150 sec
0	4.17 ± 0.04	4.15 ± 0.04	4.18 ± 0.03	4.19 ± 0.03
7	4.28 ± 0.03	4.21 ± 0.04	4.29 ± 0.04	4.22 ± 0.03
14	4.68 ± 0.02	4.37 ± 0.05	4.32 ± 0.03	4.25 ± 0.04
21	4.08 ± 0.02	4.49 ± 0.04	4.47 ± 0.03	4.41 ± 0.03
28	-	4.54 ± 0.05	4.51 ± 0.02	4.46 ± 0.02
35	-	4.61 ± 0.03	4.59 ± 0.02	4.51 ± 0.02
42	-	4.41 ± 0.03	4.36 ± 0.03	4.32 ± 0.03
49	-	4.34 ± 0.02	4.31 ± 0.03	4.26 ± 0.02

Effect on the color of tomato

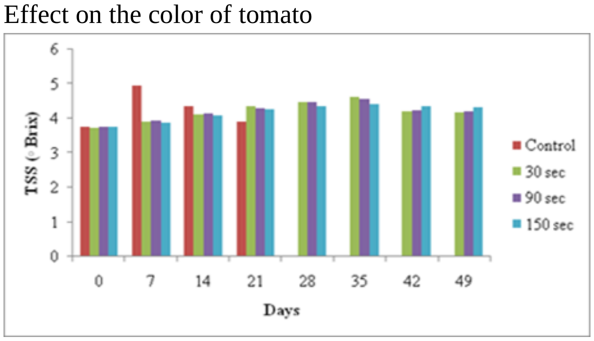

Fig. 3. Effect of coating on the color (ΔE) of tomatoes during the storage.

Tomatoes coated with different periods of dipping time showed delayed ripening till the end of the storage. When red color pigments started to synthesize, there was a decline in L* (lightness from white to black) value. At the end of storage periods the L* values for 30 sec, 90 sec and 150 sec were 43.57, 46.36 and 49.26 respectively, although, the control tomatoes had L* value of 26.69 after 21 days of storage.

The a* value for 30 sec, 90 sec and 150 sec were 39.46, 35.93 and 30.09 respectively at the end of storage period of 49 days, whereas, the control tomatoes had a* value of 47.34 after 21days of storage. The b* value of control and the coated tomatoes for different periods of dipping time started decreasing with the increase in storage period.

Total color difference (ΔE) showed increased during the storage period (fig. 3) and when compared the coated tomatoes with the control tomatoes, there were significant differences ($p < 0.05$) in total color difference and also significant differences among the coated tomatoes with different periods of dipping time.

Effect on the tritatable acidity of tomato

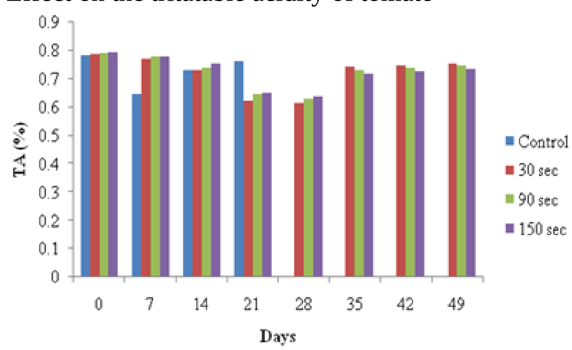

Fig.4. Effect of coating on the TA of tomatoes during the storage

The titartable acidity (TA) of tomato plays a major role and which imparts taste to the fruit. The titratable acidity (TA) of tomatoes did not vary significantly ($p <0.05$) in the coated tomatoes for different periods of dipping time over the storage period of 49 days (fig.4).

Effect on the total antioxidant capacity of tomato

Total antioxidant capacity (TAC) of the control tomatoes decreased from 12.37 mmol α- Tocopherol/g to 5.13 mmol α-Tocopherol/g at the end of storage period of 21 days. But in case of coated tomatoes, there was a slight increase TAC values over the storage period of 49 days.

Sensory evaluation

Sensory attributes of all samples were evaluated at the end of the storage period in order to examine the consumer acceptability. When the coated tomatoes were compared with the control tomatoes, there were significant differences in all parameters i.e. appearance, color, taste, texture, overall acceptability.

SUMMARY AND CONCLUSIONS

Changes in quality parameters of coated tomatoes during storage at 25 ◦C and 80 % relative humidity

The control tomatoes showed highest physiological weight loss followed by 30 sec, 90 sec and 150 sec of dipping time. PLw decreased from 3.67 % to 10.27 % for control tomatoes, 0.27 % to 1.79 % for 30 sec, 0.2 % to 1.48 % for 90 sec and 0.18 % to 1.15 % for 150 sec respectively.

In case of firmness of control and coated tomatoes, there were significant differences ($p < 0.05$) between the control and coated tomatoes. Firmness decreased from 27.17 N to 2.14 N for control after 21 days of storage. Also firmness decreased from 27.43 N to 10.12 N for 30 sec, 27.51 N to 13.24 N for 90 sec and from 27.25 N to 16.49 N respectively.

Total soluble solids of control tomatoes initially increased from 3.75 to 4.95 ◦ Brixand suddenly decreased from 4.95 to 3.91 ◦ Brix after 21 days of storage. Also TSS varied from 3.73 to 4.17 ◦ Brix for 30 sec, 3.75 to 4.2 ◦ Brix for 90 sec and 3.77 to 4.32 ◦ Brix after 49 days of storage.

The pH of tomatoes did not vary significantly ($p < 0.05$) in the coated tomatoes over the storage period of 49 days. pH for control tomatoes varied from 4.17 to 4.08 at the end of 21 days. Also pH varied from 4.15 to 4.34 for 30 sec, 4.18 to 4.31 for 90 sec and 4.19 to 4.26 for 150 sec respectively.

Total color difference (ΔE) showed increased during the storage period and when compared the coated tomatoes with the control tomatoes, there were significant differences ($p < 0.05$) in total color difference and also significant differences among the coated tomatoeswith different periods of dipping time. Total color difference increased from 25.9 to 62.55 for control, 8.09 to 38.22 for 30 sec, 3.8 to 33.22 for 90 sec and 2.78 to 26.75 for 150 sec respectively.

The titratable acidity (TA) of control and coated tomatoes initially decreased and aftera certain period of time it started to increase. TA varied from 0.785 % to 0.762 % for control at the end of 21 days. Also TA varied from 0.789 % 0.756 % for 30 sec, 0.771 % to 0.748 % for 90 sec and 0.794 % to 0.735 % for 150 sec respectively at the end of 49 days.

Total antioxidant capacity (TAC) of the control tomatoes decreased significantly from 12.37 mmol α-Tocopherol/g to 5.13 mmol α-Tocopherol/g at the storage period of 21 days. Also TAC varied from 12.45 to 14.32 mmol α-Tocopherol/g for 30 sec, 12.49 to 15.75 mmol α-Tocopherol/g for 90 sec and 12.51 to 16.29 mmol α-Tocopherol/g for 150 sec respectively. Tomatoes dipped for 150 sec were highly preferred amongst the coated samples. The sensory scores of samples were ranked in the order of preferences as 150 sec > 90 sec > 30sec on the basis of appearance, color, taste, texture, overall acceptability.

CONCLUSION

- The optimized formulation of edible coating in 1:9 ratio of carnauba wax and oleic acid,4-5 drops of neem extract and 100 ml of coconut oil.
- The optimized coating time was 150 sec which gave a thickness of 0.0411 ± 0.003 mmover the surface of tomatoes.
- On the basis of quality parameters, tomatoes dipped for 150 sec showed better resultsthan 30 sec or 90 sec.

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APPENDIX-I

Cost Calculation

Emulsion Composition

Table 3: Cost breakup of composition of coating emulsion

Sl.No	Materials	Quantity(units)	Standard Unit (Conversion) inml	Price (Rs)	Unit breakup	Price(Rs)
1	Carnauba Wax	100gm	100	300	1	3
2	Coconut Oil	1 L	1000	300	1	0.3
3	Oleic Acid	1 L	2000	900	1	0.45

For preparation of 200 ml emulsion, the overall cost of emulsion is presented in table 11.

Table 4: Cost of 200 ml of emulsion for coating tomatoes

Sl.No	Material	Required Quantity	Price (Rs)
1	Carnauba Wax	10	30
2	Coconut Oil	100	30
3	Oleic Acid	90	40.5
	Total		100.5

**Note: 200 ml Emulsion can be used for 15 kg of tomato.

Table 5: Comparison of cost of uncoated and coated tomatoes with life expectancy

SlNo	UntreatedTomatoes	Price	Shelf Life	Treated tomatoes	Price	Shelf Life
1	1	40	21	1	46.7	49

Percentage increase in price per kg of tomatoes = $\frac{46.7-40 \times 100}{40}$

= Rs.16.75/kg

Percentage increase in life expectancy of tomatoes = $\frac{49-21 \times 100}{21}$

= 133.33%