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Development of *Aloe vera* based edible coating for tomato

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A b s t r a c t. The effect of formulated *Aloe vera* based edible coating on mass loss, colour, firmness, pH, acidity, total soluble solid, ascorbic acid and lycopene on the coated tomato was investigated. The tomato in control showed a rapid deterioration with an estimated shelf life period of 19 days, based on the mass loss, colour changes, accelerated softening and ripening. On the contrary, the coating on tomatoes delayed the ripening and extended the shelf life up to 39 days. The physiological loss in weight was 7.6 and 15.1%, firmness was 36 and 46.2 N on 20th day for control and coated tomatoes, respectively. From the results, it was concluded that the use of *Aloe vera* based edible coating leads to increased tomato shelf-life.

K e y w o r d s: *Aloe vera*, edible coating, colour, firmness, tomato

INTRODUCTION

Tomato is a climacteric fruit and continues to ripen after harvest. During ripening, the green pigment chlorophyll degrades and carotenoids are synthesised (Liu *et al*., 2009). For fresh tomatoes, the two quality attributes that are most important to buyers and consumers are texture and skin colour. Texture is influenced by flesh firmness and skin strength. Softening during storage, distribution and ripening of tomatoes can be a major problem because it may increase their susceptibility to damage. There is increasing consumer concern about the eating quality of tomatoes. After harvest, ripening continues and tomatoes can become overripe very rapidly. This can result in loss of quality and restricted shelf life (Batu, 2004).

Tomatoes are harvested at different stages of maturity depending on the purpose for which they are required. Several stages of maturity are recognised – mature green fruits are those which have not begun to turn pink, while those classed as turning show some pink at the blossom end; half-ripe fruits show pink colour over most or all of the surface; ripe or red-ripe fruits are those that have developed the full colour peculiar to the type but are, at the same time, firm. Ripe fruits can be picked profitably if the market is close by. For transport to distant places, fruits are harvested at the half-ripe stage; they develop normal colour in 3-7 days. Fruits for canning or for juice extraction are harvested when they reach the ripe stage, and processed soon after (Shankara *et al*., 2005).

There is a high production of tomato fruits during the harvest time, but post-harvest processing and preservation techniques are inefficient. Therefore, fruits spoil very early because of lack of appropriate systems of preservation and processing (Ameyapoh *et al*., 2008).

Edible coatings can provide an additional protective coating for fresh products and can also give the same effect as modified atmosphere storage in modifying internal gas composition (Park *et al*., 1994). The concept of using edible coatings to extend shelf life of fresh and minimally processed produce and to protect them from harmful environmental effects has been emphasised based on the need for high quality and the demand for minimal food processing and storage technologies (Tharanathan, 2003). By regulating the transfer of moisture, oxygen, carbon dioxide, aroma, and taste compounds in a food system, edible coatings have demonstrated the capability of improving food quality and prolonging shelf life of fresh produce (Castillo and Serrano, 2005). 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 (Sonti, 2003).

Aloe vera is a tropical or subtropical plant characterised by lance-shaped leaves with jagged edges and sharp points. *Aloe vera* contains two major liquid sources, yellow latex

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(exudates) and clear gel (mucilage). Yellow latex is mainly composed of aloin, aloe-emodin and phenols. The mucilaginous jelly from the parenchymal cells of the plant is the *aloe vera* gel. *Aloe vera* can provide many benefits to human health. The gel works better through a combination of mechanisms. Composed mostly of polysaccharides, the gel appears to act as a natural barrier to moisture and oxygen which can speed up food deterioration. It can also enhance food safety. *Aloe vera* gel appears to contain various antibiotic and antifungal compounds that can potentially delay or inhibit microorganisms that are responsible for food borne illness in humans as well as food spoilage. Recently, there has been increased interest in using *Aloe vera* gel as a functional ingredient in drinks, beverages, and ice cream and as an edible coating material for fruits and vegetables driven by its antifungal activity. *Aloe vera* gel-based edible coatings have been shown to prevent loss of moisture and firmness, control respiratory rate and maturation development, delay oxidative browning, and reduce microorganism proliferation on sweet cherries (Lin and Zhao, 2007). The aim of this work was to study the effect of *A. vera*, along with functional ingredients applied as an edible coating on the change in physicochemical parameters related to tomato quality during storage and its role in extending the shelf life of tomato.

MATERIALS AND METHODS

Tomatoes (*Lycopersicon esculentum* Mill. *cv*. 'Ruchi 618') were harvested at breaker stage from a commercial farm in Mysore, Karnatake, India. At the laboratory, tomatoes were selected to obtain homogeneous batches based on colour, size, absence of injuries, and healthy. Tomatoes were divided to obtain 120 fruits in control and coated batch. The procured tomatoes were washed thoroughly with running water and surface dried before coating, else the coating would not adhere to the surface.

Aloe vera based edible coating was formed by mixing *Aloe vera* juice (500 ml) with 0.3% antioxidant rich herb, then a thickening agent (20 g) was added gradually and stirred continuously for uniform dispersion. Glycerol (2 %) was added to increase the plasticising effect. Oleic acid (3 ml) was added drop by drop to avoid precipitation. *Aloe vera* juice (150 ml) was added simultaneously during emulsion formation. Cinamaldehyde (0.2 ml), an anti-microbial compound, dissolved in tween 80 (polysorbate 80 solubilising agent) at the ratio of 1:1, was added along with oleic acid for uniform dispersion. The solution was then filtered after adding 2.5 l of water. Total soluble solids were measured before coating to maintain the solid percentage. Tomatoes were coated by dipping method.

The various maturity stages are green, breaker, turning, pink, light red and red. The best stage for giving coating to tomato was breaker and turning stage (Park, 1994). If the coating was given at the green stage, it showed a blotchy ripening and jumping of stages from mature green to breaker, turning, pink, light red and red. Similar results were reported by Ali *et al*. (1979).

During storage tomato crosses different stages (Andres *et al*., 2004). The different stages of tomato were identified by USDA colour maturity stage chart (Yang *et al*., 1987).

Physiological loss in mass was calculated according to the procedure by Valverde *et al*. (2005). Ten tomatoes from each batch were taken and the mass of individual tomatoes was recorded on the day of coating, and at every 5 days interval till it attained red stage. Cumulative mass losses were calculated by:

$$\text{Mass loss } (\%) = \frac{IW - FW}{FW} 100, \qquad (1)$$

where: IW – initial mass of sample, FW – final mass of sample.

Microstructure analysis of coating was done using SEM (Scanning Electron Microscopy). Coating was applied on a craft paper and allowed to dry. Using micrometer, the thickness of the craft paper was measured after drying, at six locations, and average of the thickness was calculated (Chaim *et al*., 1996).

Colour of the tomato was measured using the Hunter colour meter (Colour Quest XE, USA). The average value of L^*, a^*, b^* was measured and chroma value (ΔC) was calculated using the formula given below (Andres *et al*., 2004).

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

Total soluble solid concentration (TSS) was determined using digital refractometer (PAL-3, ATAGO, Japan), pH using pH meter. Titratable acidity was determined by titrating 1 ml of juice in 25 ml distilled water against 0.1 N NaOH. Ascorbic acid was determined by 2, 6-dichlorophenol indophenol visual titration method and total sugars by Phenol sulphuric acid method (Ranganna, 2004).

Firmness of the tomato was analysed using TA-XT texture analyzer (Stable Microsystems Limited, UK). The tomato was placed at the centre of the platform and the force applied by the blade to cut the tomato was measured. The specification given was the load cell 1 KN and speed 100 mm min^{-1}. The value thus obtained was used to determine the firmness of the tomato (Yang *et al*., 1987).

Lycopene was determined by extracting 10 g of sample with acetone and transferred to separating funnel containing 20 ml of petroleum ether. Upper phase petroleum ether extract containing lycopene in made up to 100 ml with petroleum ether and absorbance was measured at 503 nm using petroleum ether as blank (Ranganna, 2004).

Statistical analysis and test of significant difference ($p \leq 0.05$) was performed using SPSS software package version 10 (Valverde *et al*., 2005).

RESULTS AND DISCUSSION

Tomatoes both from control and *Aloe vera* coated showed mass loss throughout the storage period (Fig. 1). Tomatoes not coated with *Aloe vera* gel had statistically higher mass loss compared to fruit coated with *Aloe vera* gel.

The formulated *Aloe vera* based edible coating contained 8.26% solids. When it was coated on the tomatoes at this concentration, the tomatoes underwent anaerobic spoilage and gave foul smell. Hence experiments were conducted using 1, 2 and 3% solids. The loss in mass of coated and control tomatoes was monitored continuously to optimise solid percentage. Figure 1 shows the effect of the solid concentration of coating on mass loss of tomatoes. 3% solids coated tomato showed a drastic increase in mass loss of 23.09 % while compared to the control, and coating with 1% solids followed a curve very near to the control itself; it showed a decrease in mass loss at initial period of storage while at the 15th day the values were nearer to the control. Out of this, the coating with 2% solids showed a decrease in mass loss of 8.32% while compared to control 11.23%. Hence, further coatings studies were conducted using 2% solids on tomatoes. Coating thickness was related to coating solution concentration and probably influenced by physiochemical properties of the coating solution. According to Park (1994), coating thickness may vary from 4 to 13 μm depending on the fruit and vegetable. The thickness of final formulated solution with 2% solid was 6.75 μm and gauge was 25 μm. Maturity indices of coated and control were compared during storage period. Coating was applied to the field harvested fruit during its breaker stage. Control fruits attained the turning stage on 7th day, pink stage on 13th day, light red on 17th day, and red stage on the 19th day. Whereas, the coated fruit attained the turning stage on 14th day, pink stage on 28th day, light red on 35th day, and red stage on 39th day.

Scanning electron microscopy was used to obtain images of tomato skin, to study the effect of coating on the tomato skin. Figure 2a shows the SEM image of uncoated tomato skin. The uncoated tomato peel image is compared with the coated peel image to study its effects. This image clearly shows the pores on the surface of the peel. The natural waxy coat is not adequate to offer protection against water loss and high respiration rate. Edible coating help in extending the life of fruit / vegetable by restricting the rate of respiration and preventing moisture loss. A similar result is also reported by Thirupathi *et al*. (2006).

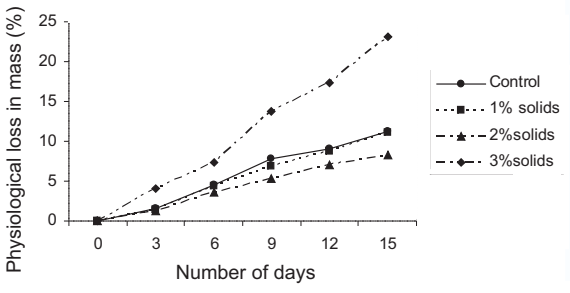

Fig. 1. Effect of coating with different solid concentrations on physiological loss in mass of tomato.

Figure 2b shows the SEM image of tomato peel coated with *Aloe vera* based edible coating with 8.26% of total solids. The SEM image shows thick coating on the tomato peel. Tomatoes coated with 8.26% total solids are prone to anaerobic degradation, due to very low respiration rate; a similar result is also reported by Zevallos and Krochta (2003).

Figure 2c shows the SEM image of tomato peel coated with *Aloe vera* based edible coating with 2% of total solids. The coating with 2% solids formed a thin and uniform semipermeable membrane for gas exchange on the surface of tomato skin.

Tomatoes, both control and coated, registered some changes in L^*, a^* and b^* values during the storage period. Table 1 shows the effect of coating on L^*, a^*, b^* and firmness values of tomatoes.

L^* means lightness (from white to black). L^*values did not change until the turning stage, indicating that there was no change in lightness when the green colour was still predominant. The initial L^* values for the control and coated tomatoes were 43.57 and 43.66 (slight difference in the initial L^* value is due to coating). When red colour pigments started to synthesise, there was a decline in L^* value; a similar result was also reported by Andres *et al*. (2004). Though there was a decrease in L^* value in both coated and control tomatoes, coating showed a significant difference in L^* value when compared to control on 20th day. L^* value of control during its red stage on the 20th day was 26.74, whereas for the coated fruit on the same day it was 40.87. L^* value of coated fruit decreased during its ripening. L^* value of coated fruit during its red stage on 40th day was 27.05.

a^* values change from negative (green colour) to positive (red colour) (Andres *et al*., 2004). a^* value of control during its red stage on the 20th day was 22.50, whereas for the coated fruit on the same day it was 8.38. The increase in a^* value was, however, slower for the tomatoes treated with *Aloe vera* gel compared to control, resulting in significant differences among the treatments. a^* value of tomato increased during its ripening, and for the coated fruit during its red stage on the 40th day it was 22.70.

The initial b^* (blue to yellow) values for control and coated tomatoes were 21.45 and 21.60, afterwards the values gradually decreased to 12.43 for control tomatoes and to 20.43 for coated tomatoes on 20th day. b^* value of coated tomato during its red stage on the 40th day was 12.71.

The chroma value (ΔC) depends on a^* and b^* values. The chroma value indicates the colour intensity (saturation) of the sample. There was a slight increase in the Chroma value from the initial value. But there were significant differences in chroma value of coated tomatoes when compared to control tomatoes. ΔC of the control was 25.62

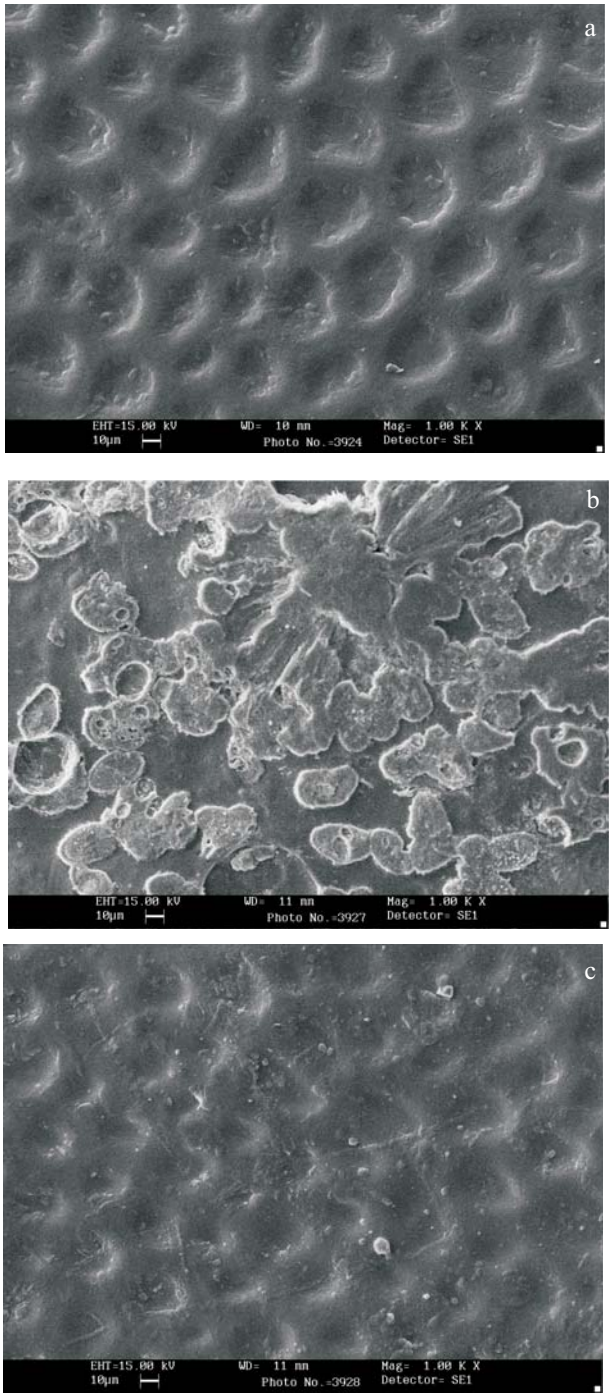

Fig. 2. SEM image of tomato skin: a – uncoated; coated with formulated edible coating with: b – 8.26%, and c – 2% total solids.

during its ripening on the 20th day, whereas for the coated fruit it was 21.51 on the same day. ΔC value increased during ripening of tomato. ΔC value of coated fruit during its red stage on the 40th day was 25.69.

Fruit firmness for both control and coated tomatoes gradually decreased during the storage period. During the ripening process, cell wall-modifying activity of several enzymes, including polygalacturonase, pectin-methyl-esterase, endo-β-mannase, α- and β-galactosidases, and β-glucanases, causes softening of the whole fruit by altering the texture due to degradation of the structural components necessary to reinforce the cell wall and the adhesion of cells. Initial values of firmness for control and coated tomatoes were 57.34 and 58.67 N. The firmness of control during its red stage on the 20th day was 31.65 N, whereas for the coated fruit on the same day it was 46.79 N. Coating showed statistical difference in firmness when compared to control on 20th day. Firmness gradually decreased for coated tomatoes after 20th day. The firmness of coated fruit during the red stage on the 40th day was 32.51 N. Coating was the most effective treatment for retardation of softening of harvested fruits and vegetables compared to the control; similar results were also reported by Keneko *et al*. (2002).

Table 2 shows the effect of coating on TSS, reducing sugar and total sugar of tomato. TSS concentration slightly increased initially and latter decreased. TSS of control during red stage on 20th day was 4.49° Brix, whereas for the coated fruit on the same day it was 4.89° Brix. There was a gradual decrease in the TSS of the coated tomatoes after 20th day, and the TSS was 4.51°Brix on 40th day. This may be due to the break-up of carbohydrates and pectin, partial hydrolysis of protein, and decomposition of glycosides into subunits during respiration causing a decrease of total soluble solids; similar results were also reported by Torgul and Arslan (2004).

The sugar content increases progressively through the maturation process and ripening, but particularly a pronounced rise occurs with the appearance of yellow pigmentation. Total sugar content of control during its red stage on the 20th day was 3.49 mg 100 g^{-1}, whereas for the coated fruit it was 3.39 mg 100 g^{-1}. Total sugar value of the coated fruit during its red stage on the 40th day was 4.31 mg 100 g^{-1}. There was a pronounced increase in the sugar content of control during the turning stage, and then it started to decline. But in the coated fruit there was drastic increase and the sugar content of tomato during the red stage was higher compared to the control, due to the controlled atmosphere maintained around the fruit which reduced the transpiration and respiration loss. Reducing sugar content increased during the ripening stage. At the initial stage, the level of reducing sugar was more, was stored in the reserved form. As the stage crossed, there was a decline in sugar content and it attained the maximum at the pink stage. Similar results were also reported by Ali *et al*. (1979). Reducing sugar value of control during its red stage on the 20th day was 2.84 mg 100 g^{-1}, whereas for the coated fruit it was 2.85 mg 100 g^{-1}. Reducing sugar value of coated fruit during its red stage on 40th day was 3.08 mg 100 g^{-1}. Whereas, there was increase in sugar content at the pink stage in both control and coated fruits, followed by a decline.

T a b l e 1. Effect of coating on *L**, *a**, *b** colour values and firmness of tomato

Days	Colour *L** value		Colour *a** value		Colour *b** value		Chroma value		Firmness (N)	
	Control	Coated	Control	Coated	Control	Coated	Control	Coated	Control	Coated
0	43.57 ±0.36a	43.66 ±0.12c	-7.77 ±0.15d	-7.58 ±0.08i	21.45 ±0.23a	21.60 ±0.09b	22.18 ±0.08a	22.89 ±0.19c	57.34 ±0.66a	58.67 ±0.53b
5	43.73 ±0.21a	44.29 ±0.24a	-4.87 ±0.06c	-6.37 ±0.32h	21.45 ±0.23a	21.60 ±0.09b	21.99 ±0.21a	22.51 ±0.23c	51.28 ±0.57a	66.22 ±0.55c
10	36.74 ±0.19b	43.97 ±0.07i	-4.40 ±0.10e	-5.27 ±0.25g	21.72 ±0.20a	21.83 ±0.09a	22.16 ±0.09a	22.45 ±0.07c	48.55 ±0.35c	54.57 ±0.45b
15	30.82 ±0.20c	44.04	18.83 ±0.76b	-4.30 ±0.10f	15.59 ±0.23b	21.90 ±0.02a	24.44 ±0.1b	22.31 ±0.09c	34.67 ±0.18d	50.70 ±0.82e
20	26.74 ±0.17d	40.87 ±0.16b	22.50 ±0.20a	8.38 ±0.08e	12.43 ±0.12c	20.43 ±0.14c	25.62 ±0.13d	21.51 ±0.09c	31.65 ±0.22e	46.79 ±0.19f
25	–	35.8 ±0.10e	–	13.93 ±0.15d	–	18.45 ±0.06d	–	23.11 ±0.08b	–	41.56 ±0.39g
30	–	33.69 ±0.17f	–	16.70 ±0.20c	–	16.51 ±0.03e	–	23.48 ±0.13b	–	37.97 ±0.27h
35	–	30.50 ±0.06g	–	20.83 ±0.21b	–	14.27 ±0.12f	–	25.24 ±0.06d	–	34.64 ±0.24i
40	–	27.05 ±0.16h	–	22.70 ±0.20a	–	12.71 ±0.11g	–	25.69 ±0.14e	–	32.51 ±0.37j

Values are mean and SD of three separate determinations. Values in the same column and row (control and coated) with different letters are significantly different ($p<0.05$).

T a b l e 2. Effect of coating on TSS, reducing sugar and total sugar of tomato

Days	TSS (°Brix)		Reducing sugar (mg 100 g^{-1})		Total sugar (mg 100 g^{-1})	
	Control	Coated	Control	Coated	Control	Coated
0	4.65±0.05c	4.63±0.03f	4.95±0.05a	4.99±0.02b	7.38±0.01a	7.45±0.05a
5	5.02±0.02a	4.70±0.02e	1.59±0.03e	3.57±0.02d	3.28±0.08e	5.64±0.03b
10	5.07±0.01a	4.84±0.02c	3.77±0.03c	2.16±0.03g	5.13±0.04c	4.45±0.05c
15	4.95±0.05b	4.94±0.02a	4.17±0.02b	1.76±0.03h	5.95±0.05b	3.49±0.03g
20	4.49±0.03d	4.89±0.02b	2.84±0.02d	2.85±0.03f	3.49±0.03d	3.39±0.02h
25	–	4.84±0.01c		3.79±0.03c		4.06±0.04e
30	–	4.80±0.01d		4.99±0.04b		3.49±0.03g
35	–	4.35±0.03h		5.46±0.04a		3.89±0.03f
40	–	4.51±0.02g		3.08±0.05e		4.31±0.03d

Explanations as in Table 1.

Table 3 shows the effect of coating on pH, acidity, ascorbic acid and lycopene of tomato. pH value of control at the time of red stage on the 20th day was 4.15, whereas for coated fruit it was 4.07. The increase in pH value may be due to break-up of acids with respiration during storage. The pH value of coated fruit was increased to 4.25 during red stage on the 40th day.

The acidity of tomato plays a major role and imparts taste to the fruit. The predominant acids in ripened tomato fruit are citric acid and malic acid. Acidity does not form a linear curve, one author said that malic acid concentration falls during ripening and citric acid increases up to turning stage, whereas another reported that malic acid increased steadily throughout maturation (Humle, 1971). The titratable acidity of control at the time of red stage on the 20th day was 0.611%, whereas for coated fruit on the same day it was 0.559%. Titratable acidity of the coated fruit during its red stage on the 40th day was 0.623%. At the red stage, both for control and coated fruit, acidity remained the same in which it showed the decline at the turning stage.

T a b l e 3. Effect of coating on pH, acidity, ascorbic acid and lycopene of tomato

Days	pH		Acidity (%)		Ascorbic acid (mg 100 g^{-1})		Lycopene (μg g^{-1})	
	Control	Coated	Control	Coated	Control	Coated	Control	Coated
0	3.81±0.01d	3.93±0.03d	0.685±0.006a	0.694±0.004a	8.67±0.01a	8.74±0.03a	0.63±0.03d	0.64±0.03d
5	3.98±0.01c	3.43±0.03e	0.579±0.003d	0.681±0.002b	8.52±0.02b	8.74±0.03a	0.93±0.01e	0.77±0.01gf
10	4.04±0.01b	3.97±0.02d	0.545±0.005e	0.657±0.002d	8.19±0.01c	8.57±0.03b	7.68±0.02c	0.93±0.01f
15	3.99±0.01c	4.13±0.03b	0.648±0.003b	0.565±0.004f	7.96±0.01d	8.64±0.04c	33.64±0.55b	0.93±0.01f
20	4.15±0.01a	4.07±0.06c	0.611±0.003c	0.559±0.003f	8.18±0.01c	8.52±0.02d	42.09±0.24a	1.39±0.01e
25		4.07±0.06c		0.537±0.002g		8.57±0.03d		2.46±0.01d
30		4.06±0.01c		0.521±0.005h		8.56±0.05d		7.67±0.01c
35		4.08±0.01bc		0.667±0.003c		6.52±0.03e		37.20±0.08b
40		4.25±0.05a		0.623±0.007e		8.28±0.02f		43.27±0.02a

Explanations as in Table 1.

Ascorbic acid content during maturity stage was continuously increasing with a slight fall during the light red stage. The ascorbic acid content of control during its red stage on 20th day was 8.18 mg 100 g^{-1}, whereas for coated fruit on the same day it was 8.52 mg 100 g^{-1}. The ascorbic acid content of the coated fruit during its red stage on 40th day was 8.28 mg 100 g^{-1}. Whereas, the coated sample a slight increase in the ascorbic acid level was observed on 40th day, because the ascorbic acid level depends upon the relative exposure to sunlight.

During ripening the chlorophyll content decreases, and there is a rapid synthesis of the red pigment lycopene. The lycopene content of control during its red stage on the 20th day was 42.09 μg g^{-1}, whereas lycopene of coated fruit on the same day was 1.39 μg g^{-1}. The lycopene content of tomato increased during its ripening. The lycopene content of coated fruit during its red stage on the 40th day was 43.27 μg g^{-1}. There was a steady increase in the lycopene content of both the control and coated tomatoes.

CONCLUSIONS

1. The firmness of control fruit during red stage on the 20th day was 31.65 N, whereas for the coated fruit on the same day it was 46.79 N. Coating was the most effective treatment for retardation of softening of harvested fruits and vegetables.

2. Total soluble solid of control fruit during red stage on 20th day was 4.49°Brix whereas for the coated fruit on the same day it was 4.89°Brix. Total sugar content of control during its red stage on the 20th day was 3.49 mg 100 g^{-1} whereas for the coated fruit it was 3.39 mg 100 g^{-1}. The titratable acidity of control at the time of red stage on the 20th day was 0.611% whereas for coated fruit on the same day it was 0.559%.

3. *Aloe vera* as an edible coating with 2% solid percentage remains a viable alternative to delay the ripening of tomato. By optimising the solid percentage it could be applicable to other fruits and vegetables too.

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