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Quality evaluation of edible film coated tomato (*Solanum lycopersicum*) fruits

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Abstract

Quality parameters of two aloe based gel coated mature green tomato fruits of variety Akshaya were compared for selecting the most efficient and economic edible film coating capable of maintaining fruit quality. Harvested fruits after surface sanitization with 2 ppm ozonized water for 10 minutes and air drying were dipped in two formulations viz., pure aloe gel (aloe gel + 1% potassium alginate) and Papaya leaf extract incorporated aloe gel (PLEAG) (Aloe gel + papaya leaf extract, 1:2 + 1% potassium alginate) @ 2% concentration for two minutes. Fruits treated with PLEAG had higher firmness and bio yield point with low pectin methyl esterase and poly galacturonase activity and high pectin content. Both formulations were equally effective in maintaining total solids as well as total and alcohol insoluble solids during the entire storage period of 36 days. Sensory perceptions of textural characters in both treatments were similar. Though no antimicrobial activity against *Erwinia* and *Rhizopus* was noticed under *in vitro*, they had suppressed postharvest infection *in vivo*, and fruit rot symptoms were not observed on coated fruits. Cost of pure aloe and PLEAG formulation for 100 kg tomatoes were INR 55.48/- and 45.87/- respectively, proving the possibility of aloe gel substitution with papaya plant leaf extracts without reducing efficiency. Dipping in 2% aloe gel + papaya leaf extract (1:2) + 1% potassium alginate for two minutes was the efficient and economic edible coating for maintaining mature green tomato quality.

Key words: Aloe vera gel, Edible film coating, Fruit quality, Mature green tomato, Postharvest fruit rot.

Introduction

It is a paradox that people from the country that produce huge quantities of horticultural produce still suffer from many nutritional deficiencies in their diet. The onus of this would predominantly go to our poor postharvest infrastructure as well as know-how and accessibility to such facilities, making India one among those countries having high postharvest losses. A national level study on post-harvest losses covering eight vegetables, five farm operations and five market channels revealed the overall total losses to be 13% for tomato (MofPi, 2018; NAAS 2019). Other major issues of postharvest loss include seasonality, non-planning and inefficient production creating gluts and shortages in the market. Prices of perishables come down drastically during glut to consumers' relief, while farmers are hit by low prices. This has created problem with regard to tomatoes in Palakkad, where favourable climatic conditions lead to bumper yield, forcing farmers to sell their produce at cheaper rates. This tomato glut has created anxiety among growers as well as researchers, and unless there are systematic solutions to manage the surplus, time and money spent on cultivation will be a mere waste. The highly perishable nature of tomatoes demands careful attention in the harvesting and subsequent post harvest processing operations in order to reduce the losses and to fetch high market prices during the lean season. Owing to lack of information on appropriate postharvest treatments, packaging, temperature etc., the harvested fruits not only lose their quality but also encounter a substantial

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postharvest loss. For fresh tomatoes, the quality attribute that is most important to buyers and consumers is texture, which is influenced by flesh firmness and skin strength. Softening during storage, distribution and ripening of tomatoes can be a major problem as it may increase their susceptibility to damage.

Edible coatings are thin layers of materials applied to the natural product surface in addition to or as a replacement for natural protective waxy coatings, and provide a barrier to moisture, oxygen and solute movement for the food. These coatings act as a barrier and help reduce water vapour loss; hence increasing the shelf life, slowing down the ripening and decay. *Aloe vera* gel is one of the most commonly used edible coatings for fruits, which is efficient, cheap, easily available, prevents spoilage due to microbial attack, controls respiration rate and prevents loss of firmness and moisture. It also has antimicrobial and anti-fungal properties against Gram positive and Gram negative bacterial pathogens. This natural product is a safe and environment friendly alternative to chemical agents. Two types of aloe vera based edible coatings suited to mature green tomato (*Solanum lycopersicum*) fruits var. Akshaya have been standardized by Chandran (2018) which could help extend their shelf life from 24 to 36 days. The textural and other quality parameters of the above two *Aloe vera* based gel coated fruits were compared here to select the most efficient and economic aloe based edible film coating.

Material and Methods

Preparation and application of edible coating

Tomato (*Solanum lycopersicum*) plants of variety Akshaya, an indeterminate high yielding variety with bacterial wilt resistance and suitable for cultivation both in rain shelter and in open field, were raised in grow bags as per Package of Practice Recommendations of KAU: Crops (KAU, 2016) under rain shelter conditions and harvested at "mature green stage" meant for distant marketing, at 85 days after transplanting. Fruits were greenish white, medium sized, flat round, corrugated and exhibit uniform colour development. The harvested fruits were washed, surface sanitized in 2 ppm ozonized water for 10 minutes (George, 2015), air dried and then dipped in either of the following two types of aloe based edible coating formulations @ 2% concentration for two minutes. Pure aloe gel (Aloe gel +1% potassium alginate) or PLEAG: Papaya leaf extract incorporated aloe gel (Aloe gel + papaya leafextract (1:2) + 1% potassium alginate).

Preparation of Pure aloe gel (Aloe gel +1% potassium alginate)

Good quality fresh *Aloe vera* leaves were procured from the local market. Aloe gel matrix which lies underneath the green outer rind was manually separated from the outer cortex of leaves and this colourless hydro parenchyma was homogenized in a blender. The resulting homogenate was filtered to remove the fibres to form 100 per cent fresh aloe gel. The filtered aloe gel was pasteurized at 70^0C for 45 minutes and then cooled immediately to ambient temperature after maintaining pH at 4 by adding citric acid (0.5-1gL^{-1}) and ascorbic acid (0.1-0.50 gL^{-1}) (Maughan,1984). The gel was thickened for the purpose of skin coating using gelling agent, potassium alginate at 1% concentration. The mixture was stored in brown amber coloured bottles in deep freezer, till use.

Preparation of papaya leaf extract incorporated aloe gel (PLEAG).

Disease free fresh leaves of papaya (*Carica papaya*) were collected from College Instructional Farm. Leaves were surface sterilized for 5 minutes in 2 ppm ozonized water, washed thoroughly with distilled water and crushed along with aloe gel prepared as per Maughan (1984) in 2:1 ratio on w/w basis. The extract was filtered to formulate papaya leaf extract incorporated Aloe gel (PLEAG), mixed with 1% gelling agent, potassium alginate and the mixture was stored in brown amber colored bottles in deep freezer, till use.

The treatments were replicated seven times in Completely Randomized Design and 100-150g fruits (2-3 numbers) were maintained per replication. The coated tomato fruits were air dried at room temperature, weighed, stored in open polystyrene trays under ambient condition [temperature (28- 32^{0}C), RH (90-95%)].

Evaluation of edible coated fruits

Shelf life was calculated as number of days from harvest till the fruits remained marketable. The fruits were rated not marketable when more than 50 per cent of the fruits in a lot showed spoilage, browning and microbial growth (O'Hare, 1995). The physical, chemical, microbial and sensory parameters of the coated fruits were analyzed at 12 days interval for 36 days for selecting the most efficient coating capable of maintaining the quality of tomato. Cost of preparation of edible coatings were also calculated and compared.

Physical parameters viz., the fruit firmness and bio yield point of the edible coated tomato samples were measured in Newton (N) using a Texture Analyser TA. HD Plus (Stable Microsystems, UK) using the compression mode test. The machine was calibrated using the test conditions 1.5mm/sec Pretest and Test speed, 10mm/sec Posttest speed, 5 mm distance, 200 pps data acquisition rate and 150 sec. typical test time. The penetration test was carried out using 2mm needle (P/2) and the pressure required to cause 5 mm deformation in whole fruits was measured thrice on each fruit.

Tomato fruits after coating were evaluated for sensory perception of textural properties viz., finger feel characters, mouth feel or oral textural characters by conducting a sensory evaluation trial with a 30-member semi - trained panel using the scores developed as shown in Table 1. Sensory perception

Table 1. Scores for assessing the sensory perception of textural properties

Parameters	Description	Scores assigned
	A. FINGER FEEL CHARACTERS	
1. Fruit Firmness: Reaction to stress/gentle squeeze between fingers		
a. Firm	ability to hold the shape	3
b. Firm with give	ability to rebound the shape	2
c. Soft	lost ability to hold the shape	1
2. Skin Tightness		
a. Compact	Small cells with tiny intercellular spaces	3
b. Spongy	Large cells with large intercellular spaces	2
c. Loose	Cells extended to feel a wrinkled appearance	1
3. Nature of coating materials - Feeling of coating viz., oily/sticky/gelatinous		
a. None		3
b. Slightly		2
c. Clearly Visible		1
4. Skin roughness- Feeling of material deposition on external surface		
a. Smooth		2
b. Rough		1
	B. MOUTH FEEL CHARACTERS	
1. Oral texture- Experienced during mastication		
a. Hard		2
b. Soft		1
2. Tomato juiciness - Assessment of structural integrity		
a. Juicy	Release of cell content into mouth when Chewed three times between molasses	2
b. Dry		1
	C. TEXTURAL APPEARANCE	
1. Glossiness - Shiny/lustrous appearance for superficial attraction		
a. High		3
b. Medium		2
c. Low		1

of quality parameters was described in detail and corresponding scores ranging from 1 to 3 were given. Fruit firmness, skin tightness, nature of coating materials and skin roughness were considered under finger feel characters. Oral texture and juiciness were assessed under mouth feel characters and glossiness under textural appearance. Chemical parameters viz., total solids, total insoluble solids (Lamb, 1977), alcohol-insoluble solids (AIS) (Moyer and Holgate, 1948), total pectin (Ranganna, 1979), activity of texture affecting enzymes viz., pectin methyl esterase (Awang et al., 2013) and polygalactouranase (Martins et al., 2008) of the edible coated fruits were assessed.

Isolation of post harvest pathogens from tomato and in vitro antimicrobial assay

Ripe tomato fruits with symptoms of bacterial soft rot (*Erwinia carotovora*) and Rhizopus rot (*Rhizopus stolonifer*) were collected from open market and the pathogens were isolated under aseptic conditions on Nutrient Agar and Potato Dextrose Agar respectively. The pathogenic isolates were purified by subculturing and the pure cultures maintained under refrigerated conditions. Artificial inoculations on tomato fruits and further re-isolations were carried out to confirm pathogenicity of the isolates. Virulant isolates of *Erwinia* and *Rhizopus* were maintained in Nutrient Agar and Potato Dextrose Agar slants respectively under refrigeration for further use.

In vitro antimicrobial assay of the two aloe based extracts was carried out against the Rhizopus and *Erwinia* isolates by modified media method and paper disc assay respectively.

Modified media method

The two aloe extracts (1ml each) were separately mixed with 100 ml Potato Dextrose Agar to make 1%, autoclaved and poured into sterile petri plates for antibacterial assay. The control sets were prepared by mixing sterile distilled water with Potato Dextrose Agar avoiding aloe based extracts. A five mm diameter agar disc taken from the pure culture of *Rhizopus* was placed in the center of all Potato Dextrose Agar plates containing (1) pure aloe based extracts (2) plant leaf extract incorporated aloe gel based extract and (3) control plates with Potato Dextrose Agar only. The Potato Dextrose Agar plates were incubated at room temperature. Resistance of growth in centimetres was recorded by measuring the colony diameter (average reading from four directions).

Paper disc assay

Sterile filter paper discs of six mm diameter were dipped in each of the two aloe based extracts for one minute and dried in laminar air flow bench under aseptic conditions. Nutrient Agar media was poured into sterile Petri plates and *Erwinia* colonies isolated from the stock culture were swabbed onto the Nutrient Agar medium. After the carrier solvents (aloe and PLEAG based extracts) evaporated from the filter paper discs, they were placed on the surface of the inoculated medium and the plates were incubated at room temperature (28^{o}C). The diameter of inhibition growth zone was measured and the degree of inhibition of the bacterial growth was recorded on a 0-4 scale (Amare, 2002) as 0 - no inhibition zone visible, 1 - inhibition zone barely distinct, 2 - inhibition zone well distinct, 3 - inhibition zone with sparse growth and 4 - inhibition zone free of visible growth.

In vivo antimicrobial assay of aloe based extracts against post harvest pathogens

Aloe based formulations were prepared and tested for their antimicrobial effect on bacterial soft rot development on mature green tomato fruits. Treated and control fruits at 100-150g were inoculated by evenly spraying with the suspension of *Erwinia* and *Rhizopus*, replicated thrice under Completely Randomised Design and stored under room temperature for 5 days. Severity of soft rot and *Rhizopus* rot on individual tomato fruit was recorded according to the area affected, using a 1-5 visual rating scale (Maharaj and Sankat, 1990).

1- Zero percent (no disease symptoms)

2- Trace - 1-10 per cent disease symptoms (spot appearing first)
3- Slight - 11-25 per cent disease symptoms (spots increasing in size as number)
4- Moderate - 26-50 per cent disease symptoms (small to large brownish sunken spots with slight to moderate mycelium growth)
5- Severe - 51 per cent to more than 75 per cent disease symptoms (large spots with wide spread mycelium growth and fruit is partially or completely rotten)

The disease index was calculated on the day of complete spoilage of untreated fruits to check the ability of the aloe based extract to prevent the fruit infection by visual examination.

Statistical analysis

The observations of the experiment were analyzed statistically in a Completely Randomized Design and significance was tested using analysis of variance technique. In analysis of sensory perception, the different scores given by the judges in the sensory panel were analyzed using the Kruskall - Wallis test to get the mean rank values for all the treatments.

Results and Discussion

Physical parameters

There was no significant difference between the fruit firmness of pure aloe gel and papaya leaf extract incorporated aloe gel coated mature green tomato fruits on the initial day (Table 2). On 12th, 24th and 36th day of storage fruits treated with papaya leaf extract incorporated aloe gel recorded a higher firmness (61.13N, 60.91N and 49.16 N respectively) when compared with pure aloe gel treated fruits. Firmness of fruits and vegetables influences all the textural parameters associated with the commodity. According to Kader et al. (1978), the textural quality of tomatoes is influenced by flesh firmness, the ratio between pericarp and locular tissue and skin toughness.

The point at which the 2mm needle of the texture analyzer punctures through the fruit skin and begins to penetrate into the fruit flesh is called the 'bio yield point' and it causes irreversible damage. There was no significant difference in the bio yield point of mature green tomatoes subjected to different treatments on the initial and 12th day of storage (Table 2). On the 24th and 36th day of storage, fruits treated with papaya leaf extract incorporated aloe gel recorded higher bio yield point of 126.42N and 137.92N respectively compared to fruits treated with aloe gel. Papaya leaf extract incorporated aloe gel coated fruit were firmer and therefore the force required to puncture through the fruit skin was more and resulting in higher bio yield point compared to aloe gel coated fruits. Similar results were reported in papaya by Marpudi et al. (2011). They observed a firmness of 2.5N and 4N respectively for aloe gel and papaya leaf extract incorporated aloe gel coated papaya fruits when stored for 15 days. They proved that the effectiveness of aloe gel coating was improved on incorporation of papaya leaf extract. Brishti et al. (2013) also noticed that papaya fruits coated with papaya leaf incorporated aloe gel recorded a higher firmness compared to aloe gel coated fruits.

Texture in food products is generally defined as the overall feeling that the food gives in the mouth and therefore comprises of properties that can be evaluated by touch (Abbott, 2004). No significant difference was found between the sensory perceptions of finger feel, mouth feel and textural appearance of mature green fruits coated with pure

Table 2. Effect of edible coatings on firmness and bioyield point of mature green tomatoes

Edible coatings @2% for 2min.	Fruit firmness (N) Days after storage				Bioyield point (N) Days after storage			
	0	12	24	36	0	12	24	36
T_1-Aloe gel	108.38	54.07	53.54	43.93	212.37	99.92	117.72	130.57
T_2- PLEAG	109.02	61.13	60.91	49.16	210.54	104.46	126.42	137.92
CD (0.05)	NS	6.08	6.37	4.47	NS	NS	6.857	2.97

Table 3. Effect of edible coatings on sensory perception of textural properties of mature green tomatoes

CHARACTERS	Sensory perception of textural characters in tomato							
	0th day		12th day		24th day		36th day	
	T_1 Score	T_2 Score	T_1 Score	T_2 Score	T_1 Score	T_2 Score	T_1 Score	T_2 Score
A. Finger feel characters								
1. Fruit firmness	3.00	3.00	3.00	3.00	2.66	2.86	2.46	2.60
2. Skin tightness	3.00	3.00	3.00	3.00	3.00	3.00	2.60	2.60
3. Nature of coating material	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
4. Skin roughness	3.00	3.00	2.27	2.40	2.33	2.20	2.26	2.26
B. Mouth feel characters								
1. Oral texture	3.00	3.00	3.00	3.00	2.76	2.80	2.26	2.28
2. Tomato juiciness	3.00	3.00	3.00	3.00	2.00	2.00	2.00	2.00
C. Textural characters								
1. Glossiness	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
KW value	0.58		1.24		1.62		0.49	
X^2 value	NS							

T_1- Aloe gel coated tomato T_2- Papaya leaf extract incorporated AG coated tomato

aloe gel and papaya leaf extract incorporated aloe gel (Table 3), indicating that papaya leaf extract incorporated aloe gel and pure aloe gel were equally effective in maintaining the sensory parameters of fruits.

Chemical parameters

There was no significant difference between mature green tomato fruits coated with the two types of edible coatings on the total solids, total insoluble solids and alcohol insoluble solids during the entire storage period (Table 4). These parameters are characteristics of a particular variety and the difference in nature of edible coating did not make any difference in chemical quality parameters of the fruits.

Excessive textural softening leads to spoilage upon storage and the basic process is the breakdown of cell walls with an enzymatic base which produces breakdown of the pectic moiety of cell walls (Van Dijk et al., 2006). The pectin moiety of cell walls is strongly related to fruit firmness and a wide range of enzymes modify this moiety during growth, maturation, ripening and senescence. Of the pectolytic enzymes involved, the two important enzymes involved in pectin breakdown are pectin methyl esterase (PME) and poly galcturonase (PG) playing an important role in the fruit softening. No significant difference of pectin methyl esterase enzyme activity was found between the fruits treated with aloe gel and papaya leaf extract incorporated aloe gel on the initial and 12th day of storage (Table 5.). But as the storage period progressed, low pectin methyl esterase enzyme activities (79.24 and 61.88 units g^{-1}respectively) were recorded by the papaya leaf extract incorporated aloe gel treated fruits on the 24th and 36th day of storage. Mature green fruits coated with PLEAG recorded lower poly galacturonase enzyme activity throughout the storage period when compared with the aloe gel treated fruits (Table 5). On the initial day the pectin content was similar for both aloe gel and papaya leaf extract incorporated aloe gel treated fruits; the

Table 4. Effect of edible coatings on total solids, total insoluble solids and alcohol insoluble solids of mature green tomatoes

Edible coatings @2% for 2 min.	Total solids (mg/L) Days after storage				Total insoluble solids (mg/L) Days after storage				Alcohol insoluble solids (mg/L) Days after storage			
	0	12	24	36	0	12	24	36	0	12	24	36
Aloe gel	88.14	86.57	83.86	84.14	59.29	58.57	53.71	53.71	62.57	57.47	47.64	34.34
PLEAG	87.71	86.57	83.43	84.14	59.86	58.71	54.14	53.71	62.36	57.71	47.07	34.79
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 5. Effect of edible coatings on pectin methyl esterase activity, poly galacturonase activity and total pectin content of mature green tomatoes

Edible coatings	Pectin methyl esterase (units g^{-1})				Poly galacturonase(units ml^{-1})				Total pectin(% unhydrogalacturonic acid)			
	Days after storage				Days after storage				Days after storage			
	0	12	24	36	0	12	24	36	0	12	24	36
Aloe gel	75.93	83.87	81.17	63.51	35.09	39.09	23.95	12.03	10.94	10.33	9.64	7.69
PLEAG	75.70	83.78	79.24	61.88	33.85	37.97	21.95	9.94	10.94	11.84	10.26	8.64
CD (0.05)	NS	NS	1.29	0.67	0.63	0.69	0.73	0.65	NS	0.08	0.13	0.20

total pectin content was higher (11.84, 10.26 and 8.64 % unhydrogalacturonic acid respectively) in the papaya leaf extract incorporated aloe gel treated fruits on the 12th, 24th and 36th day of storage (Table 5). The reduction in enzyme activity in the papaya leaf incorporated aloe gel coated mature green fruits resulted in increased fruit pectin content. According to Tieman and Handa (1994), lowered PME activity has a marked effect on the integrity of tomato fruits stored for extended periods and modifies repartitioning of cations, in particular calcium, between soluble and bound forms in ripening fruits. Considerable fruit softening occurs during ripening, which is mainly as a result of degradation of the middle lamella of the cell wall of cortical parenchyma cells. Brummell and Harpster (2001) reported that changes in cell wall structure and composition are mainly due to the combined action of enzymes including hydrolases, particularly polygalacturonase (PG), pectin methyl estarase (PME), galactosidase (Gal), pectatelyase (PL) and cellulose (Cel). The results of the quality evaluation studies in the current study are in line with the findings of Martinez-Romero et al. (2006) who reported that aloe gel has a role in the reduction of activity of poly galacturonase, pectin methyl esterase and galactosidase enzymes responsible for sweet cherry softening and pectin content maintenance. Brishti et al. (2013) also reported that treatment with aloe gel and papaya leaf incorporated aloe gel significantly reduced the loss of firmness and thereby provided a better texture for the coated papaya fruits by reduced enzyme activity.

Microbial parameters

In tomato the bacterial soft rot and *Rhizopus* rot are the two major post-harvest diseases. *In vitro* antimicrobial assay of both the edible coating formulations against *Erwinia* and *Rhizopus* showed no formation of inhibition zone. Even though *Aloe vera* and papaya leaf extracts are reported to have many antimicrobial properties, the non -formation of inhibition zone in the present study might be due to the usage of lower concentrations of aloe based extracts in the formulations.

Fruit disease index is used as a measure to indicate the effect of selected coatings on the microbial quality of fruits. When the coated mature green fruits were tested for disease index by artificially inoculating suspension of *Erwinia* and *Rhizopus*, the severity scale was 1 with no disease symptoms of bacterial soft rot and Rhizopus rot for the storage period of 36 days. In untreated fruits disease index scale on 24th day of storage was 5 (severe), with 80 per cent surface affected by *Rhizopus* rot and scale 4 (moderate) with 26-50 percent surface affected by *Erwinia* (Plate 1). The absence of disease symptoms in the coated fruits might be due to the effect of the film coating formed by aloe gel which could act as a protective barrier for the entry of these post harvest pathogens. Aloe gel and papaya leaf extract contain bioactive agents to prevent disease development in coated papaya fruits as reported by Habeeb et al., (2007). A number of plant species and their aqueous extracts have been reported to possess natural substances that are toxic to many fungi causing plant diseases (Dwivedi and Shukla, 2000; Kagale et al., 2004; Ranaware et al., 2010). Papaya leaf contains effective antifungal agents and could be used as a bio based additive (Banos et al., 2002). The extracts of papaya leaf could therefore be incorporated into aloe gel to enhance

Plate 1. Disease development on artificial inoculation with post harvest pathogens on 24th day of storage

the effectiveness of the anti-fungal activity of aloegel matrix.

Cost of coating 100 kg mature green tomatoes with pure aloe and papaya leaf extract incorporated aloe based formulation were calculated to be INR 55.48/- and 45.87/- respectively proving the possibility of substitution of aloe gel with cheap papaya plant leaf extracts so as to reduce the cost of preparation of edible films without affecting their efficiency.

Based on comparative quality evaluation studies of edible coated mature green tomato fruits, dipping in 2% concentration of papaya leaf extract incorporated aloe gel (1:2) + potassium alginate for two minutes was selected as the efficient and economic edible coating recommended for maintaining quality of mature green tomatoes. The formulations had suppressed postharvest infection by *Erwinia* and *Rhizopus in vivo* and fruit rot symptoms were not observed on coated fruits up to 24 days of storage.

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