J Bangladesh Agril Univ 20(4): 449-457, 2022 https://doi.org/10.5455/JBAU.116964

ISSN 1810-3030 (Print) 2408-8684 (Online)

Journal of Bangladesh Agricultural University

Journal home page: http://baures.bau.edu.bd/jbau

Research Article

Effects of Aloe Vera Gel and Sodium Benzoate on Quality and Shelf Life of Tomato Varieties

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ARTICLE INFO

Article history
Received: 23 Sep 2022
Accepted: 06 Dec 2022
Published: 31 Dec 2022

Keywords
Tomato,
Aloe vera gel,
Sodium benzoate,
Edible coating,
Antioxidant,
Shelf life

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ABSTRACT

One of the most popular climacteric fruits, tomatoes contain numerous nutrients that are essential to human nutrition, including vitamins, minerals, lycopene, beta-carotene, and other bioactive substances. Due to a lack of appropriate processing technique, a large amount of postharvest loss is usually experienced every year as it is a highly perishable vegetable. This study aims to increase the shelf life and quality of three tomato varieties (BARI Tomato-8, BARI Tomato-10, and BARI Tomato-11). Firstly, chemical analysis (pH, TSS, titratable acidity) of prepared aloe vera gel (AVG) along with antioxidant properties was determined. Then three tomato varieties were coated with aloe vera gel (AVG), sodium benzoate (SB), the combination of aloe vera gel and sodium benzoate, and without any coating considered as control. Treated samples were then analyzed for pH, TSS, weight loss, titratable acidity, and antioxidative activities during storage. Treated samples (10% AVG, 3% SB solution, and 3% SB +10% AVG) showed a gradual increase in pH, TSS, weight loss, and a decrease in the titratable acidity as well induced antioxidative activities differently during storage in comparison with the control one. The antioxidant capacity was calculated up to 78.25% for 10% Aloe vera gel treated samples while aloe vera gel had 15.22% radical scavenging activity (RSA). In all tomato varieties, more than 50% DPPH radical inhibition had been observed for most of the treatment groups except 3% SB after 21 days of storage. Overall, 3% SB mixed with 10% AVG showed the best results among the four treatments.

Introduction

Bangladesh is mostly an agricultural economy. Vegetables of various varieties are grown across the country. One of the most significant edible & nutritious vegetable crops in Bangladesh is the tomato (*Solanumly copersicum L.*), a key horticulture crop (Fei et al., 2006; Lemaire-Chamley, 2005; Hajong et al., 2018). Tomato belongs to the family of Solanaceae, a self-crossing annual crop (Beckles et al., 2012; Bemer et al., 2012) that is native to western South America, Mexico, and Central America (Odanaka et al., 2002; Saliba-Colombani et al., 2001). Because of its high adaptability to a variety of soil and climatic conditions, it is grown in every backyard garden and the open fields of Bangladesh. Although tomatoes can be grown year-round, their prime growing season is from December to March (Karim et al., 2009). In our country, tomatoes grow well in Mymensing, Sherpur, Jamalpur, Rajshahi, ChapaiNawabganj, Panchagarh, Dinajpur, Barishal, Bhola, Bagerhat, Kustia, Chattogram, Comilla, Gopalganj, Kishoregonj, Rajbari, Shariatpur, Habiganj, Sylhet, etc. (BBS, 2020), and 388000 metric tons of tomatoes were yielded in 70000 acres of the area during 2018-2019 (BBS, 2020). Due to its savory flavor, the tomato is considered a vegetable in food preparation even though it is technically a berry, a subset of fruit (Barrero and Tanksley, 2004; Frary et al., 2004). They can be eaten raw or cooked, in a variety of cuisines, sauces, salads, and beverages. The numerous health-promoting chemicals found in tomatoes, such as vitamins, carotenoids, and phenolic compounds, substantially account for their nutritional worth (Tieman et al., 2017; Liu et al., 2018; Pesaresi et al., 2014). These bioactive constituents have diverse physiological aspects, including anti-allergenic, anti-inflammatory, antimicrobial, antithrombotic,

Cite This Article
Das, M., Akter, F., Islam, M.A., Alim, M.A. and Biswas, M. 2022. Effects of Aloe Vera Gel and Sodium Benzoate on Quality and Shelf Life of Tomato Varieties. *Journal of Bangladesh Agricultural University*, 20(4): 449-457. https://doi.org/10.5455/JBAU.116964

vasodilatory, cardio-protective, and antioxidant effects (Shima et al., 2013). The largest source of lycopene in the human diet comes from tomatoes, which are abundant in carotenoids (Viuda-Martos et al., 2014). The nutrient content of tomatoes is increased by carotenoids and polyphenolic substances, which also enhance its sensory properties such as flavor, aroma, and texture (Raiola et al., 2014; Tohge and Fernie, 2015; Tamasi et al., 2019). Additionally, tomatoes include vitamins C and E, which are organic antioxidants along with significant amounts of metabolites such as ascorbic acid, citrate, malate, sucrose, and hexoses (Li et al., 2019).

As tomato contains about 95% moisture content (Srivastava and Handa, 2005; Xiao et al., 2009) it is highly susceptible to damage after harvest. It cannot be preserved for an extended amount of time because it is perishable. The primary issue is therefore its post-harvest processing and marketing, which requires standardization through methodical experiments. However, as consumers become more and more conscious of the value of eating fruits and vegetables for maintaining good health, edible coating for whole and minimally processed fruits and vegetables is growing in favor. In Bangladesh, it's estimated that about 25 to 50 % of the total crop of fresh fruits and vegetables is lost due to post-harvest damage (Hossain et al., 2017). These kinds of freshly harvested ripe vegetables may typically only be kept in good condition for a short time in storage. (Raffo et al., 2018; Savvashe, 2010; Prajapati et al., 2011). Besides, due to improper handling and storage of fresh food products, postharvest losses are common. Due to their perishable nature, fruits and vegetables have a limited shelf life owing to both internal and extrinsic factors, including respiration rate, ethylene generation, and transpiration, as well as extrinsic factors like ambient conditions and preservation settings. Edible coatings appear to be one cutting-edge technique among the numerous accessible postharvest technologies that have been demonstrated to offer a favorable and secure approach to prolonging the shelf life of products (Bierhals et al., 2011; Forato et al., 2015; Dong and Wang, 2018). The term "edible coatings" refers to the thin layers of edible products that are placed on a product surface to stop the transfer of solutes, moisture, and oxygen from the food sample (Chien et al., 2007; El-Anany et al., 2009). Applying the edible coating may be done by dipping, spraying, or brushing (El-Ghaouth et al., 1992; Galusand Kadzińska, 2015). In essence, the primary goals of edible coating are to prevent weight loss and to provide a modified environment during storage and transit (Ganiari et al., 2017; Ali et al., 2011).

Aloe vera is a tropical and subtropical plant that thrives practically everywhere in the country. It has two major liquid sources: a clear gel and yellow latex. Aloe Vera gel is a colorless fluid produced by translucent parenchyma cells (Elbandy et al., 2014). Aloe vera gel is particularly good for oil forming, which results in a natural barrier to moisture and oxygen. It has antioxidant as well as anti-microbial action (Wariyah et al., 2022), which allows for the extension of shelf life. It includes a range of nutrients and bioactive substances that are good for people. Aloe vera gel has 75 nutrients and 200 active ingredients such as sugar, saponins, anthraquinones, vitamins, minerals, enzymes, salicylic acid, lignin, and amino acids. The gel also demonstrates defense against some harmful pathogens by preventing their growth. Another efficient preservative is sodium benzoate, mainly used for citrus fruits. Sodium benzoate is used to preserve several types of fruit juice. In terms of preserving physical, chemical, and enzymatic properties during storage, sodium benzoate has proven to be the most successful. (Kaur et al., 2019). Although a lot of information regarding the edible coating of fresh fruit and vegetables has already been published (Khaliq et al., 2015; Khorram et al., 2017; Jiang et al., 2013; Ali et al., 2010; Ali et al., 2013) research on the efficacy of aloe vera gel and sodium benzoate as an edible coating on the quality and shelf life of Bangladeshi tomato varieties are still not available. Considering the above standpoints, the present study was performed to assess the chemical constituents of aloe vera gel and to enquire about the effect of aloe vera gel and sodium benzoate on the quality and shelf life of tomato varieties.

Materials and Methods

The laboratory experiment was conducted at the laboratories of the Agro Product Processing Technology and Nutrition and Food Technology Departments at the Jashore University of Science and Technology. To conduct the experiments, the necessary materials and methods used are furnished. Tomato fruit samples of three varieties were collected from the Bangladesh Agricultural Research Institute of Jashore.

Preparation of aloe Vera Gel (AVG)

Aloe vera leaves for making aloe vera gel were harvested from our own field. The aloe vera leaves were washed with distilled water before removing the upper green layer by using a sharp knife. The colorless hydro parenchyma was ground in a blender for gel formation. The mixture was homogenized using a vortex mixture and finally obtained the liquid of the fresh aloe vera gel (AVG; 100%). It was then pasteurized at 70°C for 45 min (Misir et al., 2014). After that, the gel was kept at room temperature (approx. 21°C) for the cooling process.

Chemical characteristics of aloe vera gel (AVG)

A chemical analysis (pH, TSS, titratable acidity) of the aloe vera gel was carried out, with particular attention paid to the moisture content, which was assessed using the static gravimetric method (AOAC, 1990), and the total phenol on the extract, which was calculated using the Folin-Ciocalteu method based on the gallic acid equivalent (GAE), and the flavonoid, which was determined using the colorimetric method based on the quercetin equivalent (Ling et al., 2019).

Preparation of Sodium Benzoate solution

The Sodium Benzoate solution was prepared at 2% and 3% concentrations. For 2% concentration, 2 g of Sodium Benzoate powder was dissolved in 100 ml of distilled water, while for 3% concentration, 3 g of Sodium Benzoate powder was dissolved in 100 ml of distilled water.

Experimental design

This experiment was conducted in a completely randomized design. Ninety fruits of the almost same size as tomato fruits of 3 varieties were gathered from the Horticulture Division, Bangladesh Agricultural Research Institute, Jashore. Fruits of each variety were divided into 5 groups and altogether 15 groups for 3 varieties. Each group consists of 6 tomato fruits.

Treatments

There were four treatments in the experiment as follows; Control (washing with distilled water), 10% Aloe vera gel (AVG), 3% Sodium Benzoate (SB) solution, and 3% SB +10% AVG mixture.

Application of the edible coating (AVG and SB) solutions

The fresh tomato fruits were dipped and rotated for 5 minutes in the AVG and SB coating solutions at room temperature to increase the coating efficiency. They were allowed to dry for 2 min at room temperature under a fan to increase the drying rate. After the application of coating solutions, the initial weights of the coated fruits were taken. One set of six (6) fruits was taken for coating each treatment. For each variety, one set of six (6) uncoated fruits was used as control. The fruits were stored in different trays at room temperature (21 ± 3°C) and at 70-75% RH during the whole period of the study.

Determination of pH of aloe vera gel and treated samples

Tomato fruits were cut into small pieces with a knife and blended with an electric blender for 1-2 minutes. Then, 10ml of the tomato juice was shifted into a beaker and the pH of the tomato was measured by using the pH meter (Ibitoy, 2005). However, according to a similar method, the pH of prepared aloe vera gel was also determined.

Determination of Total soluble solids concentration (TSS) of aloe vera gel and treated samples

TSS of the tomato juice obtained in section 2.6 for each replication was determined at 19°C using a digital refractometer. The results were presented in ^{0}Brix. Besides, following a similar technique, the TSS of prepared aloe vera gel was determined.

Determination of titrable acidity of aloe vera gel and treated samples

The tomato fruits were ground for making homogeneity. Ten grams of blended sample was mixed with 100 ml of distilled water. Following this, a 10 ml aliquot was transferred into a beaker for clear endpoint detection. Then, two drops of phenolphthalein indicator and 0.1N NaOH was added drop wise, and the solution was titrated thoroughly until a pink color was obtained.

The acid content of the tomato sample was calculated using the formula elaborated by Gharezi et al. (2012).

$$\% \text{ T.A.} = \frac{V \times M \times N \times F \times 100}{\text{Volume of tomato juice}}$$

Where V = volume of 0.1N NaOH used, M = molarity of NaOH, and F = factor of citric acid (0.0064)

A similar method had been applied for the determination of the titrable acidity of prepared aloe vera gel.

Percentage of weight loss of treated samples

Initial weight and weight at the subsequent intervals were measured to calculate the percentage of weight loss of the coated tomatoes following the standard method by AOAC (1995). The weight of the coated tomatoes was measured at 7 days, 15 days, and 21 days intervals. The following formula was applied to find out the percentage of weight loss-

$$\% \text{ weight loss} = \frac{(\text{Initial weight - Final weight})}{\text{Initial weight}} \times 100$$

Estimation of 2,2-diphenyl-1-picrylhydrazyl radical-scavenging activity of aloe vera gel and treated samples

The 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical-scavenging activities (RSA) of the extracts were determined according to the method described by Wojdylo et al.(2007) with some modifications. In brief, 150 µl of the tomato extract was mixed with 3ml of the DPPH solution in 99% methanol. After thorough shaking, the mixture was incubated at room temperature in the dark for 30 min and the absorbance

was then measured at 515 nm. The DPPH radical scavenging activity was expressed in inhibition percentage. All samples were analyzed in triplicates.

The percentage inhibition of DPPH of the test sample and calculated by the following formula:

$$\% \text{ Inhibition} = \frac{A_c - A_s}{A_c} \times 100$$

Where A_c was the control absorbance, A_s was the sample absorbance at 515 nm, obtained by measuring the same volume of solvent. Methanol (99%) was used as a blank. Results were expressed as inhibition percentages. Besides, following a similar method, radical scavenging activity (RSA) of prepared aloe vera gel was also determined.

Visual observation of tomatoes

The tomatoes were stored at 20° to 23°C and 75-80% relative humidity (RH) up to 21 days. The different parameters such as color, flavor, texture, overall appearance was observed.

Statistical analysis

All experiments were performed in triplicate. Statistical analyses were made using SPSS 22.0 (IBM SPSS Inc., Chicago, IL, USA) software. Duncan's multiple range tests were used and the levels were considered significantly different at $p \leq 0.05$.

Results and Discussion

Aloe vera gel was analyzed for chemical properties. However, treated samples (Control, washing with distilled water, 10% Aloe vera gel (AVG), 3% Sodium Benzoate (SB) solution, and 3% SB +10% AVG mixtures) were analyzed for pH, TSS, titratable acidity, weight loss, and antioxidative activities during storage. The results obtained in the study are presented in Table to Table 6.

Chemical analysis of aloe vera gel (AVG)

Results in our study revealed that the aloe vera gel's moisture content was 97.80% (Table 1), which is comparable to the 99.07% reported by Wariyah et al. (2022). pH, TSS, and titratable acidity were 4.90, 0.192, and 1.80, respectively. The values were close to the value found by Ahmed and Hussain (2013). The concentration of phenolic compound and flavonoid was 370.50 mg GAE/g extract and 18.42 mg/g extract, respectively which were close to the findings obtained by Wariyah et al. (2022). Additionally, according to the RSA value, aloe vera gel had an antioxidant activity of 15.22% whereas Wariyah et al. (2022) obtained a value of 15.73%. The variations may be due to the variety of aloe vera leaves.

Table 1. Chemical analysis of aloe vera gel (AVG)

Composition	Number
Moisture (%)	97.80± 0.22
pH	4.90± 0.11
Acidity	0.192± 0.01
TSS	1.80± 0.01
Phenolic compound (mg GAE/g extract)	370.50 ± 40.35
Flavonoid (mg/g extract)	18.42 ± 1.01
Radical scavenging activity (RSA) %	15.22± 0.25

Note: Mean ± SD, the mean is the average of three replicates for each analysis.

Effects of aloe vera gel and sodium benzoate on tomato varieties

pH of tomato fruits

pH is an important property that determines microbial growth and other biochemical changes in fruits and vegetables during storage. Before the application of aloe vera gel and sodium benzoate treatment, the pH was 4.68, 4.60, and 4.67 for BARI Tomato-8, BARI Tomato-10, and BARI Tomato-11, respectively. In the present study, an increasing trend in the pH of three varieties of tomato fruit was observed during the time of storage (Table 2). There was significant variation ($p \leq 0.05$) in the pH values of BARI tomato-10 with BARI tomato-8 and 11, and the highest pH was recorded in the control (4.73-4.83) while the lowest in 3% SB+10% AVG (4.18-4.23) after 21 days of storage. The results are quite similar to the findings obtained by Ahmed et al. (2016). It is clear from table 1 that pH values increased significantly ($p \leq 0.05$) during the storage time for all three controlled varieties of tomato. However, other treated varieties especially the treatment where3% SB mixed with 10% AVG was applied, did not increase (pH values) significantly ($p \geq 0.05$). The increase in pH values in the stored tomato fruits might be due to the ripening process and loss of organic acid through oxidation in uncoated tomato fruits observed by Campestre et al. (2002). In addition, acidity minimization i.e., increase in pH was related to the maturity and ripening in the uncoated tomato fruits (Raje et al., 1997). As aloe vera gel has antioxidant properties, it helped to reduce oxidation and slow down the ripening process and loss of organic acid. Moreover, microorganism consumes considerable amounts of acid as a source of carbon for their metabolism, which in turn increase the pH value (Carrillo et al., 1995).

Table 2. pH at the regular interval before and after application of aloe vera gel (AVG) and sodium benzoate(SB) in tomato fruits

Tomato variety	Aloe vera Gel (AVG) and Sodium Benzoate (SB)	pH at regular intervals after the application of AVG and SB			
		0 days	7 days	15 days	21 days
BARI Tomato-8	Control(Distilled water)	4.68^{Aa}± 0.01	4.71^{Ab}± 0.01	4.76^{Ac}± 0.03	4.83^{Ad}± 0.03
	10% AVG	4.33^{Ab}± 0.04	4.35^{Ab}± 0.05	4.37^{Ab}±0.02	4.39^{Ab}±0.15
	3% SB	4.26^{Ab}±0.11	4.28^{Ab}±0.15	4.30^{Ab}±0.01	4.38^{Aa}± 0.12
	3% SB+10% AVG	4.16^{Aa}± 0.02	4.18^{Aa}± 0.02	4.20^{Aa}±0.15	4.22^{Aa}±0.05
BARI Tomato-10	Control(Distilled water)	4.60^{Bd}± 0.10	4.64^{Bc}± 0.15	4.69^{Bb}± 0.01	4.73^{Ba}±0.02
	10% AVG	4.29^{Ba}± 0.01	4.31^{Ba}± 0.01	4.33^{Ba}±0.03	4.35^{Ba}± 0.01
	3% SB	4.21^{Ba}± 0.13	4.22^{Ba}± 0.03	4.23^{Aa}± 0.12	4.25^{Ba}± 0.15
	3% SB+10% AVG	4.12^{Bb}± 0.05	4.14^{Bb}± 0.05	4.15^{Bb}± 0.01	4.18^{Bb}±0.05
BARI Tomato-11	Control (Distilled water)	4.67^{Aa}±0.05	4.70^{Ab}±0.15	4.75^{Ac}±0.05	4.79^{Cd}± 0.05
	10% AVG	4.32^{Ac}±0.02	4.34^{Ac}±0.02	4.31^{Cc}± 0.01	4.35^{Bd}±0.02
	3% SB	4.26^{Ab}± 0.01	4.28^{Ab}± 0.03	4.30^{Bb}± 0.03	4.38^{Ad}± 0.05
	3% SB+10% AVG	4.16^{Ab}± 0.05	4.18^{Ab}± 0.03	4.21^{Ab}±0.01	4.23^{Ab}±0.03

Note: Mean ± SD, the mean is the average of three replicates for each analysis. Different Uppercase letters indicate differences (p≤0.05) among varieties on the same day, and different lowercase letters indicate differences (p≤0.05) of means among storage days within the same treatment. AVG = Aloe vera gel, SB = sodium benzoate, BARI = Bangladesh Agricultural Research Institute.

Total soluble solids

Initially, the total soluble solids (TSS) of BARI Tomato-8, BARI Tomato-10, and BARI Tomato-11 ranged between 4.10°Brix, 4.17Brix, and 4.18°Brix, respectively. Table 3 shows that after 21 days of storage, the TSS was the highest in control (4.46°Brix) of BARI Tomato-8 fruits, which was the lowest in-sample treated with 3% SB (4.36°Brix). For BARI Tomato-10, the highest TSS was recorded in the sample treated with 3%SB+10%AVG (4.71°Brix) and the lowest in the control sample (4.61°Brix) after 21 days of storage. In the case of BARI Tomato-11, the highest TSS was recorded in control (4.79°Brix) while the lowest was in 3%SB+10%AVG (4.68°Brix) after 21 days of storage. It was also observed that the TSS content of all three varieties was found to increase considerably during storage in all treatments. Moreover, significant differences exist among the treatment irrespective of storage periods and tomato varieties. The increase in TSS content of all three varieties of tomato fruits during the storage period might be the conversion of carbohydrate and pectic substances into soluble solids, soluble pectin, and soluble organic acids (Campestre et al., 2002) that are usually related to the fruit maturity. In the gel-coated tomato fruits, the conversion rate of soluble mono and disaccharides into organic acids is faster than the conversion of decreasing trend in TSS. This might be due to microbial activity. These results agreed with the findings of Manzano et al. (1997).

Table 3. Total Soluble Solid (TSS) at the regular interval before and after application of aloe vera gel

Tomato variety	Treatment	TSS at regular intervals after application of AVG and SB			
		0 days	7 days	15 days	21 days
BARI Tomato-8	Control	4.10^{Aa}± 0.05	4.20^{Ad}± 0.15	4.33^{Ab}± 0.03	4.46^{Ac} ± 0.03
	10% AVG	4.09^{Aa}±0.13	4.18^{Ab}±0.03	4.30^{Ac}± 0.02	4.41^{Ad}±0.12
	3% SB	4.03^{Ac}± 0.05	4.13^{Ab}± 0.02	4.21^{Aa}± 0.15	4.36^{Ad}±0.12
	3% SB+10% AVG	4.09^{Aa}±0.01	4.19^{Ab}±0.01	4.31^{Ac}±0.03	4.43^{Ad}±0.05
BARI Tomato-10	Control	4.17^{Bb}± 0.05	4.31^{Bc}± 0.15	4.43^{Ba}± 0.05	4.61^{Bd}±0.15
	10% AVG	4.31^{Bb}± 0.04	4.42^{Bc}± 0.02	4.54^{Ba}± 0.01	4.66^{Bd}± 0.05
	3% SB	4.25^{Bb}± 0.05	4.36^{Bc}± 0.03	4.48^{Ba}±0.15	4.65^{Bd}± 0.12
	3% SB+10% AVG	4.43^{Ba}± 0.01	4.52^{Bb}± 0.02	4.60^{Bc}± 0.03	4.71^{Bd}± 0.01
BARI Tomato-11	Control	4.18^{Ba}± 0.15	4.33^{Bb}± 0.15	4.66^{Cc}± 0.12	4.79^{Cd}± 0.15
	10% AVG	4.25^{Ca}± 0.05	4.48^{Cb}± 0.03	4.67^{Cc}± 0.05	4.77^{Cd}± 0.15
	3% SB	4.29^{Ca}±0.11	4.39^{Bb}±0.12	4.62^{Cc}± 0.01	4.75^{Cd}± 0.03
	3% SB+10% AVG	4.15^{Cb}± 0.10	4.25^{Cc}± 0.15	4.51^{Cd}±0.02	4.68^{Ba}± 0.05

Note: Mean ± SD, the mean is the average of three replicates for each analysis. Different uppercase letters indicate differences (p≤0.05) among varieties on the same day, and different lowercase letters indicate differences (p≤0.05) of means among storage days within the same treatment. AVG = Aloe vera gel, SB = sodium benzoate, BARI = Bangladesh Agricultural Research Institute.

Titratable acidity

It was found that the titratable acidity (TA) decreased with the extension of storage time (Table 4). There were significant differences (p≤0.05) in TA among different varieties (Table 4). For BARI Tomato-8, the highest TA was found in untreated fruits at 0.576% and 0.091% on the 1st and 21st day of storage, respectively, while changes of titratable acidity (TA) were the lowest

for 3% SB+10% AVG treated one (0.267% and 0.261% on the 1st and 21st day of storage). Similar trends were observed in the case of BARI Tomato-10 and BARI Tomato-11 (Table 4). For BARI Tomato-10, the highest TA was found in untreated fruits at 0.497% and 0.062% on the 1st and 21st day of storage, respectively, whereas the lowest changes of TA were observed in 3% SB+10% AVG. On the other hand, BARI Tomato-11 recorded the highest TA in untreated fruits as 0.407% to 0.068% on the 1st and 21st day of storage, respectively. Although titratable acidity decreased competing with the storage period, there was no significant difference (p≥0.05) at all except in the control one. This was mainly a result of delaying the ripening process caused by the coating of aloe vera gel and sodium benzoate treatment. It is evidenced that aloe vera gel and sodium benzoate edible coating can modify the internal atmospheric conditions resulting in reduced respiration and transpiration rate of coated tomato fruits that could have slowly decreased the acid content (Gonzalez-Aguilar et al.,1999).

Table 4. Titratable Acidity (TA) at the regular interval before and after application of aloe vera gel (AVG) and sodium benzoate (SB) in tomato fruits

Tomato variety	Treatment	TA at regular intervals after application of AVG & SB			
		0 days	7 days	15 days	21 days
BARI Tomato-8	Contr	0.576^{Aa}± 0.15	0.166^{Aa}± 0.15	0.166^{Aa}± 0.15	0.091^{Aa}± 0.01
	10%AVG	0.357^{Aa}± 0.02	0.356^{Aa}± 0.02	0.356^{Aa}± 0.02	0.324^{Aa}± 0.15
	3%SB	0.348^{Aa}± 0.15	0.347^{Aa}± 0.15	0.347^{Aa}± 0.15	0.299^{Aa}± 0.15
	3%SB+10%AVG	0.267^{Aa}± 0.15	0.267^{Aa}± 0.15	0.267^{Aa}± 0.15	0.261^{Aa}± 0.12
BARI Tomato-10	Control	0.497^{Ba}± 0.03	0.151^{Ba}± 0.03	0.151^{Ba}± 0.03	0.062^{Bc}± 0.02
	10%AVG	0.251^{Bb} ± 0.13	0.249^{Bb} ± 0.13	0.249^{Bb} ± 0.13	0.186^{Bb}±0.03
	3%SB	0.387^{Ba}± 0.02	0.385^{Ba}± 0.02	0.385^{Ba}± 0.02	0.275^{Bb}± 0.15
	3%SB+10%AVG	0.256^{Ba}± 0.01	0.256^{Ba}± 0.02	0.256^{Ba}± 0.02	0.250^{Bb}± 0.05
BARI Tomato-11	Control	0.407^{Ca}± 0.15	0.156^{Ba}± 0.15	0.156^{Ba}± 0.15	0.068^{Bb}± 0.15
	10%AVG	0.238^{Cb} ±0.15	0.237^{Cb} ±0.05	0.237^{Cb} ±0.05	0.150^{Cc}± 0.03
	3%SB	0.354^{Ca}±0.13	0.354^{Ca}±0.03	0.354^{Ca}±0.03	0.269^{Cc}± 0.12
	3%SB+10%AVG	0.275^{Ca}± 0.15	0.275^{Ca}± 0.15	0.275^{Ca}± 0.15	0.254^{Cc}± 0.02

Note: Mean ± SD, the mean is the average of three replicates for each analysis. Different upercase letters indicate differences (p≤0.05) among varieties on the same day, and different lowercase letters indicate differences (p≤0.05) in means among storage days within the same treatment. AVG = Aloe vera gel, SB = sodium benzoate, BARI = Bangladesh Agricultural Research Institute.

Weight loss (%)

There was a rapid increase in the weight loss percentage of three varieties during the storage (Table 5). In the case of BARI Tomato-8, the highest weight loss percentage was recorded at 10% AVG (0.69%) whereas the lowest in 3%SB+10%AVG 0.53%) after 7 days of storage, which was found to increase gradually up to 21 days of storage and ranged between 1.03 and 1.75% (Table 5). For BARI Tomato-10, it was found that the weight loss was the highest in control from the 7 to 21 days of storage, which ranged from 1.14% to 2.44% while the lowest being in 3% SB+10% AVG (ranging from 0.51% to 1.39% after 7 to 21 days of storage). In the case of BARI Tomato-11, the highest loss after 7 days of storage was observed in tomato fruit treated with 10% AVG (0.68%) and the lowest in the treatment of 3% SB+10% AVG (0.32%), which become the highest in control (2.41%) and the lowest in 3% SB+10% AVG (1.29%) after 21 days of storage. Ahmed et al. (2016) observed weight loss of tomatoes at different storage conditions of 3 to 5% after 21 days of storage period. It was clear from the study that the control sample lost the maximum weight with the extension of the storage period. However, the application of aloe vera gel and sodium benzoate has some effect on the reduction of weight loss of tomato during storage, which might be due to the coating layers of aloe vera gel and the effect of sodium benzoate to reduce microbial damage that significantly reduced the respiration rate i.e., minimum weight loss occurred (Salunkhe et al., 1974).

Antioxidant activity

Result illustrates the total antioxidant activity of selected tomato varieties based on the DPPH free radicals scavenging activity expressed as the percentage inhibition (Table 6). The antioxidant activity of fruits and vegetables denotes the strength to fight against the oxidation process by trapping the free radicals (Kamal et al.,2019). The fresh tomato fruits exhibited DPPH radical inhibition by 67.94%, 68.52%, and 68.08% for BARI Tomato-8, BARI Tomato-10, and BARI Tomato-11, respectively. All tomato varieties showed a decreasing trend of DPPH radical scavenging activity in all treatments after 21 days of storage, except 10% AVG, and 3%SB + 10%AVG, where the DPPH scavenging activity was found to increase. That means 10% aloe Vera gel, and 3%SB + 10%AVG coated tomato fruits can scavenge more free radicals compared to other treatment groups applied to the tomato fruits. More than 50% DPPH radical inhibition has been observed for

most of the treatment groups except 3% SB after 21 days of storage in all tomato fruit varieties. From the study, it can be claimed that aloe vera gel can protect from antioxidant loss in tomato fruits by creating a thin layer on the fruit surface. The antioxidant capacity of tomato fruits depends mainly on different bioactive compounds e.g., total phenolic, ascorbic acid, carotenoids, flavonoids, and so on (Kamal et al., 2019).

Table 5. Weight Loss Percentage (WLP) at the regular interval after application of aloe vera gel (AVG) and sodium benzoate (SB) in tomato fruits

Tomato variety	Tratment	WLP at regular intervals after application of AVG and SB		
		7 days	15 days	21days
BARI Tomato-8	Control	0.60^{b}± 0.001	1.14^{c}± 0.001	1.75^{b}±0.005
	10%AVG	0.69^{b}± 0.003	0.99^{a}± 0.002	1.41^{a}±0.002
	3%SB	0.54^{b}± 0.005	0.69^{b}± 0.005	1.38^{b}± 0.011
	3%SB+10%AVG	0.53^{b}± 0.011	0.60^{b}± 0.001	1.03^{c}± 0.002
BARI Tomato-10	Control	1.14^{a}± 0.002	0.66^{a}±0.002	2.44^{a}± 0.003
	10%AVG	0.75^{a}± 0.001	0.74^{b}±0.005	1.51^{a}± 0.001
	3%SB	0.62^{a}± 0.002	0.79^{a}± 0.011	1.47^{a}± 0.005
	3%SB+10%AVG	0.51^{c}± 0.012	0.73^{b}±0.002	1.39^{b}± 0.002
BARI Tomato-11	Control	0.62^{b}± 0.001	1.42^{b}± 0.001	2.41^{a}± 0.015
	10%AVG	0.68^{b}± 0.004	0.79^{b}± 0.003	1.46^{a}± 0.002
	3%SB	0.62^{a}± 0.003	0.88^{a}±0.002	1.62^{a}± 0.005
	3%SB+10%AVG	0.32^{c}± 0.001	0.64^{b}± 0.001	1.29^{b}± 0.001

Note: Mean ± SD, the mean is the average of three replicates for each analysis. Different lowercase letters indicate differences (p≤0.05) in means among storage days within the same treatment. AVG = Aloe vera gel, SB = sodium benzoate, BARI = Bangladesh Agricultural Research Institute.

Table 6. Antioxidant Activity (% inhibition of DPPH*) of tomato fruits of different varieties after applications of Aloe vera gel (AVG) and Sodium-benzoate (SB) at 21th day

Tomato variety	At 0 day	After 21 days of storage			
		Control	10% AVG	3% SB	3% SB + 10% AVG
BARI Tomato-8	67.94^{Aa}± 0.10	46.95^{Ba}± 0.15	72.14^{Ca}± 0.25	26.95^{Da}± 0.35	68.14^{Aa}± 0.10
BARI Tomato-10	68.52^{Aa}± 0.15	56.56^{Bb}± 0.15	78.25^{Cb}± 0.35	25.86^{Db}± 0.15	70.25^{Ab}± 0.15
BARI Tomato-11	68.08^{Aa}± 0.25	50.12^{Bc}± 0.15	78.04^{Cb}± 0.50	25.05^{Db}± 0.25	72.45^{Eb}± 0.25

Note: Mean ± SD, the mean is the average of three replicates for each analysis. Different uppercase letters indicate differences (p≤0.05) among storage days with different treatments and different lowercase letters indicate differences (p≤0.05) in varieties on the same day with the same treatment. AVG = Aloe vera gel, SB = sodium benzoate, BARI = Bangladesh Agricultural Research Institute.

Overall appearance of fruits

The overall appearance of Aloe Vera3% SB + 10% AVG coated tomato fruits stored at 20° to 23°C and 75-80% relative humidity (RH) were found well after 21 days of storage, which retained better bright green color than the uncoated fruits. This implies that ripening has been delayed in the coated tomato fruits. In contrast, 3% SB coated fruits were slightly soft at the end of the storage whereas control fruits damaged. During storage period the flavor was satisfactory in AVG coated tomato fruits. Also 3% SB+10% AVG coated tomatoes cooked shiny and attractive, and did not produce any bad odor or off-flavor. Overall, 3% SB mixed with 10% AVG showed the best results among the four treatments. Control tomatoes showed severe symptoms of dehydration and spoilage during storage periods, which might be due to high respiration rate.

Conclusion

Aloe vera gel and sodium benzoate showed higher total phenolic content and antioxidant activity than the control in all varieties. The study results revealed that 3%SB mixed with 10% AVG showed the best performance in extending the shelf life up to 21 days. Therefore, this study concluded that the incorporation of anti-microbial compounds, such as Aloe vera gel and Sodium benzoate as edible films or coatings provides a better way to expand the safety and shelf-life of tomato fruits, which could save the extra cost for their preservation and improve the commercial value of tomato fruits.

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