American Journal of Bioscience and Bioengineering
2025, Vol. 13, No. 4, pp. 64-76
https://doi.org/10.11648/j.bio.20251304.11

Research Article

Effect of Chlorination and Aloe Gel on Chemical Attributes of Tomato (*Solanum lycopersicum* L.) Fruits Stored in Horticulture Laboratory of Haramaya University, Ethiopia

Girma Gutema[1,*], Tewodros Bezu[2], Fikreyohannes Gedamu[2]

[1]Department of Horticulture, Faculty of Agriculture, Wallaga University Shambu Campus, Shambu, Ethiopia

[2]Department of Plant Sciences, College of Agriculture and Environmental Sciences, Haramaya University, Haramaya, Ethiopia

Abstract

Post-harvest loss is the most challenging obstacle, which decreases the amount and quality of tomato fruits intended for consumption in Ethiopia. A study was aimed to see the impact of Sodium hypochlorite (NaOCl) and Aloe Gel (AG) on some chemical qualities of tomato fruits at ambient condition. The shanty PM tomato fruits harvested at turning stage were used as experimental material. The treatment was arranged as a factorial experiment using a completely randomized design with three replications, and data were analyzed using SAS statistical software. The treatments comprised of four rates of NaOCl (0 ppm, 100 ppm, 200 ppm, and 300 ppm) and five levels of AG (0%, 25%, 50%, 75%, and 100%). The result of the study indicated that the treatments have significantly ($p \leq 0.01$) maintained the titratable acidity (TA) and ascorbic acid. Fruit samples treated with 200-ppm NaOCl +100% AG displayed the highest value of fruit titratable acidity (0.34%), minimum value of fruit TSS to TA ratio (as low as 15.0) at the end of storage period. Ascorbic acid content was significantly maintained at higher level (14.63) by use of 300 NaOCl + 75 AG. While the total soluble solid (TSS) was significantly affected by the interaction of the treatments only at the 12th and 20th day, the interaction of the treatments did not show any significant effect on the pH of the fruits during the storage period. Based on cost and benefit analysis of the treatments from the present experiment, the combination of NaOCl and AG treatment, i.e. 200 ppm NaOCl + 100% AG could be suggested for maintaining the quality attributes like TA and TSS to TA of the stored fruits. Beside this, 300 NaOCl + 75% AG treatment could be used in keeping ascorbic acid at normal level. However, to reach at conclusive recommendation further experiments that consider different tomato varieties, maturity stages and postharvest treatments are recommended.

Keywords

Coating, Disinfection, Postharvest, Storage, Sodium Hypochlorite

*Corresponding author: girmag100@gmail.com (Girma Gutema)

Received: 28 July 2025; **Accepted:** 8 August 2025; **Published:** 26 August 2025

1. Introduction

Tomato (*Solanum lycopersicum L.*) is highly marketed and the second most significant crop after potato, with an annual yield of approximately 163 million tons [1]. Tomato is an excellent source of proteins, essential amino acids, fiber, vitamins, minerals, and mono-unsaturated fatty acids. In addition, tomatoes are also high in secondary metabolites (lycopene, carotenoids, phenols, chlorophyll, phenols, flavonoids, and organic acids), which have been linked to protect humans from chronic degenerative diseases like cancer, cardiovascular disease, and neurological disorders [2, 3]. However, most of these important nutrients like vitamins, sugars, and organic acids in tomato fruits are lost quickly unless they are preserved with pre-storage treatments immediately after harvest.

Tomato is cultivated as a crop with a high yield and a comparatively short growing season in Ethiopia. The total area used for tomato production grew from 5,235.42 hectares in 2018 to 6,433.73 hectares in 2021, and the yield increased to 41,948.27 tonnes in 2021, with an average national yield of 6.52 tonnes ha-1 year, according to CSA report [4, 5]. However, the production of this valuable crop is limited by post-harvest harvest quality and quantity loss in the country. Significant postharvest quality losses of tomatoes, ranging from 2.5 to 45.3%, have been reported in a number of studies carried out throughout Ethiopia [6-9]. As the major causes of these losses, improper harvesting time and method; poor post-harvest handling and pre-storage treatment as well as damage by microorganisms and insect pests are reported by researchers [10, 11].

Therefore, exploring an alternative solution for reducing post-harvest loss of the chemical attributes of such valuable crop is very important in this regard. Sodium hypochlorite and aloe gel are among the possible pre-storage treatments by which the loss can be minimized [12, 13]. Ease of application, effective removal of pesticides and foreign substances, flexibility of application, broad bactericidal activity, and low cost are some of the benefits of treatment with sodium hypochlorite [14]. However, the quantity of freely accessible chlorine in the water that encounters the organism cells determines the suppressive or killing action of chlorine solution [15]. Optimizing its concentration for particular crop is therefore crucial in such condition.

Aloe *gel* is the mucilaginous gel obtained from the squeezing of the clear jelly-like substance of the parenchyma tissue of aloe plant leaves and is renowned for its antibacterial and antioxidant properties, which also contribute to the preservation of fruits. The antioxidant and antimicrobial properties of the plant is due to the presence of bioactive compounds such as aloin, aloetic acid, aloe- emodin, anthranol, isobarbaloin, barbaloin, ester of cinnamic acid, and emodin. These compounds can make it a best edible coating for effectively maintaining the shelf life and quality of stored fruit crops [16-18]. So far, several research activities have been conducted to see the effect of AG and NaOCl on chemical attributes of tomato fruits [19-21]. However, the concept that focuses on investigating the effect of the combined AG and NaOCl has not given consideration by researchers. Therefore, the aim of the current research was to investigate the combined impact of sodium hypochlorite and aloe gel treatments on some chemical attributes of tomato fruits stored under ambient condition.

2. Materials and Methods

2.1. Description of Study Area

The tomato was grown at the Tony Farm research site of Haramaya University located in Dire Dawa administration in 2021. The laboratory experiment was then conducted at Haramaya University, Horticulture laboratory from October 16 to November 14, 2021. The area receives an average annual rainfall of 760 mm [22]. The average minimum and maximum temperatures of the storage room were 17.53°C and 24.85°C with air relative humidity of 74.04%.

2.2. Experimental Material

A fruit of tomato variety shanty PM was used as experimental material. Shanty is a commercial hybrid variety with a semi-determinate growth pattern, high yielding, powdery mildew resistance characteristics [23]. It was introduced to Ethiopia by Hazera genetics LTD (Greenline PLC) in 2009 and became a widely grown tomato variety in eastern Ethiopia.

2.3. Treatments and Experimental Design

The experiment consisted of four concentration levels of NaOCl (0 ppm 100 ppm, 200 ppm, and 300 ppm) and five AG levels (0%, 25%, 50%, 75%, and 100%). The experiment was arranged as a 4 x 5 factorial with 20 treatment combinations using a completely randomized design with three replications. The durations for NaOCl dipping and AG coating of the fruits were five (5) minutes [24] and two (2) minutes [25] respectively.

2.4. Experimental Procedures

2.4.1. Production of Tomato Fruits

Tomato seedlings were purchased from Roshanara Roses commercial vegetable nursery located in Debrezeit. The tomato seedlings were transplanted at 100 cm between rows and 30 cm between plants on 600 m^2 of well-prepared land (15 x 40 m) as per the recommendation of [26]. There were 40 rows in total, with 50 plants on each row. A total of 2000 seedlings were planted. NPS (19% N, 38% P_2O_5, and 7% S) and Urea (46%N) were applied to the field at rates of 200 kg ha^{-1} and 150 kg ha^{-1}, respectively, during the transplanting [27]. The experimental area received a combined dose of NPS and half of Urea during planting, with the remaining Urea applied at early flowering stage. During the growing season, other agronomic activities, including irrigation, weeding, cultivation as well as disease and pest management were applied uniformly to the entire experimental area as per the requirement of the plants.

2.4.2. Preparation of Postharvest Treatments

Healthy aloe (Aloe pubescence) plant leaves were collected from the Haramaya area. The aloe gel was then prepared by following the procedure described by [25]. The tapering point of the leaf top and the short sharp spines located along the leaf margins were removed and then the knife was introduced into the mucilage layer below the green rind to separate the gel. The extracted gel was then filtered and pasteurized at 70 ºC for 45 minutes and stored in clean, sterilized glass bottles in a refrigerator at an average temperature of 6 ºC. The obtained liquid was 100% gel and was considered fresh aloe gel. Then the 25%, 50%, and 75% gel concentrations were obtained by diluting 25, 50, and 75 milliliters of the pure (100%) AG in 75, 50, and 25 milliliters of sterile distilled water, respectively. Sodium hypochlorite (NaOCl) solution or chlorine bleach (5%) was purchased and each concentration was prepared based on the percent active ingredient of the NaOCl as described by [28]. Accordingly, each of 20ml, 40ml and 60ml of 5% NaOCl was diluted in 10 liters of distilled water to prepare a solution with a 100 ppm, 200 ppm and 300 ppm concentration of chlorine, respectively. The pH of the chlorine solution was between 6.5 and 7.

2.4.3. Fruit Sample Preparation

Tomato fruits at turning maturity stage were harvested from middle rows, all directions and in the middle of the tomato vines. The fruits were immediately transported to the horticulture laboratory of Haramaya University. The fruits were then sorted and precooled to reduce field heat, soil particles and microbial population. 21 fruits of the prepared samples encompassing 1260 fruits were used for each post-harvest treatment per replication. Tomato fruits selected for chemical analysis were stored in the open space of the horticulture laboratory on a table at an ambient average temperature and relative humidity. A digital psychrometer (Model: ALNOR® 8612 SN03057107, Germany) were used for measuring air temperature and relative humidity of the storage laboratory room throughout the storage period.

2.5. Data Collection

Twenty-one (21) tomato fruit samples subjected to different levels of NaOCl and AG treatments in each experimental plot were used in the experiment. The data were collected every four-day intervals starting on the first day (day zero) of storage. At each interval, two fruits were taken and crushed to determine its chemical qualities like pH, total soluble solids, titratable acidity, total soluble solids to acid ratio and ascorbic acid content.

2.6. Chemical Analysis

2.6.1. pH

The pH of the crushed fruits was measured following the procedures described by [29] using a digital pH meter (model-ME 962P). Accordingly, the pH meter was first calibrated using a buffer solution of pH 4.0, 7.0, and 9.2 at room temperature. The sample was then taken in a 50 ml beaker, stirred, an electrode of a pH meter was put in it, and a direct reading from the pH meter was taken when the reading stabilized. The electrode of pH meter was washed with distilled water and rinsed with tissue paper between each sample tests.

2.6.2. Total Soluble Solids (°Brix)

Total soluble solids were determined by using the methods described by [30]. The digital hand refractometer (Model-ATAGO® PR-32α) with a range of 0 to 32 °Brix, and a resolution of 0.2 °Brix was used. The refractometer was standardized against distilled water (0 percent TSS). Two drops of clear juice were placed on the prism of a refractometer at room temperature. The readings were then recorded as °Brix. Between samples, the prism of the refractometer was rinsed with distilled water and dried before use.

2.6.3. Titratable Acidity (%)

It was estimated by the acid-alkaline titration method as described in [31]. About 10 g of homogenized fruit pulp was taken into a 100 ml beaker and the volume was made up to the mark with 50ml distilled water. It was thoroughly mixed and then filtered with muslin cloth. 10 ml of filtered sample was titrated against 0.1 N NaOH (Sodium hydroxide) using three drops of 1% phenolphthalein solution as an indicator. The observed titre value was used to calculate the acidity using the formula indicated below, and the results were expressed as the percentage of citric acid as it is the most abundant acids and the largest contributor to the total titratable acidity in tomatoes [32].

$$TA(\%) = \frac{\text{Titre} \times 0.1\text{N NaOH} \times 0.064 \times \text{V. made with distilled water}}{\text{Weight of sample (g)} \times \text{V. of an aliquot taken}} \times 100$$

2.6.4. Total Soluble Solids to Acid Ratio (TSS to TA)

Total soluble solid to acid ratio was calculated by dividing the value of total soluble solid (°Brix) by the value of the percentage of titratable acidity as described by [33].

$$Sugar\ to\ Acid\ ratio = \frac{°Brix\ of\ tomato\ juice}{Total\ acid\ of\ tomato\ juice}$$

2.6.5. Ascorbic Acid (AA)

The dye solution was standardized prior to ascorbic acid determination. For standardization of dye solution, 5 ml of standard ascorbic acid solution was taken in a conical flask and 5 ml of 3% metaphosphoric acid solution was added. They were thoroughly mixed and titrated against indophenol dye solution to get the pink color end point and its persistence for 15 seconds, and the burette readings were taken. The dye factor was then calculated $as, dye\ factor = 0.5/average\ burette\ reading$.

The 2, 6-dichlorophenolindophenol standard [34] method no. 967.21 was used to determine the ascorbic acid content (mg $100g^{-1}$) of tomato. A 10 g of tomato juice extract was diluted to 50 ml with 3% metaphosphoric acid in a 100 ml beaker. The aliquot was filtered with muslin cloth, and 10ml of clear juice was titrated with the standard dye to a pink end-point (persisting for 15 seconds). The ascorbic acid content was then calculated using the following formula from the titration value, dye factor, dilution, volume of aliquot taken for titration, and sample weight.

$$AA = \frac{Titre \times Dyefactor\ \times V.madeup}{Aliquot\ taken\ for\ titration\ x\ Weight\ of\ sample} \times 100$$

2.7. Data Analysis

The collected data were subjected to analysis of variance (ANOVA) using SAS statistical software [35] in accordance with [36]. The significant differences among the treatments were computed using the Duncan Multiple Range Test (DMRT).

3. Results and Discussion

3.1. The pH

The interaction of NaOCl and AG did not show a significant effect on the pH of tomato fruits during storage period. However, aloe gel coating had a highly significant ($P < 0.001$) effect on the same parameter throughout the storage duration and the chlorinated water treatment showed its significant effect on the 16th ($P < 0.001$), 20th ($P \leq 0.05$), 24th ($P < 0.01$), and 28th ($P < 0.01$) days after storage. The tomato fruits exposed to pure aloe gel (100%), which is statistically similar with 75% treatment, had a lowest pH (3.66 to 4.30) compared to 75%, 50%, 25%, and 0% during the storage period. This result is consistent with the report of [20], who stated that the pH range of the coated tomato fruit was from 3.13 to 4.56 during storage experiments at ambient temperature. Compared with control fruit samples, the slower trend of pH increment, which is statistically similar to 200 ppm NaOCl treatment, was observed in tomato fruits disinfected with 300 ppm NaOCl between 16th to 28th days of after storage. [37] also tested 200 g/mL sodium hypochlorite for strawberry sanitization and confirmed that treatments did not change pH values compared with fresh samples.

Table 1. *Effect of Sodium hypochlorite (NaOCl) dipping and Aloe gel (AG) coating on pH of tomato fruits during storage.*

Treatments		**Storage duration (days)**						
NaOCl (ppm)	**AG (%)**	**4**	**8**	**12**	**16**	**20**	**24**	**28**
0	0	3.76^{a}	3.93^{a}	4.20^{a}	4.36^{a}	4.50^{a}	4.65^{a}	4.65^{a}
100	0	3.76^{a}	3.93^{a}	4.18^{ab}	4.33^{a}	4.49^{a}	4.63^{a}	4.64^{a}
200	0	3.75^{a}	3.92^{a}	4.15^{abc}	4.31^{ab}	4.47^{ab}	4.60^{ab}	4.62^{ab}
300	0	3.75^{a}	3.90^{a}	4.12^{abcd}	4.30^{ab}	4.43^{ab}	4.58^{ab}	4.59^{abc}
0	25	3.75^{a}	3.85^{abc}	3.98^{bcde}	4.25^{bc}	4.39^{abc}	4.57^{ab}	4.54^{bcd}
100	25	3.73^{a}	3.87^{a}	3.98^{abcde}	4.21^{cd}	4.36^{bc}	4.53^{abc}	4.54^{bcd}
200	25	3.72^{a}	3.85^{abc}	3.95^{cdef}	4.16^{d}	4.35^{bc}	4.48^{bcd}	4.50^{cde}
300	25	3.73^{a}	3.86^{abc}	3.93^{defg}	4.15^{d}	4.30^{cd}	4.41^{cde}	4.45^{defg}
0	50	3.72^{a}	3.83^{abc}	3.89^{efgh}	4.14^{de}	4.28^{cd}	4.42^{cde}	4.47^{def}
100	50	3.70^{ab}	3.77^{abcd}	3.88^{efghi}	4.08^{ef}	4.21^{de}	4.35^{def}	4.42^{efgh}
200	50	3.67^{abc}	3.73^{bcd}	3.85^{efghi}	4.02^{fgh}	4.15^{ef}	4.30^{efg}	4.40^{fgh}
300	50	3.68^{abc}	3.73^{bcd}	3.81^{efghi}	4.03^{fg}	4.14^{ef}	4.27^{fgh}	4.41^{efgh}
0	75	3.66^{abc}	3.71^{cd}	3.78^{efghi}	4.01^{fgh}	4.08^{f}	4.22^{fghi}	4.38^{fghi}

Treatments		Storage duration (days)						
NaOCl (ppm)	AG (%)	4	8	12	16	20	24	28
100	75	3.66^{abc}	3.70^{cd}	3.75^{fghi}	3.99^{ghi}	4.06^{fg}	4.20^{ghi}	4.38^{fghi}
200	75	3.65^{abc}	3.71^{cd}	3.74^{fghi}	4.00^{gh}	4.02^{fghi}	4.16^{hijk}	4.34^{hij}
300	75	3.66^{abc}	3.71^{cd}	3.75^{fghi}	4.01^{fgh}	4.03^{fgh}	4.18^{ghij}	4.35^{hij}
0	100	3.66^{abc}	3.70^{cd}	3.71^{ghi}	3.95^{hi}	3.95^{ghij}	4.12^{ijk}	4.30^{ijk}
100	100	3.64^{abc}	3.69^{cd}	3.69^{hi}	3.93^{ij}	3.92^{hij}	4.09^{ijk}	4.36^{ghij}
200	100	3.58^{bc}	3.64^{d}	3.66^{i}	3.87^{jk}	3.89^{j}	4.03^{k}	4.27^{jk}
300	100	3.56^{c}	3.61^{d}	3.72^{fghi}	3.84^{k}	3.92^{ij}	4.05^{jk}	4.24^{k}
CV%		1.8	2.4	3.1	0.9	1.7	1.7	1.2

Means with the same letter (s) in a column are not significantly different at a 5% level of significance according to DMRT.

The untreated fruits on the other hand showed a highly increasing trend of pH between the 4th and 28th days after storage (Table 1). Such an excessive increase in fruit pH is undesirable, because it negatively affects the sensory quality of the fruits and upsets their sugar-to-acid ratio [38].

Aloe gel coating retards excessive moisture loss by covering natural openings of the skin of the fruits; thus, it decelerates the pH increment. The work of [21], who used 100% aloe vera gel and 2% calcium chloride to treat tomato fruits and reported the significance of the treatment in maintaining pH at a normal level. Coating mango fruits with 75% aloe gel has also been suggested to regulate the excessive increase in mango fruit pH [39]. The present study also revealed that the application of 100% AG significantly maintained the pH of tomato fruits under storage.

3.2. Total Soluble Solids (TSS)

The interaction of NaOCl dipping and AG coating did not show a significant effect on the total soluble solid content of the stored tomato fruits except on the 12th and 20th days after storage. But, the main effects of NaOCl and AG were highly significant ($P < 0.001$) starting from the 8th and 4th day, respectively. The total soluble solids of all fruit samples were continuously increasing regardless of treatments applied until the 16th day. However, the rate of TSS increment at the commencement of the storage period was relatively faster in untreated fruits, which also resulted in a higher TSS value for these samples. Thus, the maximum TSS value of 4.72 to 5.74 ^{o}Brix was recorded from control fruits between 4th and 16th days (Table 2). Coating tomato fruits with pure aloe gel (100%) kept the increment of total soluble solids of the tomato fruits at a lower level compared to its lower concentrations up to the 20th day after storage. This could be due to the slower decrease in acidity in the coated fruits, resulting in a slower ripening process [40].

Table 2. Effect of Sodium hypochlorite (NaOCl) dipping and Aloe gel (AG) coating on TSS (^{o}Brix) of tomato fruits during storage.

Treatments		Storage duration (days)						
NaOCl (ppm)	AG (%)	4	8	12	16	20	24	28
0	0	4.72^{a}	4.97^{a}	5.51^{a}	5.74^{a}	5.66^{cd}	5.26^{j}	4.92^{j}
100	0	4.71^{a}	4.95^{a}	5.49^{ab}	5.73^{ab}	5.64^{cdef}	5.27^{j}	4.94^{ij}
200	0	4.71^{a}	4.93^{ab}	5.48^{ab}	5.71^{abc}	5.62^{efg}	5.33^{i}	4.95^{ij}
300	0	4.69^{ab}	4.92^{ab}	5.46^{bc}	5.71^{abc}	5.61^{fgh}	5.35^{hi}	4.97^{hi}
0	25	4.67^{abc}	4.89^{bc}	5.43^{c}	5.70^{bcd}	5.58^{hij}	5.38^{ghi}	4.97^{hi}
100	25	4.66^{abc}	4.85^{cd}	5.38^{d}	5.69^{cd}	5.55^{jk}	5.40^{fgh}	4.98^{ghi}
200	25	4.64^{abcd}	4.85^{cd}	5.36^{d}	5.67^{de}	5.54^{kl}	5.40^{fgh}	4.99^{gh}
300	25	4.62^{bcde}	4.84^{cd}	5.14^{e}	5.65^{e}	5.70^{a}	5.42^{efg}	4.99^{gh}

Treatments		Storage duration (days)						
NaOCl (ppm)	AG (%)	4	8	12	16	20	24	28
0	50	4.60^{cdef}	4.81^{de}	5.12^{ef}	5.61^{f}	5.69^{ab}	5.42^{efg}	5.00^{fgh}
100	50	4.59^{cdef}	4.78^{def}	5.09^{fg}	5.59^{fg}	5.67^{bc}	5.43^{cdefg}	5.01^{efg}
200	50	4.59^{cdef}	4.78^{efg}	5.08^{fg}	5.57^{g}	5.65^{cde}	5.43^{cdefg}	5.02^{efg}
300	50	4.59^{cdef}	4.77^{efg}	5.06^{gh}	5.56^{gh}	5.65^{cde}	5.45^{cdef}	5.03^{def}
0	75	4.56^{defg}	4.75^{fgh}	5.03^{hi}	5.52^{hi}	5.63^{cdef}	5.46^{cde}	5.03^{def}
100	75	4.54^{efg}	4.73^{ghi}	5.02^{hi}	5.52^{hi}	5.63^{cdef}	5.47^{cde}	5.04^{de}
200	75	4.54^{efg}	4.70^{hij}	4.99^{ij}	5.49^{ij}	5.59^{ghi}	5.48^{cd}	5.04^{cde}
300	75	4.53^{fg}	4.69^{ij}	4.97^{jk}	5.46^{jk}	5.58^{ij}	5.49^{bc}	5.05^{cde}
0	100	4.52^{fg}	4.67^{jk}	4.95^{jkl}	5.44^{k}	5.56^{jk}	5.49^{bc}	5.07^{bcd}
100	100	4.52^{fg}	4.65^{jkl}	4.94^{kl}	5.43^{kl}	5.55^{jk}	5.53^{ab}	5.08^{bc}
200	100	4.50^{g}	4.62^{kl}	4.91^{lm}	5.40^{lm}	5.53^{kl}	5.55^{a}	5.10^{b}
300	100	4.48^{g}	4.61^{l}	4.89^{m}	5.38^{m}	5.51^{l}	5.58^{a}	5.15^{a}
CV (%)		1.00	0.60	0.50	0.40	0.30	0.50	0.40

Means with the same letter (s) in a column are not significantly different at a 5% level of significance according to DMRT.

The current finding supports the work of [41] who reported that the TSS concentration slightly increased initially and then decreased in the case of tomatoes coated with 100% aloe vera gel. The rapid decline of TSS in fruits that received control treatment on the other hand is therefore, due to the absence of coating material, which slows down the ripening and respiration processes of stored fruits by regulating oxygen availability and macromolecular degradation. Hence, the high TSS value might be due to the degradation of polysaccharides to simple sugars (the conversion of starch to sugar) during ripening [42]. It is clear from the present study that using the 100% AG treatment alone had significantly regulated TSS of the stored fruits at optimum level.

3.3. Titratable Acidity (TA)

An interaction of NaOCl dipping and AG coating exerted a significant interaction effect on the total titratable acidity (%) of tomato fruits during storage, except for 8th and 12th days. The total titratable acidity was decreased in all fruit that received each treatment, but, the rate of reduction was relatively more pronounced in fruits subjected to control treatment. The maximum fruit acidity from 0.65% to 0.33% was observed in fruits treated with 300 ppm NaOCl +100% AG, followed by statistically similar result from 200 ppm NaOCl +100% AG across the storage period. Similar to this finding, [43] indicated 0.67% TA of tomato fruits harvested at the turning stage. Contrariwise, the control and lower concentrations of sole chlorine treatment had the lowest value of less than 0.40% during the 28 days after storage (Table 3). The fall in titratable acidity has been suggested to be due to the metabolic activity of tomato fruits during ripening because stored organic acids (i.e., citric acid) are converted into sugars to supply intermediates to the tricarboxylic acid cycle during increases in respiration [44, 45]. A reduction in acidity was therefore expected in terms of the rate of increase in the respiration of fruit cells.

Table 3. Effect of Sodium hypochlorite (NaOCl) dipping and Aloe gel (AG) coating on TA (%) of tomato fruits during storage.

Treatments		Storage duration (days)						
NaOCl (ppm)	AG (%)	4	8	12	16	20	24	28
0	0	0.35^{a}	0.31^{a}	0.25^{a}	0.21^{a}	0.19^{a}	0.17^{a}	0.13^{a}
100	0	0.38^{bc}	0.35^{b}	0.30^{b}	0.28^{b}	0.19^{a}	0.18^{ab}	0.17^{b}
200	0	0.38^{bc}	0.36^{bc}	0.32^{bc}	0.29^{b}	0.24^{b}	0.20^{bc}	0.18^{b}

Treatments		Storage duration (days)						
NaOCl (ppm)	AG (%)	4	8	12	16	20	24	28
300	0	0.39^{bcd}	0.38^{bcd}	0.33^{c}	0.30^{bc}	0.25^{b}	0.22^{c}	0.19^{bc}
0	25	0.41^{d}	0.40^{d}	0.32^{bc}	0.30^{bc}	0.28^{c}	0.19^{ab}	0.17^{b}
100	25	0.40^{cd}	0.39^{cd}	0.34^{cd}	0.32^{cd}	0.30^{cd}	0.26^{d}	0.21^{c}
200	25	0.45^{e}	0.42^{de}	0.36^{de}	0.34^{de}	0.32^{d}	0.27^{de}	0.19^{bc}
300	25	0.45^{e}	0.41^{de}	0.38^{e}	0.37^{fg}	0.34^{e}	0.28^{def}	0.20^{bc}
0	50	0.46^{e}	0.44^{ef}	0.41^{f}	0.36^{ef}	0.36^{ef}	0.27^{de}	0.20^{bc}
100	50	0.50^{f}	0.46^{fg}	0.43^{f}	0.37^{fg}	0.36^{ef}	0.29^{efg}	0.26^{d}
200	50	0.52^{fg}	0.48^{gh}	0.46^{g}	0.39^{gh}	0.38^{fg}	0.30^{fgh}	0.27^{de}
300	50	0.51^{f}	0.49^{ghi}	0.47^{g}	0.41^{hi}	0.39^{g}	0.31^{gh}	0.29^{defg}
0	75	0.54^{gh}	0.51^{hij}	0.46^{g}	0.43^{ij}	0.40^{gh}	0.28^{def}	0.28^{def}
100	75	0.55^{hi}	0.52^{ijk}	0.48^{g}	0.45^{j}	0.42^{h}	0.30^{fgh}	0.30^{efgh}
200	75	0.56^{hi}	0.55^{jkl}	0.51^{h}	0.48^{k}	0.45^{i}	0.31^{ghi}	0.30^{efgh}
300	75	0.56^{hi}	0.54^{jkl}	0.53^{hi}	0.51^{k}	0.47^{ij}	0.32^{hi}	0.31^{fghi}
0	100	0.57^{ij}	0.55^{kl}	0.53^{hi}	0.50^{kl}	0.48^{j}	0.33^{hi}	0.32^{ghi}
100	100	0.59^{j}	0.57^{lm}	0.55^{i}	0.52^{l}	0.51^{k}	0.32^{hi}	0.31^{fghi}
200	100	0.62^{jk}	0.60^{mm}	0.58^{j}	0.56^{m}	0.54^{l}	0.34^{i}	0.34^{i}
300	100	0.65^{l}	0.62^{n}	0.60^{j}	0.57^{m}	0.57^{m}	0.46^{j}	0.33^{hi}
CV%		2.9	4.7	3.2	3.5	3.8	5.6	6.9

Means with the same letter (s) in a column are not significantly different at a 5% level of significance according to DMRT.

At the end, the statistically highest and similar TA values of 0.34% and 0.33% were recorded from fruits treated with 200 ppm NaOCl + 100% AG and 300 ppm NaOCl +100% AG, respectively. The reason for delayed TA reduction in treated fruit samples could be due to the potential of aloe gel coating and chlorination in controlling the rate of respiration and preserving organic acid. The finding of [44], who reported the effectiveness of aloe vera gel coating to maintain the titratable acidity of tomato fruits, also supports this result. Tomato fruits dipped in chlorinated water have also been reported to have higher TA as compared to hot water dipped fruits [46]. From the present study findings, a combination of 200 ppm NaOCl with 100% AG concentrations, showed a statistically higher and economically beneficial effect in preserving the TA of stored fruits at a desirable level.

3.4. Total Soluble Solids to Acid Ratio (TSS to TA)

The TSS to TA ratio of the stored tomato fruits was significantly affected by interaction of NaOCL dipping and AG coating. A general increment in the TSS to TA ratio was observed in all treatments. However, fruits that received NaOCl and AG treatments revealed slower trends. The study results indicated that the control fruit exhibited a highest TSS to TA ratio (13.69 to 38.42) during storage period (Table 4). A combination of 300 ppm with 100% AG and 200 ppm NaOCl with 100% AG resulted in statistically similar and lower TSS to TA ratio at the end of storage duration.

Table 4. *Effect of Sodium hypochlorite (NaOCl) dipping and Aloe gel (AG) coating on TSS to TA of tomato fruits during storage.*

Treatments		Storage duration (days)						
NaOCl (ppm)	AG (%)	4	8	12	16	20	24	28
0	0	13.49^{a}	16.03^{a}	22.35^{a}	27.90^{a}	30.34^{a}	31.61^{a}	38.42^{a}

Treatments		Storage duration (days)						
NaOCl (ppm)	AG (%)	4	8	12	16	20	24	28
100	0	12.56^{b}	14.28^{b}	18.13^{b}	20.50^{b}	29.75^{a}	29.35^{b}	29.14^{b}
200	0	12.40^{b}	13.70^{b}	17.32^{c}	19.71^{bc}	23.46^{b}	26.25^{c}	28.16b
300	0	12.14^{b}	12.97^{c}	16.55^{cd}	19.24^{c}	22.20^{b}	24.70^{c}	26.73^{bc}
0	25	11.43^{c}	12.23^{de}	16.99^{c}	18.79^{cd}	20.00^{c}	28.84^{b}	28.78^{b}
100	25	11.55^{c}	12.45^{cd}	15.83^{d}	17.79^{d}	18.53^{d}	20.78^{d}	23.42^{c}
200	25	10.31^{d}	11.55^{ef}	14.92^{e}	16.69^{e}	17.51^{de}	20.27^{d}	26.88^{bc}
300	25	10.28^{d}	11.83^{de}	13.52^{f}	15.29^{fg}	16.76^{ef}	19.60^{def}	25.50^{bc}
0	50	10.00^{d}	10.94^{fg}	12.53^{g}	15.59^{f}	15.85^{fg}	20.53^{d}	25.53^{bc}
100	50	9.19^{e}	10.43^{gh}	11.84^{g}	15.12^{fg}	15.77^{fg}	18.74^{defg}	19.30^{d}
200	50	8.84^{ef}	9.97^{hi}	11.05^{h}	14.28^{gh}	15.03^{gh}	18.12^{efgh}	18.60^{de}
300	50	9.01^{e}	9.74^{hij}	10.79^{h}	13.56^{hi}	14.64^{ghi}	17.59^{fgh}	17.37^{de}
0	75	8.45^{fg}	9.32^{ijk}	10.94^{h}	12.84^{ij}	14.09^{hi}	19.74^{de}	18.17^{de}
100	75	8.26^{g}	9.08^{jkl}	10.47^{hi}	12.31^{jk}	13.42^{ij}	18.03^{efgh}	16.81^{de}
200	75	8.09^{gh}	8.56^{lm}	9.79^{ij}	11.44^{kl}	12.43^{jk}	17.49^{fgh}	16.82^{de}
300	75	8.11^{gh}	8.72^{klm}	9.38^{j}	10.71^{lm}	11.87^{kl}	17.16^{gh}	16.30^{de}
0	100	7.94^{gh}	8.53^{lm}	9.35^{j}	10.88^{l}	11.59^{klm}	16.82^{gh}	15.88^{de}
100	100	7.67^{hi}	8.16^{mn}	8.99^{jk}	10.44^{lmn}	10.89^{lmn}	17.50^{fgh}	16.40^{de}
200	100	7.26^{ij}	7.71^{n}	8.47^{kl}	9.64^{mn}	10.24^{mn}	16.34^{h}	15.00^{e}
300	100	6.89^{j}	7.44^{n}	8.15^{l}	9.47^{n}	9.66^{n}	12.16^{i}	15.61^{de}
CV%		3.2	4.0	3.7	4.3	4.8	5.6	9.4

Means with the same letter (s) in a column are not significantly different at a 5% level of significance according to DMRT.

In the present study, the coating attributes of AG, which regulated the increment of TSS and TA decline, also maintained the relationship between TSS and TA. Similarly, a positive effect of a 75% aloe debrana gel and cactus mucilage coating on TSS to TA ratio was reported on mango fruits [19]. Moreover, [47] indicated that significantly lower TSS to TA ratio in strawberries sanitized with alternative treatments including NaOCl. It is also clear from present finding that treating tomato fruit with a combination of 300 ppm NaOCl and 100% AG or 200 ppm and 100% AG showed an appreciated result in keeping the TSS to TA ratio of tomato fruits at an optimum level.

3.5. Ascorbic Acid (AA)

Aloe gel coating during storage had a significant ($P < 0.001$) impact on the ascorbic acid content of tomato fruit. However, beginning on the twentieth day of storage, this nutrient was significantly affected by both NaOCl ($P < 0.001$) and its combination with AG ($P < 0.01$). The constant rise of ascorbic acid in all tomato fruit samples was seen up to day 12 (Table 5). This increase in ascorbic acid could be attributed to cell wall degradation during the ripening process, which provides substrates for ascorbic acid synthesis [48]. Fruits treated with control, NaOCl alone, and 25% AG showed a rapid increase in ascorbic acid during storage, followed by a gradual decline commencing from 16th day. Starting from the 20th day, an overall decrement in the ascorbic acid content of fruit samples was observed irrespective of treatment variation. However, the treatment with a combination of higher levels of NaOCl and AG resulted in a significantly higher mean ascorbic acid content. The result is similar to the finding of [49], who stated the continuous increase in ascorbic acid content of tomato fruits during the maturity stage followed by a slight fall during the light red stage.

The higher value of ascorbic acid observed in control fruits during earlier intervals of the storage period might be due to uncontrolled ripening and respiration rate. On the other hand, the increased ascorbic acid content of coated tomatoes near the end of the storage period could be because of the coating that served as a protective layer against the auto oxidation of fruit by controlling the permeability of O_2 and CO_2 deep inside the fruit. Between the 16th and 28th days, the statistically highest ascorbic acid values, ranging from 14.94 to 15.10 mg/100 g^{-1}, which was statistically similar with the results recorded from the rest of the higher treatment concentrations as well as sole 100% AG, were obtained from a combination of 300 ppm NaOCl and 100% AG.

Table 5. *Effect of Sodium hypochlorite (NaOCl) dipping and Aloe gel (AG) coating on Ascorbic Acid (mg 100 g^{-1}) of tomato fruits during storage.*

Treatments		**Storage durations (days)**						
NaOCl (ppm)	**AG (%)**	**4**	**8**	**12**	**16**	**20**	**24**	**28**
0	0	12.52^{a}	12.58^{ab}	13.78^{a}	13.32^{g}	12.92^{f}	11.39^{d}	9.89^{e}
100	0	12.45^{a}	12.62^{a}	14.00a	13.60^{fg}	13.00^{f}	11.55^{d}	10.00^{e}
200	0	11.75^{b}	12.41^{ab}	13.70^{ab}	13.50^{fg}	13.10^{f}	11.44^{d}	10.14^{e}
300	0	11.71^{b}	11.78^{bc}	13.64^{ab}	13.45^{g}	13.11^{f}	11.42^{d}	10.12^{e}
0	25	11.26^{bcd}	11.80^{bc}	13.68^{ab}	13.60^{fg}	13.14^{f}	11.46^{d}	10.30^{e}
100	25	11.54^{bc}	11.75^{bc}	13.63ab	13.70^{defg}	13.16^{f}	11.56^{d}	10.32^{e}
200	25	10.77^{def}	11.38^{cd}	13.58^{ab}	13.74^{defg}	13.18^{f}	11.48^{d}	10.33^{e}
300	25	11.08^{cd}	11.30^{cd}	13.60^{ab}	13.69^{efg}	13.89^{e}	11.59^{d}	10.39^{e}
0	50	10.93^{de}	11.06^{cdef}	13.55^{ab}	13.95^{cdefg}	13.91^{e}	13.40^{c}	11.42^{cd}
200	50	10.25^{fg}	11.00^{cdef}	13.51^{ab}	13.95^{cdefg}	14.27^{d}	13.52^{c}	11.94^{cd}
300	50	10.23^{fg}	10.96^{cdefg}	13.47^{ab}	14.35^{abcd}	14.67^{c}	14.60^{b}	12.15^{cd}
0	75	9.83^{gh}	10.58^{defgh}	12.45^{c}	14.15^{bcdef}	14.67^{c}	14.62^{b}	12.21^{cd}
100	75	9.80^{gh}	10.40^{efgh}	13.38^{ab}	14.30^{abcde}	14.69^{c}	14.68^{ab}	12.50^{c}
200	75	9.75^{gh}	10.32^{fgh}	13.15^{b}	14.42^{abc}	14.72^{c}	14.71^{ab}	13.60^{b}
300	75	9.73^{gh}	10.20^{fgh}	12.59^{c}	14.47^{abc}	14.81^{bc}	14.75^{ab}	14.63^{a}
0	100	9.73^{gh}	9.76^{h}	12.36^{c}	14.50^{abc}	14.86^{bc}	14.80^{ab}	14.70^{a}
100	100	9.57^{h}	10.11^{h}	12.26^{c}	14.78^{ab}	15.03^{ab}	14.98^{ab}	14.85^{a}
200	100	9.55^{h}	9.85^{h}	12.21^{c}	14.94^{a}	15.19^{a}	15.15^{ab}	15.05^{a}
300	100	9.50^{h}	10.10^{gh}	12.10^{c}	14.94^{a}	15.25^{a}	15.20^{a}	15.10^{a}
CV%		2.89	4.12	2.41	2.43	1.1		3.85

Means with the same letter (s) in a column are not significantly different at 5% level of significance according to DMRT.

In line with current finding, the significance of aloe vera gel coating in retaining the ascorbic acid content of stored tomato fruits has been reported by scholars [50, 51]. The work of [52] has also revealed that 80% aloe vera gel concentrations reduced ascorbic acid oxidation and maintained its content in guava fruits. Besides this, [53] stated that tomato fruits disinfected with 200 ppm NaOCl and packed in a low-density polyethylene bag had a maximum ascorbic acid content of 10.04 mg/100 g compared to untreated fruits. Furthermore, evaluation of sodium hypochlorite solution for sanitizing strawberries was reported to be better in maintaining ascorbic acid content at a higher level compared to those only washed with water [37]. It is, therefore, possible to conclude from this study that the use of a combination of 300 ppm NaOCl and 75% AG for tomato postharvest treatment can economically reduce its ascorbic acid loss.

3.6. Economic Benefits

Cost and returns analysis was used to determine the profitability of treatment levels in relation to each other and control treatments [54]. Expected changes in cost and returns were calculated for each treatment combination. Therefore, based on the market price of 1 Kg tomato fruits existed during research activity and using marketable tomato fruits data recorded at 28th days of storage and other relevant information gathered by the researchers. The summary of the result is presented in the table 6.

Table 6. Cost and return analysis of different levels of Sodium hypochlorite and aloe gel treatment combinations.

Treatments Combination	Total returns (ETB)	Total costs (ETB)	Additional income (ETB)	Marketable tomato fruits (%) data at 28th days after storage
0+0	5	0.5	4.5	4.67[a]
100+0	8	1.03	6.97	6.50[b]
200+0	10	2.05	7.95	6.83[b]
300+0	12	3.08	8.92	13.09[c]
0+25	37	31.25	5.75	13.32[c]
100+25	38	32.28	5.72	13.33[c]
200+25	40	33.3	6.7	14.45[c]
300+25	40	34.33	5.67	28.32[d]
0+50	67	62.5	4.5	30.29[e]
100+50	70	63.53	6.47	31.95[f]
200+50	75	64.55	10.45	35.07[g]
300+50	100	65.58	34.42	45.49[h]
0+75	130	93.75	36.25	45.67[h]
100+75	150	94.78	55.22	47.74[i]
200+75	150	95.8	54.2	48.89[i]
300+75	189	96.83	92.17	50.79[j]
0+100	227	125	102	53.27[k]
100+100	250	126.03	123.97	53.39[k]
200+100	300	127.05	172.95	55.35[l]
300+100	300	128.08	171.92	55.68[l]
G. Mean	-	-	-	32.70
LSD	-	-	-	1.47
CV	-	-	-	2.71

Means with the same letter (s) in a column are not significantly different at 5% level of significance according to DMRT.

The results of the analysis showed that 200 NaOCl + 100 AG treatment combination resulted in increased returns. The highest total returns which is at par with that of 300 NaOCl + 100 AG was recorded for 200 NaOCl + 100 AG. However, the highest additional income was obtained from 200 NaOCl + 100 AG treatment. Therefore, 200 NaOCl + 100 AG should be applied as post-harvest treatment for tomato during storage since it resulted in statistically higher percentage of marketable tomato fruits, which in turn caused the highest additional income which is about 172.5 ETB for the treatment.

4. Summary and Conclusion

The interaction of NaOCl and AG did not show a continuous significant effect on most of the chemical attributes of tomato fruits during storage. The pH of the fruit sample was not significantly influenced by the interaction of AG and NaOCl throughout the storage period. The significant interaction effect of NaOCl and AG on TSS contents of tomato fruits was not observed except on the 12th and 20th days. Fruit samples treated with a blend of 200 ppm NaOCl with 100%

AG displayed the maximum value of fruit TA of about 0.34%, at the end of storage period. The TSS to TA ratio was significantly affected by the interaction of both treatments. The lowest TSS to TA ratio (15 ratio) of tomato fruits at 28^{th} day of storage period was recorded from the samples treated with 200 ppm NaOCl + 100% AG. In addition, Ascorbic acid content was economically preserved at significantly higher level (as high as 14.63 $mg100g^{-1}$) in fruit samples treated with 300 ppm NaOCl + 75% AG. Depending on the present finding and economic analysis of the treatments, a combination of sodium hypochlorite and aloe pubescence gel at concentration level of 200 ppm and 100% could be used as pre-storage treatments for maintaining the chemical quality attributes of tomato fruits such as titratable acidity and titratable acidity to total soluble solid ratio. On the other hand, the use of 300 ppm NaOCl + 75% AG was observed to be beneficial in preserving ascorbic acid content of the stored tomato fruits at optimum level. However, to give a conclusive recommendation, it is imperative to conduct further experiments with consideration of different tomato varieties, harvesting stages, chlorine forms, coating materials, and dipping durations.

Abbreviations

NaOCl	Sodium Hypochlorite
AG	Aloe Gel
SAS	Statistical Analysis System
Ppm	Parts per million
pH	Power of Hydrogen Ion
TA	Titratable Acidity
TSS	Total Soluble Solids
AA	Ascorbic Acid
CSA	Central Statistical Agency
LTD	Limited Liability Company
PLC	Public Limited Company
NaOH	Sodium Hydroxide
ANOVA	Analysis of Variance
DMRT	Duncan Multiple Range Test
ETB	Ethiopian Birr

Acknowledgments

The authors thank the Tony Farm research site and the Horticulture Laboratory of Haramaya University for facilitating and providing the required materials for research.

Author Contributions

Girma Gutema: Conceptualization, Project administration, Writing _original draft, Data curation, Formal analysis, Investigation, Methodology, Validation, Software, Writing - review & editing

Tewodros Bezu: Conceptualization, Data Curation, Methodology, Funding acquisition, Project administration, Resources, Supervision, Validation, Writing-Review & editing

Fikreyohannes Gedamu: Conceptualization, Data Curation, Methodology, Funding acquisition, Project administration, Resources, Supervision, Validation, Writing-Review & editing

Data Availability Statement

Data will be available upon request.

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Duguma, H. T. 2022. Potential Applications and Limitations Of Edible Coatings For Maintaining Tomato Quality And Shelf Life. *Int. J. Food Sci. Technol.*, *57*(3), 1353-1366. https://doi.org/10.1111/Ijfs.15407

[2] Wang, C.; Li, M.; Duan, X.; Abu-Izneid, T.; Rauf, A.; Khan, Z.; Mitra, S.; Emran, T. B.; Aljohani, A. S. M.; Alhumaydhi, F. A., Et Al. 2022. Phytochemical and Nutritional Profiling Of Tomatoes; Impact of Processing On Bioavailability-A Comprehensive Review. *Food Rev. Int*., 1-25. https://doi.org/10.1080/87559129.2022.2097692

[3] Li, N.; Wu, X.; Zhuang, W.; Xia, L.; Chen, Y.; Wu, C.; Rao, Z.; Du, L.; Zhao, R.; Yi, M., Et Al. Tomato And Lycopene And Multiple Health Outcomes: Umbrella Review. *Food Chem.* 2021, *343*, 128396. https://doi.org/10.1016/J.Foodchem.2020.128396

[4] CSA (Central Statistical Agency). 2018. Crop Production Forecast Sample Survey, 2017/18. Report on Area and Production for Major Crops (for Private Peasant Holdings "*Meher*" season). Addis Ababa, Ethiopia.

[5] CSA (Central Statistical Agency). 2021. Crop Production Forecast Sample Survey, 2020/21. Report on Area and Production for Major Crops (for Private Peasant Holdings "*Meher*" season). Addis Ababa, Ethiopia.

[6] Bantayehu, M., M. Alemayehu, M. Abera and S. Bizuayehu, 2017. Postharvest losses assessment of tropical fruits in the market chain of North Western Ethiopia. *Food Science and Quality Management, 66: 13-24.*

[7] Sipho, S. and S. W. Tilahun, 2020. Potential causes of postharvest losses, low-cost cooling technology for fresh produce farmers in Sub-Sahara Africa. *African Journal of Agricultural Research*, 16: 553-566. https://doi.org/10.5897/AJAR2020.14714

[8] Sisay, Z., K. Abegaz and A. Fisseha, 2021. Assessment on post-harvest losses of tomato (*Lycopersicon esculentem* Mill.) in selected districts of Sidama Zone-Ethiopia. Journal of Food Processing and Technology. 12.

[9] Tadesse, E. E., H. Assaye, M. A. Delele, S. W. Fanta and D. F. Huluka *et al*., 2021. Quantitative Postharvest Loss Assessment of Tomato along the Postharvest Supply Chain in Northwestern Ethiopia. In: Advances of Science and Technology, Delele, M. A., M. A. Bitew, A. A. Beyene, S. W. Fanta and A. N. Ali (Eds.), Springer, Cham, Switzerland, pp: 110-122. https://doi.org/10.1007/978-3-030-80621-7_8

[10] Bezabh Emana., Afari-Sefa V, Nenguwo N., Amsalu Ayana., Dereje Kebede., Hadija Mohammed. 2017. Characterization of pre- and postharvest losses of tomato supply chain in Ethiopia. *Agriculture and Food Security*, 6(3): 1- 11. https://doi.org/10.1186/s40066-016-0085-1

[11] Etefa, O. F., Forsido, S. F. and Kebede, M. T., 2022. Postharvest loss, causes, and handling practices of fruits and vegetables in Ethiopia: Scoping review. *Journal of Horticultural Research*, *30*(1). https://doi.org/10.2478/johr-2022-0002

[12] Tolesa, G. N. and Workneh, T. S., 2017. Influence of storage environment, maturity stage and pre-storage disinfection treatments on tomato fruit quality during winter in KwaZulu-Natal, South Africa. *Journal of food science and technology*, *54*, pp. 3230-3242. https://doi.org/10.1007/s13197-017-2766-6

[13] D'Aquino, S., Suming, D., Deng, Z., Gentile, A., Angioni, A., De Pau, L. and Palma, A., 2017. A sequential treatment with sodium hypochlorite and a reduced dose of imazalil heated at 50 C effectively control decay of individually film-wrapped lemons stored at 20 C. *Postharvest Biology and Technology, 124,* pp. 75-84. https://doi.org/10.1016/j.postharvbio.2016.10.006

[14] Liu, C., Duan, J. And Su, Y. C. 2006. Effects Of Electrolyzed Oxidizing Water On Reducing *Listeria Monocytogenes* Contamination On Seafood Processing Surfaces. *International Journal Of Food Microbiology* 106: 248-253. https://doi.org/10.1016/j.ijfoodmicro.2005.06.020

[15] Okull, D. O. And Laborde, L. F. 2004. Activity Of Electrolyzed Oxidizing Water Against *Penicilium Expansum* In Suspension And On Wounded Apples. *Journal of Food Science* 69.1: FMS23-FMS27. https://doi.org/10.1111/j.1365-2621.2004.tb17872.x

[16] Jati, I. R. A., Setijawaty, E., Utomo, A. R. and Darmoatmodjo, L. M. Y., 2022. The application of Aloe vera gel as coating agent to maintain the quality of tomatoes during storage. *Coatings*, *12*(10), p. 1480. https://doi.org/10.3390/coatings12101480

[17] Kausar, A., Zohra, S. T., Ijaz, S., Iqbal, M., Iqbal, J., Bibi, I., Nouren, S., El Messaoudi, N. and Nazir, A., 2023. Cellulose-based materials and their adsorptive removal efficiency for dyes: A review. *International journal of biological macromolecules*, *224*, pp. 1337-1355. https://doi.org/10.1016/j.ijbiomac.2022.10.220

[18] Farooq, A., Niaz, B., Saeed, F., Afzaal, M., Armghan Khalid, M., Raza, M. A. and Al Jbawi, E., 2023. Exploring the potential of aloe vera gel-based coating for shelf life extension and quality preservation of tomato. *International Journal of Food Properties*, *26*(2), pp. 2909-2923. https://doi.org/10.1080/10942912.2023.2263661

[19] Abera Girma, Kebede Woldetsadik and Wassu Mohammed. 2019. Effect of aloe gel and cactus mucilage coating on chemical quality and sensory attributes of mango (*Mangifera indica* L.). *Journal of Postharvest Technology,* 7(2): 31-43.

[20] Makonnen Tolasa, Fikreyohannes Gedamu and Kebede Woldetsadik. 2021. Impacts of harvesting stages and pre-storage treatments on shelf life and quality of tomato (*Solanum lycopersicum* L.). *Cogent Food and Agriculture*, 7(1): 1863620. https://doi.org/10.1080/23311932.2020.1863620

[21] Zebider Shite, Yibekal Alemayehu, Fikreyohannes Gedamu. 2021. The Quality of Tomato (*Solanum Lycopersicum* L.) After Pre Storage $CaCl_2$ and Edible Coating Treatment. *Advances in Life Science and Technology*, 89: 1-20. Available online: www.iiste.org

[22] Petros Yohannes and Berecha Regasa Gutu. 2015. Genetic Variability and Path Coefficient Analysis for Yield and Yield Related Traits in Commons Bean (*Phaseolus vulgaris* L.) Accessions at Haramaya University, East Hararge, Ethiopia. Doctoral dissertation, Haramaya University.

[23] MoANR (Ministry of Agriculture and Natural Resources). 2016. Crop Variety Register issue No. 19, Addis Ababa, Ethiopia.

[24] Nasrin, T. A. A., Molla, M. M., Hossaen, M. A., Alam, M. S. and Yasmin, L. 2008. Effect of postharvest treatments on shelf life and quality of tomato. *Bangladesh Journal of Agricultural Research*, 33(4): 579-585. https://doi.org/10.3329/bjar.v33i4.2291

[25] Kator, L., Hosea, Z. Y. and Ene, O. P. 2018. The Efficacy of Aloe-vera coating on postharvest shelf life and quality tomato fruits during storage. *Asian Research Journal of Agriculture*, 8(4): 1-9. https://doi.org/10.9734/ARJA/2018/41540

[26] Asfaw Zeleke and Eshetu Derso (eds). 2015. Production and management of major vegetable crops in Ethiopia. Ethiopian Institute of Agricultural Research, Addis Ababa, Ethiopia. Printed at Eth-Cana Printing Press 149 pages Addis Ababa, Ethiopia. ISBN: 978-99944-66-25-2.

[27] Tufaha Mohammed, Wassu Mohammed, and Kebede Woldetsadik. 2020. Response of Tomato (*Solanum lycopersicum* L.) Varieties to Blended Nps Fertilizer Rates at Dire Dawa, Eastern Ethiopia (MSc THesis, Haramaya university).

[28] Eifert, J. D., and Sanglay, G. C. 2002. Chemistry of chlorine sanitizers in food processing. *Dairy, Food and Environmental Sanitation,* 22(7): 534-538.

[29] AOAC (Association of Official Analytical Chemists). 2007. Official methods of analysis (17th ed.). AOAC Press.

[30] Dargie Tsegay, Buzayehu Tesfaye, Ali Mohammed, Haddis Yirga and Andnet Bayleyegn. 2013. Effects of harvesting stage and storage duration on post-harvest quality and shelf life of sweet bell pepper (*Capsicum annuum* L.) varieties under passive refrigeration system. *International Journal of Biotechnology and Molecular Biology Research*, 4: 98-104. https://doi.org/10.5897/IJBMBR2013.0

[31] AOAC (Association of Official Analytical Chemists). 2000. Official methods of analysis (17th ed.). AOAC Press.

[32] Agius, C., von Tucher, S., Poppenberger, B. and Rozhon, W. 2018. Quantification of sugars and organic acids in tomato fruits. *MethodsX*, (5): 537-550. https://doi.org/10.1016/j.mex.2018.05.014

[33] Caron, S. J., Ruta, V., Abbott, L. F. and Axel, R., 2013. Random convergence of olfactory inputs in the Drosophila mushroom body. *Nature*, *497*(7447), pp. 113-117.

[34] AOAC. (1994). Association of Official Analytical Chemists. Official Methods of Analysis. Washington, D. C.

[35] SAS institute. 2013. Base SAS 9.4 procedures guide: Statistical procedures, 40.

[36] Gomez, K. A. and Gomez, A. A., 1984. *Statistical procedures for agricultural research*. John Wiley and Sons.

[37] Alexandre, E. M., Brandao, T. R. and Silva, C. L. 2012. Assessment of the impact of hydrogen peroxide solutions on microbial loads and quality factors of red bell peppers, strawberries and watercress. *Food Control*, 270.98" (2): 362-368. https://doi.org/10.1016/j.foodcont.2012.04.012

[38] Tigist Tadesse, Tilahun Seyoum and Kebede Woldetsadik, 2013. Effects of variety on the quality of tomato stored under ambient conditions. *Journal of Food Science and Technology*, 50(3): 477- 486.

[39] Ochiki, S., Wolukau, J. N. and Gesimba, M. R. 2014. Effect of various concentrations of Aloe vera coating on postharvest quality and shelf life of mango (*Mangifera indica* L.) fruits Var. 'Ngowe'. *African Journal of Biotechnology*, 13(36). https://doi.org/10.5897/AJB2014.13996

[40] Ullah, A., Abbasi, N. A., Shafique, M. and Qureshi, A. A. 2017. Influence of edible coatings on biochemical fruit quality and storage life of bell pepper cv. "Yolo Wonder". *Journal of Food Quality*, 2017: 1-11. https://doi.org/10.1155/2017/2142409

[41] Kanmani, V. M., Sashidevi, G. 2017. Application of biodegradable Aloe vera gel for extending the shelf-life of tomato. *Food Science Research Journal* 8(2): 132-137. https://doi.org/10.15740/HAS/FSRJ/8.2/132-137

[42] Mezemer Samuel, Abera Solomon, and Kebede Woldetsadik. 2017. Effect of bee wax and linseed oil coatings and frequency of dipping on the biochemical and organoleptic quality of fresh orange juice (*Citrus sinensis* cv. Valencia). *Journal of Postharvest Technology,* 5(2): 17-28.

[43] Getinet, H., Tilahun Seyoum and Kebede Woldetsadik. 2008. The effect of cultivar, maturity stage and storage environment on quality of tomatoes. *Journal of Food Engineering*, 87(4): 467-478. https://doi.org/10.1016/j.jfoodeng.2007.12.031

[44] Khatri, D., Panigrahi, J., Prajapati, A. and Bariya, H. 2020. Attributes of Aloe vera gel and chitosan treatments on the quality and biochemical traits of post-harvest tomatoes. *Scientia Horticulturae*, 259: 108837. https://doi.org/10.1016/j.scienta.2019.108837

[45] Sree, K. P., Sree, M. S., Supriya, P. and Samreen. 2020. Application of chitosan edible coating for preservation of tomato. *International Journal of Chemical Studies*, 8(4): 3281-3285. https://doi.org/10.22271/chemi.2020.v8.i4ao.10157

[46] Meaza Melkamu, Tilahun Seyoum and Kebede Woldetsadik. 2009. Effect of different cultivation Practices and postharvest treatments on tomato quality. *East African Journal of Sciences*, 3(1), 43-54. https://doi.org/10.4314/eajsci.v3i1.42785

[47] Coswosck, K. H. C., Giorgette, M. A., Lepaus, B. M., SILVA, E. M. M. D., SENA, G. G. S., AZEVEDO, M. C. D. A. and SÃO JOSÉ, J. F. B. D. 2020. Impact of alternative sanitizers on the physicochemical quality, chlorophyll content and bioactive compounds of fresh vegetables. *Food Science and Technology*, 41: 328-334. https://doi.org/10.1590/fst.02320

[48] Singh, Y. and Yadav, Y. K. 2015. Effect of different storage environment on quality characteristics of tomato and kinnow fruits. *Agricultural Engineering International:* Center for Interdisciplinary Geriatric Research *(CIGR) Journal*, 17(1): 238-245.

[49] Athmaselvi, K. A., Sumitha, P. and Revathy, B. 2013. Development of Aloe vera based edible coating for tomato. *Journal of Biology, Agriculture and Healthcare*, 5(16): 78 - 89. https://doi.org/10.2478/intag-2013-0006.

[50] Chrysargyris, A., Nikou, A. and Tzortzakis, N. 2016. Effectiveness of Aloe vera gel coating for maintaining tomato fruit quality. *New Zealand Journal of Crop and Horticultural Science*, 44(3): 203-217. https://doi.org/10.1080/01140671.2016.1181661.

[51] Roy and Karmakar. 2019. Use of Aloe Vera Gel Coating as Preservative on Tomato. *International Journal of Bio-resource and Stress Management*, 10(5): 461-466. https://doi.org/10.23910/IJBSM/2019.10.5.2022a

[52] Rehman, M. A., Asi, M. R., Hameed, A. and Bourquin, L. D. 2020. Effect of Postharvest application of aloe vera gel on shelf life, activities of anti-oxidative enzymes, and quality of 'Gola' guava fruit. *Foods*, 9(10): 1361. https://doi.org/10.3390/foods9101361

[53] Sood, M., Kaul, R. K., Bhat, A., Singh, A. and Singh, I. 2011. Effects of harvesting methods and postharvest treatments on quality of tomato (*Lycopersicon esculentum* L.). *Annals of Food Science and Technology*, 12(1): 58-62.

[54] Rolle, R., 2017. Low cost, high impact solutions for improving the quality and shelf life of cauliflower in local markets.