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Influence of cannonball tree (*Couroupita guianensis* Aubl.) leaf extract and electrolyzed oxidizing water on postharvest quality of tomato

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ABSTRACT

Purpose: Managing postharvest losses to extend shelf life and cut down on waste is of paramount importance nowadays, especially when resources are scarce. Extracts from the leaves of the cannonball tree and electrolyzed oxidizing water were employed to improve postharvest handling procedures. **Research method:** The experiment consisted of cannonball tree leaf extracts (5 ml/L, 10 ml/L, 15 ml/L, 20 ml/L) and two pH levels of electrolyzed oxidizing water (pH 3, pH 5). Tomato treated with distilled water was considered as a control. The experiment was conducted as a Completely Randomized Design under a factorial arrangement with three replications. **Findings:** Cannonball tree leaf extracts (10 ml/L) significantly retained acceptable fruit color, firmness, high level of titratable acidity, flavonoid, carotenoid, anthocyanin, vitamin C, IC_{50} and prolonged shelf life by more than three days over other treatment combinations. Compared to untreated fruit, treated fruit decayed at a slower rate (30.7±0.4%) and lost less weight (35.4±0.7%). Additionally, electrolyzed oxidizing water (pH 5) significantly outperformed alternative postharvest management techniques to lower postharvest losses, IC_{50} (121.6±2.1 mg/Kg) activity, enhancing titratable acidity and vitamin C content, and other physico-chemical attributes and thereby increasing tomato shelf life by more than two days. **Research limitations:** No limitations were encountered. **Originality/Value:** Electrolyzed oxidizing water (pH 5) or cannonball tree leaf extract (10 ml/L) appears to be the most promising sustainable solution for reducing postharvest tomato losses.

INTRODUCTION

In terms of production, yield, and commercial value, tomatoes rank near the top of the list of most essential vegetables (Sinha et al., 2019). The annual production of tomatoes is about 387.65 thousand metric tons from 28.21 thousand hectares of land with an average yield of 50.00 $MTha^{-1}$ in Bangladesh (YAS, 2020). Poor postharvest practices lead to a loss of 15-42% of vegetables between the farm, the wholesaler, the store, and the consumer, leading to an oversupply and lower prices for consumers and fewer profits for farmers (Arah et al., 2015). As a result, enormous quantities of tomatoes are harvested and sold at throwaway prices. Additionally, microbial degradation significantly contributes to the substantial postharvest loss (Odeyemi et al., 2021). The subtropical regions' tomato output has expanded significantly in recent years (YAS, 2020), but due to the dearth of novel postharvest technology in use, postharvest management strategies could not follow a similar trajectory. Thus, sustainable postharvest loss management approaches might be the lingering strategies to reduce postharvest losses by extending the shelf life of tomatoes.

It is reflected that plants are a reliable supply of natural compounds. The Lecythidaceae family includes huge tropical deciduous trees like the cannonball tree (*Couroupita guianensis* Aubl.). The bioactive composites present in various cannonball tree plant components, include leaves, stems, flowers, bark, etc., may be employed for a variety of healing purposes. The plant's medicinal potential is due to the presence of essential oils, glycosides, ketosteroids, isatin, indurubin, and phenolic chemicals (Pandurangan et al., 2018). The chemical constituents of *C. guianensis* leaves are hydroxycinnamic acids, rosmarinic acid, triterpenic ester β-amirin palmitate, kaempferol-3-O-neohesperidoside, 4-hydroxybenzoic acid, 20,40-dihydroxy-60-methoxy-30, 7-hydroxy-5-methoxy-6,8-dimethylflavanone, 50-dimethylchalcone (Martinez et al., 2012). The phenolic and volatile substances from the leaf extracts of *C. guianensis* showed antibacterial and antifungal properties that cure several diseases (Elumalai et al., 2012).

Electrolyzed oxidizing (EO) water is produced by electrolysis of sodium chloride to yield mainly chlorine-based oxidizing products (Dewi et al., 2017; Zhang et al., 2021). It has currently been proposed as the alternative to conventional sanitation and cleaning agent as well as novel antimicrobial agents (Iram et al., 2021). It has been stated to be extremely microbiocidal against bacteria, viruses, fungi, and may signify an alternative to synthetic chemicals and traditional chlorine-based sanitizers. EO water exerts its antimicrobial effects due to its high oxidation-reduction potential (ORP) (Kim et al., 2000; Len et al., 2000). Microbial cell membranes lose electrons when exposed to an oxidizing solution with a high ORP, leading to cell death (Suslow, 2004). Due to its minimal use of the salt solution and lack of additional chemical additives, EO water has less impact on the environment chemically. (Kim et al., 2000). The effect of EO water was evaluated to improve the shelf life and quality as well as to reduce the microbial population of kumquat citrus (*Fortunella* sp.) (Kassim et al., 2016), date (*Phoenix dactylifera*) (Bessi et al., 2014). It has been proved that EO water was used for improving the postharvest quality of several horticultural products like mushrooms (Aday, 2016), and avocados (Hassan & Dann, 2019).

There are several methods that are correctly used to enhance the quality of postharvest fruits and vegetables, but they have drawbacks such as high energy consumption, complicated spraying procedures, and chemically manufactured fungicides. Consumers' worries about the presence of chemically manufactured fungicides in postharvest produce have been well-founded (Wisniewski et al., 2016). Therefore, the application of non-residue, low energy consumption and inexpensive physical preservation methods in postharvest fruits and vegetables has attracted increasing attention, including EO water (Fallanaj et al., 2016). There are no reports on the efficacy of cannonball tree leaf extract and EO water in lowering tomato postharvest losses, but a few studies have shown that field applications or postharvest treatment of EO water decreases the onset of disease and increases the shelf life of some harvested fresh produces. Therefore, the present study attempted to assess the ameliorative role of *C. guianensis* leaf extract and EO water on the postharvest physico-chemical attributes of tomatoes.

MATERIALS AND METHODS

Location of experiment, design, treatment

An experiment was carried out at the Horticulture Laboratory, Khulna University (22°80´ N, 89°53´ E), Bangladesh, from December 2021 to March 2022. In this study, the Minto Super tomato was selected as the experimental material for the investigation which was collected from the field laboratory of the Agrotechnology Discipline. The experiment was conducted as a factorial arrangement of CRD (completely randomized design) with three replications. The experiment consisted of four cannonball tree leaf extracts (5 ml/L, 10 ml/L, 15 ml/L, 20 ml/L) and two pH levels of electrolyzed oxidizing water (pH 3, pH 5) which were compared with control (distill water).

Preparation of *C. guianensis* leaf extract

Fresh leaf of *C. guianensis* was collected from the nursery of Forestry and Wood Technology Discipline of Khulna University before preparing leaf extract. Ten leaves were removed from the stem and the leaf surface was cleaned properly. A total of ten leaves were poured into the blender (Sahara Pride Blender, BD) to make the juice. No additional water was added to prepare the juice. Fresh leaf juice was filtered using Whatman No 1 filter paper, and the extract was collected to make the final solution. The four different solutions were prepared viz. 5 ml leaf extract per 1 liter of water (1:200), 10 ml leaf extract per 1 liter of water (1:100), 15 ml leaf extract per 1 liter of water (1:67), 20 ml leaf extract per 1 liter of water (1:50), respectively. The freshly harvested tomatoes were dipped for 30 seconds in different solutions that were made from *C. guianensis* leaf extract. After that, the tomatoes were sprayed with a fresh solution of leaf extract at a 2-day interval. The treatment application procedure was modified from that used by Batu and Thompson (1998). Dipping with appropriate disinfection of tomatoes not only decreases the microbial loads of the fruits but also boosts the superior quality of the tomatoes during storage (Workneh et al., 2012). The tomatoes were stored at the Horticultural Laboratory in ambient conditions (Temperature: 24°C, RH: 65-75%) to evaluate the physico-chemical attributes of tomatoes.

Preparation of EO water

Electrolyzed oxidizing water was collected from the Animal Husbandry Laboratory of Agrotechnology Discipline and the pH of water (pH 3 and pH 5) was adjusted by adding diluted HCL or NaOH and the reading was monitored using the digital pH meter (ASONE ORP Desktop Economy pH meter PH700, Japan) to obtain desire pH. The freshly harvested tomatoes were dipped for 30 seconds in EO water having pH 3 and pH 5, respectively. After that, the tomatoes were sprayed with a fresh solution of EO water at a 2-day interval. The treatment application procedure was modified from that used by Ding et al. (2015). Distill water was used for dipping in case of untreated control.

Determination of the shelf life of tomato

By detecting and judging the quality parameters like appearance (color chart), shriveling, disease incidence (scale rating: 0 means no infection, 5 means 50 % fruit area infected), etc. (Sinha et al., 2019), the shelf life of tomato fruit was assessed with respect to storage days.

Assessment of weight loss

The tomato was chosen at random from each treatment to weigh every other day and compare the weight difference from the fresh weight on the first day. The following equation (1) was used to assess weight loss:

$$\text{Weight loss (\%)} = \frac{M_0 - M_1}{M_0} \times 100 \qquad (1)$$

M_0 is the initial fresh weight of the tomato, and M_1 is the individual sampling day measured weight (Qin et al., 2015).

Determination of moisture and dry matter content

Fifty grams (50 g) of fresh fruit sample from each treatment was taken and cut into small pieces on an aluminum foil and oven-dried at 70°C until the constant weight was attained. Percent moisture content was calculated according to the following formula (2), and dry matter content (%) was calculated using the following formula (3) (Khatun et al., 2022).

$$\text{Moisture content (\%)} = \frac{\text{Fresh weight of sample (g)} - \textit{Dry eeight oof sample (g)}}{\text{Fresh weight of sample (g)}} \times 100 \qquad (2)$$

$$\text{Dry matter content (\%)} = 100 - \text{moisture content (\%)} \qquad (3)$$

Assessment of fruit decay percent

The visual quality losses (fungal decay, brushing, softening, rupturing skin) of stored tomato fruits were evaluated by visual inspection and disease scale rating, 0 means no infection, 5 means 50% fruit area infected (Sinha et al., 2019) for every two days. The fruits infected with visible fungal mycelia or 1/3 damaged was discarded from the container, and the decay percentage was determined from the total number of tomatoes.

Evaluation of fruit firmness

A food texture analyzer (Shimadzu EZ-SX, USA) was used to determine the firmness of treated tomatoes (2 mm diameter). Each fruit was penetrated at two different equilateral locations to assess its firmness. The probe speed was 2 mm/s and the penetration depth was 5 mm. The maximum force firmness was recorded in N/cm^2.

Determination of fruit color

The surface color of the tomato was determined using a chromo meter (CR-410, Konica Minolta, USA) by calculating L*, a*, b* values, where L* represents brightness, a* means redness, b* means yellowness, and hue angle (h°), chroma (C). The following equation (4) was used to assess the hue angle, and equation (5) was used to evaluate the chroma:

$$h° = \tan^{-1}(b^*/a^*) \qquad (4)$$

$$C = \sqrt{a^2 + b^2} \qquad (5)$$

Determination of pH, total soluble solids and titratable acidity of tomato fruit pulp

The pH of tomato pulp was determined using a Benchtop pH meter (HI2210, Hanna Instrument, USA, 0.01 pH resolution) using the procedure described by Mazumdar & Majumdar (2001) and Saini et al. (2006). The percentage of total soluble solids (TSS) was assessed from the reading of the digital Brix meter (Digital/Brix/RI-Check Reichert Technologies, USA). Similarly, tomato titratable acidity (TA) was evaluated using the following procedure described by Mazumdar and Majumdar (2001) and Saini et al. (2006).

Determination of flavonoid in tomato fruit pulp

Ten grams (10 g) of tomato from the sample was taken and crushed finely. Then 100 ml of 80 % methanol was added and kept in a water bath for 10 hours at 40° C. The whole solution was filtered through filter paper (Whatman No. 42). After that, the filtrate was transferred to a crucible and then evaporated to dryness over a water bath at room temperature. The final finding was weighed as a flavonoid (Mazumdar & Majumdar 2001; Saini et al., 2006).

Determination of carotenoid in tomato fruit pulp

The carotenoid content was evaluated using the procedure described by Mazumdar & Majumdar (2001) and Saini et al. (2006). The following equation (6) was used to determine the carotenoid:

$$\text{mg carotenoid/ g tissue} = 7.6\ (\text{A}.480) - 1.49\ (\text{A}.510) \times \frac{\text{V}}{1000 \times 10} \qquad (6)$$

Here, A= Absorbance of the specific wavelength, V=Final volume of the carotenoid in 80 % acetone, W= Fresh weight of the tissue extracted

Determination of anthocyanin in tomato fruit pulp

Anthocyanin was extracted with ethanolic-hydrochloride. The total procedure was described by Mazumdar and Majumdar (2001) and Saini et al. (2006). The following calculation (7 and 8) was used to assess the anthocyanin content of the tomato pulp.

$$\text{Total absorbance } (/100g\ sample) = \frac{e \times b \times c}{d \times a} \times 100 \qquad (7)$$

a = sample weight, b = volume constructed for color determination c = total volume, d = aliquot volume taken for assessment, and e = 535 nm volume

$$\text{Anthocyanin } (mg/100\ g\ FW) = \frac{Total\ absorbance}{98.2} \qquad (8)$$

Determination of vitamin C in tomato fruit pulp

In order to determine tomato vitamin C contents, 30 g of tomato pulp was weighed and melded for 3 to 4 minutes with 6 % Meta phosphoric acid. Then 15 g of the mixture was combined with 85 g of 3 % Meta phosphoric acid in a 100 ml volumetric flask. After that, the mixture was filtrated with filter paper (Whatman No. 42) and titrated immediately following the procedure described by Mazumdar & Majumdar (2001) and Saini et al. (2006). Finally, the following equation (9) was used to determine the ascorbic acid content:

$$\text{Ascorbic acid } (mg/100\ g\ FW) = V \times T \times \frac{100}{W} \qquad (9)$$

V = In titration volume of dye used, T = standardized dye value, and W = pulp weight.

Determination of free radical scavenging activity of tomato fruit pulp

The free radical scavenging activity of tomato after treatment with cannonball tree leaf extracts and electrolyzed oxidizing (EO) water were analyzed using 2,2-diphenyl-1-picrylhydrazyl (DPPH) according to the researchers (Jadid et al. 2017; Dash et al., 2022). The DPPH solution was prepared in methanol and subsequently added to various concentrations of the various extracts (25, 50, 100, 200 and 400 mg/Kg). Ascorbic acid was used as a positive control (standard). The following equation (10) was used to calculate the inhibition percentage:

$$\text{Inhibition (\%)} = \frac{\text{Blank absorbance} - \text{extract absorbance}}{\text{Blank absorbance}} \times 100 \qquad (10)$$

The IC_{50} values were calculated using a linear regression model (y=ax+b) and used to specify the antioxidant activity of different treatments.

Statistical analysis

Postharvest data were subjected to a two-way ANOVA to determine statistical differences among the treatments and treatment combinations identified by *f*-test, while their pairwise mean comparisons were estimated using Tukey's HSD (Honestly Significant Difference) test at $p \leq 0.05$ (OriginLab Corporation, Version 9.6.5, USA). All quality parameters were analyzed using a model that as cannonball tree leaf extract and electrolyzed oxidizing (EO) water as the main effects and their-2-ways interactions. To determine the relations between the variables and treatments, the principal component analysis was performed using the raw data.

RESULTS

Shelf life

The effect of postharvest treatment with *C. guianensis* leaf extract and EO water on the shelf life of tomatoes varied significantly ($p \leq 0.01$) from each other (Table 1). The interaction effect of *C. guianensis* leaf extracts and EO water was not varied significantly for the shelf life of tomatoes. Tomatoes treated with *C. guianensis* leaf extract (10 ml/L) had a maximum shelf life (16.0 ± 1.2 days), while untreated fruits (control) had a minimum shelf life (12.9 ± 0.5 days). The results revealed that tomatoes treated with *C. guianensis* leaf extract (10 ml/L) prolonged their shelf life by more than three days than untreated (control) fruits. Similarly, tomatoes treated with EO water (pH 5) had maximum shelf life (15.3 ± 1.0 days), while untreated fruits (control) had a minimum shelf life (13.3 ± 0.7 days). Tomatoes treated with EO water (pH 5) extended their shelf life by more than two days than untreated fruits.

Weight loss

The various *C. guianensis* leaf extracts and EO water effects on the weight loss of tomatoes were highly significant ($p \leq 0.01$) that as demonstrated in Table 1. The interaction effect of *C. guianensis* leaf extracts and EO water was not significant for the weight loss of tomatoes. During the storage period, gradually increased weight loss. Tomatoes treated with *C. guianensis* leaf extracts (10 ml/L) was significantly lower weight loss (35.01%) than that untreated one (control). The fruit weight loss treated with several concentrations of *C. guianensis* leaf shown as control > 20 ml/L > 15 ml/L > 5 ml/L > 10 ml/L, respectively. Alike, *C. guianensis* leaf extracts, EO water (pH 5) was significantly lower in weight loss (29.33 %) than that of untreated control. The fruit weight loss treated with EO water was ranked as control > pH 3 > pH 5.

Moisture and dry matter

The main and interaction effect of *C. guianensis* leaf extract and EO water on moisture and dry matter content were not significant ($p \leq 0.53$) (Table 1).

Fruit decay

A significant ($p \leq 0.01$) variation in fruit decay percentage was detected due to the differences between postharvest treatments with *C. guianensis* leaf extract and EO water (Table 1). The interaction effect of *C. guianensis* leaf extracts and EO water were not significant for fruit decay of tomato. The maximum (18.9 ± 1.4 %) decay occurred in untreated control and the minimum (13.3 ± 0.9 %) at *C. guianensis* leaf extract (15 ml/L) followed by (10 ml/L) (13.1 ± 0.8 %). In the case of EO water, the maximum (16.7 ± 0.9 %) decay occurred in control and the minimum (13.5 ± 0.5 %) at EO water (pH 5).

Table 1. Effect of *C. guianensis* leaf extract and EO water on shelf life, weight loss, moisture and dry matter, decay of tomato.

Treatments	Shelf life (days)	Weight loss (%)	Moisture (%)	Dry matter (%)	Fruit decay (%)
C. guianensis leaf extract (A)					
Control	12.9±0.5 d	17.5±1.3 a	13.2±0.1	86.8±0.5	18.9±1.4 a
5 ml/L	14.7±0.9 bc	12.0±0.5 c	13.1±0.1	86.5±0.6	15.5±1.2 b
10 ml/L	16.0±1.2 a	11.3±0.4 c	13.6±0.2	86.9±0.5	13.1±0.8 d
15 ml/L	14.9±0.8 b	14.6±0.8 b	13.5±0.2	86.9±0.5	13.3±0.9 d
20 ml/L	13.9±0.7 c	15.5±0.9 b	13.1±0.1	86.4±0.6	14.4±1.0 c
EO water (B)					
Distill water (Control)	13.3±0.7 c	17.2±1.2 a	12.9±0.2	86.2±0.4	16.7±0.9 a
pH3	14.5±0.9 b	13.3±0.8 b	13.1±0.3	86.9±0.5	14.9±0.6 b
pH5	15.3±1.0 a	12.1±0.5 c	13.8±0.2	87.1±0.6	13.5±0.5 c
Significance					
A	**	**	NS	NS	**
B	**	**	NS	NS	**
A×B	NS	NS	NS	NS	NS

Note: Means followed by the same letters within a column do not differ significantly whereas means having dissimilar letters differ significantly as per Tukey’s HSD test at $p \leq 0.05$, ± standard error, NS: non-significant, ** significant at $p \leq 0.01$.

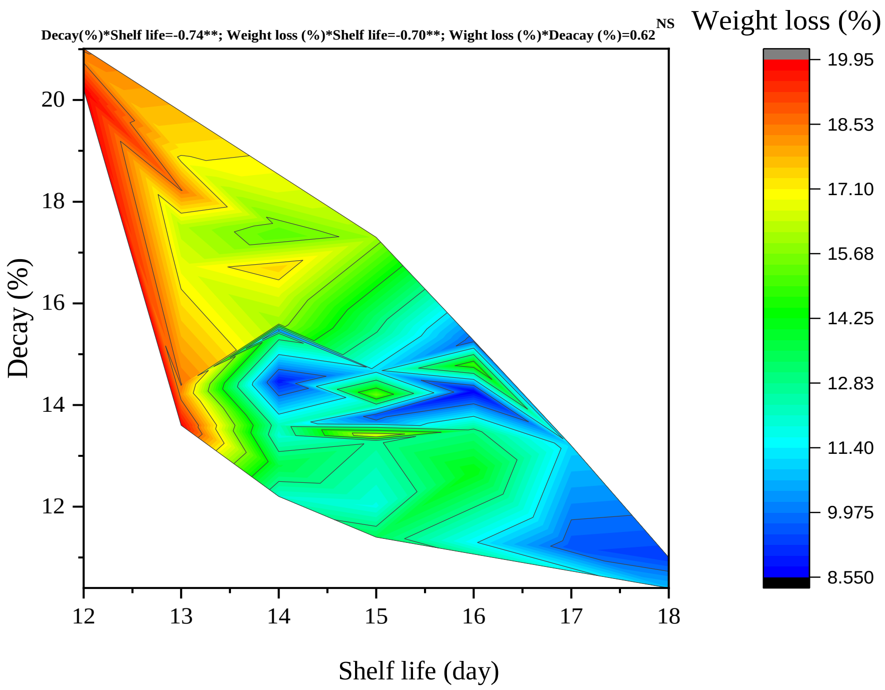


Fig. 1. Three variables contour plot representing the joint interaction among shelf life (day), fruit decay (%) and weight loss (%) of tomato. Note: Numeric value with ** specified correlation between variables significant at $p \leq 0.01$, NS: non-significant.

Relationship among shelf life, fruit decay and weight loss of tomato

A three-variable contour plot highlighted that shelf life was negatively correlated to both the decay (%) and weight loss (%) of tomatoes indicating reduced decay (%) and weight loss (%) helped to prolong the shelf life of tomatoes and vice versa (Fig. 1). The findings showed that fruits with blue color had longer shelf lives because they conserved more water and lost less weight, while tomatoes with red color had shorter shelf lives because more weight loss and deterioration were visible.

Firmness

Firmness is a key quality indicator of tomatoes. The effect of postharvest treatment with *C. guianensis* leaf extract and EO water on the firmness of tomato varied significantly ($p \leq 0.01$) from each other. The interaction effect of *C. guianensis* leaf extracts and EO water was not significant for the shelf life of tomatoes. Tomatoes treated with *C. guianensis* leaf extracts either 10 ml/L or 15 ml/L significantly overweighed the firmness level incurred by both untreated and 5 ml/L. On the contrary, when fruits treated with EO water (pH 5) exhibited a better firmness level than those untreated fruits. Between two EO water treatments, EO water with pH 5 offered a significantly higher firmness to tomato fruits than pH 3.

Tomato fruits color evaluation

Tomato appearance differs by surface color. Discoloration primarily occurs on the surface of the tomato during storage, resulting in spoilage. The brightness (L*) of the tomato was significantly ($p \leq 0.01$) varied due to differences in treatments on different days of storage. At 2-days of storage, the maximum L* value was observed when the fruits were treated with *C. guianensis* leaf extracts (10 ml/L) than that of others. A similar trend was documented for the rest of the storage period. The EO water also significantly ($p \leq 0.01$) influenced the brightness (L*) of tomatoes. The maximum L* value was found when the fruits were treated with EO water (pH 5) compared to the untreated control and the trend was consistent during the storage period.

The evolution of the red fruit color (a*) was more rapid at control as well as fruits treated with *C. guianensis* leaf extracts (5 ml/L) than that of others. On the other hand, the yellowness (b*) of the tomato decreased with the increase of storage time. The minimum b* value decreasing trend was noticed in *C. guianensis* leaf extracts (10 ml/L water) as well as EO water (pH 5). The chroma and hue angle are the most used parameters to indicate the color development of stored tomato fruits. The chroma value and hue angle significantly ($p \leq 0.05$) increased with increase of storage time of the tomato. When the fruits were treated with either *C. guianensis* leaf extracts (10 ml/L) or EO water (pH 5) gave rise to a higher hue angle value (less red) compared to the other treatments.

pH, total soluble solids and titratable acidity of tomato

The main and interaction effect of *C. guianensis* leaf extract and EO water on tomato fruit pH and total soluble solids were not significant after 10 days of storage ($p \leq 0.28$) (Fig. 2). However, a significant ($p \leq 0.05$) variation of TA was observed when fruits treated with *C. guianensis* leaf extracts. The maximum TA was found when fruits were treated with *C. guianensis* leaf extracts (10 ml/L) followed by 15, and 5 ml/L, respectively and the minimum was observed at control followed by *C. guianensis* leaf extracts (20 ml/L). However, when the tomatoes treated with EO water (pH 5) exhibited the highest TA value compared to the untreated fruits.

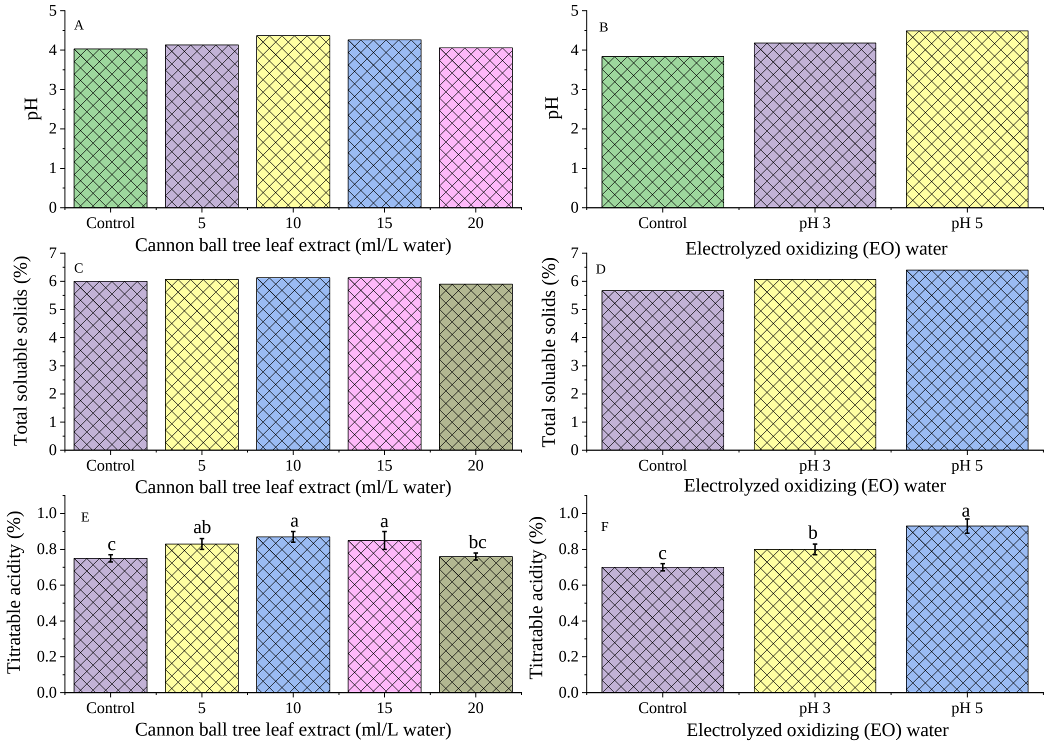


Fig. 2. Effect of *C. guianensis* leaf extracts and EO water on pH, total soluble solids and titratable acidity after 10 days of storage. Note: vertical bar represents standard error, bars that do not contribute to a letter are significantly unique based on Tukey's HSD test at $p \leq 0.05$.

Flavonoid, carotenoid, anthocyanin and vitamin C of tomato

There was significant ($p \leq 0.05$) variation in flavonoid levels among concentrations of *C. guianensis* leaf extracts (Fig. 3). The maximum flavonoid level was observed when the fruits were treated with *C. guianensis* leaf extracts (10 ml/L) followed by 15 ml/L whereas the minimum was found in untreated ones. In the case of EO water, both EO water treatments (pH 3 and pH 5) significantly ($p \leq 0.01$) demonstrated more flavonoid levels than the control. Effects of *C. guianensis* leaf extracts and EO water were significant ($p \leq 0.05$) for the carotenoid content of tomato after 10 days of storage. Tomatoes treated with *C. guianensis* leaf extracts showed better carotenoid content compared to the untreated ones. Also, the EO water (pH 3 and pH 5) treated tomatoes displayed better carotenoid content compared to the control. In the case of anthocyanin, a significant ($p \leq 0.05$) variation of anthocyanin content due to the differences in treatments. The interaction effect of *C. guianensis* leaf extracts and EO water was not significant. The highest anthocyanin content was found when the fruits were treated with *C. guianensis* leaf extracts (10 ml/L), whereas the lowest was observed in control followed by *C. guianensis* leaf extracts (20 ml/L). Alike carotenoid, EO water (pH 3 and pH 5) treated tomatoes displayed better anthocyanins content compared to the control. A significant ($p \leq 0.05$) difference in vitamin C content was found when the fruits were treated with *C. guianensis* leaf extracts and EO water. The highest vitamin C content was observed when the fruits were treated with *C. guianensis* leaf extracts (10 ml/L), whereas the lowest in control was followed by *C. guianensis* leaf extracts (20 ml/L). Similar to flavonoid and carotenoid, EO water (pH 3 and pH 5) treated tomatoes displayed better vitamin C content compared to the control.

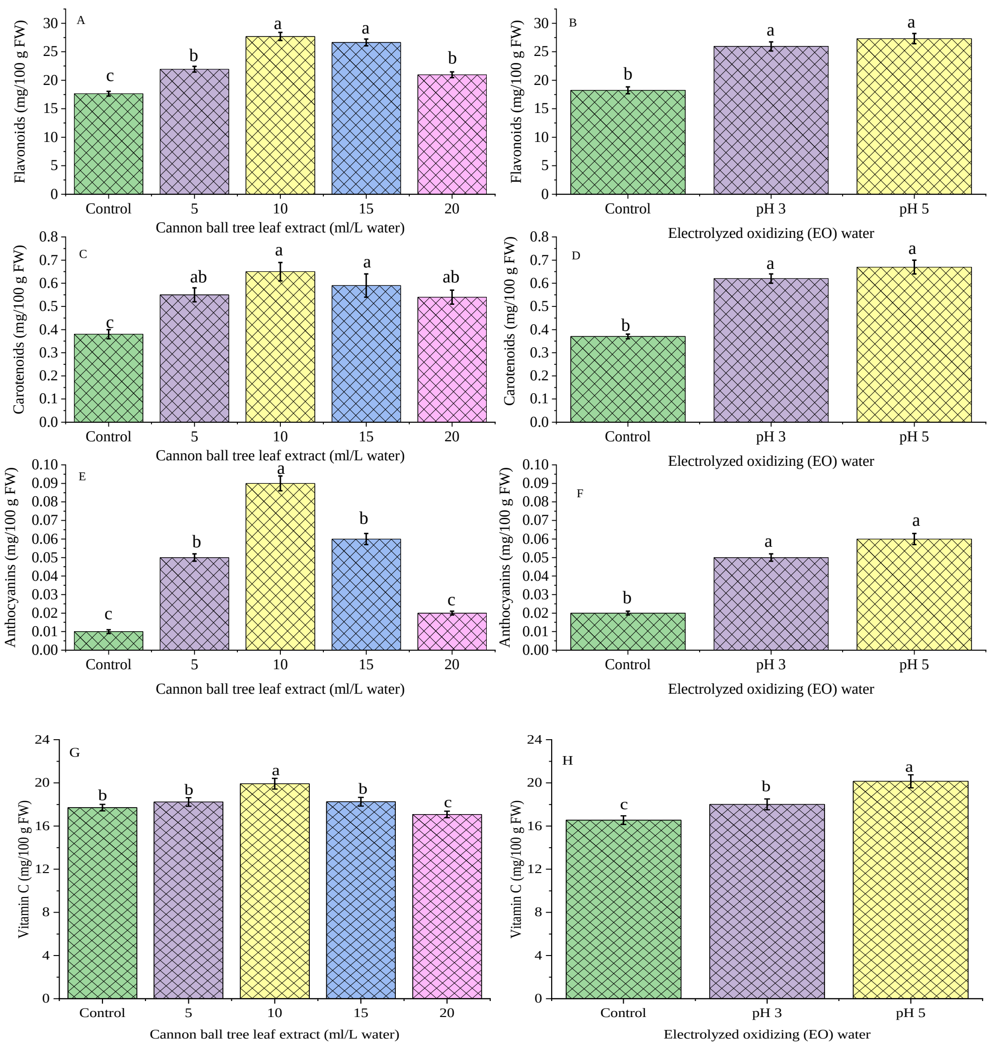


Fig. 3. Effect of *C. guianensis* leaf extracts and EO water on flavonoids, carotenoids, anthocyanins, and vitamin C after 10 days of storage. Note: vertical bar represents standard error, bars that do not contribute to a letter are significantly unique based on Tukey's HSD test at $p \leq 0.05$.

Radical scavenging activity determination

The percentage of inhibition was calculated to assess the antioxidant activity of the tomatoes treated with *C. guianensis* leaf extracts and EO water which could obstruct free radicles. Five varying concentrations (25, 50, 100, 200 and 400 mg/Kg) of different *C. guianensis* leaf extracts, as well as EO water, showed various percentages of inhibition in tomatoes. The scavenging activity of tomatoes treated with *C. guianensis* leaf extracts and EO water was increased with the rise of concentration. Tomatoes were treated with both *C. guianensis* leaf extracts and EO water and showed the best antioxidant activity at 400 mg/Kg concentrations. Among the *C. guianensis* leaf extracts, the 10 ml/L concentration (96.1 ± 2.5 %) was the highest inhibition followed by 15 ml/L, 20 ml/L, 5 ml/L, control, respectively. At the highest concentration (400 mg/Kg), the scavenging activity of 10 ml/L and 15 ml/L were higher than the ascorbic acid (standard). Similarly, the EO water at pH 5 was the highest inhibition (97.3 ± 2.2 %) followed by pH 3 and control, respectively. Alike, *C. guianensis* leaf extracts, at the highest concentration (400 mg/Kg), the scavenging activity of EO water at pH 5 was higher than the ascorbic acid (standard).

The IC_{50} value of DPPH radical scavenging activity

The results showed that tomatoes treated with *C. guianensis* leaf extracts (10 ml/L) exhibited the highest antioxidant activity (121.6 ± 2.1 mg/Kg) than the other concentration of leaf extract. Also, the EO water showed better results (Fig. 4). The IC_{50} value was measured to assess the concentration of the extract required to inhibit 50 % of radical.

Principal component analysis

Measured quality parameters were subject to PCA to assess the association among the variables. The principal component-1 (PC-1) explained 65.32 % of the total variation in the measured quality parameters as influenced by treatments (Fig. 5). Analysis of the PCA biplot displaying the loading plot indicated that a*, b*, hue angle, chroma, L*, weight, shape index (SI), vitamin C, carotenoid, anthocyanin, $IC_{50,}$ and shelf life were positively correlated with the treatments whereas weight loss (%), pH, Brix, titratable acidity, flavonoids, moisture (%), dry matter (%), and decay (%) were negatively correlated with the treatments. Among the variables fruit weight, L*, and shelf life are more positively influenced by the treatments whereas weight loss (%) and fruit decay (%) are more negatively impacted by the treatments.

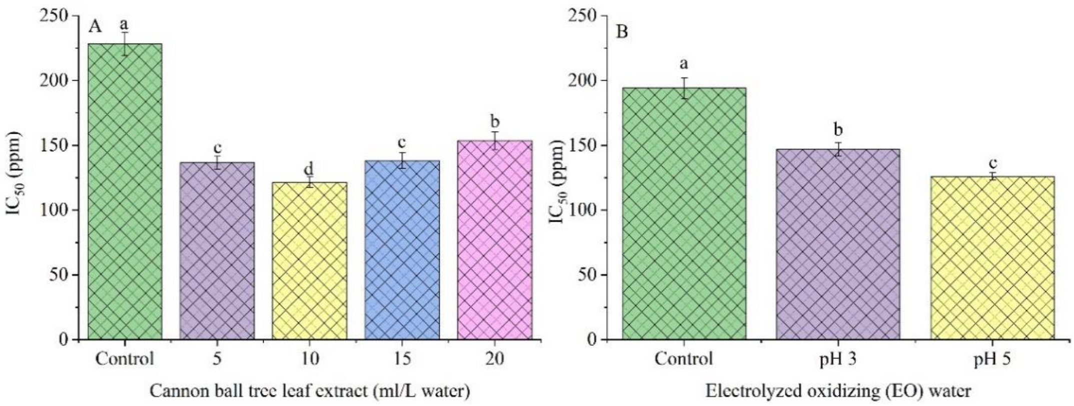
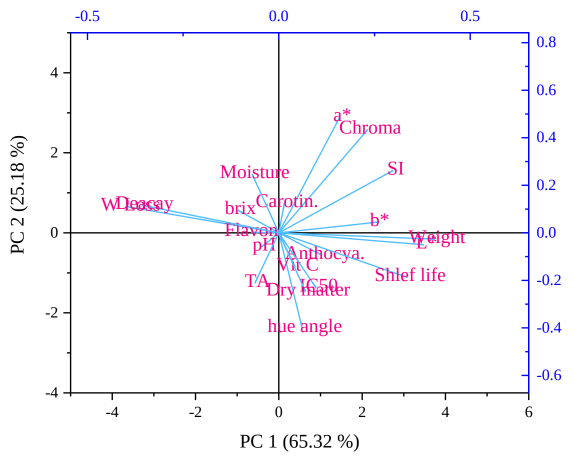


Fig. 4. Effect of tomato treated with cannonball tree leaf extract and electrolyzed (EO) water on IC_{50} value of DPPH radicle scavenging activity. Note: vertical bar represents standard error, bars that do not contribute to a letter are significantly unique based on Tukey's HSD test at $p \leq 0.05$.



Variable	PC1
a*	0.221
b*	0.283
hue angle	0.031
Chroma	0.293
L*	0.391
Weight	0.421
Weight loss (%)	-0.398
Shape Index (SI)	0.350
pH	-0.048
Brix	-0.010
TA	-0.093
Vit. C	0.035
Carotenoid	0.037
Anthocyanins	0.113
Flavonoid	-0.080
IC50	0.081
Moisture (%)	-0.056
Dry matter (%)	-0.056
Decay (%)	-0.351
Shelf life	0.336
Eigenvalue	7.895
Proportion	**0.653**
Cumulative	0.653

Fig. 5. PCA biplot (Principal component-1 PC1 vs Principal component-2 PC2) visualizing the correlations among the quality parameters affected by the cannonball tree leaf extracts and electrolyzed oxidizing (EO) water.

DISCUSSION

The leaf extract of *C. guianensis* extends the freshness of tomatoes. The leaf extract contains numerous phytochemicals that ameliorate several ailments and assist to keep fruits fresh for longer, which suggests that it may decrease the rapid metabolic rates of tomatoes. It was quite effective against both *E. coli* and *B. subtilis* in antibacterial tests (Pandurangan et al., 2018). Tomatoes' longevity can be extended with the help of EO water, which also tastes great. Previous studies have shown that EO water-treated mushrooms aid in delaying senescence (Aday, 2016). The EO water treatment delayed softening of blueberries most likely through the deactivation of cell wall-degrading enzymes (Chen et al., 2017) and regulation of reactive oxygen species (ROS) (Chen et al., 2019). It also helps maintain cellular integrity for a longer period compared with untreated fruit. The cellular integrity of treated tomatoes might help to increase the shelf life. The EO water effectively controlled citrus diseases reported by the researchers (Hussain et al., 2019). During electrolysis of EO water, HOCl is produced that penetrates cell membranes and evolves as hydroxyl radicles, which exert antimicrobial activity through the oxidation of important metabolic compounds (Mahmoud, 2007). EO water is widely used in the food industry to solve storage-related problems and prevents the growth of microbial organisms, which in turn escalates the shelf-life of food (Iram et al., 2021). In addition, water infused with EOs is also used to kill harmful bacteria and viruses on newly harvested crops and vegetables. Freshly cut carrots, bell peppers, spinach, cauliflower, tomatoes, apples, and oranges all have benefited from this method of cleaning (Huang et al., 2008). It was observed that EO water at a pH of 2.5 was extremely good at preventing the spread of *E. coli* in tomatoes (Issa-Zacharia et al., 2010). Due to its high oxidizing potential, EO water has attracted a lot of attention in the postharvest sector as a means to slow the deterioration of fruits and vegetables across a wide pH spectrum (Ippolito et al., 2021). The results revealed that *C. guianensis* leaf extracts and EO water reduced weight loss. It is possibly the postharvest treatment of tomatoes slowing down respiration and other metabolic processes and assists to retain moisture content in the fruits by inhibiting water loss from the surface. Tomatoes treated with either *C. guianensis* leaf extract or EO water reduced postharvest decay. The phytochemical ingredient in *C. guianensis* leaf extract is essential for the treatment of several diseases (Pandurangan et al., 2018). The fungus-caused avocado anthracnose disease was greatly decreased by the EO water (Hassan & Dann, 2019). Additionally, they stated that sodium hypochlorite's direct inhibitory action on the avocado fungal infection was mostly responsible for this. Similar to this study, another one reported that during tomato storage, EO water greatly decreased the occurrence of rot symptoms in tomatoes inoculated with *Fusarium oxysporum*, *Galactomyces geotrichum*, and *Alternaria* sp. (Vasquez-Lopez et al., 2016). The EO water could advance the disease resistance of postharvest citrus by stimulating the resistance of citrus. This theory was supported by the up-regulation of gene expression of a series of defense-related enzymes including chitinase, peroxidase, and phenylalanine ammonia-lyase (PAL) at 12 h after EO water treatment (Fallanaj et al., 2016). The EO water may be an effective treatment to enhance fruit disease resistance for suppressing the disease development of postharvest longans (Tang et al., 2021). Therefore, the effect of EO water on fungal diseases of postharvest fruits might be a double mechanism including the direct inhibition of pathogens and the activation of the host defense system.

Increased firmness in ripe blueberries with a lower weight loss (1%) after 21 days of storage whereas 4%-5% weight loss during storage resulted in softening of blueberries (Miller & McDonald, 1993). The findings suggested that maintaining the firmness of blueberries for an extended storage period could also be achieved by preventing weight loss. In the current study, tomatoes exhibited an increase in firmness with weight loss (%), which was consistent with previous studies. The results releveled that those tomatoes treated with either *C. guianensis* leaf extracts (10 ml/) or EO water (pH 5) promote maintaining the good color of fruits and also delay over-ripening. It might ameliorate several diseases of tomato treatments and helps to retain the glossiness of fruits (Pandurangan et al., 2018; Vasquez-Lopez et al., 2016). The chemical qualities of preserved tomatoes were enhanced by the use of EO water with the ideal pH and *C. guianensis* leaf extracts at the ideal concentration. This shift in chemical characteristics may be due to *C. guianensis* leaf extracts and EO water, which could speed up the metabolism of postharvest fruits through the up-regulation of a number of metabolic enzymes' gene expression.

The DPPH assay was used to evaluate the free radical scavenging activity of tomatoes treated with *C. guianensis* leaf extracts and EO water. It is a rapid and efficient method to determine the free radical scavenging activity. The DPPH forms a stable diamagnetic molecule after accepting an electron or hydrogen radicle (Jadid et al., 2017; Dash et al., 2022). The color changes from purple to yellow specifies a reduction in absorbance of DPPH radicle. This evidences that antioxidants found in the extract interact with the free radicals (Kedare & Singh, 2011). The lower the IC_{50} value, the higher the antioxidant activity of the extract (Li et al., 2009). Among the three extracts a leaf, flower, and fruit, flower extracts of *C. guianensis* exhibited higher activity than others signifying the existence of more antioxidants in the flowers (Pandurangan et al., 2018). On the contrary, fruit extract showed maximum inhibition (67.85 %) than others resulting in more antioxidant acidity. The fruits of *C. guianensis* contain more polyphenols which are responsible to accelerate antioxidant activity would have made it more effective than other extracts (Raveendra et al., 2016). The increased inhibition mechanism of tomatoes treated with *C. guianensis* (10 ml/L) might be the activation of defense enzymes. The EO water aids to increase shelf life and reducing fruit decay of blueberries by activating antioxidant enzymes and alleviating oxidative damage (Lin et al., 2017; Xu et al., 2016). Higher antioxidant activity moderately denotes the capacity of scavenging ROS and improve oxidative damage in plant tissues, and thereby contributing to the defeat of pathogenic infection and decay in blueberries (Wang et al., 2017; Chanjirakul et al., 2006). The EO water (pH 5) treatment could preserve anthocyanin and phenolic content, enhance ROS scavenging capacity leading to cell membrane integrity, disease resistance capacity, and reduce the incidence of tomato fruit decay. In comparison to the untreated tomatoes, the EO water (pH 5) treated tomato fruits displayed higher antioxidant activity and lower firmness and fruit decay.

CONCLUSION

C. guianensis leaf extract (10 ml/L) and EO water (pH 5) were found to effectively prevent the loss of weight, decay, firmness, and surface color in tomatoes, while also preserving titratable acidity, flavonoids, carotenoids, anthocyanins, vitamin C content, and DPPH radical scavenging, and extending shelf life by more than three days compared to untreated fruits. Therefore, the results indicated that harvested ripe tomatoes treated with either *C. guianensis* leaf extract (10 ml/L) or EO water (pH 5) would reduce postharvest losses of tomatoes and open up a new avenue for postharvest management sectors

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Conflict of interest
The authors have no conflict of interest.

REFERENCES

Aday, M. S. (2016). Application of electrolyzed water for improving postharvest quality of mushroom. *LWT-Food Science and Technology*, *68*, 44-51. https://doi.org/10.1016/j.lwt.2015.12.014

Arah, I. K., Ernest, K. K., Etornam, K. A., & Harrison, A. (2015). An overview of post-harvest losses in tomato production in Africa: causes and possible prevention strategies. *Journal of Biology, Agriculture and Healthcare, 5*(16), 78-88.

Batu, A., &Thompson, A. K. (1998). Effects of modified atmosphere packaging on postharvest qualities of pink tomatoes. *Turkish Journal of Agriculture and Forestry*, *22*(4), 365-372.

Bessi, H., Debbabi, H, Grissa, K., & Bellagha, S. (2014). Microbial reduction and quality of stored date fruits treated byelectrolyzed water. *Journal Food Quality*, *37*(1), 42-49. https://doi.org/10.1111/jfq.12072

Chanjirakul, K., Wang, S. Y., Wang, C. Y., & Siriphanich, J. (2006). Effect of natural volatile compounds on antioxidant capacity and antioxidant enzymes in raspberries. *Postharvest Biology and Technology*, *4*, 106-115. https://doi.org/10.1016/j.postharvbio.2006.01.004

Chen, Y., Hung, Y-C., Chen, M., & Lin, H. (2017). Effects of acidic electrolyzed oxidizing water on retarding cell wall degradation and delaying softening of blueberries during postharvest storage. *LWT-Food Science and Technology*, *84*, 650-657. https://doi.org/10.1016/j.lwt.2017.06.011

Chen, Y., Hung, Y-C., Chen, M., Lin, M., & Lin, H. (2019). Enhanced storability of blueberries by acidic electrolyzed oxidizing water application may be mediated by regulating ROS metabolism. *Food Chemistry*, *270*, 229-235. https://doi.org/10.1016/j.foodchem.2018.07.095

Dash, P. K., Das, S., Ray, J., & Pride, L. (2022). Optimization of strawberry precooling temperature using CoolBot: a potential post-harvest management tool pertinent to the subtropical environment. *International Journal of Postharvest Technology and Innovation*, *8*(4), 271-291. http://doi.org/10.1504/IJPTI.2022.10050416

Dewi, F. R., Stanley, R., Powell, S. M., & Burke, C. M. (2017). Application of electrolyzed oxidizing water as a sanitizer to extend the shelf-life of seafood products: a review. *Journal of Food Science and Technology*, *54*(5),1321-1332. https://doi.org/10.1007%2Fs13197-017-2577-9

Ding, T., Ge, Z., Shi, J., Xu, Y. T., Jones, C.L., & Liu, D. H. Impact of slightly acidic electrolyzed water (SAEW) and ultrasound on microbial loads and quality of fresh fruits. *LWT-food Science and Technology*, *60*(2), 1195-1199. https://doi.org/10.1016/j.lwt.2014.09.012

Elumalai, V., Naresh, M., Chinna, E., Narendar, P., & Kumar, R. (2012). Evaluation of antiulcer activity of *Couroupita Guianensis* Aubl. Leaves. *Asian Journal of Pharmacy and Technology, 2*(2), 64-66.

Fallanaj, F., Ippolito, A., Ligorio, A., Garganese, F., Zavanella, C., & Sanzani, S. M. (2016). Electrolyzed sodium bicarbonate inhibits *Penicillium digitatum* and induces defense responses against green mould in citrus fruit. *Postharvest Biology and Technology*, *115*, 18-29. https://doi.org/10.1016/j.postharvbio.2015.12.009

Hassan, M. K., & Dann, E. (2019). Effects of treatment with electrolyzed oxidizing water on postharvest diseases of avocado. *Agriculture*, *9*(11), 241. https://doi.org/10.3390/agriculture9110241

Huang, Y. R., Hung, Y. C., Hsu, S. Y., Huang, Y. W., & Hwang, D. F. (2008). Application of electrolyzed water in the food industry. *Food Control*, *19*, 329-345.

Hussain, M. S., Kwon, M., Park, E. J., Seheli, K., Huque, R., & Oh, D. H. (2019). Disinfection of *Bacillus cereus* biofilms on leafy green vegetables with slightly acidic electrolyzed water, ultrasound and mild heat. *LWT-Food Science and Technology, 116*, 108582. https://doi.org/10.1016/j.lwt.2019.108582

Ippolito, A., Mincuzzi, A., Surano, A., Youssef, K., & Sanzani, S. M. (2021). Electrolyzed water as a potential agent for controlling postharvest decay of fruits and vegetables. In: Spadaro, D., Droby, S., Gullino, M. L. (eds) Postharvest Pathology. *Plant Pathology*, *11*, 181-202. https://doi.org/10.1007/978-3-030-56530-5_12 v

Iram, A., Wang, X., & Demirci, A. (2021). Electrolyzed Oxidizing Water and its applications as sanitation and cleaning agent. *Food Engineering Review, 13*, 411-427. https://doi.org/10.1007/s12393-021-09278-9

Issa-Zacharia, A., Kamitani, Y., Morita, K., & Iwasaki, K. (2010). Sanitization potency of slightly acidic electrolyzed water against pure cultures of Escherichia coli and Staphylococcus aureus, in comparison with that of other food sanitizers. *Food Control*, *21*, 740-745.

Jadid, N., Hidayati, D., Hartanti, S. R., Arraniry, B. A., Rachman, R. Y., & Wikanta, W. (2017). Antioxidant activities of different solvent extracts of Piperretrofractumvahl. using DPPH assay. *Proceedings of AIP International Biology Conference, 1854*, 020019. https://doi.org/10.1063/1.4985410

Kassim, A., Workneh, T. S., Laing, M. D., & Basdew, I. H. (2016). The effects of different pre-packaging treatments on the quality of kumquat fruit. *CyTA Journal of Food*, *14*(5), 639-648. https://doi.org/10.1080/19476337.2016.1190407

Kedare, S. B., & Singh, R. P. (2011). Genesis and development of DPPH method of antioxidant assay. *Journal of Food Science and Technology*, *48*(4), 412-422. https://doi.org/10.1007/s13197-011-0251-1

Khatun, Z., Dash, P. K. Mannan, M. A. (2022). Influence of precooling systems on postharvest quality and shelf life of dragon fruits (*Hylocereus polyrhizus*). *Journal of Bangladesh Agricultural University*, *20*(3), 313-322. https://doi.org/10.5455/JBAU.63376

Kim, C., Hung, Y. C., & Brackett, R. E. (2000). Roles of oxidation-reduction potential in electrolyzed oxidizing and chemically modified water for the inactivation of food-related pathogens. *Journal of Food Protection*, *63*(1),19-24. https://doi.org/10.4315/0362-028X-63.1.19

Len, S. V., Hung, Y. C., Erickson, M., & Kim, C. (2000). Ultraviolet spectrophotometric characterization and bactericidal properties of electrolyzed oxidizing water as influenced by amperage and pH. *Journal of Food Protection*, *63*(11),1534-1537. https://doi.org/10.4315/0362-028x-63.11.1534

Li, X., Wu, X., & Huang, L. (2009). Correlation between antioxidant activities and phenolic contents of radix *Angelicae sinensis* (Danggui). *Molecules*, *14*(12), 5349-5361. https://doi.org/10.3390/molecules14125349

Lin, Y. F., Chen, M. Y., Lin, H. T., Hung, Y. C., Lin, Y. X., Chen, Y.H., & John, S. (2017). DNP and ATP induced alteration in disease development of Phomopsis longanae Chi-inoculated longan fruit by acting on energy status and reactive oxygen species production-scavenging system. *Food Chemistry*, *22*, 497-505. https://doi.org/10.1016/j.foodchem.2017.02.045

Mahmoud, B. S. (2007). Electrolyzed water: a new technology for food decontamination - a review. *Deutsche Lebensmittel-Rundschau*, *103*(5), 212-221.

Martinez, A., Conde, E., Moure, A., Dominguez, H., & Estevez, R. J. (2012). Protective effect against oxygen reactive species and skin fibroblast stimulation of *Couroupita guianensis* leaf extracts. *Natural Product Research*, *26*(4), 314-322. https://doi.org/10.1080/14786411003752094

Mazumdar, D. B. C., & Majumdar, K. (2001). *Methods of physico-chemical analysis of fruits*. Daya Publishing House, India. 112-115.

Miller, W. R., & McDonald, R. E. (1993). Quality of two Florida blueberry cultivars after packaging and storage. *HortScience*, *28*(2), 144-147. https://doi.org/10.21273/HORTSCI.28.2.144

Odeyemi, O. M., Kitinoja, L, Dubey, N., Musanase, S., & Gill, G. S. (2021). Preliminary study on improved postharvest practices for tomato loss reduction in Nigeria, Rwanda and India. *African Journal of Science, Technolology, Innovation and Development*, *14*(6), 1500-1505. https://doi.org/10.1080/20421338.2021.1961986

Pandurangan, P., Sahadeven, M., Sunkar, S., & Dhana, S. K. N. M. (2018). Comparative analysis of biochemical compounds of leaf, flower and fruit of *Couroupita guianensis* and synthesis of silver nanoparticles. *Pharmacognosy Journal*, *10*(2), 315-323. http://doi.org/10.5530/pj.2018.2.55

Qin, Y. Y., Liu, D., Wu, Y., Yuan, M. L., Li, L., & Yang, J. Y. (2015). Effect of PLA/PCL/cinnamaldehyde antimicrobial packaging on physicochemical and microbial quality of button mushroom (*Agaricus bisporus*). *Postharvest Biology and Technology*, *99*, 73-79. https://doi.org/10.1016/j.postharvbio.2014.07.018

Raveendra, B., Kiran, S., Kumari, V., Jyothi, R., & Bhavani, D. (2016). UV Spectrophotometric method for the estimation of roflumilast in human serum. *Pharmaceutica Analitica Acta, 7*(6),1-4. http://doi.org/10.4172/2153-2435.1000487

Saini, R. S., Sharma, K. D., Dhankhar, O. P., & Kaushik, R. A. (2006). *Laboratory manuals for analytical techniques in horticulture*. Agrobios Publishing Co. Ltd., India. 5-16.

Sinha, S. R., Singha, A., Faruquee, M., Jiku, M. A. S., Rahman, M. A., Alam, M. A., & Kader, M. A. (2019). Post-harvest assessment of fruit quality and shelf life of two elite tomato varieties cultivated in Bangladesh. *Bulletin of the National Research Centre, 43*, 185. https://doi.org/10.1186/s42269-019-0232-5

Suslow, T. V. (2004*). Oxidation-Reduction Potential (ORP) for Water Disinfection Monitoring, Control, and Documentation*. ANR Publication No. 8149; University of California Davis: Oakland, CA, USA. 1-5.

Tang, J., Chen, H., Lin, H., Hung, Y. C., Xie, H., & Chen, Y. (2021). Acidic electrolyzed water treatment delayed fruit disease development of harvested longans through inducing the disease resistance and maintaining the ROS metabolism systems. *Postharvest Biology and Technology*, *171*, 111349. https://doi.org/10.1016/j.postharvbio.2020.111349

Vasquez-Lopez, A., Villarreal-Barajas, T., & Rodriguez-Ortiz, G. (2016). Effectiveness of neutral electrolyzed water on incidence of fungal rot on tomato fruits (*Solanum lycopersicum* L.). *Journal of Food Protection*, *79*(10),1802-1806. https://doi.org/10.4315/0362-028x.jfp-15-494

Wang, C., Gao, Y., Tao, Y., Wu, X. Z., & Zhibo, C. (2017). Influence of γ-irradiation on the reactive-oxygen metabolism of blueberry fruit during cold storage. *Innovative Food Science and Emerging Technologies*, *41*, 397-403. https://doi.org/10.1016/j.ifset.2017.04.007

Wisniewski, M., Droby, S., Norelli, J., Liu, J., & Schena, L. (2016). Alternative management technologies for postharvest disease control: The journey from simplicity to complexity. *Postharvest Biology and Technology*, *122*, 3-10. https://doi.org/10.1016/j.postharvbio.2016.05.012

Workneh, T. S., Osthoff, G., & Steyn, M. (2012). Effects of preharvest treatment, disinfections, packaging and storage environment on quality of tomato. *Journal of Food Science and Technology*, *49*(6), 685-694. https://doi.org/10.1007%2Fs13197-011-0391-3

Xu, F. X., Wang, S. H., Xu, J., Liu, S. Y., & Li, G.D. (2016). Effects of combined aqueous chlorine dioxide and UV-C on shelf-life quality of blueberries. *Postharvest Biology and Technology*, *117*, 125-131. https://doi.org/10.1016/j.postharvbio.2016.01.012

YAS. (2020). *Yearbook of Agricultural Statistics*. Statistics Division, ministry of planning. Government of the People's Republic of Bangladesh. 298.

Zhang, W., Cao, J., & Jiang, W. (2021). Application of electrolyzed water in postharvest fruits and vegetables storage; A review. *Trends in Food Science and technology, 114*, 599-607. https://doi.org/10.1016/j.tifs.2021.06.005