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Elicitor-mediated sanitization in combination with edible coatings improve postharvest shelf life and antioxidant potential of mango fruit

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Abstract

Mangoes are accepted globally due to their delicious taste. However, they tend to be very susceptible to physical and biological deterioration. Deterioration can be prevented by post-harvest treatments. In present study, the effect of elicitor and edible coating was evaluated to reduce post-harvest losses in mangoes. The combinations of treatments evaluated were UV-C irradiation, ozone water and guar gum, and their combinations, followed by storage at 32 ± 3 °C. Physico-chemical and metabolic quality were evaluated for different parameters at regular intervals. The results indicated that the coating and elicitor treatments were better as compared to the control in terms of quality and appearance. The antioxidant activity and phenolic compounds was significantly higher in UV-C and ozone water treatments than in control and other treatments. The ascorbic acid level was enhanced in UV-C and guar gum coating and UV-C, ozone and guar gum coating treatments compared to the control. Mangoes treated with UV-C and ozone water remained fresh and acceptable for 19 days, whereas control fruits decayed after 13 days of storage. Hence, treatment consisting of UV-C and ozone water can be used for the preservation of mangoes.

Key words: antioxidant activity, edible coating, elicitor, mango, ozone water treatment, quality, shelf life.
Abbreviations: PLW, physiological loss of weight; TSS, total soluble solids.

Introduction

Fruits are considered as a staple food due to their composition. They are a source of antioxidants such as carotenoids, polyphenols and anthocyanins and are reported to act on free radicals produced within the body (Paliyath et al. 2008). Besides having very sweet aroma and sweet taste, fruits also have very important nutraceutical composition and good calorific values. Mango is globally ranked as the 2nd tropical fruit after banana with production about 30 million metric tons and it is oldest most important fruit (Mohammed et al. 2018). The consumption of mangoes is increasing gradually due to its health promoting attributes and its trading has become profit making in recent decades (Yahia 2011).

Generally mangoes are harvested at their commercial stage (Singh et al. 2013), and they are transported to the market with proper packing in bamboo baskets or wooden baskets (Paliyath et al. 2008). In spite of taking all necessary care, this fruit has a tendency of rapid ripening after harvesting, with a massive proportion of good quality fruits becaming damaged causing rot (Prasad et al. 2019). Moreover, mangoes are easily targeted by various microorganisms, which cause diseases like anthracnose (Zhu et al. 2008). To overcome this kind of perishable tendency, some affordable, simple, safe and eco–friendly technologies are needed for reducing the enormous post harvest losses of mango.

Edible coatings provide a protective layer around the fruit surface. These edible coatings help to slow down the transpiration process as well as reduce the production of ethylene, which is responsible for the senescence of the fruit (Huang et al. 2019). Guar gum extracted from guar beans has film forming properties due to presence of galactomannanpolysaccharide and it is extensively used in the food and confectionary industries (Vega et al. 2017). Guar gum solution is highly viscous and it is reported to act as a perfect barrier for the respiration process (Rao et al. 2010).

A cross section of review of literature pertaining to the surface coating technologies used for preservation of mango fruit reveals the use of alginate coating, pectin, carboxy methyl cellulose, chitosan, zein and gelatin based edible coatings. Also lipid components of lemongrass oil, citronella oil, coconut oil and natural ghee have been used in edible coatings (Bibi, Baloch 2011; Gol, Rao 2014; Salinus et al. 2016; Lieu et al. 2018; Salinus et al. 2018).

According to Schreiner (2006) and Ramos et al. (2013), the secondary metabolism of plants can be triggered with the post-harvest treatments of elicitors like UV-C and ozone. Ozone is widely used for sterilization of the outer surface of fruits. It is a non-thermal technique for triggering

the defense mechanism of horticultural produce. A study conducted on mangoes suggested that ozonated water alone could maintain the quality of harvested mangoes more than that of chlorinated water (Almeida et al. 2016). Ozone is an oxidizing agent and it is 1.5 times stronger than chlorine. It is an effective technique to kill a broad spectrum of microorganisms present on the fruit surface (Xu et al. 1999).

UV-C irradiation (190 to 280 nm) is also used as one of the physical elicitors proven as a beneficial treatment for extension of shelf life of the fruits and vegetables. It is also considered as an eco friendly radiation, which directly attacks the genetic material of the microorganisms present on surface and eventually leads to total sanitization by killing the microorganisms (Aguilar et al. 2001). According to these studies, the use of UV-C could extend the shelf life of mangoes up to 14 days and 7 days at 5 and 20 °C respectively, while retaining the quality attributes.

The present study was carried out to evaluate the efficacy of elicitors along with edible coating on the postharvest shelf life and quality of the mangoes.

Materials and methods

Experimental setup

Fresh mangoes (*Mangifera indica* cv "Alphanso") were harvested at physiological maturity from an orchard in the 'Saniya Kanade' (21°07'43.1"N, 72°54'46.1"E) in the vicinity of Surat city, Gujarat, India in May 2016. The fruits were free from any visual defect. Fruits were washed with tap water and they were graded for uniform size and stage of maturity. Subsequently the fruits were washed with 2% sodium hypochlorite and again rinsed with tap water so as to remove residues of sodium hypochlorite and air dried at room temperature. These mangoes were divided into eight groups containing 15 fruits per group with five replicates, using three mango fruits per replicate. Following this, fruits were treated with seven treatments: control (C); ozone water (400 mg h^{-1}; T1); UV-C (210 to 280 nm; T2); guar gum coating (0.5%; T3); UV-C and ozone water (T4); ozone water and guar gum coating (T5); UV-C and guar gum coating (T6); ozone water, UV-C and guar gum coating (T7). Thereafter, the fruits were stored in the laboratory at 32 ± 2 °C and 45 ± 2% relative humidity. The treated fruits were analyzed for their quality at 0, 5th, 10th and 15th days.

Chemicals

Guar gum and other chemicals were of analytical grade procured from Himedia Laboratories, Mumbai.

Physiological loss of weight

Physiological loss of weight (PLW) was calculated by the method described by Horwitz and Latimer (2005). The following formula was used to calculate the weight loss percentage:

$$PLW\ (\%) = Initial\ weight - Final\ weight\ /\ Initial\ weight \times 100.$$

Determination of decay percentage

For calculating the percentage of decay of the fruits, a formula used was the number of fruits decayed was divided by the total number of fruits kept in the treatment at '0' day and multiplied by 100 (Horwitz, Latimer 2005).

Total soluble solids and pH

One gram of fruit tissue was homogenized with 10 mL of distilled water in a mortar and pestle followed by centrifugation for 20 min at 5000 rpm. The supernatant was collected and used for the analysis of pH and total soluble solids (TSS). pH was measured using a digital pH meter (EI 101). The TSS content was measured by a digital refractometer (Atago, Japan) and was calculated using the formula given in AOAC (Horwitz, Latimer 2005).

Total phenolics, total antioxidant activity and ascorbic acid

Total phenolic concentration was measured by the method based on Folin-Ciocalteu reagent (McDonald et al. 2001). According to this method, 1 g of fruit tissue was homogenized with 10 mL 80% methanol followed by centrifugation at 5000 rpm for 20 min. For estimation, 0.1 mL supernatant was added to 0.9 mL of distilled water. Then 2.5 mL of Folin-Ciocalteu reagent (1:1) was added followed by addition of 2 mL of 1M sodium carbonate and allowed to incubate at room temperature for 30 min. The absorbance was recorded at 765 nm spectrophotometrically and it was expressed as mg g–1 gallic acid.

The total antioxidant activity was measured using the diphenyl-2-picrylhydrazyl (DPPH) method (Williams et al. 1995), which includes the use of 6 mg% DPPH (2.9 mL) and the 0.1 mL supernatant, which was used for the phenol estimations. The reaction mixture was incubated keeping tubes in the dark for 30 min and then absorbance was recorded against methanol at 517 nm and results expressed as percentage of antioxidant activity.

Ascorbic acid was extracted by crushing 1 g of fruit tissue with 10 mL of mixture of meta-phosphoric acid and acetic acid (6% and 2 M, respectively). The mixture was centrifuged at 5000 rpm for 20 min at room temperature. For quantitative estimation, 0.2 mL of supernatant was used and volume made up to 1 mL by adding meta-phosphoric acid and acetic acid mixture, 1 mL of 2% di-nitrophenylhydrazine was added followed by 30 µL of 10% thiourea. The mixture was incubated at 37 °C for 3 h and then 5 mL of 85% chilled H_2SO_4 was added and allowed to cool at room temperature for 15 min. The absorbance was recorded at 540 nm and expressed as mg 100 g^{-1} (Kapur et al. 2012).

Carotenoid pigments

Carotenoid pigments were estimated as per the method of

Wang et al. (2005). Briefly, 1 g of tissue was homogenized in hexane:acetone (60:40) solution and centrifuged at 5000 rpm for 20 min. The supernatant was used directly to estimate carotenoid concentration with recording absorbance at 450 nm and expressed as μg g^{-1}.

Headspace gas analysis

The Headspace Gas Analyzer (HGA, GS3/P, Systech instruments) was used to measure the exchange of O_2 and CO_2 of treated mango fruits. One fruit from each treatment was kept in a sealed glass jar for 6 h. The headspace probe was inserted through the rubber septum and the instrument was run to detect the concentration of O_2 and CO_2 generated by fruit respiration. The obtained results were expressed as percentage.

Extraction and assay of polygalacturonase enzyme activity

Extraction and assay for enzyme polygalacturonase activity of mango fruits was carried out (Srivastava, Dwivedi 2000). Briefly, 1 g of tissue was extracted with 10 mL of 0.02 M sodium phosphate buffer (pH 7.0, containing 0.02 M EDTA and 0.05% Triton X) in a pre-cooled mortar with pestle to avoid the denaturation of enzyme by atmospheric temperature. The homogenate was centrifuged at 4 °C at 10 000 rpm and supernatant was collected for assay. For analysis, 0.2 mL sodium acetate buffer (0.2 M, pH 5.0) was added to 0.1 mL NaCl (0.2 M), 0.3 mL polygalacturonic acid (1%), 0.3 mL distilled water and 0.1 mL enzyme extract, and was incubated at room temperature for 60 min. After incubation, 2 mL distilled water was added followed by addition of 3 mL dinitrosalicylic acid. The mixture was placed in boiling water bath for 5 min and 1 mL of potassium sodium tartarate (40%) was added to terminate the reaction. The absorbance was recorded at 560 nm and expressed as U h^{-1} mg^{-1} protein. Total protein concentration present in mango fruits was estimated using the method of Lowry et al. (1951).

Statistical analysis

All experiments were carried out in triplicate and data was analyzed using SPSS software version 19.0. Mean comparisons were performed using the HSD of Tukey's test, Duncan and Dunnet tests to examine if differences between treatments and storage time were significant at $p \leq 0.05$. The overall least significance difference (LSD; $p \leq 0.05$) was calculated and used to detect significant differences among the treatments and control groups (Bico et al. 2009).

Results

Physiological loss of weight

Weight loss was observed through out the storage period for fruits in the treated and control groups. The control fruits showed continuous greater weight loss, compared to treated fruits. The control fruits showed 5.02% weight loss on the 5th day and increased to 71.49% on the 15th day while the fruits treated with T7 showed 5.56% PLW on the 5th day and 15.56% on the 15th day, which was found to be least loss during the entire storage period (Fig. 1).

Decay percentage

The decay percentage of mango fruits on the 5th day was 6.67%, which was similar for T2, T3, T4 and T7, while it was 0% for T4 (Fig. 2). The decay percentage found in the control on the 5th day was 33.33%, which is considerably higher than that of any other treatment. The least decay percent was noticed in fruits treated with the combination of UV-C and ozone water (T4). In comparison with that of the control, fruits of T4 treatment showed six days of extended shelf life. A lower percentage of fruit decay in the T4 treatment indicated that the combination of UV-C irradiation and ozone water slowed senescence.

pH and TSS

The fruits from all treatments, except the control showed a slow rate of ripening. On the 10th day of fruit storage, the

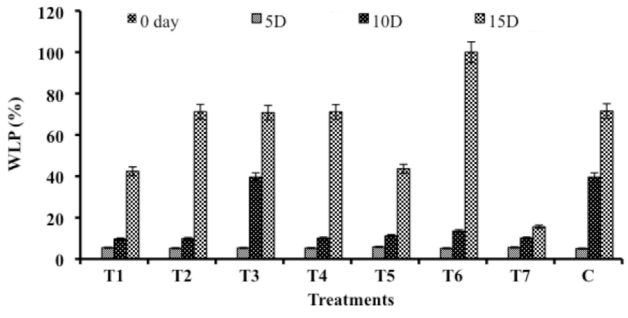

Fig. 1. Effect of elicitor and coating treatments on physiological loss of weight of stored mango fruits. Ozone water 400 mg h^{-1} (T1), UV-C (210 to 280 nm) (T2), guar gum 0.5% (T3), UV-C and ozone water (T4), ozone water and guar gum 0.5% (T5), UV-C and guar gum 0.5% (T6), ozone water, UV-C and guar gum 0.5% (T7) and control (C).

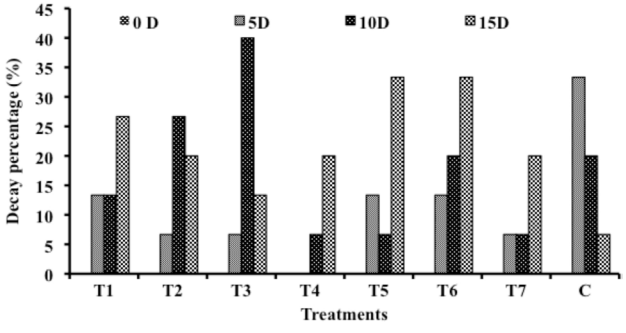

Fig. 2. Effect of elicitor and coating treatments on decay ratio of stored mango fruits. Ozone water 400 mg h^{-1} (T1), UV-C (210 to 280 nm) (T2), guar gum 0.5% (T3), UV-C and ozone water (T4), ozone water and guar gum 0.5% (T5), UV-C and guar gum 0.5% (T6), ozone water, UV-C and guar gum 0.5% (T7) and control (C).

pH in T4 treatment was significantly higher (pH 4.1) than in the control (pH 5.9). Moreover on the 5th day of storage, the TSS found in T2, T4, T6 and T7 were 1.87, 1.90, 1.83 and 1.63 °brix, respectively, whereas in T1 group the TSS was 2.37 °brix, which was significantly higher than that of any other treatment. On the 15th day of storage, the TSS in T4 was 1.3 °brix, which was significantly different than that of the control (1.5 °brix; Table 1).

Total phenolics, total antioxidant activity and ascorbic acid

Total phenolic concentration in freshly harvested fruits was 1.84 mg g^{-1}, and on the 5th day of storage in control it decreased to 0.87 mg g^{-1}, while in the T1 treatment it was significantly higher (1.96 mg g^{-1}) than in any other treatment. On the 15th day of storage period, total phenolic concentration in T4 was 1.36 mg g^{-1}, compared to 1.09 and 0.97 mg g^{-1}, respectively, in the control and T5. Antioxidant activity in T1 and T4 treatments on the 5th day was significantly higher (95.7 and 95.9%, respectively) and in control fruits antioxidant activity was 79.3%. Moreover, at the end of the storage period (15th day), total antioxidant activity observed in T4 treatment was 92.3% while in the control group – 72.1%.

On the 5th day of storage ascorbic acid concentration in T4 was 0.069 mg 100 g^{-1}, while it was only 0.056 mg 100 g^{-1} in control fruits, which was significantly lower. At the end of the storage period (15th day) ascorbic acid concentration in T4, T5, T6 and T7 was 0.051, 0.058, 0.062 and 0.059 mg 100 g^{-1}, respectively, but in control fruits it was only 0.047 mg 100 g^{-1} (Table 2).

Carotenoids

Treated and untreated fruits showed an increasing trend of carotene concentration, and significant diferences were found at the end of the storage period of the post-harvest mangoes. Initially the carotene concentration in the mango fruits was 2.82 μg g^{-1}. At the end of the storage period (15th day) carotene concentration in T1, T6 and T7 was significantly different (2.8, 2.8 and 2.5 μg g^{-1}, respectively) from that in control fruits (3.5 μg g^{-1}; Table 3).

Changes in polygalacturonase activity

Significant changes in the polygalacturonase activity were observed throughout storage period. The activity of polygalacturonase enzyme was 1.15 U h^{-1} mg^{-1} protein on 0 day (Fig. 3). On the 5th day, PG activity was reduced in T4 and T6 (0.32 and 0.35 U h^{-1} mg^{-1} protein, respectively), while activity in the control ftuits was 0.46 U h^{-1} mg^{-1} protein. Thereafter, polygalacturonase activity decreased to 0.05 and 0.04 U h^{-1} mg^{-1} p rotein on the 15th day. Polygalacturonase activity was found to be significantly lower in these two treatments (T4 and T6), compared to control and other treatments, and continuously declinig during the storage period of mango.

Headspace gas analysis

Headspace compositions of O_2 and CO_2 in treated and untreated fruits are shown in Fig. 4 and 5. In freshly harvested fruit, the O_2 concentration was 10.2% and CO_2 concentration was 13.0%. On the 5th day of storage period, the O_2 concentration in T3 and T4 was 13.1 and 11.1%

Table 1. Effect of treatments on total soluble solid and pH of mango fruits stored at 32 ± 2 °C and 45 ± 2% relative humidity. Means ± standard deviation with the different letters within a column are significantly different at $p < 0.05$ DMRT. Ozone water 400 mg h^{-1} (T1), UV-C (210 to 280 nm) (T2), guar gum 0.5% (T3), UV-C and ozone water (T4), ozone water and guar gum 0.5% (T5), UV-C and guar gum 0.5% (T6), ozone water, UV-C and guar gum 0.5% (T7) and control (C)

Treatments	Day 0	Day 5	Day 10	Day 15
		Total soluble solids (°Brix)		
T1	1.86 ± 0.05 e	2.36 ± 0.05 a	2.30 ± 0.00 a	1.60 ± 0.00 bc
T2	1.86 ± 0.05 e	1.86 ± 0.05 e	1.86 ± 0.06 b	1.36 ± 0.05 d
T3	1.86 ± 0.05 e	2.03 ± 0.05 cd	2.00 ± 0.00 b	1.40 ± 0.00 d
T4	1.86 ± 0.05 e	1.90 ± 0.00 de	1.93 ± 0.06 b	1.36 ± 0.05 d
T5	1.86 ± 0.05 e	2.16 ± 0.05 bc	1.93 ± 0.06 b	1.76 ± 0.05 a
T6	1.86 ± 0.05 e	1.83 ± 0.05 e	1.63 ± 0.06 c	1.70 ± 0.00 ab
T7	1.86 ± 0.05 e	1.63 ± 0.05 f	1.53 ± 0.12 c	1.80 ± 0.00 a
C	1.86 ± 0.05 e	2.26 ± 0.05 ab	2.33 ± 0.12 a	1.56 ± 0.05 c
		pH		
T1	3.78 ± 0.02 g	4.63 ± 0.01 d	4.72 ± 0.05 d	4.81 ± 0.01 g
T2	3.78 ± 0.02 g	4.58 ± 0.01 e	4.62 ± 0.00 e	5.36 ± 0.01 c
T3	3.78 ± 0.02 g	4.12 ± 0.01 f	4.40 ± 0.02 f	5.89 ± 0.01 a
T4	3.78 ± 0.02 g	4.06 ± 0.01 g	4.12 ± 0.02 g	5.13 ± 0.01 d
T5	3.78 ± 0.02 g	4.71 ± 0.01 c	4.90 ± 0.02 c	4.90 ± 0.01 f
T6	3.78 ± 0.02 g	5.06 ± 0.01 a	5.11 ± 0.01 b	5.38 ± 0.00 b
T7	3.78 ± 0.02 g	4.84 ± 0.01 b	5.06 ± 0.01 b	4.95 ± 0.01 e
C	3.78 ± 0.02 g	4.85 ± 0.01 b	5.88 ± 0.02 a	4.82 ± 0.01 g

Table 2. Effect of treatments on ascorbic acid, total phenolics, and total antioxidant activity of mango fruits stored at 32 ± 2 °C and 45 ± 2% relative humidity. Means ± standard deviation with the different letters within a column are significantly different at $p < 0.05$ DMRT. Ozone water 400 mg h^{-1} (T1), UV-C (210 to 280 nm) (T2), guar gum 0.5% (T3), UV-C and ozone water (T4), ozone water and guar gum 0.5% (T5), UV-C and guar gum 0.5% (T6), ozone water, UV-C and guar gum 0.5% (T7) and control (C)

Treatments	Day 0	Day 5	Day 10	Day 15
		Ascorbic acid (mg 100 g^{-1})		
T1	4.79 ± 0.10 a	5.39 ± 0.13 b	5.36 ± 0.09 d	4.97 ± 0.36 c
T2	4.79 ± 0.10 a	3.88 ± 0.18 e	4.85 ± 0.05 e	4.70 ± 0.27 c
T3	4.79 ± 0.10 a	4.88 ± 0.10 c	5.33 ± 0.18 d	5.12 ± 0.31 bc
T4	4.79 ± 0.10 a	6.88 ± 0.10 a	5.36 ± 0.27 d	5.12 ± 0.46 bc
T5	4.79 ± 0.10 a	5.24 ± 0.05 bc	6.85 ± 0.05 c	5.79 ± 0.13 ab
T6	4.79 ± 0.10 a	4.30 ± 0.13 d	7.03 ± 0.13 bc	6.21 ± 0.10 a
T7	4.79 ± 0.10 a	3.39 ± 0.13 f	7.30 ± 0.13 b	5.94 ± 0.05 a
C	4.79 ± 0.10 a	5.61 ± 0.18 b	8.00 ± 0.09 a	4.70 ± 0.22 c
		Total phenolics (mg g^{-1})		
T1	1.84 ± 0.09a	1.96 ± 0.03 a	1.35 ± 0.06 b	1.15 ± 0.02 c
T2	1.84 ± 0.09 a	1.41 ± 0.03 e	1.08 ± 0.02 c	1.24 ± 0.02 b
T3	1.84 ± 0.09 a	1.60 ± 0.02 d	1.34 ± 0.04 b	1.04 ± 0.02 de
T4	1.84 ± 0.09 a	1.42 ± 0.00 e	1.68 ± 0.00 a	1.36 ± 0.02 a
T5	1.84 ± 0.09 a	1.47 ± 0.02 e	1.34 ± 0.02 b	0.97 ± 0.01 e
T6	1.84 ± 0.09 a	1.82 ± 0.02 b	1.34 ± 0.02 b	1.06 ± 0.03 d
T7	1.84 ± 0.09 a	1.74 ± 0.02 c	0.98 ± 0.04 c	1.15 ± 0.03 c
C	1.84±0.09 a	0.87±0.01 f	1.33±0.07 b	1.09±0.03 cd
		Total antioxidant activity (%)		
T1	95.9 ± 0.10a	95.7 ± 0.08 a	85.5 ± 0.17 e	72.7 ± 0.27 e
T2	95.9 ± 0.10 a	94.9 ± 0.03 b	81.5 ± 0.12 f	77.0 ± 0.26 d
T3	95.9 ± 0.10 a	95.7 ± 0.08 a	93.1 ± 0.10 b	66.2 ± 0.13 f
T4	95.9 ± 0.10 a	95.9 ± 0.11 a	93.9 ± 0.18 a	92.3 ± 0.33 a
T5	95.9 ± 0.10 a	95.0 ± 0.14 b	91.8 ± 0.28 c	72.4 ± 0.39 e
T6	95.9 ± 0.10 a	94.4 ± 0.03 c	93.0 ± 0.40 b	79.5 ± 0.19 c
T7	95.9 ± 0.10 a	95.1 ± 0.20 b	87.4 ± 0.12 d	83.9 ± 0.39 b
C	95.9 ± 0.10 a	79.3 ± 0.05 d	92.4 ± 0.15 c	72.1 ± 0.22 e

respectively; the CO_2 concentration in T3 and T4 was 10.30% and 11.60% respectively. On 15th day of storage period, the O_2 concentration in T4 and T5 treated mangoes was significantly lower (8.7 and 12.2%, respectively); the CO_2 concentration in T3 and T4 treated mangoes showed a slight increase to 11.8 and 9.1%, respectively.

Discussion

Freshly harvested mango fruits contain a large amount of moisture and respiration accelerates as the ripening process takes place (Baloch, Bibi 2012). The moisture content declines very quickly through the peel in the

Table 3. Effect of treatments on carotenoid concentration (μg g^{-1}) of mango fruits stored at 32 ± 2 °C and 45 ± 2% relative humidity. Means ± standard deviation with the different letters within a column are significantly different at $p < 0.05$ DMRT. Ozone water 400 mg h^{-1} (T1), UV-C (210 to 280 nm) (T2), guar gum 0.5% (T3), UV-C and ozone water (T4), ozone water and guar gum 0.5% (T5), UV-C and guar gum 0.5% (T6), ozone water, UV-C and guar gum 0.5% (T7) and control (C)

Treatments	Day 0	Day 5	Day 10	Day 15
T1	2.82 ± 0.00 g	3.37 ± 0.00 a	3.92 ± 0.00 a	2.76 ± 0.00 e
T2	2.82 ± 0.00 g	2.06 ± 0.01 f	2.69 ± 0.00 f	3.98 ± 0.00 a
T3	2.82 ± 0.00 g	1.15 ± 0.01 g	2.80 ± 0.00 d	3.94 ± 0.01 b
T4	2.82 ± 0.00 g	2.74 ± 0.02 d	3.41 ± 0.00 c	3.97 ± 0.00 ab
T5	22.82 ± 0.00 g	2.43 ± 0.01 e	3.52 ± 0.00 b	3.85 ± 0.01 c
T6	2.82 ± 0.00 g	0.31 ± 0.00 c	2.57 ± 0.00 g	2.78 ± 0.00 e
T7	2.82 ± 0.00 g	3.14 ± 0.00 b	2.74 ± 0.00 e	2.49 ± 0.01 f
C	2.82 ± 0.00 g	2.06 ± 0.02 f	2.34 ± 0.00 h	3.48 ± 0.00 d

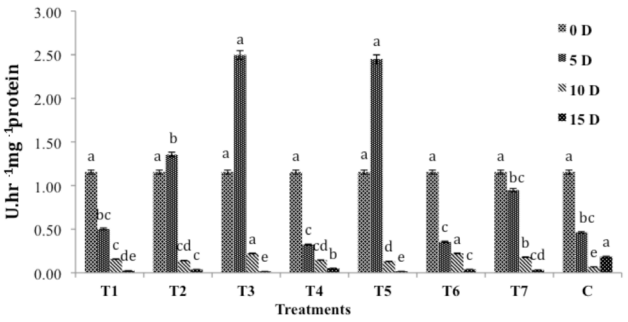

Fig. 3. Effect of elicitor and coating treatments on polygalacturonase activity. Ozone water 400 mg h^{-1} (T1), UV-C (210 to 280 nm) (T2), guar gum 0.5% (T3), UV-C and ozone water (T4), ozone water and guar gum 0.5% (T5), UV-C and guar gum 0.5% (T6), ozone water, UV-C and guar gum 0.5% (T7) and control (C).

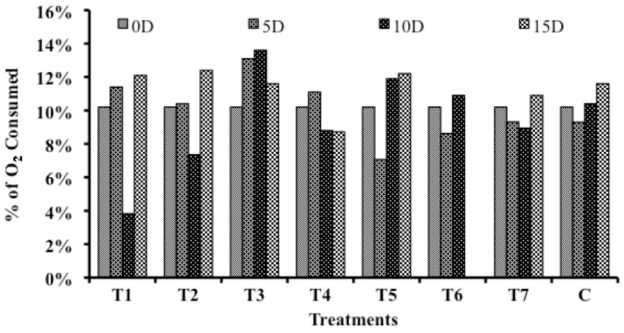

Fig. 4. Effect of elicitor and coating treatments on O_2 consumption. Ozone water 400 mg h^{-1} (T1), UV-C (210 to 280 nm) (T2), guar gum 0.5% (T3), UV-C and ozone water (T4), ozone water and guar gum 0.5% (T5), UV-C and guar gum 0.5% (T6), ozone water, UV-C and guar gum 0.5% (T7) and control (C).

form of vapour, so this diffusivity mechanism is ultimately responsible for the decreasing weight of the fruit (Dissa et al. 2011). Eventually the decrease in water content results in shrinkages on the fruit surface (Baraiya et al. 2014). Higher weight loss in control fruits was attributed to the effect of ethylene on moisture content of stored mango (Kad et al. 2017). Metabolic activity and increase of ethylene concentration can be slowered down by edible coatings that act as moisture barrier (Mandal et al. 2018).

Fruits and vegetables contain a large number of organic molecules that attract microorganisms after harvesting (Chun, 2010). The decay of the fruit is mainly due to moisture loss and infection (Chien et al. 2007). This finding is more or less in accordance with that of Aguilar et al. (2007).

As mangoes harvested from an orchard were at their physiological maturity stage, the process of ripening started in the fruit causing the conversion of organic acids into sugars (Paliyath et al. 2008). When fruit began to ripe, initially its acidity is high, so its pH was low, but when organic acids start to convert into the sugars the fruit starts to become less acidic/sour and sweeter in nature (Vyas et al. 2015). This relation seems to be applicable to TSS as well, as with the formation of sugars and proteins and other micronutrients during ripening, the TSS starts to increase. The slow changes in pH and TSS might be due to slow respiration rate which inhibits the conversion of acids into sugars and other micronutrients.

Phenolics are considered as a defense system of the fruit. They prevent fruits from any kind of bacterial or fungal infections and phenolics have a potential for scavenging free radicals (Gol, Rao 2014). Further, phenols play important role in the maintenance of its taste, aroma and flavour (Diaz et al. 2012). Antioxidants of fruit (ascorbic acid, carotenoids etc.) are essential attributes of fruit.

The level of ascorbic acid decreases with time of storage and oxidation take place (Nasution et al. 2015). When fruits are about to start their ripening process, the total phenolics and total antioxidant activity decreases. The levels of phenolics and ascorbic acid were maintained throughout the storage period and their levels were found to be high in fruits treated with ozone and UV-C. These results are in accordance with Monaco et al. (2014), and Aguilar et al. (2001) who also reported that organic acids of mango were not altered and were maintained by the UV-C treatment.

Medicottet et al. (1986) and Knee et al. (1972) reported that ripening of mango was accompanied by breakdown of chlorophyll and increased carotenoid level. The conversion of the chrophyll into colour pigments is due to a high rate of respiration, which uses atmospheric oxygen for conducting metabolic activities (Gol, Rao 2014). The slow accumulation of the carotene in fruits treated with ozone and UV-C might be due to the altered rate of respiration. Almeida et al. (2016) concluded that carotene levels and other antioxidant levels were high in mangoes treated with ozonated water. This combination of physical elicitors slowing down the physiological activity was also reported by Huyskens et al. (2011).

The loss of firmness in fruits is an important process of ripening in climacteric fruits. The degradation of cell wall results in the softening of fruits with respect to conversion of protopectin into pectin catalyzed by polygalacturonase

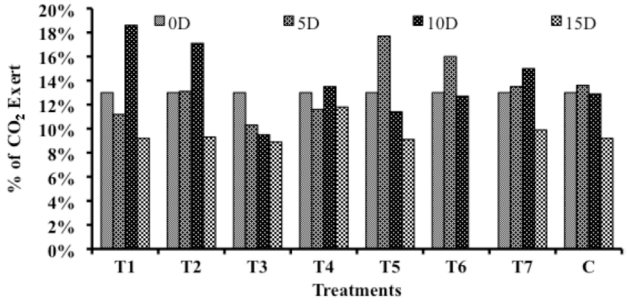

Fig. 5. Effect of elicitor and coating treatments on release of CO_2. Ozone water 400 mg h^{-1} (T1), UV-C (210 to 280 nm) (T2), guar gum 0.5% (T3), UV-C and ozone water (T4), ozone water and guar gum 0.5% (T5), UV-C and guar gum 0.5% (T6), ozone water, UV-C and guar gum 0.5% (T7) and control (C).

(Baraiya et al. 2016). The reduction in the activity of polygalacturonase indicates the slower breakdown of the complex cell wall compounds. The loss of the firmness of the postharvest fruits is due to the degradation of the pectin, lignins and the destruction of the middle lamella (Lefever et al. 2004). The degradation of the pectin is due to polygalacturonic acid, which also known as pectin depolymerase, which triggers the softening of the fruits (Downs et al. 1992). Barka et al. (2008) also observed similar changes and suggested that irradiation can reduce significant activity of polygalacturonase, as compared to that of a control.

During ripening some O_2 is consumed by the fruit for conducting metabolic reactions and CO_2 is lost from the fruit, this indicating respiration by the fruit. Rai et al. (2011) reported a similar kind of pattern of O_2 and CO_2 exchange during ripening.

Conclusions

In the present study, the efficacy of physical elicitors and edible coating of guar gum was evaluated for beneficial effect on shelf life extension and quality maintenance of mango. The results obtained from the present study indicate that the combination of UV-C irradiation and ozone can maintain the antioxidant activity of the mango at room temperature. Moreover, this combination was effective in retention of the TSS, pH and carotene of mango. The post-harvest shelf life of mango was extended by six days, as compared to that of the control. This technology is eco-friendly, cost effective and does not require excessive man power. Therefore, this treatment combination can be useful for management of postharvest losses of perishable fruits and vegetables in India as well as in other countries.

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