Journal of Food Science and Technology (Iran)

Homepage:www.fsct.modares.ir

Scientific Research

Investigating the effects of UV-C and ultrasonic treatments on the shelf life of Langra mango fruits

Hasan Shorakaie [1], Abdolmajid Mirzaalian Dastjerdi[2*], Mostafa Ghasemi*[3], Somayeh Rastegar[4]

1- MSc. Graduated student, Department of Horticulture, University of Hormozgan, Bandar Abbas, Iran
2- Associate Professor, Department of Horticulture, University of Hormozgan, Bandar Abbas, Iran.
3- Assistant Professor, Horticulture Crops Research Department, Qazvin Agricultural and Natural Resources Research and Education Center, AREEO, Qazvin, Iran.
4- Horticulture, University of Hormozgan, Bandar Abbas, Iran.

ARTICLE INFO

Article History:

Received:2022/10/24
Accepted: 2023/11/27

Keywords:

Irradiation,
Qualitative traits,
Shelf life,
Nutritional value,
Climacteric
.

DOI: 10.22034/FSCT.21.147.16.

*Corresponding Author E-Mail:
majiddastjerdy@gmail.com

mostafaghasemi1417@gmail.com

ABSTRACT

The current research aimed to maintain mango fruit quality and prolong fruit shelf life (*Manjifera indica* cv. Langra). A factorial experiment was conducted as a completely randomized design with three replications (18 fruits per replication). Mango fruits were harvested at mature green stage from a commercial mango orchard in Roodan city, Hormozgan province. The first factor was ultraviolet irradiation (UV-C) (25 W power) at three levels (0, 5, and 10 minutes). The second factor was ultrasonic irradiation with a frequency of 35 kHz (280 W power) at three levels (0, 3, and 6 min). The third factor was storage time at five levels (0, 10, 20, 30, and 40 days). After using the treatments at the mentioned UV-C and ultrasonic proportions, the fruits were stored in a cold, humid environment (10 °C and 80-85% relative humidity). Sampling and measurements were carried out at different times. Based on the results, ultraviolet and ultrasound treatments prevented the increase in L* (lightness), a*, b*, and pH values. Also, they prevented the decrease in fruit ascorbic acid over time. The highest ascorbic acid content (11.3 mg/100 g) occurred in response to the 3-minute ultrasound treatment. Ultraviolet treatments delayed the decrease in ascorbic acid content through storage time, compared to the control. However, the 5- and 10-minute ultraviolet treatments had no significant difference from each other. The 6-minute ultrasound treatment significantly suppressed the decrease in fruit weight. On the 40th day of storage, the lowest L* value in fruit flesh (89.44) occurred in response to the 5-minute ultraviolet treatment. Therefore, the 5-minute ultraviolet treatment can be recommended for the optimal maintenance of mango fruit appearance (L*). The 3-minute ultrasound treatment can be recommended for the optimal maintenance of ascorbic acid in mango fruits when stored for 40 days.

[DOI: 10.22034/FSCT.21.147.16]

1. Introduction

Mango is an important tropical fruit, recognized worldwide for its high nutritional value. It has gained popularity as one of the most important export fruits in many countries. Mango production in Asia accounts for 72.9% of mango production globally, and India is the largest producer, producing more than 39% of the total world production. According to the Food and Agriculture Organization at the United Nations, the total amount of mango production worldwide was approximately 42.7 million tons [1]. The total cultivation area in Iran was 2146 ha and the total mango production was 23627 tons in 2022 [2].

Since mango is a climacteric fruit [3], it can complete its ripening stages in the postharvest period. Harvesting at the ripe stage (completely yellow) is associated with fruit tissue softness and increases susceptibility to physical damage in storage and transportation. It also decreases the likelihood of supplying the fruit to distant markets [4]. Thus, in regions of commercial mango production, mango fruits are harvested at the mature green stage or when the fruit begins to change color. The fruits are stored in appropriate conditions, and if necessary, postharvest treatments are applied. Storage temperatures for mango fruits are usually between 10 and 15 °C, with humidity levels that range between 90-95%. In such circumstances, fruit quality can be maintained for 2 to 4 weeks [4].

Changes in fruit color and appearance can happen in mango due to shriveling and a decrease in fruit freshness, thus problematizing the duration of mango shelf life at the postharvest stage [5]. Nowadays, prevalent applications of chemical compounds increase the shelf life of horticultural products and control postharvest diseases, but limitations exist due to environmental considerations. Modern procedures in the industrial scales are expanding quickly to enable non-thermal methods for fruit preservation. Non-thermal methods protect the product without applying heat, so they prevent heat-induced changes in product quality [6 and 7]. Ultraviolet iradiation is a category of non-ionizing irradiation that operates at a wavelength of 100-400 nm. It is divided into three groups, i.e., UV-A that operates at a wavelength of 315-400 nm, UV-B at 280-315 nm, and UV-C at 100-280 nm [8]. UV-C rays have the strongest effect when used at 201-251 nm, thus significantly suppressing bacteria, viruses, protozoa, fungi, and algae. Protein and nucleic acids can absorb this irradiation and undergo photochemical changes that may lead to cell death [9]. UV-C irradiation has been successfully applied on products such as carrots [10], green

[DOI: 10.22034/FSCT.21.147.16]

peppers [11], strawberries and cherries [12], broccoli [13], and mangoes [14]. These applications maintained fruit quality, delayed senescence, and suppressed fruit decay in storage conditions.

Further to its antimicrobial properties, this irradiation can initiate biological stress, thus causing the accumulation of phytoalexin compounds, stimulating defense mechanisms in plant cells, and increasing antioxidant activity, modifying plant cell walls, and ultimately preserving fruit tissue integrity [6 and 14]. In the previous research by González Aguilar et al. [14], applying UV-C irradiation on mango fruits (Haden variety) caused the least decay in fruits that were exposed to the treatment for 5 and 10 minutes. The treatment reduced fungal contamination and increased marketability in the storage period. The 10-minute treatment was more effective than the 5-minute treatment on increasing fruit shelf life at the postharvest stage. UV-C irradiation at 6.6 kJ/m^2 delayed the increase in ripening index and postponed color changes from green to yellow in mango fruit skin during storage [15].

Ultrasound waves comprise a non-thermal method that increases the shelf life of fresh fruits in the storage period [16 and 17]. Its major range of frequency is between 20 kHz and 100 MHz and is not audible to humans [17]. Using ultrasound as a physical treatment not only eradicates the microorganisms from the fruit surface, but also neutralizes them and increases the fruit shelf life. Previous research showed that ultrasound treatment can counter bacteria, molds, and yeasts, thus prolonging shelf life and maintaining fruit quality [18] in strawberries [19], lychees [20], plums [21 and 22], and peaches [17 and 23]. In relevant research, the effect of ultrasound at 25 MHz was evaluated on the biochemical features of mango fruits at 23 °C and 80% humidity during three weeks. The results showed that the ultrasound treatment caused the least decay and fruit contamination compared to the control, and the fruits were more marketable after the storage period [24]. The combined treatment of ultrasound and salicylic acid was also effective in reducing fruit decay in peaches stored at 20°C [23]. Since mango fruits are an important source of income in the south of Iran, their short shelf life and a lack of information on irradiation treatments can give reason to apply these treatments on mango fruits (Langra cultivar) to achieve a longer shelf life in this commercial variety in the south of the country. Thus, this experiment aimed to evaluate the effects of UV-C irradiation and ultrasound treatment as a safe and effective treatment combination to study the physical properties, fruit quality, and storage life of this mango variety.

[DOI: 10.22034/FSCT.21.147.16]

2- Materials and Methods

Langra mango fruits were harvested at the mature green stage in a commercial orchard in Roodan city, Hormozgan province, in 2015. Immediately after harvest, the fruits were transferred to Hormozgan University, Faculty of Horticultural Science Laboratory. A total of 2430 uniform fruits were selected in terms of skin color, size, physical integrity, lack of mechanical damage and disease. The fruits were cleaned before conducting the experiments. The experimental layout was a factorial arrangement in a completely randomized design with three repetitions. The first factor was UV-C irradiation, applied at 254 nm at three duration levels (0, 5 and 10 minutes), the second factor was ultrasound irradiation at three duration levels (0, 3 and 6 minutes), and the third factor was storage time at five periods (0, 10, 20, 30, and 40 days). The fruits were first exposed to ultrasound treatment at 28 kHz (using 280 watts). Then, UV-C irradiation was immediately applied at 25 watts. After using the ultrasound and UV-C irradiation ratios, the fruits were placed in ventilated plastic containers and transferred to a cold room at 10 °C and 80-85% relative humidity. Each container or replicate had 18 fruits [6, 25 and 26]. Fruit weight loss, firmness, and color indices were measurable in the samples. Color indices comprised L* (brightness degree), a* (redness degree) and b* (yellowness degree). Other measurable variables were sugar content, titratable acidity, ascorbic acid, and total phenol during the storage time.

2.1. Fruit weight loss

To measure the percentage of fruit weight loss, the following formula was used [27]:

$$WL\ (\%) = \frac{W1-W2}{W1} \times 100$$

where WL is fruit weight loss, W1 is the initial fruit weight before storage (g) and W2 is the fruit weight in storage (g).

2-2- Fruit texture firmness

Fruit tissue firmness was measured using a penetrometer (model FT-327, Holland) equipped with a 10 mm probe. After removing the fruit skin, the probe was inserted into the equatorial region of the fruit to measure tissue firmness. The results were expressed as the maximum force required to penetrate the probe tip into the fruit tissue (kg/cm^2).

2-3. Fruit tissue and skin color

Color parameters such as L* (lightness degree), a* (redness degree) and b*

[DOI: 10.22034/FSCT.21.147.16]

(yellowness degree) were determined by a chromameter device (Minolta CR400, Japan) at three points of each fruit [28]. The index L* indicates the lightness or darkness of the color (0=black and 100=white). a* indicates the axis that moves from green (-a) to red (+a), and b* indicates the axis from blue (-b) to yellow (+b).

2.4. Soluble solids (TSS)

Total soluble solids were determined using a digital refractometer (model DBR95, Taiwan) based on light refraction, and the results were expressed as °Brix [29].

2.5. Titratable acidity (TA)

Titratable acidity was measured according to major organic acids in the fruit. To determine the titratable acidity, 5 ml of the extract was mixed with 45 ml of distilled water and 3-4 drops of phenolphthalein. Then, titration was done using sodium hydroxide (0.1 N NaOH). Observing a pink color indicated the end of the titration. The amount of consumed NaOH was recorded and entered into the following formula to calculate the titratable acidity [30]:

$$TA\ (\%) = [(V \times N \times meq) / Y] \times 100$$

where TA is the percentage of acid (citric acid) that can be titrated, V is the solution volume (ml) used in the titration, N is the normality of the solution (0.1), and meq is the equivalent weight of the major acid in mango fruits (citric acid), which was equal to 0.67, and Y was the fruit juice volume (ml).

2.6. Ascorbic acid

Ascorbic acid content was measured by mixing 1 ml of fruit juice with five ml of metaphosphoric acid. After three minutes of centrifugation, the supernatant was removed and titrated with indophenol. The appearance of a purple color indicated the end of the titration. The amount of consumed indophenol was recorded, and the value entered into the following formula to calculate the ascorbic acid content.

$$AA = (V \times F \times Y \times 100) / (W \times T)$$

where AA is the ascorbic acid content per 100 g of fresh fruit weight, V is the volume of indophenol (ml) used in titration, F is the indophenol factor (0.25) for a standard ascorbic acid solution, Y is the fruit mixture volume and metaphosphoric acid (6), W is sample weight (1 g), and T is sample volume for titration (5 ml) [31].

[DOI: 10.22034/FSCT.21.147.16]

2.7. Total phenol content

Total phenol content was measured using the Folin-Ciocalteu reagent according to a method by Singleton and Rossi [32]. Therefore, 0.5 grams of fruit tissue was homogenized with three ml of 85% methanol and 300 µl of it was mixed with 1500 µl of a diluted Folin reagent (10%). After five minutes, 1200 µl of sodium carbonate (7%) was added to the solution. After rotating for 90 minutes on the shaker, the absorbance value was measured using a spectrophotometer at 760 nm. The result was compared with a standard curve of gallic acid at 0, 10, 20, 30, 40, 50, 60, 70, 80, 90 and 100 mg per liter. Total phenol content was calculated based on mg of gallic acid per gram of sample.

Data were analyzed by MSTATC software and the comparison of mean values was done via Duncan's Multiple Range Test ($p \leq 0.05$).

3-Results and Discussion

3.1. Fruit weight loss

The simple effects of ultrasound, storage time, and the interaction effect of ultrasound and time on fruit weight loss (%) were significant ($p \leq 0.05$). However, no significance was observed on this index by the simple effect of ultraviolet, the interaction effect of ultraviolet and ultrasound, the interaction effect of ultraviolet and storage time, and the interaction effect of ultraviolet, ultrasound, and storage time. Comparison of mean values of interaction effect by ultrasound and storage time showed that although the amount of fruit weight loss increased with longer storage time, fruits treated with ultrasound showed a lower weight loss than the control at any time. By 40 days of storage, the difference of all three ultrasound levels was significant (Fig. 1).

[DOI: 10.22034/FSCT.21.147.16]

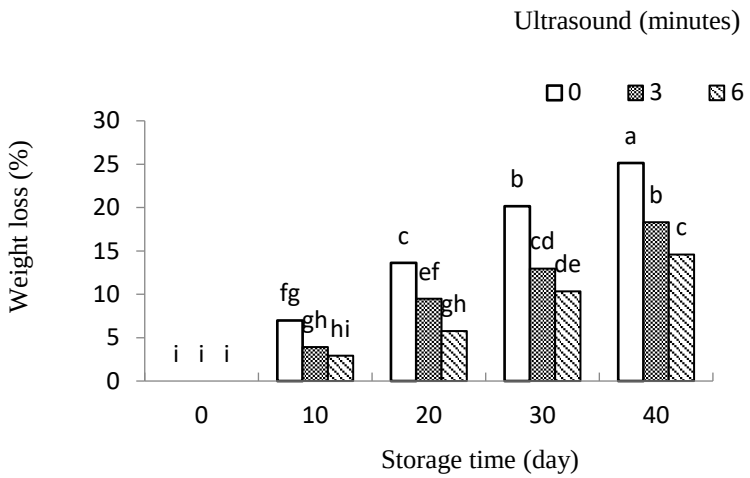

Fig 1. Interaction effect of ultrasound treatments and storage time on mango fruit weight loss

Similar to this research, using 40 kHz ultrasound at 350 watts for 8 minutes caused a significant decrease in banana juice loss after 10 days of storage. Ultrasound treatment controlled fruit weight loss by maintaining membrane integrity and reducing membrane peroxidation [33]. Ultrasound at 20 kHz and 400 watts for 10 minutes caused a significant decrease in moisture loss from mushrooms in all days of storage (3, 6 and 9 days), compared to the control. This may be due to inhibition of enzymes and intracellular water activity and reduction of respiratory metabolism by the ultrasound treatment [34]. Mozafar et al. [35] reported that ultrasound treatment can cause the inactivation of enzymes involved in the breakdown of cell wall polysaccharides and the middle lamella between plant cells. Jacklin et al. [36] reported that ultrasound can disrupt hydrogen bonds and van der Waals bonds in polypeptide chains, thus changing the secondary and tertiary structure of proteins and loss of enzymatic biological activities.

Chen et al. [37] reported that ultrasound treatment reduces lipid peroxidation and plant membrane dysfunction by stimulating the activity of antioxidant enzymes and biologically active compounds. Zhi et al. [38] reported that ultrasound treatment strengthened cellular wall structures and reduced membrane peroxidation in jujube fruits during the storage period. Lagnica et al. [39] also reported that ultrasound treatment delayed weight loss in edible mushrooms during storage.

3.2. Fruit firmness

Only the simple effect of storage time was significant on fruit firmness. However, no significant differences were caused by the effects of ultraviolet, ultrasound, the

[DOI: 10.22034/FSCT.21.147.16]

interaction effect of ultraviolet and ultrasound, the interaction effect of ultraviolet and storage time, the interaction effect of ultrasound and storage time, and the interaction effect among ultraviolet, ultrasound, and storage time on fruit firmness ($p\leq0.05$). Comparison of mean values showed that an increase in storage time caused a significant decrease in fruit firmness (Fig. 2).

Applying the ultrasound treatment at 35 kHz and 400 W for 3 minutes did not significantly affect mushroom firmness after 7 days of storage compared to the control [40]. Nonetheless, reports exist that UV-C delayed the depolymerization of cellular walls. It inhibited cellular wall hydrolases such as polygalacturonase and pectin methylesterase, thus delaying fruit softening [41 and 42]. The effect of UV-C irradiation at 6.6 kJ/m^2 was evaluated on the postharvest quality of mango fruits, showing that the UV-C treatment effectively maintained fruit firmness [15].

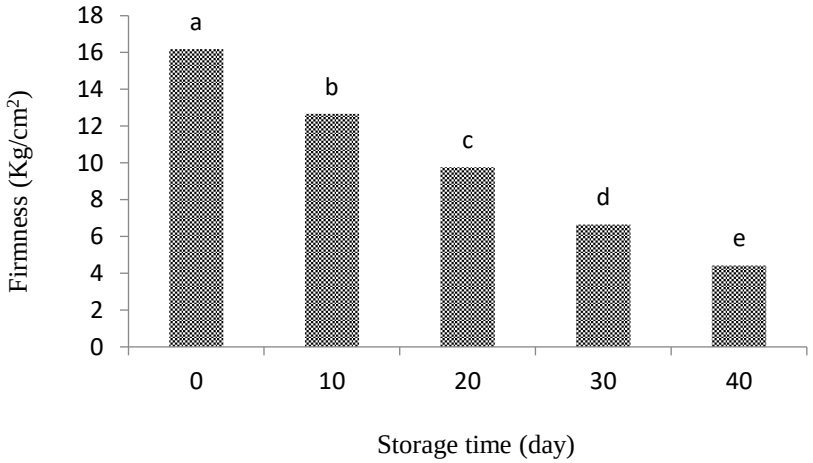

Fig. 2 Main effect of storage duration on firmness of mango fruit flesh

3.3. Fruit color

The interaction effects of ultraviolet, ultrasound, and storage time were significant on all color parameters including L* (brightness), a* (redness) and b* (yellowness) ($p\leq0.01$).

With the increase in the storage time of Langra mango fruits from the 0th day of storage to the 40th day, the amount of L*, a* and b* increased in the mango fruit tissue. The comparison of mean values showed that the L* value (brightness) of fruit flesh increased over time, and the color contrast decreased. Ultraviolet and ultrasound treatments prevented the increase in brightness. On the 40th day of storage, the lowest amount of L* in the fruit flesh (89.44) occurred in response to the 5-minute

[DOI: 10.22034/FSCT.21.147.16]

ultraviolet treatment (Table 1). The highest a* value (redness) in fruit flesh (-2.68) occurred in the control treatment on the 40th day of storage. The increase in a* value in fruit flesh through storage time showed that the green color of the fruits decreased whereas the redness increased. Irradiation treatments prevented the increase in this variable and inhibited the decrease in fruit greenness (Table 2). The highest b* value (yellowness) in fruit flesh (44.72) occurred in the control treatment (no irradiation) on the 40th day of storage, thus showing that irradiation prevented the increase in yellowness through time. Based on the results, the yellowness of fruit flesh increased through time, but irradiation treatments prevented the occurrence of more yellowness in the fruit flesh (Table 2).

In relevant research, the effects of ultraviolet irradiation at 6.6 KJ/m^2 per square meter were evaluated on mango fruit quality (Kaew Kamin variety) after harvest. The results showed that ultraviolet irradiation delayed the ripening and loss of greenness in the fruit skin during storage, whereas the yellowness of the fruit flesh was not affected [15]. The delay in green color loss may be attributable to the decrease in chlorophyll oxidase and chlorophyllase activities, thus reducing chlorophyll degradation and maintaining tissue greenness [13]. A study by Promyou and Supapvanich [43] showed that UV treatments did not affect the b* value (yellowness) in the fruit skin and flesh of yellow bell peppers.

Table 1. The effect of UV-C, ultrasound and storage time treatments on L* of mango fruit flesh

Treatments		Storage time (day)				
UV-C (	Ultrasound (minute)	0	10	20	30	40
0	0	56.7	64.03	76.92 l	86.5	93.7
0	3	54.7	61.03	74.76	85.9	92.0
0	6	57.7	62.046	73.54	86.5	91.1
5	0	51.7	59.86	72.89	84.5	90.5
5	3	50.3	60.33	71.56	84.5	89.4
5	6	50 z	60.7 st	70.72	84.5	89.5
10	0	58.6	69.9 p	83.68 i	88.4	98.4
10	3	58.6	68.17	80.63	86.6	97.2
10	6	58.4	66.94	80.08	89.4	96.0

In each column, means with the same letter or letters have no significant difference in Duncan's test (P≤0.05).

Table 2. The effect of UV-C, ultrasound and storage time treatments on a* of mango fruit flesh

Treatments		Storage time (day)				
UV-C (min	Ultrasound (minut	0	10	20	30	40
0	0	-10	-7	-5	-4.55	-2
0	3	-12	-7	-5	-4	-3
0	6	-8.9	-7	-5	-4	-3
5	0	-11	-7	-5	-4	-3

[DOI: 10.22034/FSCT.21.147.16]

5	3	-10	-7	-5	-4	-4
5	6	-12	-7	-5	-4	-4
10	0	-88	-7	-6	-5 d-	-4
10	3	-94	-8	-6	-5	-4
10	6	-10	-8	-6	-5	-4

In each column, means with the same letter or letters have no significant difference in Duncan's test (P≤0.05).

Table 3. The effect of UV-C, ultrasound and storage time treatments on b* of mango fruit flesh

Treatments		Storage time				
UV-C (minute)	Ultrasound (minute)	0	10	20	30	40
0	0	23.23 z	31.88	35.78 lm	39.3 fg	44.72 a
0	3	24.046 yz	31.57	35.04 mn	39.04	43.76
0	6	24.65 y	32.02	34.9 mn	38.67	43.76
5	0	24.7 y	30.61	34.59 mno	38.1	43.76
5	3	24.7 y	29.84	34.35 nop	37.77	42.64
5	6	24.78 y	29.83	34.24 nop	37.26	41.72
10	0	25.01 y	29.08	33.55 opq	36.31	41.26
10	3	24.81 y	28.35	33.34 pq	36.54	40.81
10	6	25.84 y	26.46 x	32.94 qr	36.71	40.1 ef

In each column, means with the same letter or letters have no significant difference in Duncan's test (P≤0.05).

3.4. Total soluble solids (TSS)

Only the storage time significantly affected the TSS (p≤0.01), whereas the effects of UV-C, ultrasound, and their interaction effects were not significant (P≤0.05). As observed, the TSS content increased significantly through storage time (Fig. 3).

Most changes in relation to fruit ripening emerge from the breakdown of polymeric carbohydrates, especially sugars in the cell wall, which modify the fruit taste and texture. Thus, the total soluble solids increase with ripening. During storage, the breakdown of complex sugars into simple ones and the breakdown of polymeric carbohydrates are among effective factors that increase the total soluble solids in fruits [44 and 45].

In research by Chen et al. [20], ultrasound treatment did not have a significant effect on the total soluble solids in lychees. Other reports exist on the effects of these treatments on fruit soluble solids. In grapes, the highest amount of soluble solids occurred in response to the ultrasound treatment [18]. Aday et al. [46] showed that treating strawberries with ultrasound for 10 minutes effectively maintained the soluble solids and cell wall integrity in storage. Xu et al. [47] suggested that ultrasound treatments can delay the ripening process and increase soluble solids by changing ethylene biosynthesis and ethylene signaling pathways. Ultraviolet and ultrasound treatments did not have significant effects on mango soluble solids in this research due to the duration of exposure or irradiation

[DOI: 10.22034/FSCT.21.147.16]

intensity, thus requiring additional experiments.

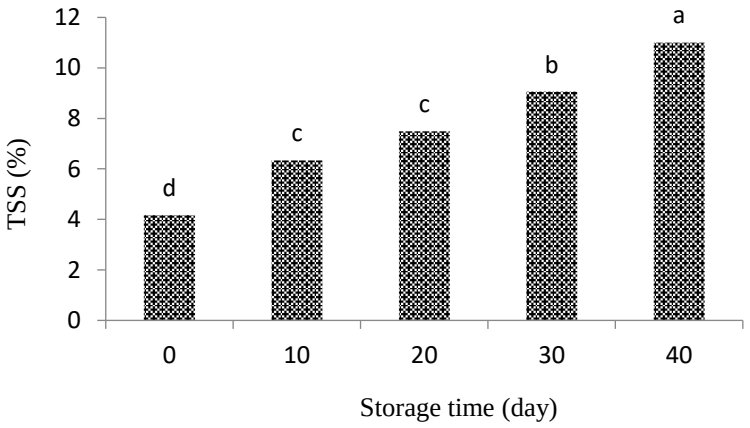

Fig 3 Main effect of storage duration on the amount of TSS of mango fruit

3.5. pH

The simple effects of ultraviolet, ultrasound, storage time, interaction effects of ultraviolet and ultrasound, ultraviolet and storage time, and the interaction effect of ultraviolet, ultrasound, and storage time were significant on fruit juice pH. However, the interaction effect of ultrasound and storage time was not significant.

According to the results, the pH of mango juice gradually increased through storage time from the beginning of storage until the 40th day. However, the effects of ultraviolet and ultrasound were not significant until the 20th day, and became significant from the 30th day onward. As can be seen, on the 30th and 40th days of storage, the highest pH of the fruit juice occurred in the non-irradiation treatment. The lowest pH value (6.00) was observed in response to the 10-minute ultraviolet treatment and the 3-minute ultrasound treatment (Table 4). Previous research indicated that the pH increases in most fruits during storage, thus confirming the results of the current research. This increase in pH was mainly because of a decrease in organic acids during the storage period [48]. The increase in pH may correlate with a decrease in titratable acidity in fruits. Ultraviolet and ultrasound treatments can maintain titratable acidity by reducing fruit respiration and preventing the increase in pH [49, 50 and 51].

Table 4. The effect of UV-C, ultrasound and storage time treatments on pH of mango fruit flesh

Treatments	Storage time (day)

[DOI: 10.22034/FSCT.21.147.16]

UV-C (minute)	Ultrasound (minute)	0	10	20	30	40
0	0	3.48 l	3.85 k	4.43 j	5.68 fg	6.62 a
0	3	3.5 l	3.77 k	4.4 j	5.45 hi	6.64 a
0	6	3.4 l	3.84 k	4.56 j	5.63 fgh	6.6 a
5	0	3.48 l	3.85 k	4.53 j	5.56 gh	6.56 a
5	3	3.48 l	3.9 k	4.59 j	5.52 gh	6.61 a
5	6	3.48 l	3.87 k	4.54 j	5.53 gh	6.62 a
10	0	3.48 l	3.86 k	4.51 j	5.3 i	6.1 bc
10	3	3.49 l	3.82 k	4.4 j	5.79 ef	6.00 cd
10	6	3.47 l	3.83 k	4.51 j	5.9 de	6.23 b

In each column, means with the same letter or letters have no significant difference in Duncan's test ($P \leq 0.05$).

3.6. Titratable acidity

Regarding titratable acidity, only the effect of storage time was significant ($p \leq 0.01$). The effects of ultraviolet and ultrasound irradiation and their interaction effects were not significant on fruit titratable acidity.

Through time in storage, the titratable acidity gradually decreased in Langra mango fruit tissue. The highest amount of titratable acids in the fruits was observed immediately after harvest (2.785%), and the lowest was observed after 40 days of storage (0.597%) (Fig. 4). The decrease in titratable acid content in mango fruits through storage time was consistent with previous results by Jalili-Marandi et al. [52] on apple.

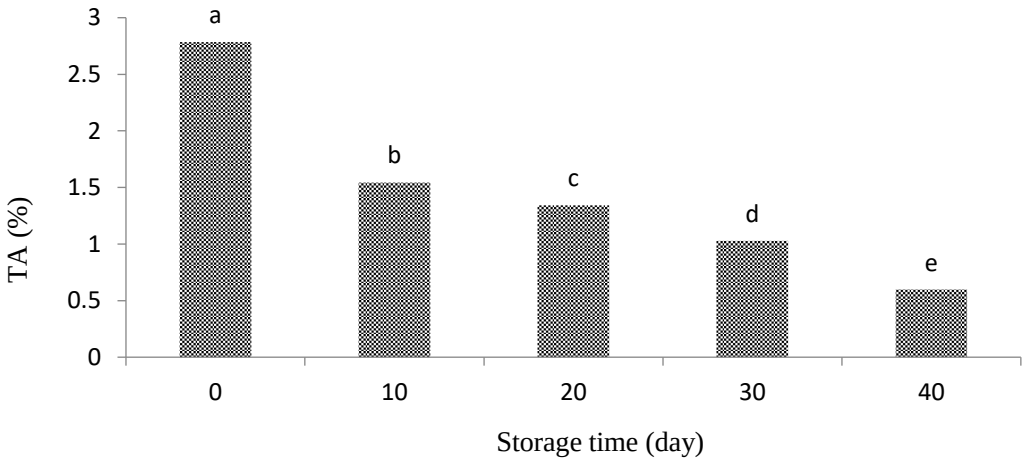

Fig 4. Main effect of storage duration on the content of titratable acid in mango fruit

[DOI: 10.22034/FSCT.21.147.16]

Titratable acids are an important factor in maintaining fruit quality in storage. The amount of these acids depends directly on the concentration of organic acids in the fruit [44]. Organic citric and malic acids are consumed in respiration, thus their concentration decreases after harvest, during ripening as a climacteric fruit, and in storage [53]. In a study by Bal et al. [18], after 60 days of storage, the titratable acid content of ultrasound-treated grapes was significantly higher than untreated control grapes. The ultrasound treatment reportedly delayed physiological maturation in fruits. Some studies also showed that UV treatment decreased respiration rate and resulted in higher titratable acid content in strawberries [51] and peaches [50].

3.7. Ascorbic acid

Regarding ascorbic acid content, only the simple effect of ultrasound, storage time, and the interaction effect of ultraviolet and storage time were significant. However, no significance was observed by the simple effect of ultraviolet irradiation, the interaction effect of ultraviolet and ultrasound, the interaction effect of ultrasound and storage time, and the interaction effect of ultraviolet, ultrasound, and storage time ($p \leq 0.05$). Figures 5 and 6 show the simple effect of ultrasound and the interaction effect of ultraviolet and storage time, respectively. The simple effect of 3-minute ultrasound treatment caused a significant difference with the 6-minute treatment and the control. The 3-minute ultrasound treatment caused the highest ascorbic acid content (11.3 mg/100 grams). The interaction effect of ultraviolet and storage time also showed that the decrease in ascorbic acid content was delayed by the ultraviolet treatment, similar to the effect of ultrasound. However, there was no significant difference between the 5-minute and 10-minute UV treatments. The highest ascorbic acid content occurred on the 40th day of storage (5.65 mg/100 g) in response to the 10-minute ultraviolet treatment.

Ascorbic acid is one of the most important antioxidants. Its content decreases gradually in storage because ascorbic acid functions as an electron donor to neutralize free radicals [54]. Ascorbic acid content decreases via cellular respiration or by ascorbate oxidase activity that degrades ascorbic acid [55].

Barka [56] experimented on tomatoes and Jalili-Marandi et al. [52] on apples, showing that fruits treated with UV-C irradiation retained more vitamin C than the control. UV-C irradiation reportedly caused stress in plant tissues, thus stimulating the biosynthesis of secondary metabolites that function in defense mechanisms and triggering antioxidant activity via molecules

[DOI: 10.22034/FSCT.21.147.16]

such as vitamin C [57]. In mango, fruit quality and antioxidant capacity were reportedly maintained in freshly harvested mango fruits using UV-C irradiation [14]. Freitas et al. [58] attributed higher levels of ascorbic acid in pineapple skin of UV-C-treated pineapple fruits because the treatment affected the ascorbate-glutathione cycle. Reddy et al. [59] reported a positive correlation between the decrease in ascorbic acid levels and the increase in ascorbate oxidase activity. Ultrasound treatment may also prevent ascorbic acid loss by removing oxygen species from active tissues and preventing their inhibitory activity [60]. Ali et al. [61] reported higher amounts of vitamin C in guava fruits treated with ultrasound. Combining UV-C rays and ultrasound treatments can entail positive results that may be attributable to the removal of dissolved oxygen that destroys vitamin C. Free oxygen molecules emerge from cavitation and a possible decrease in ascorbate oxidase activity in the fruit [62].

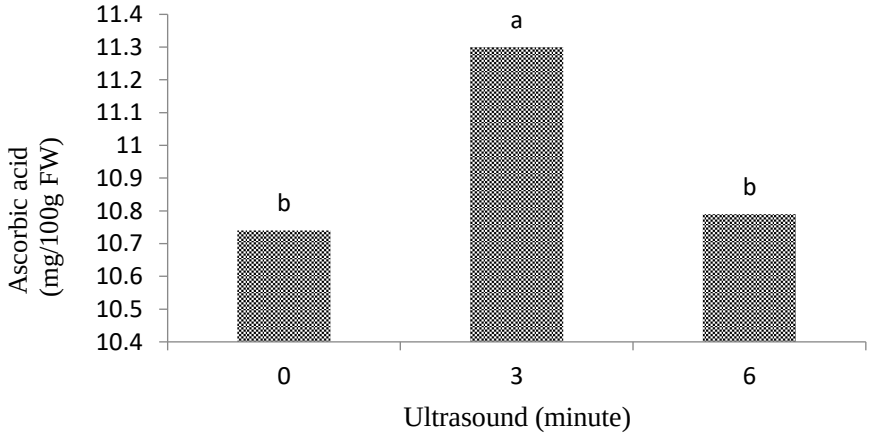

Fig 5. Main effect of ultrasound on the amount of ascorbic acid in mango fruit

[DOI: 10.22034/FSCT.21.147.16]

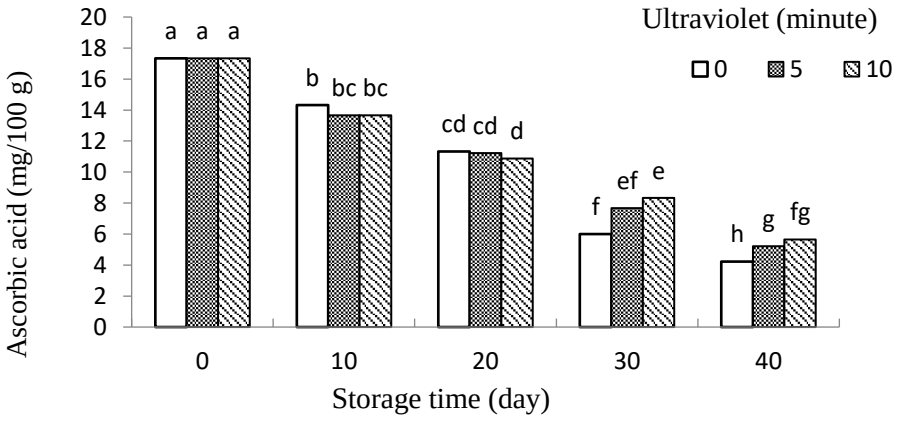

Fig 6. The effect of UV and time on the amount of ascorbic acid in mango fruit

3.8. Total phenol

The effect of ultraviolet irradiation and ultrasound was not significant on the total phenol content in mango fruit tissue ($p \leq 0.05$). Only the effect of storage time was significant on this parameter ($p \leq 0.01$). Through storage time, the total phenol content decreased (Fig. 7).

Phenolic components are an important group of secondary metabolites that substantially affect the quality of products and their sensory attributes, such as bitterness, taste, and color. Phenolic compounds are highly unstable and undergo changes during the storage period. Various reports indicated that the amount of phenolic compounds in fruits decreases while fruit ripening is gradually completed [13], thus confirming the current results of this research.

Similar to the current research, a previous study showed that the effect of ultraviolet was not significant on the phenolic content of blueberry fruits (Collins cultivar) [63]. However, a study by Bravo et al. [64 and 65] showed that ultraviolet irradiation increased the total phenolic content and antioxidant activity in tomatoes. It was observed that the combined use of ultraviolet irradiation and ultrasound caused a significant increase in phenol content and the bioactive compounds in tomatoes during the storage period [66]. In a study by Bal et al. [19], a relatively higher amount of phenolic compounds occurred in grapes treated with ultrasound. The increase in total phenol content after ultrasound and ultraviolet treatments can be attributed to the activation of a number of pathways that orchestrate the biosynthesis of phenolic compounds and several key enzymes such as phenylalanine ammonia lyase (PAL). These enzymes synthesize some phenolic compounds such as flavonoids, chlorogenic acids, and coumarin while they catalyze phenylpropanoids [67].

[DOI: 10.22034/FSCT.21.147.16]

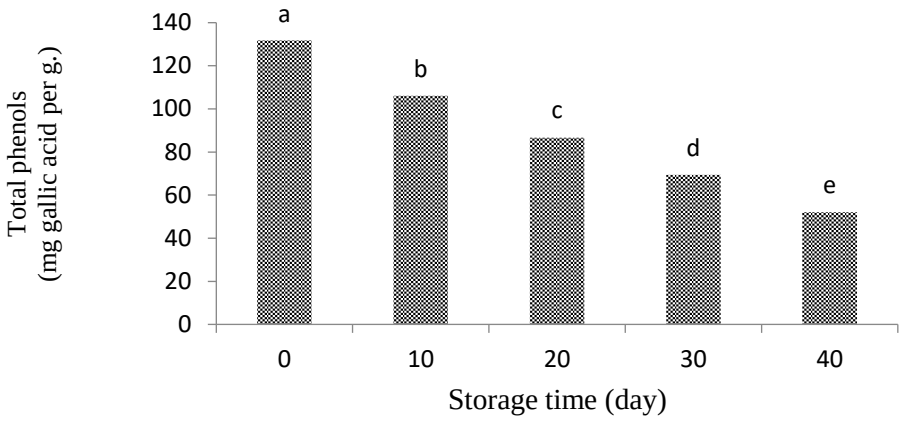

Figure 7. Main effect of storage duration on the amount of phenol in mango fruit

4-Conclusion

Ultraviolet irradiation and ultrasound are non-chemical methods that can control diseases and increase the shelf life and quality of fruits and vegetables. In this study, mangoes were maintained in cold storage for 40 days after ultraviolet treatment. Using the ultraviolet treatment for five minutes optimally preserved the appearance of the fruits. Using the ultrasound treatment for three minutes optimally preserved the ascorbic acid content in fruits. Postponing the deterioration of green color and maintaining the appearance of the fruit with ultraviolet treatment may be related to the decrease in chlorophyll-oxidase and chlorophyllase activities, thus leading to lower levels of chlorophyll degradation, and tissue greenness that remains for a longer time. Ultrasound treatment may also delay ascorbic acid loss by removing active oxygen species in the fruit tissue, thus preventing their inhibitory role and suppressing cellular respiration. Therefore, ultraviolet treatment for five minutes can be suggested for the optimal maintenance of fruit appearance. Ultrasound treatment for three minutes can best preserve the ascorbic acid content in Langra mango fruits and thus contribute to quality maintenance during the storage period.

5- Acknowledgements

The authors thank the University of Hormozgan for their financial supports.

6- References

[1] FAO STAT. 2021. FAO Statistics, Food and Agriculture Organization of the United Nations, Rome, Italy. http://faostat.fao.org/.

[2] Anonymous. 2021. Surface cultivation statistics and production and yield of mango products in Iran. Ministry of Agriculture. [in Persian].

[DOI: 10.22034/FSCT.21.147.16]

[3] Prasanna, V., Prabha, T. N. and Tharanathan, R. N. 2007. Fruit Ripening Phenomena—An Overview. Food Science and Nutrition, 47, 1–19.

[4] Mirzaalian-dastjerdi, A. M., Kalantari, S., babalar M. Zamani, Z. 2013. Effects of Maturity Stage and Storage Temperature on the Quality of 'Langra' Mango (*Mangifera indica* L.) Fruit. Iranian Journal of Horticultural Science. 44(1): 43-59.

[5] Rastegar, S. and Gholamshahipour, H. 2017. Effect of postharvest treatment with putrescine and nitric oxide on some quality attributes of mango fruit. Research in Pomology, 2(1): 1, 1-14 [in Persian].

[6] Khaleghi A, Dadbin E, Asghari Marjanlou A. 2019. The Effect of UV-C Irradiation on Rot Control and Postharvest Quality of Greenhouse Tomato (*Solanum lycopersicum* cv. Newton). Journal of Statistical Planning and Inference, 10 (3) :13-22 [in Persian].

[7] Liu, C., Cai, L., Han, X. and Ying, T. 2011. Temporary effect of postharvest UV-C irradiation on gene expression profile in tomato fruit. Gene, 486: 56–64.

[8] McKenzie, RL., Björn, LO., Bais, A. and Ilyasd, M. 2003. Changes in biologically active ultraviolet radiation reaching the Earth's surface. Photochemical and Photobiological Sciences, 2:5–15.

[9] Gonzalez-Aguilar, G.A., Ayala-Zavala, J., Olivas, G., de la Rosa, L. and Álvarez-Parrilla, E. 2010. Preserving quality of fresh-cut products using safe technologies. Journal für Verbraucherschutz und Lebensmittelsicherheit, 5(1)65-72.

[10] Mercier, J., Roussel, D., Charle, M.T. and Arul, J. 2000. Systemic and local response associated with UV-C and pathogen–induced resistance to *Botrytis cinerea* in stored carrot. Phytopathology, 90(9): 981–986.

[11] Mercier, J., Baka, M., Reddy, B., Corcuff, R. and Arul, J. 2001. Shortwave ultraviolet irradiation for control of decay caused by *Botrytis cinerea* in bell pepper: Induced resistance and germicidal effects. Journal of the American Society for Horticultural Science, 126: 128–133.

[12] Marquenie, D., Michiels, C.; Geeraerd, A.; Schenk, A.; Soontjens, C.; Van Impe, J. and Nicolaï, B. 2002. Using survival analysis to investigate the effect of UV–C and heat treatment on storage rot of strawberry and sweet cherry. International Journal of Food Microbiology, 73(2-3): 187-196.

[13] Costa, L., Vicente, R.A., Civello, P.M., Chaves, A.R. and Martinez, G.A. 2006. UV-C treatment delays postharvest senescence in broccoli florets. Postharvest Biology and Technology, 39: 204–210.

[14] Gonzalez-Aguilar, G.A., Zavaleta-Gatica, R. and Tiznado-Hernandez, M.E. 2007. Improving postharvest quality of mango 'Haden' by UV-C treatment.

[DOI: 10.22034/FSCT.21.147.16]

Postharvest Biology and Technology, 45(1):108-116.

[15] Promyou, S. and Supapvanich, S. 2016. Physicochemical Changes in 'Kaew Kamin' Mango Fruit Illuminated with Ultraviolet-C (UV-C) during Storage. Journal of Agricultural Science and Technology (JAST). 18: 145-154.

[16] Ercan, S.S. and Soysal, C. 2013. Use of ultrasound in food preservation. Natural Science, 8 (2): 5-13.

[17] Bal, E. 2013. Effects of exogenous polyamine and ultrasound treatment to improve peach storability. Chilean Journal of Agricultural Research, 73 (4): 435-440.

[18] Bal, E., Kok, D. and Torcuk, A I. 2017. Postharvest putrescine and ultrasound treatments to improve quality and postharvest life of table grapes (*Vitis vinifera* L.) cv. Michele Palieri. Journal of Central European Agriculture, 18(3): 598-615.

[19] Cao, S., Hu, Z., Pang, B., Wang, H., Xie, H. and Wu, F. 2010. Effect of ultrasound treatment on fruit decay and quality maintenance in strawberry after harvest. Food Control, 21 (4), 529-532.

[20] Chen, Y., Jiang, Y., Yang, S., Yang, E., Yang, B. and Prasad, K.N. 2012. Effects of ultrasonic treatment on pericarp browning of postharvest litchi fruit. Journal of Food Biochemistry, 36:613-620.

[21] Chen, Z., Zhu, C. 2011. Combined effects of aqueous chlorine dioxide and ultrasonic treatments on postharvest storage quality of plum fruit. Postharvest Biology and Technology, 61: 117-123.

[22] Bal, E. 2016. Effect of postharvest calcium chloride and ultrasound treatments on storage period and fruit quality of modified atmosphere packed fruit in plum cv. Santa Rosa. Fruit Science, 1:12-18.

[23] Yang, Z.F., Cao, S.F., Cai, Y.T. and Zheng. Y.H. 2011. Combination of salicylic acid and ultrasound to control postharvest blue mold caused by *Penicillium expansum* in peach fruit. Innovative Food Science and Emerging Technologies, 12:310-314.

[24] Valente M. and Didier ,L. 2013. Changes of ultrasound characteristics of mango juice during fruit ripening. In: International Conference of Agricultural Engineering CIGR-AgEng 2012, Valencia, Spain, July 8-12, 2012. CIGR; EurAgEng; Agro Ingenieria. s.l.: s.n., 6 p. International Conference of Agriculture Engineering, Valence, Espagne, 8 July 2012/12 July 2012.

[25] Bolton, J. R. and Linden, K. G. 2003. Standardization of methods for fluence (UV dose) determination in bench-scale UV experiments. Journal of Environmental Engineering, 129, 209–215.

[26] Kek, S.P., Chin, N.L. and Yusof, Y.A. 2013. Direct and indirect power ultrasound assisted pre-osmotic treatments in convective drying of guava slices. Food and Bioproducts Processing, 91: 495–506.

[27] Hosseini Farahi, M. and Haghanifard, Z. 2017. Effects of aloe vera gel, salicylic acid

[DOI: 10.22034/FSCT.21.147.16]

and hot water on fruit decay and quality properties of sweet lemon fruit during storage. Journal of Crop Production and Processing, 7 (3): 63-78.

[28] Pek. Z., Helyes, L. and Lugasi, A. 2010. Color changes and antioxidant content of vine and postharvest ripened tomato Fruits. Horticultural Science, 45:466-468.

[29] Anon, A. 2011. Fruits, vegetables and derived products–determination of ascorbic acid–part2: routine method, standard No. 14617-2. Iranian National Standardizations Organization, 1st Edition.

[30] Roussos, P.A., Sefferou, V., Denaxa, N.K., Tsantili, E. and Stathis, V. 2011. Apricot (*Prunus armeniaca* L.) fruit quality attributes and phytochemicals under different crop load. Scientia Horticulturae, 129(3), 472-478.

[31] Ahmad A., Hayat S. and Ali, B. 2007. Salicylic acid: Biosynthesis, metabolism and physiological role in plants. In: Salicylic Acid – A Plant Hormone, Springer, 1: 1-14.

[32] Singleton, V.L. and Rossi, J.A. 1965. Colorimetry of total phenolics with phosphomolybdic-phosphotungstic acid reagents. American Journal of Enology and Viticulture, 16(3): 144-158.

[33] Chen, B., Huang, J., Wang, J. and Huang, L., 2008. Ultrasound effects on the antioxidative defense systems of *Porphyridium cruentum*. Colloids and Surfaces B: Biointerfaces, 61, 88-92.

[34] Zhi, H., Liu, Q., Xu, J., Dong, Y., Liu, M. and Zong, W., 2017. Ultrasound enhances calcium absorption of jujube fruit by regulating the cellular calcium distribution and metabolism of cell wall polysaccharides. Journal of the Science of Food and Agriculture, 97(15), 5202-5210.

[35] Lagnika, C., Zhang, M. and Mothibe, K.J., 2013. Effects of ultrasound and high pressure argon on physico-chemical properties of white mushrooms (*Agaricus bisporus*) during postharvest storage. *Postharvest Biology and Technology*, 82, 87-94.

[36] Barka, E. A., Kalantari, S., Makhlouf, J. and Arul. J. 2000. Impact of UV-C Irradiation on the Cell-wall Degrading Enzymes during Ripening of Tomato (*Lycopersicon esculentum* L.) Fruit. Journal of Agricultural and Food Chemistry, 48(3): 667-671.

[37] Stevens, C., Liu, J., Khan, V. A., Lu, J. Y., Kabwe, M. K., Wilson, C. L., Igwegbe, E. C. K., Chalutz, E. and Droby, S. 2004. The Effects of Low-dose Ultraviolet Light-C Treatment on Polygalacturonase Activity, Delay Ripening and Rhizopus Soft Rot Development of Tomatoes. Crop Protection, 23(6): 551-554.

[38] Promyou, S. and Supapvanich, S. 2012. Effect of ultraviolet-C (UV-C) illumination on postharvest quality and bioactive compounds in yellow bell pepper fruits (*Capsicum annuum* L.) during storage,

[DOI: 10.22034/FSCT.21.147.16]

African Journal of Agricultural Research, 7(28): 4084-4096.

[39] Kazemi, M., Aran, M. and Zamani, S. 2011. Effect of salicylic acid treatments on quality charactristics of apple fruits during storage, American Journal of Plant Physiology, 6(2): 113-119.

[40] Maidani, J. and Hashemi Dezfuli, A. 2016. Postharvest Physiology, Agricultural Education Publication [in Persian].

[41] Aday, M.S., Temizkan, R., Buyukcan, M.B. and Caner, C. 2013. An innovative technique for extending shelf life of strawberry: Ultrasound. LWT-Food Science and Technology, 52, 93–101.

[42] Xu, Y., Zhang, L., Zhong, J., Shu, J., Ye, X. and Liu, D., 2013. Power ultrasound for the preservation of postharvest fruits and vegetables. International Journal of Agricultural and Biological Engineering, 6(2), 116-125.

[43] Perkins-Veazie, P. 2007. Blueberry fruit response to postharvest application of ultraviolet radiation. Postharvest Biological Technology, 10:1005-1016.

[44] Jiang, Y. and Li, Y. 2001. Effects of Chitosan Coating on Postharvest Life and Quality of Longan Fruit. Food Chem., 73 : 139-143.

[45] Lu, J. Y., Stevens, C., Khan, V. A., Kabwe, M. and Wilson, C. L. 1991. The effect of ultraviolet irradiation on shelf-life and ripening of peaches and apples. Journal of Food Quality. 14, 299-305.

[46] Baka, M., Mercier, J., Corcuff, R., Castaigne, F. and Arul, J. 1999. Photochemical treatment to improve storability of fresh strawberries. Journal of Food Science, 64, 1068-1072.

[47] Jalili Marandi, R., Naseri, L., Haji Taghilo, R. and Korsandi, A. 2012. The Effect of UV-C Irradiation on Fruit Quality and Storage Life of Two Apple Cultivars. e Plant Production (Scientific Journal of Agriculture), 35(2), 53-63. [in Persian].

[48] Hadian-Deljou, M. and Sarikhani, H. 2012. Effect of salicylic acid on maintaining post- harvest quality of apple cv. Golabe-Kohanz. Journal of Crops Improvement, 14(2):71-82. [in Persian].

[49] Hosseini, M. 2012. The effect of putrescine and heat treatment on the shelf life and quality of two varieties of pear (Shahmiveh and Spadna). Master's thesis, Department of Horticultural Science and Engineering, University of Tehran [in Persian].

[50] Atress, Amal SH., El-Mogy, M.M., Aboul-Anean, HE. and Alsanius, BW. 2010. Improving strawberry Fruit Storability by Edible Coating as a Carrier of Thymol or Calcium Chloride. Journal of Horticultural Science and Ornamental Plants, 2(3): 88-97.

[51] Barka, E.A. 2001. Protective enzymes against reactive oxygen species during ripening of tomato (*Lycopersicum esculentum*) fruits in response to low

[DOI: 10.22034/FSCT.21.147.16]

amounts of UV-C. Australian Journal of Plant Physiology, 28(8): 785-791.

[52] Liu, L.H., Zabaras, D., Bennett, L.E., Aguas, P. and Woonton, B.W. 2009. Effects of UV-C, red light and sun light on the carotenoid content and physical qualities of tomatoes during post-harvest storage. Food Chemistry, 115: 495–500.

[53] Freitas, A., Moldao-Martins, M., Costa, H. S., Albuquerque, T. G., Valente, A., and Sanches- Silva, A. 2015. Effect of UV-C radiaiton on bioactive compounds of pineapple (*Ananas comosus* L. Merr.) by-products. Journal of The Science of Food and Agriculture, 5, 44–52.

[54] Reddy, K. P., Khan, P. A., Patnaik, S., Mohanty, G. B., and Kumar, K. B. 1986. Ascorbate oxidase activity in rice shoot apices during panicle initiation. Plant and Cell Physiology, 27: 725–728.

[55] Guimaraes J.T., Silva, E.K. Ranadheera, C.S. Moraes, J. Raices, R.S.L. Silva M.C., Ferreira, M.S. Freitas, M.Q. Meireles, M.A.A. Cruz, A.G. 2019. Effect of high-intensity ultrasound on the nutritional profile and volatile compounds of a prebiotic soursop whey beverage, Ultrason. Sonochem, 55: 157–164.

[56] Ali, G., Russly, A. R., Jamilah, B., Azizah, O., and Mandana, B. 2011. Effect of heat and thermosonication on kinetics of peroxidase inactivation and vitamin C degradation in seedless guava (*Psidium guajava* L.). International Food Research Journal, 18(4), 1289–1294.

[57] Jagadeesh, S. L., Charles, M. T., Gariepy, Y., Goyette, B., Raghavan, G. S. V., and Vigneault, C. 2011. Influence of postharvest UV-C hormesis on the bioactive components of tomato during post-treatment handling. Food and Bioprocess Technology, 4: 1463–1472.

[58] Veazie P.P., Collins K.J., and Howard L. 2008. Blueberry fruit response to postharvest application of ultraviolet radiation. Postharvest Biology and Technology, 47: 280-285.

[59] Bravo, S., Garcia-Alonso, J., Martin-Pozuelo, G., Gomez, V., Garcia-Valverde, V., Navarro- Gonzalez, I., and Periago, M. J. 2013. Effects of postharvest UV-C treatment on carotenoids and phenolic compounds of vine-ripe tomatoes. International Journal of Food Science and Technology, 48: 1744–1749.

[60] Bravo, S., Garcia-Alonso, J., Martin-Pozuelo, G., Gomez, V., Santaella, M., Navarro-Gonzalez, I. and Periago, M. J. 2012. The influence of post-harvest UV-C hormesis on lycopene, β-carotene, and phenolic content and antioxidant activity of breaker tomatoes. Food Research International, 49: 296–302.

[61] Esua, O.J. Nyuk Ling Chin, N.L., Yusof, Y.A., and Sukor, R. 2019. Effects of simultaneous UV-C radiation and ultrasonic energy postharvest treatment on bioactive

[DOI: 10.22034/FSCT.21.147.16]

compounds and antioxidant activity of tomatoes during storage. Food Chemistry, 270: 113–122.

[62] Maharaj, R., Arul, J. and Nadeau, P. 2014. UV-C irradiation effects on levels of enzymic and non-enzymic phytochemicals in tomato. Innovative Food Science and Emerging Technologies, 21: 99–106.

[DOI: 10.22034/FSCT.21.147.16]

مجله علوم و صنایع غذایی ایران

سایت مجله: www.fsct.modares.ac.ir

مقاله علمی_پژوهشی

بررسی اثر تیمارهای فرابنفش و فراصوت بر عمر پس از برداشت میوه انبه رقم لانگرا

حسن شرکایی[۱]، عبدالمجید میرزاعلیان دستجردی[۲*]، مصطفی قاسمی[۳*]، **سمیه رستگار**[۴]

۱- دانش آموخته کارشناسی ارشد، گروه علوم باغبانی، دانشگاه هرمزگان.

۲- دانشیار گروه علوم باغبانی، دانشگاه هرمزگان، بندرعباس، ایران.

۳- هیئت علمی بخش زراعی باغی. مرکز تحقیقات و آموزش کشاورزی و منابع طبیعی استان قزوین، سازمان تحقیقات، آموزش و ترویج کشاورزی، قزوین، ایران.

۴- دانشیار گروه علوم باغبانی، دانشگاه هرمزگان، بندرعباس.

اطلاعات مقاله

تاریخ های مقاله :

تاریخ دریافت: ۱۴۰۱/۸/۲

تاریخ پذیرش: ۱۴۰۲/۹/۶

کلمات کلیدی:

پرتودهی،

صفات کیفی،

عمر انباری،

ارزش غذایی،

فرازگرا

DOI: 10.22034/FSCT.21.147.16.

مسئول مکاتبات: *

majiddastjerdy@gmail.com

mostafaghasemi1417@gmail.com

چکیده

به‌منظور افزایش کیفیت و عمر انباری میوه‌های انبه رقم لانگرا، آزمایشی به‌صورت فاکتوریل با سه فاکتور در قالب طرح کاملاً تصادفی با سه تکرار (هر تکرار ۱۸ میوه) انجام شد. میوه‌های انبه در مرحله سبز بالغ از یک باغ تجاری انبه در شهرستان رودان استان هرمزگان برداشت شدند. فاکتور اول پرتوتابی اشعه **فرابنفش** (UV-C) با شدت ۲۵ وات در سه سطح (۰، ۵ و ۱۰ دقیقه)، فاکتور دوم پرتوتابی فراصوت (اولتراسونیک) با فرکانس ۳۵ کیلو هرتز و توان ۲۸۰ وات در سه سطح (۰، ۳ و ٦ دقیقه) و فاکتور سوم زمان انبارمانی در پنج سطح (۰، ۱۰، ۲۰، ۳۰ و ٤۰ روز) بودند. میوه‌ها پس از تیمار با نسبت‌های ذکر شده از UV-C و فراصوت به سردخانه با دمای۱۰ درجه سانتی‌گراد و رطوبت نسبی ۸۰-۸۵ درصد منتقل شدند و نمونه‌گیری و اندازه‌گیری‌ها در زمان‌های مختلف انجام شد. تیمارهای فرابنفش و فراصوت از افزایش L^* (روشنایی)، a^*، b^* گوشت میوه و pH و کاهش اسید آسکوربیک میوه با گذشت زمان ممانعت کردند. در تیمارهای فراصوت، بیشترین آسکوربیک اسید (۱۱/۳ میلی‌گرم در ۱۰۰ گرم) در پرتوتابی فراصوت سه دقیقه مشخص شد. در تیمارهای فرابنفش نیز کاهش اسید آسکوربیک با گذشت زمان کمتر از شاهد بود اما بین پرتوتابی پنج و ده دقیقه تفاوت معنی‌دار نبود. تیمار فراصوت ٦ دقیقه از کاهش معنی‌دار وزن میوه جلوگیری کرد. در روز ٤۰ انبارمانی، کمترین مقدار L^* گوشت میوه (۸۹/٤٤) متعلق به تیمار فرابنفش پنج دقیقه بود. بنابراین طی ٤۰ روز انبارمانی میوه انبه، تیمار فرابنفش به‌مدت پنج دقیقه به‌دلیل حفظ ظاهر میوه (L^*) و تیمار فراصوت سه دقیقه به‌دلیل داشتن بیشترین اسید آسکوربیک میوه انبه قابل توصیه می‌باشند.

[DOI: 10.22034/FSCT.21.147.16]