



Utilization of Acetyl Salicylic Acid and Irradiation as Postharvest Treatments for Storage of Persimmon Fruits Cv."Costata"

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Mature Persimmon fruits "Costata cv." were used to study the effect of Acetyl Salicylic Acid (ASA) at rates 0, 2, 3% and/or irradiation (IRD) with 0.0, 1.0, 2.0 KGy doses, using CO⁶⁰ source at 2g /Sec as a trial for prolonging fruit marketing period and extending its shelf life with good quality, after cold storage treatment. Nine treatments including control were stored for 75 days at 0 ± 1°C with 80 ± 2% relative humidity to measure weight loss, fruit firmness and decay percentages. Where, fruit quality parameters during shelf life were evaluated after 7 days of transference to room temperature (23 ± 2°C). Results showed a close relationship between high irradiation dose (2 KGy) and rate of detrimental effects by accelerating ripening process and softening during storage and shelf life to obtain less marketing fruits. Adding ASA at either 3 or 2% to fruits irradiated with 2 KGy, slightly reduced the decline in fruit quality. Furthermore, non-treated cold stored fruits dominated 2 KGy treatment, in this respect. However, fruit constituent values were gradually progressed and 1 KGy dose recorded the highest storability effect in keeping fruits firm with less deterioration response as

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combined with 2% ASA, compared with sole ones. Moreover, improving effect in fruit components *i.e.*, acidity, VC, SSC, sugar, T. flavonoids, β -Carotene and reduction in tannin contents were retained with 1 KGy treatment as combined with 2% ASA followed in descending order by 3% ASA. In general, irradiation of persimmon fruits at dose (2 KGy) was not suitable for preserving stored fruits. Also, sole radiation treatment at 1 KGy was less effective than sole treatment of ASA at either 2 or 3% rates, in this respect. Therefore, irradiation with 1 KGy combined with ASA treatment at 2% can be recommended for improving storability of persimmon "Costata cv." fruits with the maintenance of good marketable and preferable nutritional parameters up to extended shelf life.

Keywords: *Costata persimmon; irradiation; acetyl salicylic acid; postharvest treatments; fruit quality; shelf life.*

1. INTRODUCTION

Persimmon fruits are not left to ripe on the trees and harvested at mature stage to be artificially ripened for commercial production and marketing [1]. The role of its certain bioactive molecules *i.e.*, carotenoids, tannins, flavonoids, anthocyanidin, catechin, *etc.* is high lighted [2] according to fruit climacteric behavior that responsible for its short shelf-life during transportation [3]. In Egypt, limited information is available among keeping satisfactory quality during postharvest and storage as major problem for persimmon cultivation and distribution. Thus, it is of important to optimize the postharvest care of fruit ripening, where studies interested in extending shelf life are economically important for increases their useful life. Postharvest shelf life indicate the suitability of any fruit for its distant marketing [4], where rapid softening during post harvest period is the most limiting factor for distribution and storage of this cultivar [5]. He also added that fruits harvested at commercial maturity produce only a low amount of ethylene less than $1.0 \text{ nL g}^{-1} \text{ h}^{-1}$ event peak production. It has been demonstrated that inhibition of ethylene action reduced decays, ripening stage and senescence in several species of fruits [6]. In climacteric fruits, low temperature can be used to achieve a delay in the onset of ripening and in result increase of postharvest life. At the end of pre-climacteric stage, persimmon fruits are at their best quality and extension of marketing period as exposed to cold storage enriched with postharvest treatments [7]. On the Karajpersimmon, results indicated that fruits stored at 0°C had higher firmness and lower disease incidence than those stored at higher temperature [8]. Salicylic acid (SA) or ortho-hydroxybenzoic acid and related compounds in ASA form belong to a diverse group of plant phenols. It involved in regulation of various processes in plant, including induction of disease

resistance [9]. Meanwhile [10] suggests on the role of SA in thermo-genesis and disease resistance meets some qualifying criteria for a plant hormone [11]. SA as a plant hormone plays essential role in inhibiting ethylene biosynthesis by producing higher polyamine levels that reduces ethylene action and decrease activity of cell wall degrading enzymes that could delay fruit ripening and tended to increase postharvest life of horticultural products [12]. In kiwi fruits, the pattern of decrease in endogenous SA level was related to accelerate softening while the application of ASA (as derivative of SA) slowed down the softening rate of fruit by inhibiting ethylene production and maintaining higher endogenous levels of SA [13,14].

Recently, consumers are looking for fruit free of chemical residues. Food Standard Aust. New Zealand, 2011 mentioned to the approval of irradiation of persimmons at a minimum dose of 150 gray (Gy) and a maximum of 1 KGy does not pose a significant human health risk for consumers. Irradiation is broadly effective against pathogens with doses not significantly reduce quality and may even extend shelf life [15]. Ultraviolet irradiation is widely used, its low cost and easy application makes it a good alternative strategy for fresh fruit preservation and to control microorganism in food products [3,16]. Where, Gamma rays is more energetic form of radiation and many studies have demonstrated that most fresh fruits and vegetables irradiated at doses of 1 KGy or less did not exhibit any significant change in appearance, texture, flavor or nutrient quality [17,18]. Additionally, lower irradiation doses followed by cold storage are required for inhibition of fungal growth [19].

Therefore, this study was initiated to throw light on the efficiency of ASA and radiation treatments on fruit quality as a trial to extend its shelf life

and prolonging the marketing period of Costata persimmon cv. under cold storage conditions.

2. MATERIALS AND METHODS

2.1 Sampling

Persimmon fruit Cv."Costata" were harvested at commercial mature stage (two thirds of fruit surface was colored) during October, 2014 and 2015. Tested trees grown in a private orchard located at Giza Governorate Egypt, in loamy soil under flood irrigation system, on 12 years old with similar growth vigor and received the usually horticultural practice. Greenish-yellow color maturity fruits were selected undamaged, uniform in shape, freedom from blemishes, pathogen infection and immediately transferred to the laboratory of Agriculture Development Systems (ADS) project in the Faculty of Agriculture, Cairo University.

2.2 Treatments and Storage

Two hundred sixteen fruits were taken, washed, air dried and divided into nine treatments with four replicates each of 6 fruits.

2.3 Irradiation Treatments

Two groups, 72 fruits per each were irradiated as follows: Group 1: 1KGy. Group 2: 2KGy using CO60 source at 2g/Sec dose rate at National Centre for Radiate Res. & Tech., Nasr City, Cairo, Egypt. The dose rate delivered during the experimental duration was 1KGy/hr., as monitored by radio-chromic film [20]. After irradiation treatment, fruits were transferred to a cold storage room.

2.4 Application of Acetyl Salicylic Acid (ASA)

ASA was applied as sole treatment or in combination with irradiated fruits by immersing fruit for 5 min. in a solution of 1.0, 2.0 mmol/L ASA (PH 3.5) where control fruits (at 0.0, ASA or radiation) were immersed 5 min. in distilled water [13].

Persimmon fruit treatments were as follows:

- T₁. Control.
- T₂. Radiation 1KGy.
- T₃. Radiation 2KGy.
- T₄. ASA 2.0 mmol/L.
- T₅. ASA 3.0 mmol/L.

- T₆. ASA 2.0 mmol/L + Rad. 1 KGy.
- T₇. ASA 2.0 mmol/L + Rad. 2 KGy.
- T₈. ASA 3.0 mmol/L + Rad. 1 KGy.
- T₉. ASA 3.0 mmol/L + Rad. 1 KGy.

Treated fruits were air dried packed in carton boxes, cold stored at $0 \pm 1^{\circ}\text{C}$ with $80 \pm 2\%$ relative humidity. Quality parameters were recorded during 75 days of storage at 15 days intervals included.

2.5 Measurements

2.5.1 Loss in fruit

$$\text{Weight loss (\%)} = \frac{\text{Initial Wt.} - \text{final Wt.}}{\text{Initial Wt.}} \times 100.$$

2.5.2 Fruit firmness

Fruit firmness was measured using Ametek pressure tester, fitted with an 8 mm hemispherical probe (probe penetration 2 mm), the results calculated as Newton units.

2.5.3 Fruit decay percentages

Fruit decay percentages were expressed as percent of discarded fruits from the original sample.

After cold storage the fruits were left at room temperature ($23 \pm 2^{\circ}\text{C}$) for one week as ending of shelf life period and the following parameters were carried out.

2.5.4 Fruit diameter

Fruit diameter was determined using a universal fruit caliper/inches (with diameter range 0.8–4.0).

2.5.5 Severity of skin browning

Severity of skin browning was visually assessed and calculated as described by [21] on a scale of (0–3) according to amount of browning on fruit surface.

2.5.6 SSC content

S.S.C content was determined using a T/C hand refractometer.

2.5.7 Total acidity (expressed as mallic acid%)

Total acidity was determined by titrating 5 ml juice with 0.1N sodium hydroxide using phenolphthalein as an indicator.

2.5.8 Vitamin C content

Vitamin C content was assessed using 2, 6-dichlorophenol indophenols dye and 2% oxalic acid as a substrate [22].

2.5.9 Total sugar content

Total sugar content was determined using the phenol and sulphuric acid [23].

2.5.10 Total flavonoids content

Total flavonoids content was determined of crude extract by the aluminum chloride colorimetric method and the result was expressed as mg rut in equivalent per g dry weight [24].

2.5.11 Total tannin contents

Total tannin contents were estimated using potassium permanganate volumetric method according to [25].

2.5.12 β -Carotene

β -Carotene was determined in fresh peel, grounded with acetone, filtered and the absorption was measured at 470 nm using Zeiss Jena Spectrocolorimeter [26].

2.6 Statistical Analysis

Mean values for both seasons were tabulated and analysed as completely randomized blocks design with three replicates. An analysis of variance was used to analyze difference between means and the LSD test was applied for mean separation at $P = 0.05$. [27].

3. RESULTS AND DISCUSSION

After irradiation and at the next day, measurements of tested fruits showed no differences between the irradiated and control samples in all treatments.

3.1 The Effects of Irradiation and Acetyl Salicylic Acid on Fruit Weight Loss, Firmness and Decay% of Cold Stored Persimmon Fruits Are Shown in Table 1

Data in Table 1 indicated that all fruit quality assessments were directly proportional to the storage period. In general, the percentages of both weight loss and decay of persimmon fruit

was increased with extending storage period up to 70 days. While, fruit firmness was decreased as storage period increased.

3.1.1 Loss in fruit weight

Losses in irradiated fruits were in proportion to radiation dose and reflected an increase in loss values to the maximum mean with 2 KGy dose and decreased with 1 KGy dose to be significantly equal with cold stored control. Whereas, ASA treatments at 3% recorded lower values than 1 KGy treatment. Using 1 KGy in combination with ASA at either 2 or 3% showed similar loss in fruit weight patterns with lowest values up to 30 storage days. After that 1 KGy + 2% ASA dominated in this respect followed by 1 KGy + 3% ASA treatment.

3.1.2 Fruit firmness

It is an indicator for the degree of fruit ripening and shelf life. Table 1, shows a gradual decrease in fruit firmness as fruits ripened through storage time to reach approximately half of the initial firmness value that considered the minimum threshold as marketing. After 45 days of storage. A sharp decrease in firmness was observed with 2 KGy and its combinations with ASA at either 2 or 3% maintained firmness up to unsatisfactory values comparing with cold stored control. However, fruits treated with 1 KGy exhibited an increase in fruit firmness. Also, higher firmness values were significantly obtained with sole treatments of ASA at either 2% or 3%. Furthermore, clear improvement with equal effects as pre-mentioned ASA rates were combined with 1 KGy. After 75 days, different treatments cleared the same trend with severe decline in fruits treated with 2 KGy. Whereas fruits treated with 1 KGy + ASA at either 2 or 3% were more firmer with significant differences. But, untreated cold stored fruits recorded moderate decrease, in this respect.

3.1.3 Fruit decay percentages

Was positively proportionate with the increment of ripening values. Good results of intact fruits were significantly recorded with different treatments up to 30 days storage, meanwhile moderate percentages of decayed fruits were mainly caused by 2 KGy dose as well as its both combination with ASA rates to be higher than control with no signs of pathogenic organisms. Sole treatment of ASA at 2% reduced decay %, but decay incidence raised with ASA at 3% to be significantly equal to 1 KGy treatment.

These results were in accordance with [7] who demonstrated that cold stored persimmon fruits gave satisfied values as main limiting factor for fruit softening and water loss. [8] on persimmon reported that cold storage achieved a reduction in decay % with moderate firmness that improved storability and in result increase of postharvest life. Concerning ASA, the positive effect of SA on fruit firmness has been previously reported by [28, 29], where ASA decreases ethylene production [30] and inhibits degrading enzymes of both cell wall and membrane that decreased fruit softening rate [10]. The improvement in fruit firmness and lower weight loss values in fruits treated with low rate of SA was confirmed with those obtained by [31]. SA application greatly decreased fruit transpiration with reducing in hydrolytic enzymes activity [8]. The decrease in respiration rate and fruit weight loss may also influenced by stoma closing resulted from SA treatment [13]. Moreover, the reduces in fruit weight may be resulted from salicylic acid as an electron donor produces free radicals which prevents metabolic activity that reduces weight [32].

As for irradiation treatments, the similarity in reducing fruit weight losses by 1 KGy and cold stored control was in line with [18] and [33] who observed that decrease would certainly be higher if samples were not refrigerated. Lowering decay %, weight loss % and respiration rate was revealed by [34, 35] who stated that irradiation has regulatory approval for application to produce for shelf-life extension storability and the highest dose allowed is 1 KGy fruit tissue injury caused by higher doses results from increased peroxides and catechol oxides activities and decreased catalase activity [36]. He added that low doses reduced decay%, weight loss% in peach and apricot. Maintaining the firmness higher with 1KGy dose resulted from reduction in activities of cell wall degrading enzymes was confirmed by [3, 14] as used UV-C on strawberry. The combined effect between 2% ASA and 1KGy reflected best results for storability of persimmon fruits according to the advantages of irradiation as a non-thermal process that kills spoilage organisms and pathogenic bacteria in fruits and vegetables [37] as well as delaying the fruit senescence [19]. At the same time SA as a plant hormone inhibiting ethylene biosynthesis and delaying the fruit senescence [30, 8] that lowered softening rate, especially at 2 mM and showed better results [4] on apricot.

3.2 The Effects of Irradiation and Acetyl Salicylic Acid on Persimmon fruit Quality during Cold Storage for 75 Days and Plus Subsequent 7 Days at $23 \pm 2^\circ\text{C}$ are Shown in Table 2

3.2.1 Effect on persimmon fruit quality during cold storage for 75 days

Irradiation of stored fruits appeared a close relationship between high dose (2 KGy) and rate of detrimental effects resembled by severe skin Brown Index, reduction in VC content, total sugars, β -Carotene and increase in total tannins by accelerating ripening process during cold storage periods and shelf life. In proportion to the absorbed dose and storage time, the shrinkage fruit diameter as well as SSC, acidity and total flavonoids levels were significantly declined. On the contrary, fruits irradiated at lower dose of 1 KGy developed quality contents for SSC, VC, total sugar and T. flavonoids significantly in similar to control, but increased than control values for fruit diameter, acidity and β -Carotene besides advance in reduction of skin browning and total tannins. Concerning ASA treatment, the results revealed that Sole treatments of ASA were effective in increasing fruit diameter, fruit chemical constituents values and reducing browning index than either control or 1 KGy dose. Where, the improvement was significantly higher in 3 % ASA treated fruits than those of 2 % ASA, in this respect. The combined effect between irradiated fruits with and ASA treatment showed a slight improvement in the abovementioned quality parameters as 2 KGy combined with ASA at 2% or 3% to be less than control, where 2 KGy + 3 % ASA significantly advanced.

In general, this work is linearly correlated to some author reporting that gamma rays as supplementary treatments to fruit cold storage reduces metabolic activities i.e., respiration rate and ethylene production that decreased activity of degrading enzymes causing delay in fruit ripening and increase postharvest life of horticultural products [38, 34] beside its effects on physical and chemical properties [33] on mushroom, [3] on peach, [39] on apricot and [40] on flavonoids of strawberries).

According to the effect on respiration rate which alter fruit moisture can be reflect on fruit diameter [41].

Table 1. Effect of irradiation (IRD) and Acetyl Salicylic Acid(ASA) on weight loss, firmness and decay% of cold stored ($0 \pm 1^\circ\text{C}$) Costata persimmon fruits (Means of two seasons)

Treatments		Days in storage				
IRD doses (KGy)	ASA rates (%)	15	30	45	60	75
Loss in fruit weight (%)						
0.0	0.0	1.16 c	1.98 d	3.73 d	5.12 c	7.17 c
	2.0	0.87 f	1.49 f	2.86 f	4.13 e	5.97 e
	3.0	1.06 d	1.82 e	3.39 e	4.46 d	6.35 d
1.0	0.0	0.97 e	1.89 d	3.37 d	4.95 c	6.76 c
	2.0	0.69 g	1.15 g	2.34 h	3.47 g	5.19 g
	3.0	0.74 g	1.22 g	2.59 g	3.80 f	5.58 f
2.0	0.0	1.44 a	2.49 a	4.55 a	7.15 a	10.36a
	2.0	1.34 b	2.32 b	4.28 b	6.78b	9.84 b
	3.0	1.25 b	2.16 c	4.01 c	6.89 b	9.95 b
Fruit firmness						
0.0	0.0	25.16b	22.54 d	19.95 d	16.49f	12.84 f
	2.0	25.97 b	23.76 b	21.56 b	19.32 c	13.56 d
	3.0	25.73 b	22.96 c	20.39 c	18.75 e	14.32 c
1.0	0.0	25.89 b	23.50 b	21.23 b	18.05 e	13.59 e
	2.0	26.40 a	24.81 a	22.63 a	21.01 a	15.66 a
	3.0	26.27 a	24.52 a	22.49 a	20.77 b	14.91 b
2.0	0.0	23.07 c	19.04 f	16.65 f	12.18 h	8.48 l
	2.0	23.20 c	19.60 e	17.49 e	12.76 g	9.36h
	3.0	23.43 c	19.77 e	17.42 e	12.97 g	9.77 h
Fruit decay (%)						
0.0	0.0	1.38 c	2.37 c	3.16 c	4.11 c	6.14 d
	2.0	0.25 e	0.96 e	1.38 f	2.09 f	3.16 g
	3.0	1.04 c	1.53 d	2.52 d	3.27 d	4.41 e
1.0	0.0	0.69 d	1.86 d	2.08 e	2.56 e	3.88 f
	2.0	0.00 f	0.00 f	0.71 g	1.55 g	2.04 i
	3.0	0.00 f	0.32 f	0.89 g	1.68 g	2.52 h
2.0	0.0	2.26 a	3.71 a	5.88 a	7.93 a	10.75 a
	2.0	1.71 b	3.01 b	4.72 b	6.69 b	9.63 c
	3.0	1.96 b	3.13 b	4.95 b	7.08 b	9.29b

Means having the same letters within a column are not significantly different at 5% level

Table 2. Effect of irradiation (IRD) and Acetyl Salicylic Acid (ASA) on fruit quality of cold stored (0±1oC) Costata persimmon fruits and after shelf life "one week" (Means of two seasons)

IRD doses (KGy)	ASA rates (%)	Fruit (D)/Inch	Skin Brown Index (0 - 3)	SSC (%)	Acidity (%)	VC (mg/100g F W)	Total sugars (g/100g FW)	Flavon. Contents (mg/100g FW)	Total tannins (mg/100g FW)	β-Carotene (mg/100g FW)
After cold storage periods										
0.0	0.0	2.13 e	1.34 d	12.97 d	2.211 f	175.0 d	12.75 d	4.028 e	3.767 d	537 e
	2.0	2.17 c	0.93 f	13.86 c	2.223 d	181.7 c	13.37 c	4.442 d	3.377 f	589 c
	3.0	2.19 b	0.73 g	14.07 b	2.228 c	183.9 c	13.68 b	4.728 c	3.182 g	614 b
1.0	0.0	2.15 d	1.14 e	13.19 d	2.216 e	177.8 d	12.96 d	4.163 e	3.572 e	562 d
	2.0	2.22 a	0.32 h	14.68 a	2.248 a	189.5 a	14.26 a	5.269 a	2.792 i	653 a
	3.0	2.21 a	0.44 h	14.53 a	2.233 b	185.6 b	13.99 a	4.998 b	2.987 h	649 a
2.0	0.0	2.09 g	2.08 a	12.05 f	2.196 h	158.3 f	11.80 g	3.054 h	4.653 a	440 h
	2.0	2.11 f	1.75 b	12.38 e	2.201 g	162.2 e	12.11 f	3.328 g	4.157 b	578 g
	3.0	2.12 f	1.54 c	12.65 e	2.206 f	166.1 e	12.42 e	3.613 f	3.962 c	512 f
Cold stored fruits, plus subsequent 7 days (shelf life) at 23± 2°C										
0.0	0.0	2.03 e	1.41 d	13.29 e	2.147 f	155.1 f	13.01 e	3.967 f	3.842 d	548 e
	2.0	2.08 c	0.97 f	13.86 c	2.158 d	163.3 d	13.63 c	4.533 d	3.445 f	601 c
	3.0	2.09 c	0.77 g	14.08 c	2.163 c	166.8 c	13.95 b	4.824 c	3.246 g	627 b
1.0	0.0	2.05 d	1.19 e	13.55 d	2.152 e	159.7 e	13.32 d	4.248 e	3.643 e	574 d
	2.0	2.15 a	0.34 h	15.12 a	2.183 a	174.0 a	14.55 a	5.376 a	2.848 i	680 a
	3.0	2.12 b	0.46 h	14.75 b	2.168 b	170.4 b	14.37 a	5.102 b	3.046 h	662 a
2.0	0.0	1.99 g	2.17 a	12.18 h	2.132 i	145.3 f	12.04 g	3.117 h	4.621 a	470 g
	2.0	2.01 f	1.84 b	12.42 g	2.137 h	148.9 f	12.35 f	3.396 g	4.239 b	496 f
	3.0	2.01 f	1.62 b	12.70 f	2.142 h	152.5 f	12.66 f	3.873 f	4.410 c	3

Means having the same letters within a column are not significantly different at 5% level,FW= Fresh Weight.

Pointing to specific effect of ASA on fruit quality data, its effect as plant hormone inhibiting ethylene biosynthesis and maintaining higher endogenous SA levels may lead to delaying fruit senescence where the high concentration of ASA causes activation of some enzymes such as oxidase and peroxidase that enhance wooden cells and reduce fruit quality parameters. These trends are partially in line with [31,12] on kiwi, [11] on pomegranates, [8] on persimmon and [42] on mango.

4. CONCLUSION

These results were suggested that persimmon fruits irradiated with high radiation dose (2 KGy) was not suitable for preserving stored fruits. However, low ones (1KGy) is less effective than 2% or 3% ASA rates, in this respect. As 1KGy combined with ASA and cold stored a positive effect appeared for improving fruit storability, fruit firmness, chemical fruit quality characteristics and reducing loss in fruit weight, decay% as well as rate of browning besides. Best results were obtained when ASA added at rate 2%. Also, 1KGy combined with 3% ASA treatment gave positive results where such treatments considered the promising under cold storage for 75 days and subsequent 7 days (shelf life) at 23°C. Meanwhile, 2KGy dose recorded general deterioration aspects either alone or in combination with either ASA rates. In general, radiation at dose 1KGy combined with 2% ASA can be used for improving storability with preferable nutritional quality and extension of shelf life of "Costata" persimmon.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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