Journal of Agricultural Science and Food Technology
Vol. 5 (8), pp. 170-177, October, 2019
ISSN: 2465-7522
Full Length Research Paper
https://doi.org/10.36630/jasft_19039
http://pearlresearchjournals.org/journals/jasft/index.html

# Effect of Storage, Waxing and Gamma Irradiation on the Quality of Kinnow *Citrus reticulata* Blanco

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Accepted 25 October 2019

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## ABSTRACT

**The use of ionizing irradiation is the newest approach adopted to prevent the spread of regulated pests and has been demonstrated with no or little effect on the quality of foods. In the current study, we tested the secondary effect of waxing and gamma irradiation applied within the range for control of some quarantine pests on the sensorial and the physicochemical properties of Kinnow *Citrus reticulata* Blanco at the Nuclear Institute for Food and Agriculture (NIFA) Peshawar, Pakistan. Both waxed and non-waxed Kinnow were irradiated and then stored at room temperature 15°C±2, relative humidity RH60 ±5% for one month. The study showed no significant change in the biochemical and organoleptic properties of the Kinnow fruit at 0.5kGy dose of gamma radiation. Percentage of weight loss was increased with storage time for both waxed (F=121.04, P < 0.001) and non-waxed (F=58.96, P < 0.001) fruits. Minimum reduction in vitamin C content was recorded with increased storage time and irradiation. Increase in acidity and total soluble solids were also recorded in both irradiated and no-irradiated samples over 30 d storage time. No change in sensorial quality was observed in the irradiated fruits. Overall results revealed that irradiation up to 0.5kGy applied as phytosanitary treatment is safe. Fruit waxing followed by irradiation is effective in maintaining the sensory quality of Kinnow for at least 30 days storage period and therefore, recommended as an effective post-harvest technique for fresh fruits.**

**Keywords: Export, Fruit waxing, Kinnow, Quarantine, Postharvest, Phytosanitary, Irradiation.**

## INTRODUCTION

Pakistan stands among the top ten citrus-producing countries and sixth largest producer of Kinow (Birney, 2012). Its export plays an important role in the national economy of Pakistan with a substantial amount of foreign exchange of approximately 15.9 million rupees Ministry of Food, Agriculture and Livestock (MINFAL, 2011; Ahmad et al., 2018). Citrus is 40% of the total fruits produced in Pakistan, and are cultivated over 1.95 million hectares with an annual production of 1.9 million tons (MINFAL, 2011; Haught, 2010). It is grown mainly in Sargodha, Multan, Faisalabad, Sahiwal, Khanewal, in Punjab province and many parts of Khyber Pukhtunkhwa (KPK) such as Dargai, Haripur, Rustam and Dir districts. The world trade organization (WTO) regulations for export of fresh agriculture commodities require disinfestations of the pests prior to export. The citrus scale insects and citrus psyllids (Hemiptera: Psyllidae) are the key pests of citrus fruits in Pakistan and regulated in many parts of the world. Pakistan consequently, looses much of its export potential due to the presence of these pests as their eggs and nymphs can be transported with fresh fruits to the importing countries (Hennessey et al., 2014). Recently irradiation has been adopted as safe measure for disinfestations of quarantine pests (Hallman, 2012) and proved effective in reducing losses during long-term storage of fruits and vegetables (Heather and Hallman, 2008; Hallman, 2011; Follett and Wall, 2012) and therefore, has gained much importance in the export of fresh agricultural commodities (Benkeblia, 2000; Gómez-Simuta et al., 2017). Studies on mandarins Citrus reticulata (Jobin et al., 1992) and clementines Citrus clementina, (Mahrouz et al., 2002) have shown promising results. Irradiation up to 500 Gy is reported safe with no effect on soluble solids, titratable acidity, appearance and organoleptic quality of grapefruit Rio Red (Hallman and Martinez, 2001). Specific studies on the quality of irradiated Pakistani Kinnow mandarin are limited especially in the context of their irradiation for the control of quarantine pests.

Current studies were conducted to see the effect of irradiation, storage and waxing on the quality of Pakistani Kinnow after their treatment with recommended radiation doses within the rage for control of quarantine pest.

## MATERIALS AND METHODS

### Bioassays

Two Boxes (10 kg each) of export quality waxed 'Kinnow' were collected from Taj International 'Kinnow' processing factory at Kot Momin, Sargodha district of Pakistan. Un-waxed fresh fruits were harvested from orchards in the same area and transported in wooden crates lined with paper to the Nuclear Institute for Food and Agriculture Peshawar (NIFA), Pakistan. Fruits with uniform size (4 inch in diameter) and maturity index 3, (yellow to orange color) were selected and grouped into waxed and non-waxed fruits. The diseased and bruised fruits were discarded and all others were washed with tap water and air-dried under a ceiling fan.

### Irradiation

All samples except the controls were irradiated at 0.20, 0.30, 0.40, and 0.50 kGy (Khan et al., 2016a) in a Cobalt60 source (Isseldovatel, USSR) with a dose rate of 170Gy/hour measured with a Frickie dosimeter at the time of the experiment. Both the control and the irradiated samples were stored at uniform room temperature 15±2°C, RH 60±5% for 4 weeks.

### Physicochemical Properties

Physico-chemical properties were judged using the methodology described in the Association of Official Analytical Chemists (Feldsine et al., 2002) in food and nutrition laboratory at NIFA. Post irradiation and storage weight loss was measured at 7 to 10 days interval from three fruits in each treatment. The percent weight loss was calculated as (mo – mt)/mo*100, where mo = fresh weight, mt weight at storage interval.

### *Titratable Acidity*

The titratable acidity (%) was determined using AOAC methods 22.008 (1984) and 22.058 (1984) (Mahrouz et al., 2004; Khalil et al., 2009). An aliquot of 10 ml of the fruit extract (10 g of fruit pulp in volumetric display at 100 mL of distilled water and homogenized in a blender) was taken and titrated with 0.1 N NaOH using phenolphthalein at 1% as the indicator.

### *Total Soluble Solids*

A composite sample was created from the fruits and a 10 g sample of fruit pulp was homogenized and the Brix was measured with a hand refractometer (Brix, Atago, Japan). Before taking readings, the electrodes were washed with distilled water. Three replicates per treatment were carried out in all instances.

### *Ascorbic Acid*

Ascorbic acid content was determined by titration. For this purpose, 1mL of juice was diluted with 1N oxalic acid solution and percent vitamin C content was approximated by using the formula. Ascorbic acid content = FxTx100x100/ DxS, where:

F= Factor for standardization = mL ascorbic acid/ ml of dye

T= ml of dye used in sample – ml of dye used in blank

D= ml of the sample taken for titration

S= ml of dilute solution taken for titration.

Vitamin C content (mg ⁄ 100 g) was measured with a direct colorimetric method which is based on the measurement to the extent of which a 2,-dichlorophenol-indo-phenol solution is decolorized by ascorbic acid in extracted samples and in standard ascorbic acid solutions (AOAC, 1984) method no. 43.064). As interfering substances reduce the dye slowly, rapid de coloration measures mainly the ascorbic acid.

### Sensorial Quality

For sensorial quality (taste, texture and physical appearance) ten-trained judges from within the Food and Nutrition division and Entomology division of the institute were constituted. Taste and visual quality were estimated according to 10 points hedonic scale with 10 being the best (Larmond, 1977) for fruit taste, texture and physical appearance. The tests on physical appearance of wax and non-wax fruits were carried out weekly on randomly selected fruits from both treated and control groups.

### Firmness

Flesh firmness was measured by Penetrometer Italy with a force gauge having a 6-mm diameter flathead probe. Measurements were taken at four locations on the surface of all fruits in each treatment.

### Taste

For this parameter, fruits slices were provided to the panelists in white plates labeled with random three-digit

**Table 1.** Post irradiation weight loss (%) of waxed and non-waxed Kinnow mandarin stored at room temperature (15°C±2, RH 60±5%).

| Dose (Gy) | Weight Loss (% g) of Waxed Kinnow During Storage (Days) | | | Weight Loss (% g) of Non-Waxed Kinnow During Storage (Days) | | |
|---|---|---|---|---|---|---|
| | Day 8 | Day 18 | Day 30 | Day 8 | Day 18 | Day 30 |
| 0 | $3.08^{de}$ | $6.37^{cde}$ | $16.77^{ab}$ | $5.93^{d}$ | $18.28^{abcd}$ | $27.48^{a}$ |
| 200 | $3.02^{de}$ | $7.80^{abc}$ | $9.79^{abc}$ | $9.94^{bcd}$ | $15.52^{abcd}$ | $23.88^{a}$ |
| 300 | $2.54^{e}$ | $6.61^{bcde}$ | $10.30^{abc}$ | $7.37^{d}$ | $17.56^{abcd}$ | $20.12^{abc}$ |
| 400 | $3.09^{de}$ | $6.74^{bcd}$ | $10.65^{ab}$ | $7.85^{cd}$ | $16.28^{abcd}$ | $22.21^{ab}$ |
| 500 | $2.73^{de}$ | $8.16^{abc}$ | $11.49^{a}$ | $5.89^{d}$ | $15.89^{abcd}$ | $26.37^{a}$ |

For each parameter, means followed by the same letter within a column are not significantly different from each other (p<0.05; Tukeys HSD test using Statistix 8.1).

**Table 2.** Ascorbic acid (mg/100 ml) in waxed and non-waxed Kinnow after irradiation and storage at 15 ± 2°C, RH 65±5.

| Dose (Gy) | Vitamin C Contents of Waxed Kinnow During Storage (Days) | | | | Vitamin C Contents of Non-waxed Kinnow During Storage (Days) | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 8 | 18 | 29 | 1 | 8 | 18 | 29 |
| 0 | $23.33^{ab}$ | $21.67^{bc}$ | $16.33^{fg}$ | $16.17^{fg}$ | $23.0^{a}$ | $21.83^{ab}$ | $18.17^{def}$ | $13.67^{h}$ |
| 200 | $23.50^{a}$ | $22.17^{abc}$ | $17.83^{ef}$ | $15.50^{g}$ | $22.17^{ab}$ | $21.67^{ab}$ | $18.83^{cde}$ | $16.0^{fgh}$ |
| 300 | $23.00^{ab}$ | $20.50^{cd}$ | $19.50^{de}$ | $16.17^{fg}$ | $22.50^{ab}$ | $21.33^{abc}$ | $18.50^{def}$ | $16.50^{efg}$ |
| 400 | $23.00^{ab}$ | $19.50^{de}$ | $17.50^{f}$ | $15.50^{g}$ | $22.50^{ab}$ | $21.33^{abc}$ | $17.33^{efg}$ | $15.17^{gh}$ |
| 500 | $23.33^{ab}$ | $19.50^{de}$ | 19.50d$^{e}$ | $15.17^{g}$ | $22.17^{ab}$ | $20.25^{bcd}$ | $17.0^{efg}$ | $15.0^{gh}$ |

For each parameter, means followed by the same letter within a column are not significantly different from each other (p<0.05; Tukeys HSD test using Statistix 8.1).

number. The panelists evaluated the taste of the sample according to the proposed hedonic scale and recorded their opinion on the sheet of what they preferred or disliked and if they would choose the product for purchase.

### Appearance

Samples of wax and non-wax fruits (coded with a random three-digit number) were offered individually to the panelists' committee in white plates. Evaluators were asked to observe each fruit and indicate the degree of their likeness in terms of fruit appearance according to the hedonic scale.

### Statistical Analysis

A factorial design having two factors of irradiation dose and storage time with three replications was followed. Statistical analysis was conducted for each of the measured traits by ANOVA and the means were separated by Tukey’s Honesty test (Tukey, 1953) using Statistix 8.1.

## RESULTS

### Weight Losses

Effect of the various treatments on weight loss for waxed and un-waxed fruit during 30 days storage is shown in Table 1. There was significant variation in percent weight loss with storage time (F=121.04, P < 0.001), but insignificant variation (F= 0.61, p=0.66) was recorded among the irradiation doses for waxed fruit. The combined effect of treatments and storage time on weight loss was also in significant (F=0.59, P = 0.77). For non-waxed fruit percent weight loss also increased significantly with storage time (F=58.96, P < 0.001), but insignificantly (F= 0.38, p=0.82) among the irradiation doses. Non-significant change in weight loss was also recorded from interaction among the treatments and storage time (F=0.93, P ≤ 0.51). Percent weight loss was maximum for non-waxed (27.48) fruits followed by waxed (16.77) after a period of 30 d storage time and no irradiation.

### Ascorbic Acid

Effect of the various treatments on ascorbic acid for waxed and non-waxed fruit during 30 days storage is shown in Table 2. Content of vitamin C varied significantly with both storage time (F=459.56, P < 0.001), and irradiation doses (F= 10.21, p<0.001) for waxed fruit. The combined effect of radiation and storage time on loss in the vitamin content was also significant (F=10.09, p< 0.001). For non-waxed fruits, similar results were obtained with both storage time (F=236.27, P < 0.001), and among the irradiation doses (F= 3.70, p<0.01). The interaction among the treatments and storage time on loss in the vitamin content was also significant (F=2.13, p < 0.03). This indicates that the loss

**Table 3.** Acidity of waxed and non-wax Kinnow after their irradiation and storage at 15±2 °C, RH 65±5.

| Dose (Gy) | Acidity of Waxed Kinnow During Storage (Days) | | | | Acidity of Un-Waxed Kinnow During Storage (Days) | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 8 | 18 | 29 | 1* | 8 | 18 | 29 |
| 0 | $1.155^{EF}$ | $1.35^{CD}$ | $1.357^{CD}$ | $1.47^{BC}$ | ----- | $0.99^{E}$ | $0.93^{G}$ | $0.94^{F}$ |
| 200 | $1.02^{F}$ | $1.03^{F}$ | $1.34^{CD}$ | $1.54^{AB}$ | ----- | $0.704^{M}$ | $0.83^{K}$ | $1.02^{D}$ |
| 300 | $1.089^{EF}$ | $1.08^{EF}$ | $1.50^{AB}$ | $1.54^{AB}$ | ----- | $0.94^{F}$ | $0.83^{K}$ | $1.07^{B}$ |
| 400 | $1.16^{EF}$ | $1.18^{E}$ | $1.33^{D}$ | $1.42^{BCD}$ | ----- | $0.633^{N}$ | $0.87^{I}$ | $1.06^{C}$ |
| 500 | $1.18^{E}$ | $1.18^{E}$ | $1.44^{BCD}$ | $1.63^{A}$ | ----- | $0.84^{J}$ | $1.280^{A}$ | $0.89^{H}$ |

For each parameter, means followed by the same letter within a column are not significantly different from each other (p<0.05; Tukeys HSD test using Statistix 8.1). * data was not recorded.

**Table 4.** Total soluble solids (Brix) of waxed and non-waxed kinnow fruit after their irradiation and storage at 15±2°C, RH 65± 5.

| Dose | Post Irradiation TSS (Brix) of Waxed Fruit During Storage (Days) | | | Post Irradiation TSS (Brix) of Non-Waxed Fruit During Storage (Days) | | |
|---|---|---|---|---|---|---|
| | Day 8 | Day 18 | Day 29 | Day 8 | Day 18 | Day 29 |
| 0 | $11.13^{h}$ | $12.33^{cde}$ | $13.67^{a}$ | $11.13^{hi}$ | $12.33^{cd}$ | $14.0^{a}$ |
| 200 | $11.33^{gh}$ | $11.40^{fgh}$ | $11.50^{fgh}$ | $11.33^{ghi}$ | $11.50^{fgh}$ | $11.40^{fgh}$ |
| 300 | $11.33^{gh}$ | $12.90^{bcd}$ | 13.0b$^{c}$ | $10.60^{i}$ | $12.90^{bcd}$ | $13.0^{bc}$ |
| 400 | $12.0^{efg}$ | $12.17^{def}$ | 13.0b$^{c}$ | $12.0^{efg}$ | $12.17^{def}$ | $13.0^{bc}$ |
| 500 | $12.0^{efg}$ | $12.0^{efg}$ | $13.50^{ab}$ | $12.0^{efg}$ | $12.0^{efg}$ | $13.50^{ab}$ |

For each parameter, means followed by the same letter within a column are not significantly different from each other (p<0.05; Tukeys HSD test using Statistix 8.1).

**Table 5.** Firmness of waxed and non-waxed Kinnow fruit after their irradiation and storage at 15±2°C, RH 65± 5.

| Dose (Gy) | Firmness of Waxed Kinnow During Storage (Days) | | | | Firmness of Non-Waxed Kinnow During Storage (Days) | | | |
|---|---|---|---|---|---|---|---|---|
| | Day 0 | Day 8 | Day 18 | Day 29 | Day 0 | Day 8 | Day 18 | Day 29 |
| 0 | $2.74^{ab}$ | $2.63^{abc}$ | $1.97^{def}$ | $1.90^{ef}$ | $2.40^{abcd}$ | $2.067^{abcde}$ | $1.85^{bcde}$ | $1.57^{de}$ |
| 200 | $2.80^{a}$ | $2.80^{a}$ | $2.20^{abcdef}$ | $2.07^{abcdef}$ | $2.70^{a}$ | $2.20^{abcde}$ | $2.18^{abcde}$ | $1.80^{cde}$ |
| 300 | $2.53^{abcd}$ | $2.47^{abcde}$ | $2.17^{bcdef}$ | $2.13^{bcdef}$ | $2.40^{abcd}$ | $2.22^{abcde}$ | $1.86^{bcde}$ | $1.55^{e}$ |
| 400 | $2.63^{abc}$ | $2.63^{abc}$ | $2.27^{abcdef}$ | $2.00^{def}$ | $2.53^{abc}$ | $2.26^{abcde}$ | $1.87^{abcde}$ | $1.75^{cde}$ |
| 500 | $2.63^{abc}$ | $2.63^{abc}$ | $2.03^{cdef}$ | $1.70^{f}$ | $2.63^{ab}$ | $2.27^{abcde}$ | $2.19^{abcde}$ | $2.03^{abcde}$ |

For each parameter, means followed by the same letter within a column are not significantly different from each other (p<0.05; Tukeys HSD test using Statistix 8.1).

in vitamin C content is affected both by storage time and by irradiation.

### *Acidity*

Effect of the various treatments on acidity for waxed and non-waxed fruit during 30 days storage is shown in Table 3. Acidity increased significantly with both storage time (F=272.50, P < 0.001), and among the irradiation doses (F= 15.30, p<0.001) for waxed fruit. The interactive effect of both treatments and storage time on acidity was also significant (F=10.64, p < 0.001). For non-waxed fruit, acidity was significantly different from both storage time (F=39831, P < 0.0001), and among the irradiation doses (F= 8817, p<0.0001). The interactive effect of treatments and storage time on acidity was also significant (F=14676, p < 0.0001).

### Total Soluble Solids (TSS)

The data on TSS of Kinnow is presented in Table 4. The effect of waxing and irradiation, as well as the combine effect of storage time and irradiation dose, was significant (P < 0.001) on TSS. The TSS values increased over time in both irradiated as well as non-irradiated waxed and non-waxed fruits.

### Sensorial Quality

The data on sensorial quality: firmness (Table 5), appearance (Figures 1 and 2), and taste (Figures 3 and 4) are shown. For external appearance, initial scores of 8.4 to 8.5 (Figure 2) were received for all treatments of waxed Kinnow. The appearance of irradiated and waxed Kinnow reduced from 8.5 to 7 points in all treated Kinnow except the untreated control where it was 6.5 by the end of 29 d at room temperature (15±2°C). The value of 6.5 is still in an acceptable range of appearance which means that Kinnow can be stored at this temperature for at least up to one month. The score values for appearance decreased with the advancement of storage time (from 8.5 to7.0) in treated samples, and from 8.5 to 6.5 in the non-treated waxed fruits, however, these

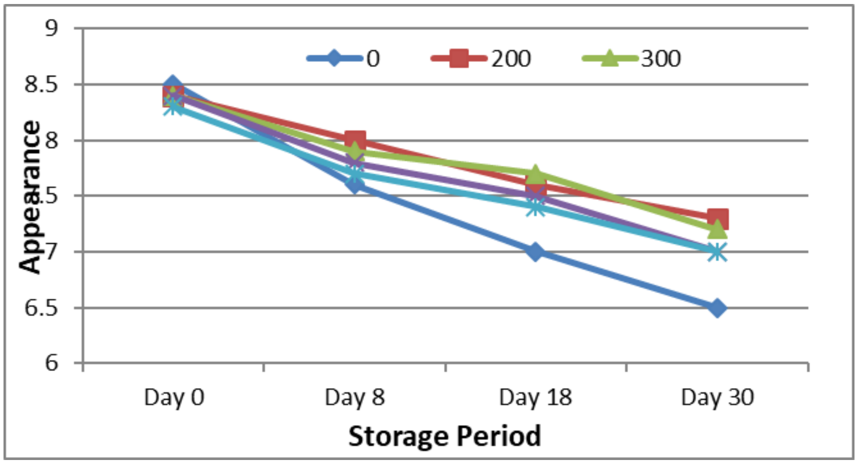


**Figure 1.** Appearance of waxed Kinnow at post irradiation and storage for 30 day. No significant change in appearance was observed in all treatments except control ($p<0.05$; Tukeys HSD test using Statistix 8.1).

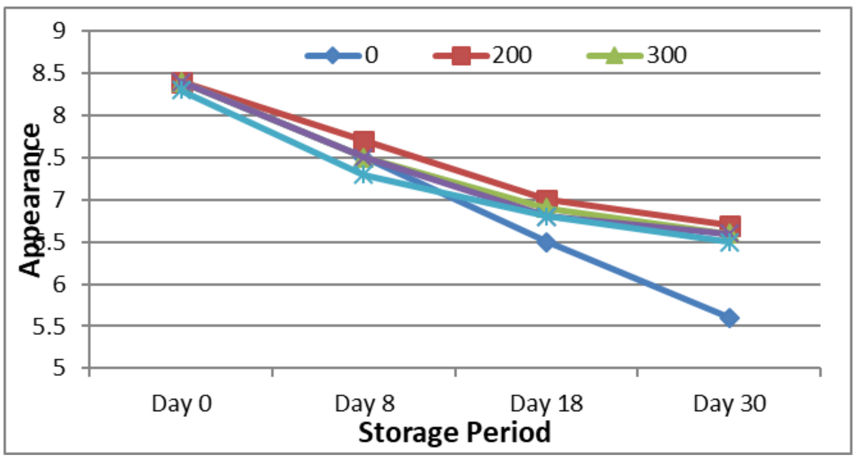


**Figure 2.** Appearance of non-waxed Kinnow at post irradiation and storage for 30 days. No significant change in appearance was observed in all treatments except control ($p<0.05$; Tukeys HSD test using Statistix 8.1).

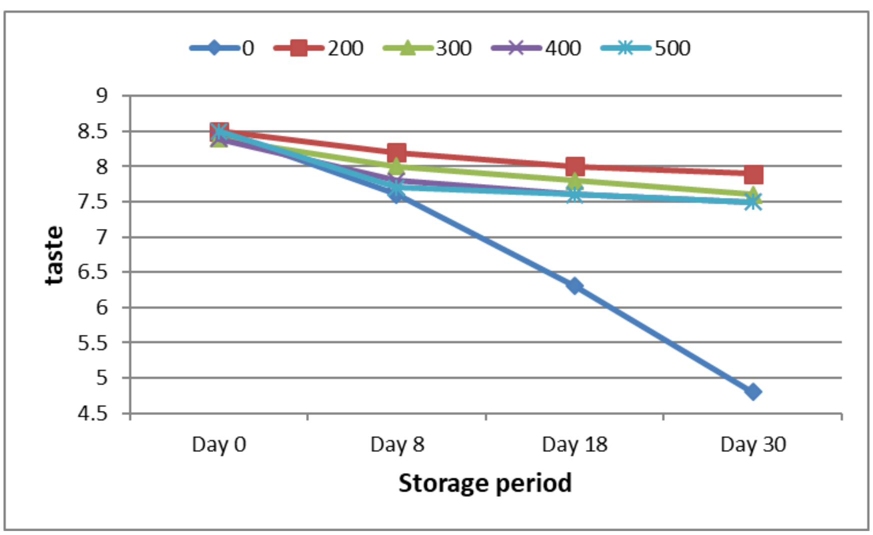


**Figure 3.** Taste of waxed Kinnow post irradiation and storage for 30 days. No significant change in taste was observed in all treatments except control ($p<0.05$; Tukeys HSD test using Statistix 8.1).

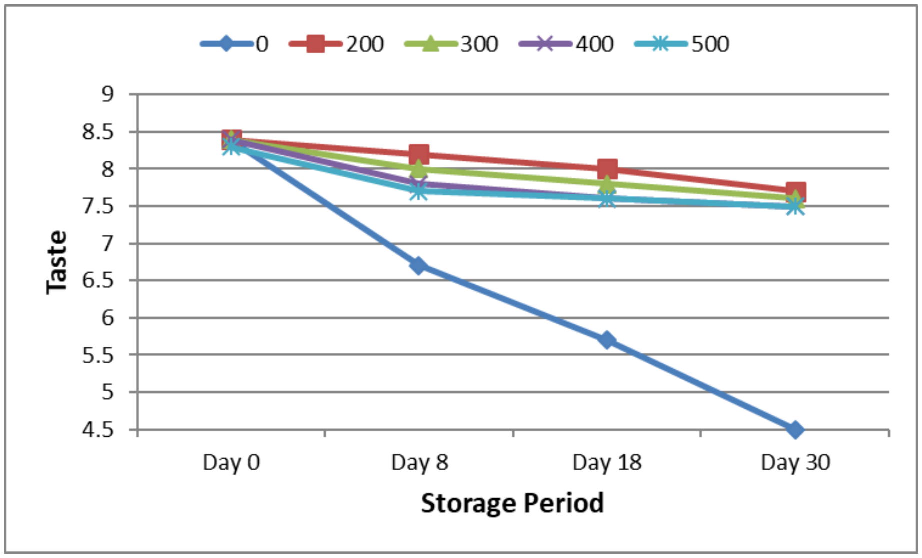


**Figure 4.** Taste of non-waxed Kinnow post irradiation and storage for 30 days. No significant change in taste was observed in all treatments except control ($p<0.05$; Tukeys HSD test using Statistix 8.1).

values still remained within the acceptable range. A higher score (7.5) was recorded for waxed at 0.20 kGy-treated fruits while this score was minimum (6.5) for untreated fruits. The appearance of treated and non-waxed Kinnow reduced from 8.4 to 6.5 points in all irradiated' non waxed Kinnow except the untreated control where it was 5.6 by the end of 29 d at room storage temperature (15±2°C) Figure 2.

### Taste

Data on the taste of waxed and non-waxed Kinnow after irradiation and storage is shown in Figures 3 and 4. Taste of irradiated waxed Kinnow reduced from 8.5 to 7.5 points in all irradiated Kinnow except the untreated control where it was 4.8 by the end of 29 d at room storage temperature (15±2°C). The value of 4.8.0 is below the medium range of taste which means that waxed Kinnow stored at this temperature without proper radiation will lose consumer acceptance and if stored beyond 30 days at room temperature. Similar results were obtained for non-waxed Kinnow.

## DISCUSSION

Irradiation destroys bacteria, insects and mould that contaminate food (Urbain, 1986; Ahmad, 1998) and prevent food losses. Present studies on the assessment of the sensorial and biochemical properties of Kinnow were conducted to understand the effect of irradiation on export quality fruits. As Pakistan is the major exporter of Kinnow and mangoes, the demand for zero tolerance of pest species on the exportable fresh commodities has to be met. In order to meet these challenges we conducted irradiation studies on some of the quarantine pests of these fruits for the determination of effective doses needed to control mango and citrus scale insects, we recommended a dose of 220 to 222Gy for the control of mango scale and citrus red scale (Khan et al., 2016a; Khan et al., 2016b) and 204 for citrus psyllids (Khan, 2016).

In order to further see the effect of these and higher doses of irradiation on the quality of irradiated fruits, we found that fruits irradiated within the range and above up to 0.5kGy did not cause any significant change in the biochemical or organoleptic properties of mangoes (Khan unpublished data) and citrus and it was concluded that ionizing radiation is an effective method in controlling associated pests with no biochemical and sensorial losses to fresh Kinnow. Our results generated data similar to those conducted by (Jobin et al., 1992) on mandarin and (Mahrouz et al., 2002) on Clementine with no or little effect on soluble solids, titratable acidity, appearance and organoleptic quality of grapefruit 'Rio Red' (Hallman and Martinez, 2001). Other investigators (O'Mahony et al., 1985; Fingelkurts and Fingelkurts, 2009) could not find a significant change in the quality of oranges due to their irradiation within the doses range from 0.60 to 0.80 kGy. Similar results were reported by (Nagai and Moy, 1985) who irradiated Valencia' oranges at even higher doses of 1kGy and could not find any significant change in the sensorial and biochemical composition of oranges. Abdullah et al. (2018) concluded similar studies on Kinnow with a radiating dose of 1.5 kGy along with refrigerated storage for extension in the shelf-life of Kinnow up to 1week with no changes in sensory and physicochemical properties. Fruits, when stored for a longer time, face many challenges including increased sensorial, physiological and pathological disorders. A decrease in weight loss occurs due to constant respiration and evaporation of water from the fruit surface. This causes shriveling and roughness on the fruit surface (Ahmed et al., 1979; Hagenmaier and Baker, 1993) resulting in deformation and finally decay of fruits (McGornack, 1975; Porat et al., 2000). In the present studies, high weight loss was recorded from non-waxed fruits possibly due to open surface pores which allowed free evaporation of moisture. Eventually, the water evaporated more rapidly from non-waxed fruit than from waxed fruit (Hagenmaier and Baker, 1993). Our studies also showed significant weight loss reduction in waxed fruit due to storage period. The action of irradiation and storage time was insignificant, indicating the storage duration is the only factor contributing to weight loss.

The loss in vitamin C content is affected both by storage time and irradiation. All the citrus fruits are rich sources of ascorbic acid involved in performing many biological functions of the body. Prevention of vitamin C loss during storage of fresh fruits is not possible as accelerated decrease of ascorbic acid might be due by enhanced respiration causing increased enzymatic activity and rapid degradation of ascorbic acid, especially in non-waxed fruit samples. Other studies have shown no or little effect of irradiation on the loss of ascorbic acid (Figueiredo et al., 2014). Sucrose, glucose and fructose constitute the main sugars in citrus fruits. Increase or decrease in TSS is an indication of metabolic activity of the fruit. All treated fruits on the $8^{th}$ day after irradiation had lower TSS, because of the presence of optimum level of water. With the passage of time, TSS increased due to moisture loss. This increase was higher in non-waxed samples, as compared to wax samples. These results are partly in agreement with those of (McGuire, 2000) wherein he found that irradiated fruits had lower soluble solids as compared with non-irradiated fruits. Other investigators (O'Mahony et al., 1985; Golding et al., 2015) could not find significant differences in total soluble solids between irradiated and non-irradiated oranges after 6 weeks of storage.

## CONCLUSION

In light of all the above findings from this study and other studies, it is concluded that phytosanitary irradiation of fresh fruits including Kinnow as phytosanitary treatment is safe and does not cause any significant change in the biochemical and organoleptic properties of fresh fruits.

## ACKNOWLEDGEMENT

We are thankful to Dr. Nizakat Bibi Deputy Chief Scientist (DCS), Mr. Muhammad Nisar Principal Scientific Assistant for helping in sample preparation and data recording. Special thanks are extended to Dr. Guy Hallman for helpful comments and critical review of the manuscript.

## FUNDING

This study was partly supported by the International Atomic Energy Agency (IAEA), Austria.

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