Quality of mandarins (*Citrus reticulata* Blanco) influenced by gamma irradiation

Ayça AYLANGAN, Erhan İÇ

Turkish Atomic Energy Authority, Saraykoy Nuclear Research and Training Center, Saray Mah. Atom Cad. No: 27, 06983, Kazan- ANKARA, TURKEY

Abstract

Mandarins (*Citrus reticulata* Blanco) are consumed in large quantities in Turkey and one of the most important exports of the citrus fruits. There were 9829 bearing and 1885 non-bearing trees for mandarin in Turkey where had produced approximately 874 thousand tons mandarin in 2012. Mediterranean fruit fly (*Ceratitis capitata*) is a pest of high economic importance, affecting production of several fruit species specially mandarins. Mediterranean fruit fly infestation in mandarin's fruits has been estimated to be 10 – 30 % and also cause major problems to exports due to quarantine restrictions. Over the centuries, efforts have been made to control storage losses and maintain the quality of foods. Food irradiation is a technology which approved the efficiency for solving insect disinfestation and phytosanitary problems in citrus trade. In this research, the mandarins (*Citrus reticulata* Blanco) were irradiated at different dose levels (0.5, 1.0 and 1.5 kGy) and stored during 45 days. The alcohol insoluble pectin, ºBrix (Total soluble solid), titratable acidity, pH, total carotenoids and vitamin C contents were analyzed after the irradiation in 0, 15, 30 and 45 days at during the storage time. Results showed that these physicochemical and chemical parameters (except vitamin C) were not influenced significantly by irradiation. These results therefore indicate that gamma irradiation is a harmless and highly effective quarantine treatment technique for mandarin and irradiation process become more conventional for insect quarantine applications.

Keywords: Mandarin, fruit quality, gamma irradiation

Introduction

World trade in agricultural commodities continues to grow. As agricultural trade expands the risk of introducing exotic insects into new areas where they may become plant pests increases. The establishment of new pests can be costly due to increased crop damage, control programs, and quarantine restrictions on trade (Follett and Weinert, 2012). Citrus fruits are one of the most important horticultural crops in Turkey both for local consumption and international export. Mediterranean fruit fly (*Ceratitis capitata*) is a major problem in citrus production sector in Turkey. Ionizing radiation is an effective alternative disinfestation quarantine treatment against the Mediterranean fruit fly (*Ceratitis capitata*) (Hallman and Loaharanu, 2002), which is the one of the world's most damaging fruit pests (Alonso et al., 2007).

Irradiation exposes food to radiant energy from gamma, e-beam (high-energy electrons) or X-rays that penetrate objects and break molecular bonds including DNA of living organisms. By inhibiting cellular reproduction, irradiation can neutralize pest and food safety problems. Low doses of irradiation only disrupt cellular activity enough to prevent reproduction (Ferrier, 2010). The food irradiation process in Turkey has been shown to be very promising through its contributions to conservation, reducing post-harvesting losses, and the possibility of improving food availability. Irradiation of fresh foods including fruit and vegetables is permitted at doses not exceeding 1.0 kGy (Palou et al., 2007). At the same time, the Food Irradiation Regulation in Turkey recommend a dose of 1.0 kGy for disinfestation (Anonymous, 1999).

Quality of irradiated citrus fruit is affected by factors related to the fruit itself (for example; cultivar, physical, physiological condition), the irradiation treatment (source, dose) and the postharvest fruit handling (postharvest treatment, storage conditions). In literature, as a function of these factors, both beneficial (extension of shelf life) and detrimental effects have been reported for citrus fruit like oranges, grapefruit, lemons and limited information is available for mandarins (Ladaniya et al., 2004; Alonso et al., 2007; Mohamed et al., 2011). The present work was carried out to examine the combined effects of gamma irradiation and storage time on the fruit quality (alcohol insoluble pectin, ºBrix, titratable acidity, pH, total carotenoids and C vitamin contents) of mandarin (*Citrus reticulata* Blanco).

Material and methods

Samples

Mandarin (*Citrus reticulata* Blanco) samples of fresh, fully mature and free from any type of injury or deterioration were obtained from a local company (Özler Ziraat Tic. San. A.Ş., Adana). The samples were irradiated at the doses of 0.5 kGy, 1.0 kGy and 1.5 kGy from the ^{60}Co source at TAEA, Sarayköy Nuclear Research and Training Center (Ankara, Turkey). Unirradiated samples served as controls. The absorbed dose was checked by Harwell perspex dosimetry (Harwell Gammachrome YR®, Perspex Dosimeter, Batch 62, Harwell, UK). Table 1 demostrate that dosimetry measures of mandarin samples.

Table 1. Dosimetry measures of mandarin samples

Target dose (kGy)	**Mesured dose mean**	**Dmax/Dmin**
0	0	0
0.5	0.501±0.11	1.36
1.0	1.039±0.54	1.25
1.5	1.6675±0.38	1.39

ºBrix degree

ºBrix degree (Total soluble solid content) of the mandarin juice samples were measured with Abbe (Atago, Japan) refractometer and expressed in ºBrix (Anonymous, 1991).

pH determination

pH value in fruit juice was measured with a pH meter (Mettler Toleda, MD220, Switzerland).

The alcohol insoluble pectin

The alcohol insoluble pectin of mandarin fruits was measured according to AOAC (1980).

Titratable acidity

Total acidity of mandarin fruits was determined by titration with 0.1 M NaOH to pH 8.2 (AOAC, 1999) and express as % citric acid.

Measurement of total carotenoids

Total carotenoids were measured according to Alasalvar et al. (2005). The homogenate was filtered through a Whatman No.4 filter paper and washed until the residue colorless. Finally, the filtrate was brought to 100 ml with the extraction solvent, to afford the extract, and absorbance at 471 and 477 nm were measured against an acetone blank using a Jenway 6505 UV/Vis spectrophotometer. Total carotenoids were calculated according to the following equation.

Total carotenoids (%) = (Abs_{max}/250) × [(25ml acetone × dilution × 100) / sample weight]

HPLC analysis of ascorbic acid

Ascorbic acid (AA) analysis was performed according to Gökmen et al. (2000). The separation of AA could be achieved on a C18 column using 0.2 M KH2PO4 (pH 2.4) as the mobile phase at a flow rate of 0.5 ml/min. AA content was detected at 254 nm in room temperature. AA standard solutions were prepared at 50, 100, 150, 200 and 250 µg/mL concentration.

Results

Data in Table 2 demonstrate the effect of gamma irradiation on the pectin, ºBrix degree, titratable acidity and pH presented in mandarin fruits during the storage periods. Among polysaccharides extracted from plant materials, pectin, an extremely complex polysaccharide found in cell walls and middle lamellae of higher plants, is widely employed as a functional ingredient in food and pharmaceutical applications due to its valuable gelling and stabilizing properties. Citrus peel is the most commercial sources for pectin (Methacanon et al., 2014). In irradiated mandarin pell samples, the lowest pectin content is found as 38.99 g / 100 g dry matter (1.5 kGy, 15th day), the highest pectin content is found as 54.21 g / 100 g dry matter (1.5 kGy, 0 th day). Expect from 1.5 kGy irradiated samples, pectin value is almost remain unchained in irradiated samples during 45 day storage.

Whereas ºBrix level increased in control, 0.5 kGy and 1.0 kGy irradiated samples during storage period, it was not change in 1.5 kGy irradiated samples. Also, ºBrix level decreased depend on irradiation dose in all samples. It was found that the lowest ºBrix level was 9.6 in 0.5 kGy irradiated sample on 30 th day, the highest ºBrix level was 11.1 in 0.5 kGy and 1.0 kGy irradiated sample on 45 th day.

Titratable acidity (TA) of mandarin fruits was express as % citric acid. In literature, it was reported that total acidity of mandarin varied between 0.3 and 1.5 % (Kefford, 1959). Whereas it was observed that ºBrix level increased in the maturation of mandarin, TA of mandarin decreased gradually. It was determined to have insignificant decrease during the storage period in control samples.

Table 2. Pectin, ºBrix, titratable acidity and pH results of mandarin samples

	Storage time (Day)			
	0	**15**	**30**	**45**
Pectin (g/100g dry matter)				
0.0 kGy	40.55	43.89	44.80	39.57
0.5 kGy	47.28	49.18	42.72	45.68
1.0 kGy	47.95	43.31	50.69	47.61
1.5 kGy	54.21	38.99	50.68	43.05
ºBrix				
0.0 kGy	10.3	10.6	10.2	11.1
0.5 kGy	10.7	10.6	9.6	11.1
1.0 kGy	10.5	10.5	10.3	11.1
1.5 kGy	10.4	10.1	10.0	10.6
Titratable acidity (Citric Acid, %)				
0.0 kGy	1.10	1.05	1.02	1.05
0.5 kGy	0.90	1.09	1.10	1.01
1.0 kGy	1.23	0.95	1.16	1.12
1.5 kGy	1.13	0.97	1.07	0.91
pH				
0.0 kGy	3.32	3.38	3.51	3.43
0.5 kGy	3.44	3.28	3.46	3.49
1.0 kGy	3.27	3.46	3.38	3.38
1.5 kGy	3.34	3.39	3.48	3.60

While TA increased the 0.5 kGy irradiated samples, it decreased 1.5 kGy irradiated samples during storage. It was identified that the lowest TA value was 0.90 % in 0.5 kGy irradiated samples, the highest TA value was 1.23 % in 1 kGy at 0th day. It was determined that TA value arised from the most significant decrease with increasing irradiation dose in the 15th day of storage. TA value was found 0.71 % in control samples as it was determined 0.57 % in 1.5 kGy irradiated samples. Decrease in TA derived from increasing irradiation dose was relatively small in other storage periods (30th and 45th day). It was observed to decrease independently of the irradiation dose in irradiated samples during storage period.

Mohamed et al. (2011) irradiated mandarin fruits at 0, 0.3, 0.6, 1.2 and 2.4 kGy irradiation doses and storaged up to 60 days. They found that titratable acidity of mandarin fruits gradually declined during the different intervals of storage. However, treating the studied fruits with gamma radiation before storage induced a remarkable effect on stopping the decline of titratable acidity and maintaining fruit quality. They found that an irradiation dose of 0.6 kGy was the optimum for retarding the decline in titratable acidity due to the storage effect. Ladaniya et al. (2004) concluded that 1.5 kGy irradiation dose delayed the decrease of titratable acidity of the storaged mandarin fruits.

The pH value of mandarin samples was not show a change during storage except for the 1.5 kGy irradiated samples.

Palou et al. (2007) reported that X-ray irradiation at doses lower than 1.0 kGy had no detrimental effects on the quality of the cultivar ‘Clemenules’, which can be considered a highly tolerant mandarin cultivar. Although there were slight differences in most of the quality parameters between gamma irradiated and control fruits, these were minimal and did not influence the commercial value of gamma treated mandarins compared to control fruit.

Figure 1 shows the effect of irradiation and storage time on the total carotenoids content of the mandarin samples. Total carotenoids in control samples varied between 1.61 and 2.19 mg/100 g. In case of irradiated samples, total carotenoids were in ranges 1.53 – 1.96 mg/100 g, 1.63 – 2.21 mg/100 g and 1.55 - 1.89 mg/ 100 g, in 0.5, 1.0 and 1.5 kGy samples, respectively. Thus, the profile of total carotenoids in mandarin was very variable, for this reason we don’t obtained a result that irradiation process had decreased total carotenoids content of mandarin samples.

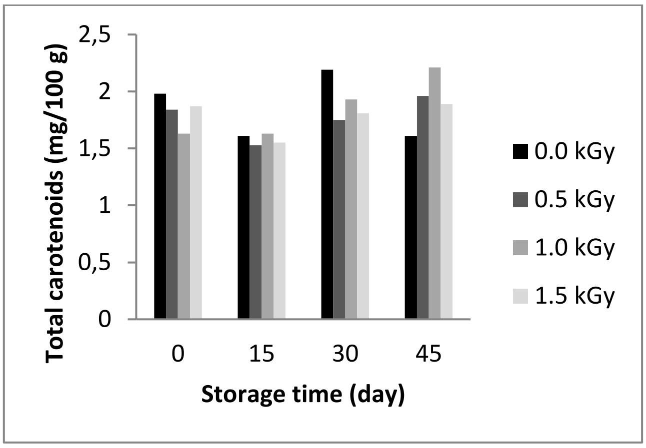

Figure 1. Total carotenoid results of mandarin (*Citrus reticulata* Blanco) samples

As could be seen from Figure 2, irradiation process effects the vitamin C contents in mandarin samples. The decrease of vitamin C content was significant in 1.0 kGy and 1.5 kGy irradiated samples. Vitamin C content was decreased after the 30 day storage in control samples. Mohamed et al. (2011) concluded that an irradiation dose of 0.6 kGy was the optimum dose for maintaining vitamin C in mandarin fruits during storage. Also, they founded that vitamin C was degraded continuously in samples with progress of storage periods. However, irradiated fruits retarted the rate of degradation. Rojas Argudo et al. (2012) reported that 510 Gy and 875 Gy X - ray irradiation did not affect the content vitamin C in 'Clemenules' clementine mandarins. Mahrouz et al. (2002) found that vitamin C content increased in 0.3 kGy irradiated 'Nour' mandarin fruits. Ladaniye et al. (2003) concluded that Vitamin C content was less in 'Nagpur' mandarin fruit treated with 0.5, 1.0 and 1.5 kGy as compared with 0 kGy. During storage, vitamin C content increased after 30 days and then decreased gradually upto 75 days. At the begining of the storage, vitamin C content in 'Nagpur' mandarin fruit was low in irradiated fruit as compared with non-treated fruit and remained so upto 75 days. Abdellaoui et al., (1995) founded that increase in vitamin C content of 'Clementine' mandarin treated with 0.3 – 0.5 kGy has been reported during storage.

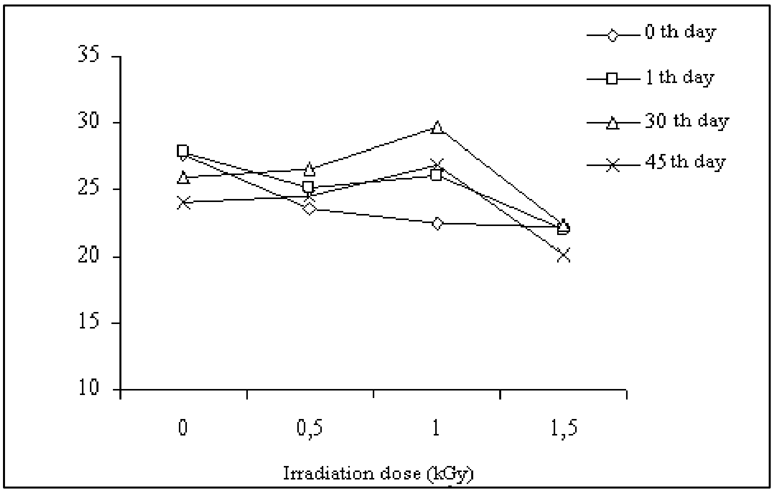

Figure 2. Effect of irradiation on the Vitamin C content of mandarin (*Citrus reticulata* Blanco)

Conclusions

Provided that irradiation treatment plants become more common in the future, this is a significant result for citrus industry because this cultivar is the most important World citrus trade and irradiation is an effective alternative disinfestation quarantine treatment against Mediterranean fruit fly without detrimental effects in fruits. Rojas Argudo et al. (2012) reported that irradiation treatment plants become more common in the future for insect quarantine applications.

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