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Full Length Research Paper

Effect of X-ray irradiation on the physical and chemical quality of America red globe grape

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The use of irradiation as a phytosanitary treatment has expanded in recent years. It plays important roles in developed and developing countries, facilitating international trade in irradiated fresh fruit. To evaluate the potential of X-ray irradiation as a quarantine treatment for America red globe grapes, we investigated the effect of X-ray irradiation by 0.2, 0.4, 0.6 and 1.0 kGy on the physical and chemical quality of fresh grape. Irradiation by 0.2 and 0.4 kGy could reduce the respiration rate of fresh grape and extend the shelf life of fruit. There was no significant effect of irradiation on other physical and chemical quality of grapes (weight loss, total soluble solids, titratable acidity, protein, mineral, sweet and taste). The irradiation treatments also had a better appearance than the control grapes after 14 days. Therefore, irradiation as a quarantine treatment for fresh grapes is possible.

Key words: X-ray irradiation, quarantine treatment, physical-chemical, grape.

INTRODUCTION

World trade in horticultural food products has become increasingly liberalized following the World Trade Organization. The importation of fresh fruits often needs phytosanitary treatments to meet quarantine requirements of importing countries (Heather and Hallman, 2008). Since 1997, America red globe grapes from California without quarantine pest that China inhibited could be transported to China through Tianjin, Haikou, Guangzhou, Dalian, Shanghai and Nanjing port. But once quarantine pest like live fruit flies, thrips and mites were intercepted from America Red Globe grapes, an appropriate quarantine treatment would be enforced.

Although methyl bromide can be used to control pests of concern to China, for fruits especially and fresh commodities in general, ionizing irradiation is a superior treatment to methyl bromide fumigation or any other treatment from the standpoint of preserving commodity quality. At present, irradiation (including gamma ray, X-ray, electron beam) is an approved phytosanitary treatment with the potential to disinfect a wide variety of fresh commodities of many quarantine pests. In 2003, the International Plant Protection Convention (IPPC) approved the International Standard for Phytosanitary Measures (ISPM) No.18-Guidelines for the use of irradiation as a phytosanitary treatment, which facilitated international trade in irradiated fresh fruit (FAO, 2003). In 2009, the IPPC adopted eight irradiation treatments for various insect pests, including a generic dose of 0.15 kGy for fruit flies of the family Tephritidae, for inclusion in ISPM No.28 on phytosanitary treatments for regulated pests (FAO, 2009a). Until 2011, fourteen irradiation treatments were approved (FAO, 2011).

Recently, Food and Agriculture Organization (FAO) and International Atomic Energy Agency (IAEA) initiated a coordinated research on the development of generic irradiation doses for quarantine treatments (IAEA, 2009). The U.S. Department of Agriculture (USDA) suggested the IPPC to take 0.4 kGy as a generic dose for insect irradiation treatment, excluding lepidopteran pupae and adults. But when applied in a commercial scale, this target dose can increase to 2 to 3 times (Heather and

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Hallman, 2008). So it also places an added responsibility on researchers to ensure that the maximum absorbed dose approved for each quarantine pest has an adequate tolerance by fruits. Among different phytosanitary measures, irradiation is the most tolerated treatment by the fresh commodities (Heather and Hallman, 2008). Low dose irradiation has been recommended to prolong shelf life and delay ripening of fruits.

In the literatures, few studies were done for irradiation as a phytosanitary treatment of grapes. The main insects that attack grapes are fruit flies, moths, thrips and mites. Irradiation treatment for fruit flies of the family Tephritidae (generic) was 150 Gy (FAO, 2009b). For moths, USDA approved 0.4 kGy as a generic dose, excluding lepidopteran pupae and adults (APHIS, 2007). For thrips and mites, there is no generic irradiation dose (International Database on Insect Disinfestation and Sterilization), but 150 to 250 Gy to thrips and 200 to 350 Gy to mites can prevent reproduction of actively reproducing adult (Heather and Hallman, 2008).

For irradiation effect on quality of grapes, Al-Bachir (1999) evaluated the effect of gamma irradiation on weight loss, spoilage and total loss of two local table grape varieties (Baladi and Helwani), and found that the storage periods can be extended by 50% using the optimal doses, 0.5 to 1.0 kGy for Helwani and 1.5 to 2.0 kGy for Baladi. However, information is not available on the physiological responses of fresh grapes to different dose levels of irradiation.

Under these considerations, our work researched the effect of X-ray irradiation on the quality of America red globe grapes from California. The purpose was to investigate the effect of X-ray irradiation on the physical and chemical quality of grape to get the optimal dose for quarantine treatment of fresh grapes.

MATERIALS AND METHODS

Fruits

Post harvested America Red Globe grapes without any quarantine treatment were packaged according to the requirements of APHIS, and then transported from California to Tianjin Port less than 15 days by ventilated containers with 0 to 1.5°C. The air change rate of ventilated container was 15 m^3/h. The total quantity of grape used in this experiment was randomized and divided into five groups of 5 kg fruits each. Four groups were irradiated respectively with 0.2, 0.4, 0.6 and 1.0 kGy, one group, as control and three replications for each treatment including the control. The grapes were packed in polyethylene film (there were 6 mm diameter holes on the film, the space between holes was 13 mm) and kept at room temperature for 1 day before irradiation.

After treatments, the fresh grapes were stored at 1.5°C ± 0.5 (the temperature precision display of storage chamber is ± 0.5°C. In order to avoid damaging the grapes below zero, we set the storage temperature as 1.5°C) and 75% ± 5 RH in a temperature and humidity chamber (Binder 720, Neckarsulm, Germany) for 22 days, and were kept at room temperature for 1 h before physical-chemical analysis.

X-ray irradiation

The fruits of each group were exposed to X-rays from a source with electron beam energy of 6 MeV (Tsinghua University, China). The dose rate was 8.76 Gy/min. For each irradiation treatment, the actual doses were measured using PTW-UNIDOs (Freiburg, German) at three different heights among each group. Mean and standard error (SE) were 0.200 ± 0.012, 0.400 ± 0.020, 0.600 ± 0.017 and 1.000 ± 0.021 kGy, respectively.

Physical-chemical analysis

Weight loss

Each group was weighed (Precisa 4000C, Swiss) after physical and chemical measurement, quantified each group fruits before the next physical and chemical measurement. Weight loss was calculated as percentage loss of initial weight.

Respiration measurement

Respiration rates of control and irradiated grapes were measured by gas chromatography (Agilent 6890, TCD detector, Santa Clara, California, USA) according to the method of Liu et al. (2010) as follows: Each replicate fruits were placed in a given volume of container, sealed and incubated for 2 h at 21°C. Briefly, 0.5 ml syringe was used to collect the gas produced by fruits, then a GC instrument was used to carry detection three times, and finally the mean data was use to obtained the actual respiration rate. The respiration rate was expressed in ml $CO_2 kg^{-1} h^{-1}$.

Total soluble solids

The juice of grapes was extracted, and then the content of total soluble solids was measured using a hand digital fruit refractometer (GMK-701R, Korea). The SSC was expressed in percentage.

Titratable acidity

Titratable acidity was measured by titrating 5 ml of juice with 0.1 N NaOH to a pH of 8.1, and it was expressed as g tartaric acid 100 ml^{-1} juice.

Protein

The content of crude protein (N × 6.25) in grapes was measured with Kjeltec 2300 Protein Analyzer after irradiation according to AOAC (2005). The result was expressed in g/100 g.

Mineral content

Minerals were extracted from the samples by dry ashing method as described by Szentmihályi et al. (2009). The mineral content was determined using Agilent 7500 ICP-MS (USA).

Sensory evaluation

The sensory evaluation was performed through 10 semi trained panelists, age from 25 to 50 including female and male. They tested the control and irradiated grapes randomly at interval for several days, and evaluated the sweetness, taste and overall appearance,

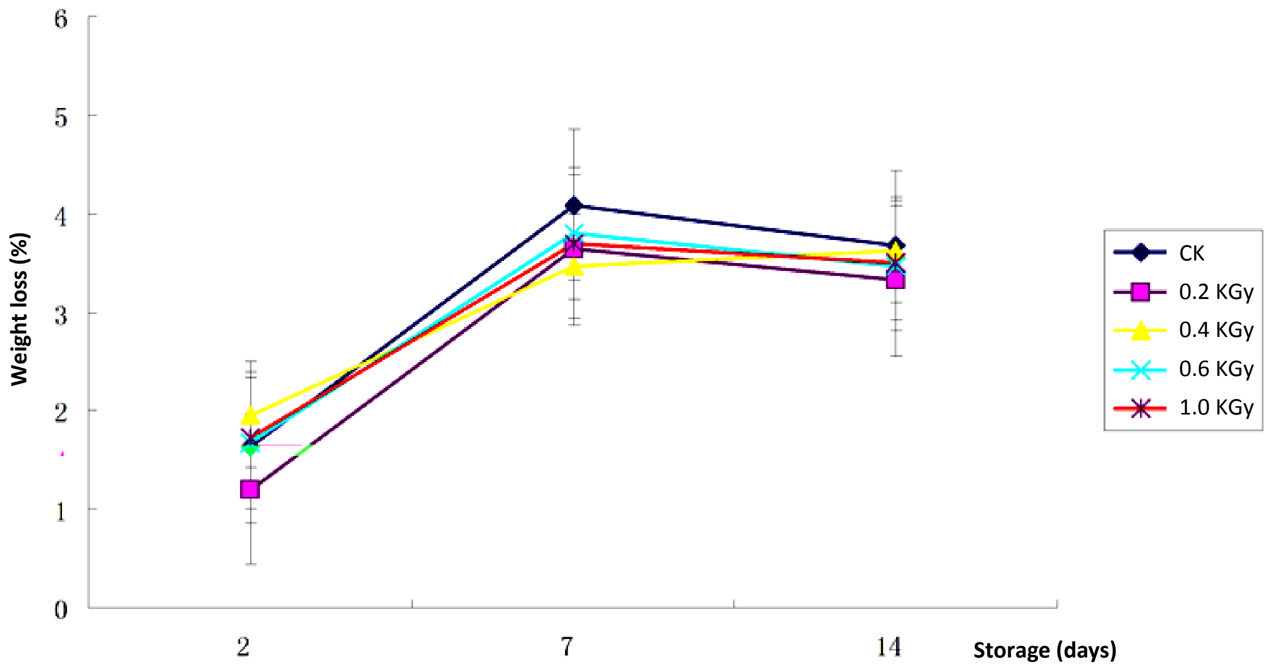

Figure 1. Weight loss of grapes during storage.

judging on a 10-score scale where 1 = extremely unpleasant, 5 = fair and 10 = excellent (Alonso et al., 2007).

Statistical analysis

The results were treated with analysis of variance (ANOVA) and multiple comparisons for quantitative (continuous) treatments (irradiation doses) at interval for several days and was tested based on Tukey's test at 5% significance using SPSS 13.0 (Statistical Program for Social Sciences, 2004).

RESULTS AND DISCUSSION

Weight loss

Weight loss of grapes during storage at 2, 7 and 14 days was observed (Figure 1). The results demonstrate that the five treatments had similar behavior during storage. There was no significant difference between the control and irradiated ($p>0.05$). On day 2, the weight loss of grapes from control irradiated at 0.2, 0.4, 0.6 and 1.0 kGy presented 1.6, 1.2, 2.0, 1.7 and 1.7%, respectively. On days 7 and 14, the weight loss increased to 3.3% to 4.1%. From the whole distribution of weight loss during storage, grapes irradiated at 0.2 kGy showed a slightly lower result from others (except grapes irradiated at 0.4 kGy on day 7), but there was no statistical difference.

This result is in agreement with Zaman et al. (2007) who found that there were no remarkable changes in the moisture contents of gamma irradiated bananas during the storage period. Whereas Al-Bachir (1999) reported that 'Baladi' grape irradiated at 0.5 kGy had weight loss higher than the control fruit after 4 weeks in storage period, but there was no difference in weight loss between control and irradiated 'Helwani' grape.

Respiration

The respiration rates of grapes during storage are shown in Figure 2. It was observed that the respiration rates of grapes irradiated at 0.2 and 0.4 kGy on 3 h-14 days storage period were lower than the control, 0.6 and 1.0 kGy treatment. With increasing storage days, the difference rate between 0.2/0.4 kGy and the control ascended gradually. It demonstrated that irradiation at 0.2 and 0.4 kGy X-rays reduced the respiration of fresh grapes. At 0.6 and 1.0 kGy treatment, the respiration rates were higher than at 3h and 1 d', but after 1 day, it was reversed. It was probable that X-rays can stimulate the respiration rate with 0.6 and 1.0 kGy during a short time.

This research found that there were statistical differences among the five treatments ($p<0.05$) during different storage days, indicating that X-ray could influence the respiration rates of fresh grapes at different doses, which is in agreement with Aina et al. (1999) and Singh and Pal (2009). Singh and Pal (2009) reported that positive influence of irradiation on the respiratory behavior of fresh guava fruit declined during long-term storage at low temperature. While respiration of fruits plays a dominant role in fruits postharvest activity, it has a practical importance in physical and chemical change of

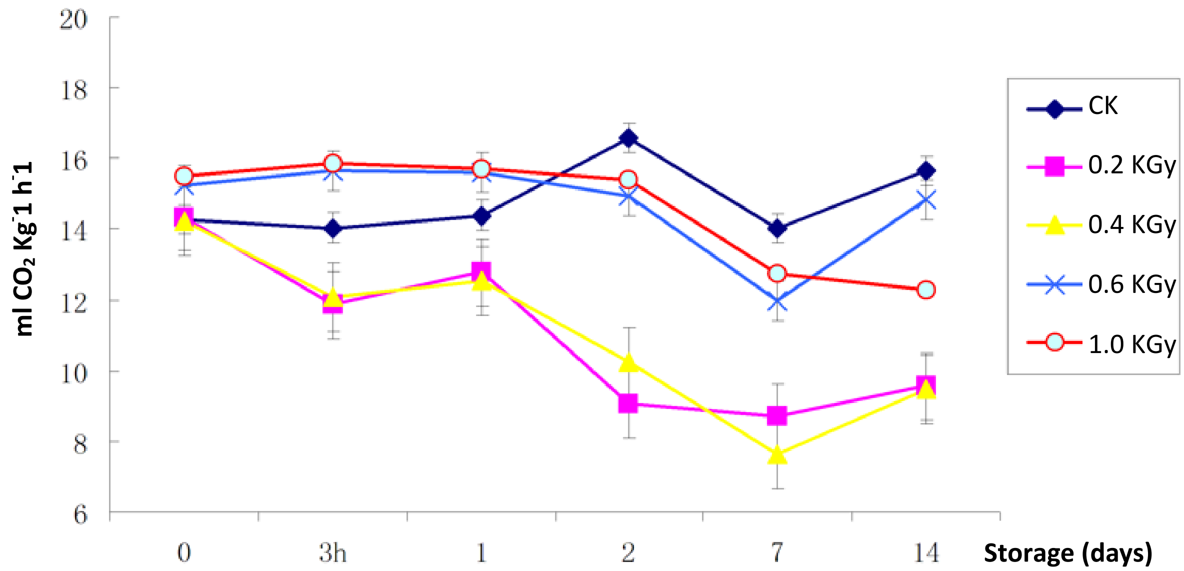

Figure 2. Respiration rate of grapes during storage.

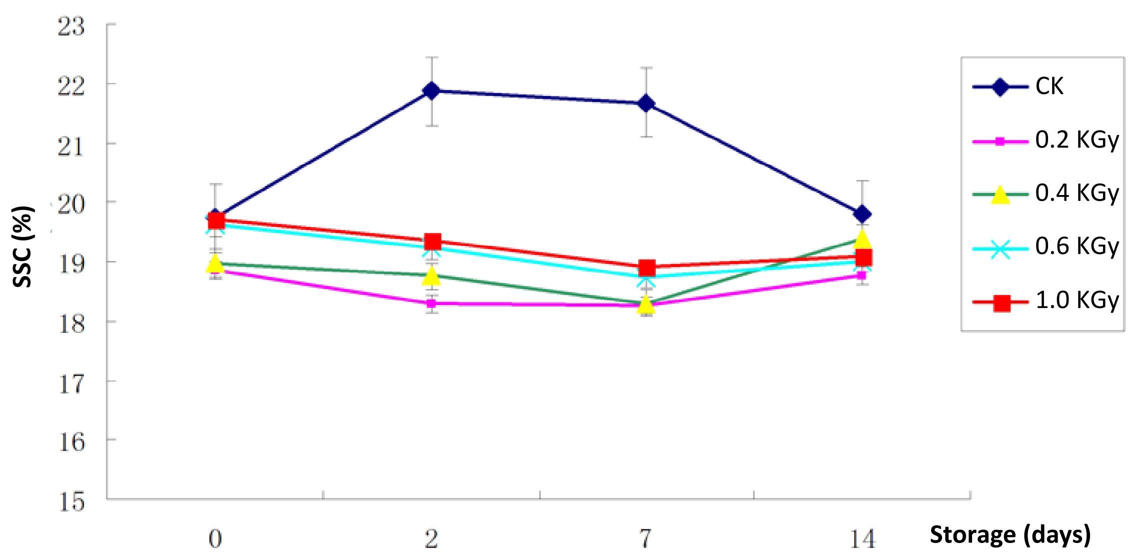

Figure 3. SSC of fresh grapes during storage.

fruits, shelf life extension and ripening delay (Pan and Xie, 2009).

Total soluble solids

Irradiated fresh grapes showed lower values in total soluble solids content on days 2 and 7 (Figure 3), which was significantly different from the control ($p<0.05$). Sreenivasan et al. (1971) also reported that irradiation of guava fruit at 0.3 kGy dose resulted in slower rate of sugar accumulation during storage. The changes in SSC of bananas, mangoes and papaya were also prevented in response to ionizing radiation treatment (Sreenivasan et al., 1971; Singh and Pal, 2009). But on day 14, the difference between irradiated grapes and the control was not significant ($p>0.05$), and the total soluble solids content of the control decreased gradually.

Titratable acidity

The obtained values of titratable acidity of all fruits are shown in Figure 4. The values varied from 1.0% to 1.3%.

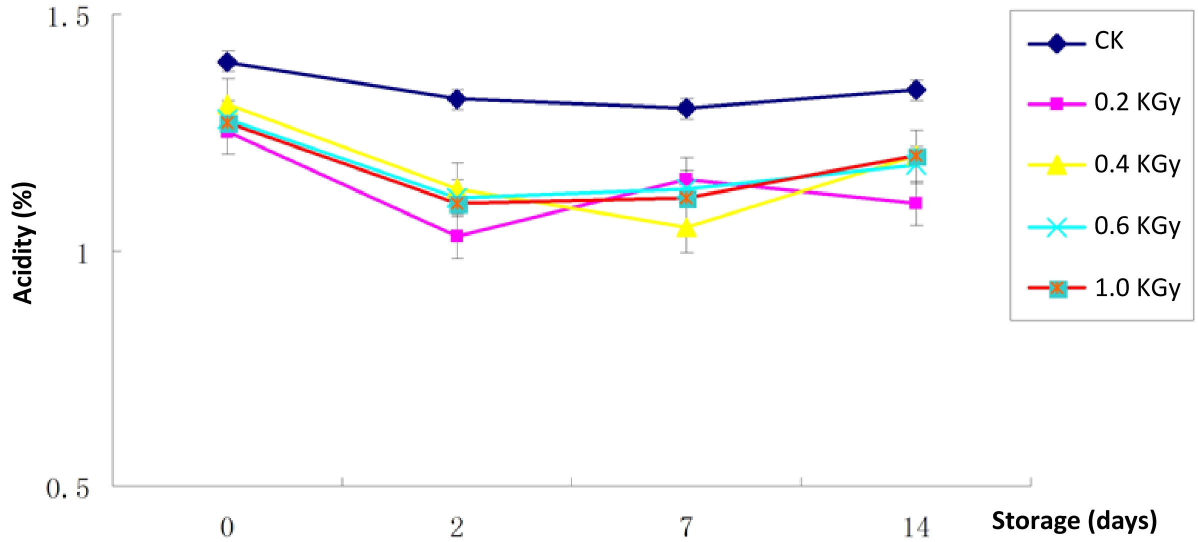

Figure 4. Titratable acidity of fresh grapes during storage.

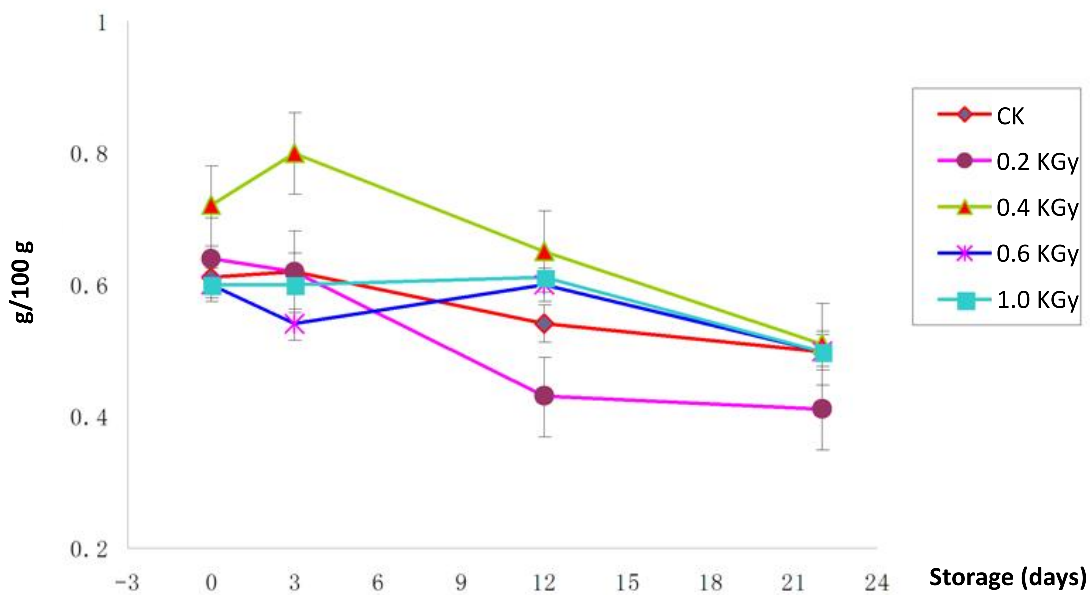

Figure 5. Protein of fresh grapes during storage.

On days 2 and 7, the acidity of four irradiated had a significant difference ($p<0.05$) with the control. The value of the control is always above irradiated treatments. Baghel et al. (2005) also reported the retention of titratable acid in fruit treated with 0.1 kGy dose of ionizing radiation.

On day 14, the difference between irradiated and the control was not remarkable, although the value of the control was higher than irradiated fruits. Sabato et al. (2009) observed that the changes of acidity of the irradiated mangoes could be associated with the metabolism of the grapes.

Protein

The total content of grapes protein during storage is presented in Figure 5. Only on day 3, that there were significant differences between 0.2 and 0.4 kGy, 0.4 and 0.6 kGy, 0.4 and 1.0 kGy ($p<0.05$). The value of 0.4 kGy was higher than others. But on days 12 and 22, significant differences among different doses had disappeared.

This result is in agreement with Marriott (1980). And with the storage days, the gap among different treatments

Table 1. Mineral content (mg/kg) of grapes during storage.

Mineral	Storage (day)	Dose (kGy)				
		0	0.20	0.40	0.60	1.0
Mg	3	63.4 ± 2.05^a	45.3 ± 2.24^a	51.4 ± 2.67^a	50.7 ± 1.69^a	53.5 ± 1.93^a
	12	56 ± 2.3^a	58 ± 3.0^a	58 ± 2.5^a	56 ± 2.1^a	57 ± 2.1^a
	22	64 ± 1.25^a	58 ± 2.16^a	56 ± 1.83^a	79 ± 2.67^a	66 ± 3.02^a
K	3	1391 ± 23.4^a	1099 ± 20.6^a	1211 ± 18.9^a	1409 ± 27.1^a	1247 ± 22.5^a
	12	1631 ± 27.3^a	1617 ± 30.1^a	1397 ± 25.7^a	1471 ± 26.1^a	1574 ± 24.4^a
	22	1507 ± 37.2^a	1590 ± 20.7^a	1465 ± 28.3^a	1663 ± 33.8^a	1538 ± 37.4^a
Ca	3	72 ± 4.2^a	52 ± 2.9^a	57 ± 4.0^a	48 ± 3.6^a	56 ± 3.1^a
	12	70 ± 3.4^a	80 ± 3.6^a	84 ± 3.7^a	69 ± 4.2^a	77 ± 2.3^a
	22	48 ± 2.7^a	45 ± 2.5^a	46 ± 2.6^a	57 ± 2.7^a	50 ± 1.8^a
Fe	3	7.5 ± 0.4^a	8.1 ± 0.6^a	8.8 ± 0.6^a	6.4 ± 0.2^a	8.2 ± 0.5^a
	12	3.9 ± 0.3^a	4.1 ± 0.4^a	3.8 ± 0.3^a	4.2 ± 0.3^a	4.0 ± 0.2^a
	22	3.9 ± 0.4^a	3.7 ± 0.2^a	3.7 ± 0.3^a	3.4 ± 0.2^a	3.8 ± 0.2^a
Zn	3	0.35 ± 0.02^a	0.34 ± 0.03^a	0.33 ± 0.02^a	0.32 ± 0.02^a	0.33 ± 0.01^a
	12	0.33 ± 0.03^a	0.33 ± 0.03^a	0.29 ± 0.01^a	0.18 ± 0.02^a	0.24 ± 0.02^a
	22	0.17 ± 0.02^a	0.19 ± 0.01^a	0.19 ± 0.01^a	0.11 ± 0.00^a	0.12 ± 0.01^a
Mn	3	0.78 ± 0.03^a	0.43 ± 0.01^a	0.54 ± 0.03^a	0.39 ± 0.01^a	0.47 ± 0.02^a
	12	0.45 ± 0.02^a	0.52 ± 0.02^a	0.55 ± 0.03^a	0.52 ± 0.04^a	0.50 ± 0.03^a
	22	0.40 ± 0.01^a	0.45 ± 0.02^a	0.43 ± 0.02^a	0.66 ± 0.05^a	0.45 ± 0.03^a
Cu	3	1.05 ± 0.04^a	1.09 ± 0.01^a	0.88 ± 0.01^a	1.01 ± 0.02^a	1.05 ± 0.07^a
	12	1.46 ± 0.05^a	1.18 ± 0.04^a	1.15 ± 0.02^a	1.40 ± 0.03^a	1.29 ± 0.04^a
	22	0.87 ± 0.04^a	1.02 ± 0.03^a	1.17 ± 0.02^a	0.97 ± 0.02^a	0.92 ± 0.02^a
Cr	3	0.32 ± 0.01^a	0.20 ± 0.01^a	0.20 ± 0.02^a	0.19 ± 0.02^a	0.21 ± 0.01^a
	12	0.17 ± 0.01^a	0.17 ± 0.00^a	0.16 ± 0.01^a	0.13 ± 0.00^a	0.16 ± 0.00^a
	22	0.21 ± 0.00^a	0.21 ± 0.00^a	0.21 ± 0.01^a	0.28 ± 0.01^a	0.25 ± 0.02^a

[a]Mean ± SE; b, On same day, means with the same letter are not significantly different at the level of 5% ($p<0.05$).

went down gradually.

Mineral content

The results of mineral composition of grapes are shown in Table 1. There were no significant differences between irradiated grapes and the control ($p>0.05$). This indicates that irradiation with doses less than 1.0 kGy do not result in decreasing mineral content of fresh grapes.

Sensory evaluation

The effect of irradiation on the sensory of fresh grapes is shown in Table 2. With a multiple comparison on the level of 5%, on days 3 and 7, sweetness, taste and appearance had no remarkable changes among the four treatments, which was in agreement with the research on sensorial analysis of kiwi fruit (Harder et al., 2009). After 14 days, the appearance scores of the control was the lowest, and also had a significant difference with the irradiated treatments ($p<0.05$). This may indicate that irradiation up to 1.0 kGy can increase the shelf life of grapes.

Conclusion

The history of research on ionizing irradiation as a phytosanitary treatment is almost as long as the history of any other phytosanitary treatment. It is used for modest interstate shipments among the US states, mangoes and papaya from Australia to New Zealand and for a few shipments of mangoes from India to the USA. Other countries are considering to begin using it.

Table 2. Results of sensory evaluation for grapes during storage days.

Storage (day)	Dose (kGy)	Sweetness	Taste	Appearance
3	Control	7.8 ± 0.42[a]	8.5 ± 0.53[a]	8.8 ± 0.42[a]
	0.2	7.9 ± 0.57[a]	8.3 ± 0.48[a]	8.9 ± 0.32[a]
	0.4	7.8 ± 0.42[a]	8.2 ± 0.42[a]	8.8 ± 0.42[a]
	0.6	7.8 ± 0.42[a]	8.2 ± 0.63[a]	8.6 ± 0.52[a]
	1.0	7.9 ± 0.52[a]	8.3 ± 0.57[a]	8.7 ± 0.62[a]
7	Control	7.8 ± 0.42[a]	8.3 ± 0.48[a]	8.2 ± 0.42[a]
	0.2	8.0 ± 0.47[a]	8.1 ± 0.57[a]	8.5 ± 0.53[a]
	0.4	7.9 ± 0.32[a]	8.1 ± 0.31[a]	8.6 ± 0.52[a]
	0.6	7.8 ± 0.42[a]	8.1 ± 0.57[a]	8.3 ± 0.48[a]
	1.0	7.8 ± 0.42[a]	8.1 ± 0.31[a]	8.2 ± 0.42[a]
14	Control	8.0 ± 0.47[a]	8.0 ± 0.67[a]	6.6 ± 0.52[b]
	0.2	8.1 ± 0.32[a]	8.1 ± 0.57[a]	7.5 ± 0.53[a]
	0.4	8.2 ± 0.42[a]	8.0 ± 0.47[a]	7.5 ± 0.71[a]
	0.6	7.7 ± 0.48[a]	8.0 ± 0.67[a]	7.4 ± 0.70[a]
	1.0	8.0 ± 0.47[a]	8.0 ± 0.47[a]	7.5 ± 0.53[a]

[a,b]Mean ± SE; on same day, means with the same letter are not significantly different at the level of 5% ($p<0.05$).

Irradiation has the potential to solve many phytosanitary problems and is the most tolerated treatment for fresh commodities in general (Heather and Hallman, 2008).

This work showed that irradiation can reduce the respiration rate of fresh grapes. The irradiated grapes had a better appearance than the control on day 14. In addition, there was no remarkable difference found in weight loss, the soluble solids, titratable acidity after 14 days, and protein and mineral content between the irradiated and the control after 22 days of storage. From the current results, X-ray irradiation up to 1.0 kGy had no negative effect on the physical and chemical quality of fresh grape. It is therefore possible to consider irradiation as a quarantine treatment for fresh grapes.

REFERENCES

Aina JO, Adesiji OF, Ferris SR (1999). Effect of γ-irradiation on post-harvest ripening of plantain fruit (*Musa paradisiaca*) cultivars. J. Sci. Food Agric. 79: 653-656.

Al-Bachir M (1999). Effect of gamma irradiation on storability of two cultivars of Syrian grapes (*Vitis vinifera*). Radiat. Phys. Chem. 55: 81-85.

Alonso M, Palou L, Rio MA, Jacas JA (2007). Effect of X-ray irradiation on fruit quality of *Clementine mandarin* cv.'Clemenules'. Radiat. Phys. Chem. 76: 1631-1635.

AOAC (2005). Official method of analysis of AOAC international. AOAC, USA.

APHIS (US Department of Agriculture Animal and Plant Health Inspection Service) (2007). Treatment Manual. http://www.aphis.usda.gov/ppq/manuals/port/Treatment Chapters.htm.

Baghel BS, Gupta N, Khare A, Tiwari R (2005). Effect of different doses of gamma radiation on shelf life of guava. Indian J. Hort. 62: 129-132.

FAO, IPPC (2003). ISPM 18: Guidelines for the use of irradiation as a phytosanitary measure. https://www.ippc.int/file_uploaded/1249306780422_ISPM_18_E.doc

FAO, IPPC (2009a). ISPM 28: Phytosanitary treatments for regulated pests. https://www.ippc.int/file_uploaded/1323949527_ISPM_28_2007_En_2011-11-29_Refor.pdf

FAO, IPPC (2009b). ISPM 28, Annex 07: Irradiation treatment for fruit flies of the family Tephritidae (generic). https://www.ippc.int/file_uploaded/1323950176_PT_07_2009_En_2011-12-01_Reforma.pdf

FAO, IPPC (2011). Adopted Standards. https://www.ippc.int/index.php?id=ispms&no_cache=1&L=0

Harder MNC, Toledo TCF, Ferreira ACP, Arthur V (2009). Determination of changes induced by gamma radiation in nectar of kiwi fruit (*Actinidia deliciosa*). Radiat. Phys. Chem. 78: 579-582.

Heather NW, Hallman GJ (2008). Pest management and phytosanitary trade barriers. Wallingford, UK: CAB International.

IAEA (2009). Report of the first research coordination meeting on the development of generic irradiation doses for quarantine treatments. Vienna, Austria, 5-9 October.

International Database on Insect Disinfestation and Sterilization http://nucleus.iaea.org/sso/NUCLEUS.html?exturl=http://www-ididas.iaea.org/IDIDAS/default.htm

Liu B, Zhang FH, Wang YJ (2010). Toxicity of phosphine to *Carposina sasakii* Matsumura (Lepidoptera: Carposinadae) at low temperature. J. Econ. Entomol. 103(6): 1988-1993.

Marriott J (1980). Bananas: Physiology and biochemistry of storage and ripening for optimum quality. Crit. Rev. Food Sci. Nutr. 13: 41-88.

Pan YG, Xie JH (2009). Postharvest physiology of fruits and vegetables. Beijing: Chemistry and Industry Press.

Sabato SF, Silva JM, Cruz N, Salmieri S, Rela PR, Lacroix M (2009). Study of physical-chemical and sensorial properties of irradiated Tommy Atkins mangoes (*Mangifera indica* L.) in an international consignment. Food Control. 20: 284-288.

Singh SP, Pal RK (2009). Ionizing radiation treatment to improve postharvest life and maintain quality of fresh guava fruit. Radiat. Phys. Chem. 78: 135-140.

Sreenivasan A, Thomas P, Dharkar SD (1971). Physiological effects of gamma radiation on some tropical fruits. Disinfestation of Fruit by Irradiation, International Atomic Energy Agency, Vienna, pp. 65-91.

Szentmihályi K, Héthelyi É, Virág V, Then M (2009). Mineral elements in muscat sage plant (*Salvia sclarea* L.) and essential oil. Acta Biol. Szegediensis. 53: 35-38.

Zaman W, Paul D, Alarm K, Ibrahim M, Hassan P (2007). Shelf life extension of banana (*Musa sapientum*) by gamma radiation. J. Biol. Sci. 15: 47-53.