ISSN 1819-1894

# Asian Journal of Agricultural Research

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Asian Journal of Agricultural Research 6 (1): 12-20, 2012
ISSN 1819-1894 / DOI: 10.3923/ajar.2012.12.20


# Effect of Gamma Irradiation on the Quality (Colour, Firmness and Total Soluble Solid) of Tomato (*Lycopersicon esculentum* Mill.) Stored at Different Temperature

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## ABSTRACT

A considerable amount of tomato is damaged after harvest every year (20-30% annually) which has impact on the total vegetable production in Bangladesh. Gamma irradiation doses of 250, 500 and 750 Gray (Gy) were analyzed compared to those of unirradiated ones on 1st, 8th and 13th day of irradiation stored at 4, 12 and 25°C to observe whether it could combat the loss. Radiation did not affect colour of tomato and it did not differ significantly with dose as well. However, storage time had effect on colour at 12 and 25°C at some aspect whereas no effect at 4°C in both irradiated and unirradiated tomatoes. Significant firmness was lost in irradiated tomatoes stored for 13 days at 4°C while no such significant differences in firmness was observed at 12 and 25°C. Immediate firmness loss was observed in irradiated tomatoes stored at 25°C and firmness decreased more in 500 and 750 Gy treated tomatoes than 250 Gy treated ones at 4 and 25°C whereas no such difference was observed between irradiation doses at 12°C. Radiation had no effect on percent sugar. Highest percentage of tomato loss was found at 25°C in both irradiated and unirradiated tomatoes but 750 Gy treated tomatoes showed promising result at all storage temperatures. Considering firmness loss,Total Soluble Solid (TSS) (%sugar) and damage during storage, a dose of 750 Gy and storage temperature 12°C stood out as ideal combination for BARI Hybrid-3 tomato in Bangladesh to combat annual post harvest loss.

**Key words:** Surface colour, fruit firmness, total soluble solid (%sugar), gamma irradiation, storage temperature, tomato

## INTRODUCTION

The physical appearance of tomato (*Lycopersicon esculentum* Mill.) such as colour and texture are the major important attributes of quality that determine consumer preference and purchasing decision (Anonymous, 2009; Camelo and Gomez, 2004). Red colour of tomato is the most important external characteristic to assess ripeness where colour and colour uniformity contribute directly to quality and marketability (Anonymous, 2009). Fruit colour is essential indicator of quality in tomatoes as in other fruits like santol, strawberry, dragon and orchard (Chutichudet *et al*., 2008; Resende *et al*., 2008; Wall and Khan, 2008). Firmness is another important quality factor for which various research have been conducted to improve firmness of tomato during storage (McDonald *et al*., 1999). To date, various studies have been performed on stored tomato quality.

For instance, the firmness behavior of tomatoes (Van Dijk *et al.*, 2006) and the effect of heat treatment on firmness, fruit decay and flavour volatiles were observed (McDonald *et al.*, 1999). Low temperature effect like 3°C and safe storage temperature like 12, 20 and 25°C on various enzymes of stored tomato was reported (Van Dijk *et al.*, 2006). Increasing temperature (21-26°C and 27-32°C) application and the consequence on antioxidant concentrations of off-vine tomato was recorded by Gautier *et al.* (2008).

Temperature effect was also observed on the stored greenhouse LSL (long shelf life) tomato where 12.5°C was found to be the more favourable between 12.5 and 20°C for both red and breaker stage (Wrzodak and Adamicki, 2007). Besides these, combination of hot water and radiation treatment was also applied on tomato fruits to control fungal decay (Barkai-Golan *et al.*, 1993). Ionizing radiation is an economically viable technology for reducing postharvest losses, extending shelf-life of perishable commodities and maintaining hygienic quality of fresh produce (Mitcham, 1999; Boylston *et al.*, 2002; Cheour and Mahjoub, 2003; Gonzalez-Aguilar *et al.*, 2004). It is already known that irradiation has minimal detrimental effects on tomato (Kader, 1986). In 1987, the Food and Drug Administration (FDA) approved the use of radiation treatments of up to 1000 Gy for fresh commodities (Paull and Armstrong, 1994).

The quality of fresh products usually starts to decrease when firmness and colour uniformity loss are observed after harvest which is one form of post-harvest loss. Tomato is high perishable fruit vegetable; however, when near-optimal temperature and relative humidity is maintained it could be stored potentially for 2-4 weeks in air (Kader, 2002). Environmental conditions have strong impact on most of the quality traits of tomato such as colour and firmness of fruits and food products are affected by heat, cold, water, moisture and storage time (Causse *et al.*, 2002). Different symptoms of quality deterioration, like too low or too rapid colouring, fruits softening and moulds breakdown, could have been pronounced during the storage of tomatoes (Herregods, 1971). About 20-30% post harvest losses of tomato fruits are observed every year in Bangladesh which creates considerable gap between the gross production and net availability (Naqvi, 2005). In this study, the effect of gamma irradiation on the firmness, colour and Total Soluble Solid (TSS) of the hybrid tomato BARI Hybrid-3 is reported stored at different storage temperatures.

## MATERIALS AND METHODS

**Tomato collection and storage:** Local variety of tomato, BARI Hybrid-3, (*Lycopersicon esculentum* Mill.) was collected from local farmers at the day of harvest. The colour of tomato at the time of collection was greenish yellow to yellowish red. After collection tomatoes were washed with normal water and wiped with soft clean cloth and then packed in perforated polythene bag each with 19 tomatoes. A total of such 12 bags were prepared among which three bags were used for irradiated and one bag for unirradiated (control) tomatoes in each storage temperature studied (4, 12 and 25°C). Tomatoes were maintained at these temperatures during the entire experimental period. Experiments were replicated in 3 times at similar condition.

**Irradiation treatment:** Tomatoes within the bags were irradiated on the following day of collection at the Institute of Food and Radiation Biology, Atomic Energy Research Establishment, Savar, Dhaka, Bangladesh using gamma-rays emitted from $Co^{60}$ irradiator at doses of 250, 500 and 750 gray (Gy).

**Quality analyses:** Tomatoes were subjected to colour, firmness and Total Soluble Solids (TSS) (% sugar) after irradiation. The research was conducted from January 2009 to April 2010. Data were recorded 3 times during the entire storage period. First data were recorded immediately after the irradiation while 2nd and 3rd data were recorded at 8th and 13th day of post-irradiation. The data on colour and firmness and sugar were generated from 30 (10 from each replica) and 27 (9 from each replica) tomatoes from each experimental condition, respectively. Therefore, in total 360 tomatoes for colour and firmness and 324 tomatoes for TSS (% sugar) were used. It is to be noted that the same 10 tomatoes were subjected to colour and firmness each time of data record in each batch while different tomatoes were subjected to sugar determination. During each measurement only the edible quality of tomatoes were used while non edible fruits (tomatoes with black spot/mold/rotting etc.) were discarded.

**Colour analysis:** Surface colour measurements of tomatoes were made using a chroma meter (Cr-410, Konica Minolta, Sensing Inc., Japan). A standard white reference tile was used for calibration. Readings were taken at four different points externally. Colour measurements were recorded as L*, a* and b* (L* = lightness, a* = ranging from green to red and b* = ranging from blue to yellow).

**Firmness analysis:** A fruit texture analyzer (GS-20, Serial No. 2003-FTA-109, version 6.63) was used to measure the whole fruit firmness of tomato at four positions.

**TSS (% sugar) measurement:** To measure TSS (% sugar) flesh from inner juicy part and outer pericarp was taken together, weighed to 10 g and was mashed with mortar and pestle. The liquid sample was then measured with a digital Refractrometer measuring percent sugar (model: DR-103, Bellingham+Stanley Ltd., England, UK).

**Data analysis** One way ANOVA was performed using statistical software MINITAB, USA (Version 13.1). ANOVA was performed within irradiated and unirradiated tomatoes, different storage time and different storage temperatures to see whether there are any significant differences. When the $p = 0.05$, 0.01 or 0.001, the difference is significant but if $p>0.05$ then it is not significant.

## RESULTS

**Effect of irradiation and storage temperature on colour:** Different parameters of colour i.e., L* (lightness), a* (green to red) and b* (blue to yellow) of external surface of tomatoes were analyzed. Comparative analysis of colour parameters were performed between irradiated and unirradiated ones kept at different temperatures and among different doses of irradiation. Changes of colour were also analyzed among the unirradiated tomatoes kept at different temperatures (Table 1). At 4°C the lightness L* of tomato increased in irradiated tomatoes significantly on 1st and 8th day post-irradiation while no significant difference in a* and b* was observed between unirradiated and irradiated tomatoes (Table 1). However, on 13th day of post-irradiation L*, a* and b* did not differ significantly. At 12 and 25°C no significant colour difference was observed between unirradiated and irradiated tomatoes (Table 1). Colour did not differ significantly within irradiated tomatoes stored at 4, 12 and 25°C ($p>0.05$).

Table 1: Surface colour of tomato after irradiation treatments and storage at different temperatures for 13 days

| | 1st day of irradiation | | | 8th days of irradiation | | | 13th days of irradiation | | |
|---|---|---|---|---|---|---|---|---|---|
| Dose (Gy) | L* | a* | b* | L* | a* | b* | L* | a* | b* |
| **4°C** | | | | | | | | | |
| 0 | 56.4 | 27.2 | 51.1 | 54.3 | 36.0 | 50.2 | 53.3 | 40.2 | 44.3 |
| 250 | 62.9 | 24.9 | 47.4 | 58.1 | 31.5 | 45.1 | 57.4 | 36.1 | 44.0 |
| 500 | 63.5 | 22.3 | 48.7 | 60.7 | 31.5 | 46.3 | 58.9 | 36.2 | 45.0 |
| 750 | 62.2 | 25.4 | 47.4 | 60.5 | 32.8 | 46.8 | 59.2 | 35.0 | 44.5 |
| **12°C** | | | | | | | | | |
| 0 | 61.5 | 24.1 | 47.2 | 58.8 | 37.1 | 44.4 | 56.5 | 40.0 | 40.3 |
| 250 | 61.8 | 24.2 | 46.5 | 60.5 | 36.6 | 44.7 | 53.4 | 37.7 | 37.9 |
| 500 | 61.9 | 24.4 | 46.8 | 58.7 | 36.5 | 44.2 | 55.9 | 37.2 | 39.3 |
| 750 | 64.1 | 22.9 | 48.3 | 60.3 | 37.9 | 45.8 | 53.8 | 40.0 | 39.3 |
| **25°C** | | | | | | | | | |
| 0 | 64.3 | 24.9 | 50.1 | 58.1 | 36.6 | 44.4 | 58.5 | 37.6 | 43.7 |
| 250 | 58.8 | 27.4 | 45.1 | 54.6 | 34.4 | 40.9 | 52.7 | 35.4 | 38.5 |
| 500 | 62.0 | 26.9 | 47.5 | 57.8 | 35.3 | 43.2 | 56.9 | 39.4 | 42.7 |
| 750 | 60.4 | 28.4 | 46.3 | 58.9 | 36.2 | 43.6 | 56.5 | 38.3 | 40.8 |

L*: black to white, if L* value decrease darkness increase, a*: green to red, if a* value increase redness increase, b*: blue to yellow, if b* value increase yellowness increase. Individual values are means of chromameter measurements of 22 to 30 tomatoes (4 observations/tomato)

The values of L* and b* decreased while a* increased with the increase of storage period in both the irradiated and unirradiated tomatoes stored at 4, 12 and 25°C (Table 1). However, the changes in L*, a* and b* values during low temperature (4°C) storage was not significant ($p>0.05$). At 12°C, the values of L* varied significantly ($p = 0.028$) while the variations of a* and b* were insignificant ($p>0.05$) between 1st and 8th day post-irradiation. In contrast, no significant differences in L* ($p>0.05$) but a* and b* varies significantly ($p = 000$ and $p = 0.001$, respectively) between 8th and 13th day stored tomatoes. At 25°C, L*, a* and b* varied insignificantly between 1st and 8th day tomatoes ($p>0.05$) while significant differences in L*, a* and b* was observed between 8th and 13th day stored tomatoes ($p = 0.001$) (Table 1).

During 13 days of storage period L* did not differ significantly ($p>0.05$) but a* ($p = 0.006$) and b* ($p = 0.010$) of colour varies significantly with temperature (Table 1).

**Effect of irradiation and storage temperature on firmness:** Although firmness loss was observed in both irradiated and unirradiated tomatoes (Fig. 1), significant firmness was lost in irradiated tomatoes than unirradiated ones at 4°C stored for 13 days ($p = 0.003$) (Fig. 1). No significant differences in firmness was observed between unirradiated and irradiated tomatoes stored for 13 days at 12°C ($p>0.05$). At 25°C, immediately after irradiation significant ($p = 0.005$) loss of firmness was observed at higher radiation doses (500 and 750 Gy). However, no significant ($p>0.05$) firmness loss was recorded at 8th and 13th day of storage (Fig. 1).

Among irradiated tomatoes, at 4°C more firmness loss was observed at 500 and 750 Gy treated tomatoes than 250 Gy treated tomatoes stored for 8 ($p = 0.013$) and 13 days ($p = 0.022$ ) while no such differences was evident on 1st day of irradiation ($p>0.05$). In contrast, at 25°C more firmness loss was observed at 500 and 750 Gy treated tomatoes than 250 Gy treated tomatoes on 1st day of irradiation ($p = 0.008$) while no such differences was shown on 8th and 13th day ($p = 0.947$, $p = 0.903$). At 12°C no significant firmness difference was observed within irradiated tomatoes ($p>0.05$).

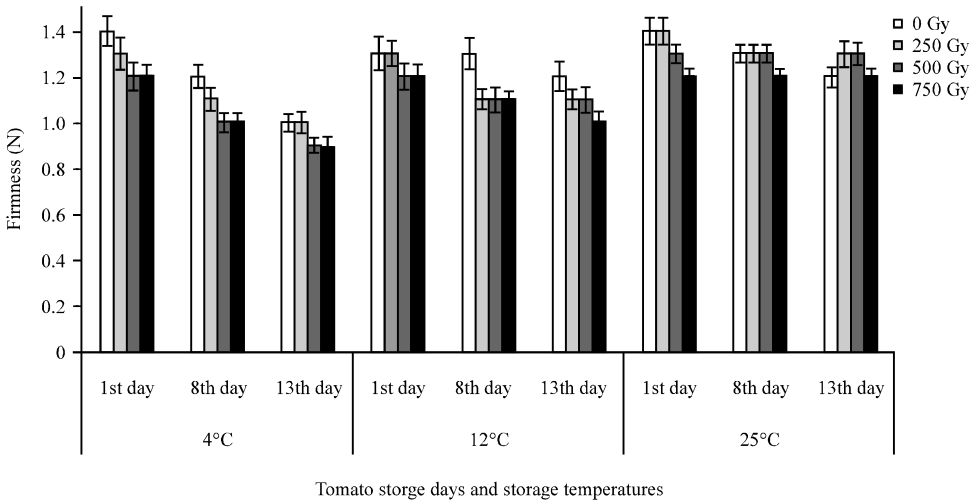


Fig. 1: Firmness (in Newtons) of tomatoes exposed to 0, 250, 500 and 750 Gy irradiation during storage at 4, 12 and 25°C temperature. Vertical bars represent standard error

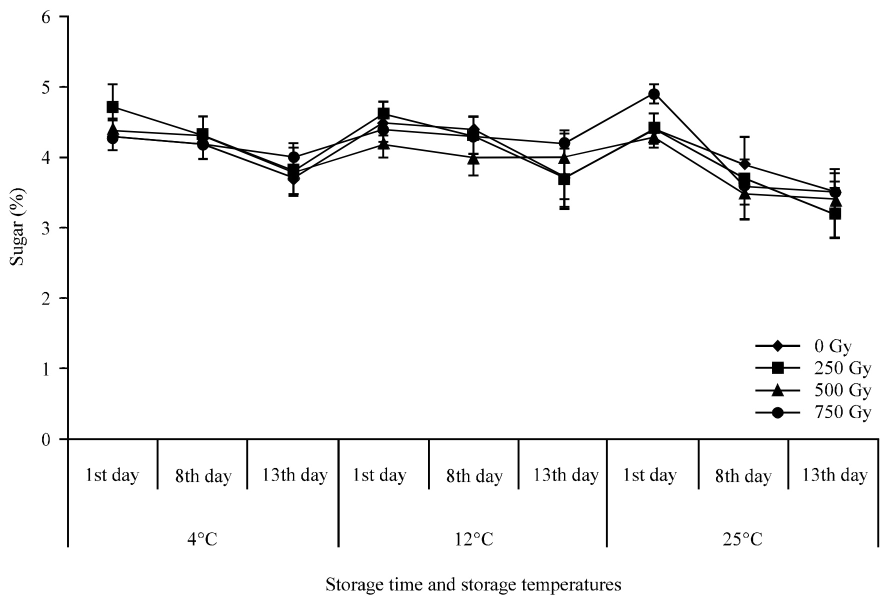


Fig. 2: Total soluble solids (%sugar) for tomatoes during storage at 4, 12 and 25°C temperature following irradiation at 0, 250, 500 and 750 Gy. Vertical bars represent standard error

Firmness was significantly affected by storage time at both 4 and 25°C. It decreased more in 13 days stored tomatoes than 8 days storage at 4°C ($p = 0.013$) and 25°C ($p = 000$) in all unirradiated and irradiated tomatoes. However, at 12°C firmness was not affected significantly ($p>0.05$) during storage period.

During 13 days of storage period firmness did not vary significantly with temperature ($p>0.05$) in unirradiated tomatoes.

**Effect of irradiation and storage temperature on TSS (%sugar):** In all unirradiated and irradiated tomatoes percent sugar concentration decreased within 8 days at 25°C while at 4 and

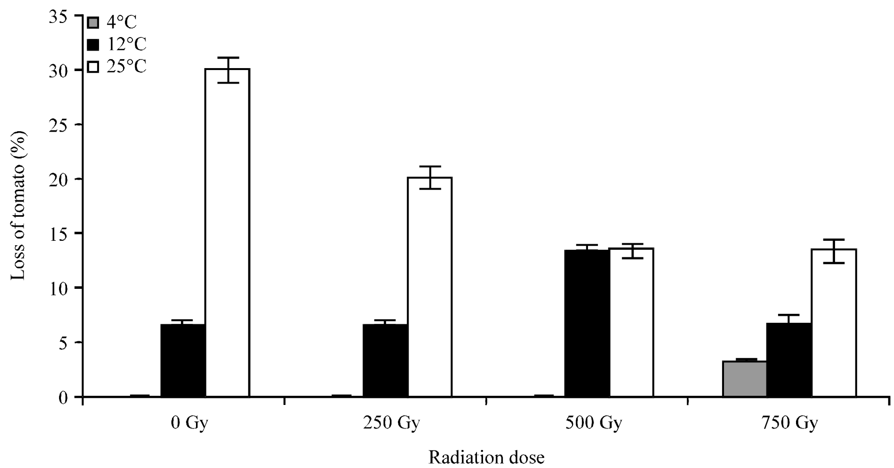


Fig. 3: Percentage of tomato loss during storage at 4, 12 and 25°C temperature following irradiation at 0, 250, 500 and 750 Gy. Vertical bars represent standard error

12°C no such changes occurred (Fig. 2). However, there was no significant difference ($p>0.05$) in percent sugar between treated and non-treated tomatoes on 1st , 8th and 13th days of irradiation stored at 4, 12 and 25°C storage temperature. Percent sugar reduced gradually in tomatoes stored for 13 days at 4°C ($p = 0.005$) although it did not change significantly in tomatoes stored at 12 and 25°C ($p>0.05$). Also no significant differences was observed between percent sugar of unirradiated tomatoes stored at different temperatures ($p>0.05$).

**Storage loss of irradiated and unirradiated tomatoes kept at different temperatures:** Loss of tomatoes during storage conditions was recorded and considerable amount of loss of unirradiated tomatoes was observed at 12 and 25°C (6.66 and 30%, respectively). On the other hand, no loss of unirradiated tomatoes was found up to 13th day of storage at 4°C. In irradiated tomatoes the storage loss was higher at 25°C (Fig. 3).

## DISCUSSION

At all storage temperature both L* and b* decreased and a* increased during storage period in both irradiated and unirradiated tomatoes (Table 1). However, no significant changes in L*, a* and b* occurred with time ($p>0.05$) at 4°C whereas significant colour changes occurred at 12°C ($p = 0.028$, $p = 000$ and $p = 0.001$, respectively) and 25°C ($p = 0.001$). This result suggests that darkness and redness of colour of tomato was increased but yellowness decreased with time while on 1st day they were greenish yellow to yellowish red in colour. This is usually happened because of the presence of own photoreceptors that ripen the mature green tomatoes even after harvest (Alba *et al*., 2000). In other experiment with tree tomatoes lightness L* of tomatoes was found to be declined with time which supports our present findings at 12 and 25°C (Mwithiga *et al*., 2007). However, contrasting finding was observed within the santol fruits where the lightness L* increased with time (Chutichudet *et al*., 2008).

Besides the storage time we also observed whether there is any difference in colour between irradiated and unirradiated tomato. We found that L*, a* and b* of colour of tomato did not affected by radiation treatment if stored at 12 and 25°C but causes trace increase in L* if stored at 4°C even for 1 day (Table 1). Therefore, irradiation has no effect on total colour of tomato (L*, a* and b*) when stored at 12 and 25°C but has effect on lightness if stored at 4°C. Also we did not observe any specific dose effect on colour. In contrast, minor changes were observed in visible colour in irradiated dragon fruit. On top of that, at the highest dose red colour of dragon fruit became duller and whitish flesh became grayish or yellowish (Wall and Khan, 2008). Therefore, it could be concluded that the doses applied to tomatoes have similar impact on colour of tomato. On the other hand, it was observed that temperature affected a* and b* of colour ($p = 0.006$ and $p = 0.010$, respectively) of unirradiated tomatoes which coincide with the findings of McDonald *et al.* (1999) who observed increasing tendency of a* and b* values of tomato fruit colour with increasing treatment temperature. Gautier *et al.* (2008) reported that increasing fruit temperature (from 21 to 26°C) enhances red fruit colouration and chlorophyll degradation in off-vine fruits.

Irradiated tomatoes became softer significantly at 4 and 25°C. This post irradiation behaviour is not unusual as several researchers found irradiation induced firmness loss in tomatoes (Assi *et al.*, 1997; Ahmed *et al.*, 1972; Bramlage and Lipton, 1965). The softening of tomato fruit in response to irradiation usually occur due to some biochemical and physiological process like membrane damage, specific cell wall enzymes and so on (Hatton *et al.*, 1984; Barka *et al.*, 2000). However, it is not obvious that irradiation will cause firmness loss of tomato rather it might depends on storage condition like temperature. For instance, at 16°C storage temperature tomato fruit exposed to UV-C were significantly firmer than unirradiated and even irradiation retards softening (Barka *et al.*, 2000) and in our present work we found no difference in firmness at 12°C between unirradiated and irradiated tomatoes.

In the present study, we observed that at 25°C firmness loss occurred significantly immediately after irradiation (Fig. 2). Irradiation has an immediate effects of decreasing firmness in vegetables (Kertesz *et al.*, 1984) including tomato the softening of which is typically evident within hours following treatment, even for mature green fruit (Ahmed *et al.*, 1972; Bramlage and Lipton, 1965). For this electrolyte leakage is found to be responsible which is immediately enhanced by irradiation, leading to immediate loss of firmness (Assi *et al.*, 1997). Not only in tomato, in potato (Hayashi *et al.*, 1992) and carrot (Skou, 1963) also this sort of process was reported.

Irradiation causes significant softening of whole fruit which is dose dependent. For example, 730 or 2210 Gy and 720 or 1410 Gy decrease firmness of mature green sunny tomatoes significantly within 5 and 24 h of irradiation, respectively (Assi *et al.*, 1997). Present research states that firmness decreased more in 500 and 750 Gy treated tomatoes than 250 Gy treated ones at 4 and 25°C. In 'Mosambi' sweet orange and dragon fruits also fruit firmness decreased as the gamma irradiation doses increased (Ladaniya *et al.*, 2003; Wall and Khan, 2008). Similar result was evident in diced tomato where more firmness loss was more at higher dose (50% loss at 3.7 kGy) than at lower one (20% loss at 500 Gy) (Prakash *et al.*, 2002). However, no such dose response was found in tomatoes stored at 12°C in our present findings rather we observed insignificant differences in firmness between 250, 500 and 750 Gy treated tomatoes.

Firmness was significantly affected by storage time at both 4 and 25°C, it decreased with time progression. However, firmness of diced tomato does not decrease with storage time (Prakash *et al.*, 2002). The reason might be the variation of cultivar as it is known that whole fruit firmness differs in several tomato cultivars (Ahrens and Huber, 1990). Radiation did not affect TSS (% sugar) in stored tomatoes. Similar result was found in dragon fruits stored for 12 days at 10°C (Wall and Khan, 2008). Sugar decreased with time at 4°C ($p = 0.005$) but no such effects were observed on sugar of tomato at 12 and 25°C ($p>0.05$). In unirradiated tomatoes we observed insignificant changes in sugar stored at different temperatures ($p = 0.415$) which correspond the result found in off-vine tomato fruit (Gautier *et al.*, 2008).

## CONCLUSIONS

Temperature is an important factor for long time storage. Similarly, quality maintenance is also an important issue which should be assured during storage. Considering the result altogether, a dose of 750 Gy combined with 12°C storage temperature could be ideal for this variety to reduce the annual post harvest loss as this storage temperature and up to 1000 Gy is regarded as safe for fresh commodities. This combination could also lower the price for the consumer and increase the farmer's income. However, considering the economic condition of the farmers, availability of electricity and low temperature storage facility, storage of this tomato variety at 25°C after irradiation with 750 Gy could be cost-effective.

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