The impact of gamma irradiation and storage on the physicochemical properties of tomato fruits in Ghana

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Abstract

Objectives: Tomato is a popular fruit that makes significant contributions to human nutrition for its content of sugars, acids, vitamins, minerals, lycopene, and other constituents. The fruit, however, has a short shelf life due to its climacteric nature. In view of this, an experiment was conducted to determine the effect of postharvest treatment on the physicochemical properties of fresh tomato fruits.

Materials and Methods: Freshly harvested tomato fruits were subjected to 0, 1, 2, 3, and 4 kGy gamma radiation and stored at 10 ± 1°C and 28 ± 1°C. Parameters analysed during the study include pH, total titratable acidity, weight loss, total solids, and moisture content of the sample.

Results: At both storage temperatures, results of the analyses were in the range of 2.80%–38.67% for weight loss, 0.23%–0.51% for total titratable acidity, 3.5%–5.0% for total soluble solids, 94.43%–96.53% for moisture content, and pH was generally low in the samples stored at 10 ± 1°C. Generally, gamma irradiation had an effect on the total soluble solids, total titratable acids, pH values, and moisture content and physiological weight loss at both storage temperatures.

Conclusion: From the study, storing Burkina variety at a low temperature preserves the tomato fruits better than storing them at ambient temperature.

Key words: tomato; storage; gamma irradiation; physicochemical properties; Burkina variety.

Introduction

Tomato (Solanum lycopersicon L.) is a horticultural crop produced and consumed worldwide (Nunes, 2008; Aghdam et al., 2019). Its consumption is second only to the potato as a vegetable (Javanmardi and Kubota, 2006; FAO, 2012). The crop belongs to the Solanaceae family and has its origin in the South American Andes (Naika et al., 2005). Though botanically it is a berry, it is usually considered as a vegetable due to its savoury flavour. Tomato is a versatile fruit vegetable that can be consumed fresh in salads or cooked in sauces, soups, and meat or fish dishes. It can also be processed into purées, juices, ketchup, powders, canned whole, or chopped.

Health benefits conferred by certain vegetables and fruits are the consequence of the presence of health-promoting phytochemicals such as carotenoids, flavonoids, phenylpropanoids, tocopherols, and ascorbic acid (vitamin C), with potent antioxidant properties, in their edible parts (Simonne et al., 2006; Toor and Savage, 2006). Ripened fruit of tomato (S. lycopersicon L.) is known to contain significant amounts of these compounds thereby making it contribute...
to a healthy, well-balanced diet. It is also a principal dietary source of the carotenoid lycopene in the human diet (Giovannucci, 2002).

The fruit is mainly composed of water, soluble, and insoluble solids (Pedro and Ferreira, 2007; Nikbakht et al., 2011). Soluble solids are made up of mainly sugars, like sucrose and fructose, and salts while insoluble solids are mainly constituted by fibres, such as cellulose and pectin (Pedro and Ferreira, 2005). Usually, excluding seeds and skin, tomato presents 4.5%-8.5% total solids, depending on variety, soil, and climatic conditions (Pedro and Ferriera, 2005).

Organic acids mostly citric acid and other micronutrients, such as carotenoids, and vitamins A and C are also found in tomato (Pedro and Ferreira, 2007; Nikbakht et al., 2011). It is also rich in minerals, essential amino acids, sugars, and dietary fibres. Tomato contains some amounts of vitamins B, E, and K, as well as iron and phosphorus.

Several methods have been used as treatment measures to aid in the preservation of fruits and vegetables (Aghdam et al., 2018). These include hot air, drying (dehydration), blanching, use of chemicals like CaCl₂, the use of gamma irradiation, electron beams, and X-rays. Gamma irradiation has been used to extend the shelf life as well as improve some qualities of some tomato varieties (Desai and Joshi, 2018; Munir et al., 2018). According to Arah et al. (2016), many Ghanaian farmers over the years have had a good harvest due to the enhanced research in the breeding of new varieties that are able to withstand conditions that lead to poor harvest. However, little research has been done locally, in the area of postharvest treatments, to enhance the shelf life of tomato fruits.

This has led to severe postharvest losses (Aidoo et al., 2014). In view of this, a study was conducted to determine the effect of gamma irradiation on the shelf life of tomato fruits on the Ghanaian Market. The objective of the study was to determine the impact of gamma irradiation and storage on the physicochemical properties of ripened tomato fruits sourced from the Accra Central Market.

Materials and Methods

Experimental site

The study was conducted at the Food and Medical Laboratory, Dosimetry Laboratory at the Gamma Irradiation Facility (GIF) of the Radiation Technology Centre, and the Nuclear Chemistry and Environmental Research Centre which are located on the premises of the Ghana Atomic Energy Commission.

Sample preparation

The fruits used were obtained from distributors at the Accra Central Market in Accra, Ghana.

Fruits of the Burkina variety of tomato [which are normally available in the late dry season and early rainy season in Ghana (February to May), round robust, and have less moisture content (MC) as compared with the other varieties like Pectofake, Akoma, Chibli, and Roma], at the red ripened stage, were sorted out for uniformity in shape, size, weight, and without any mechanical injuries or defects. Selected fruits were cleaned and dried, prior to irradiation at the GIF.

Irradiation of tomato fruits

Packs of 10 tomato fruits (three replicates) were each put in a low-density polyethylene bag of thickness 0.025 mm and sealed. The packaged samples were taken to the GIF for irradiation at doses of 0 kGy (control), 1.0 kGy, 2.0 kGy, 3.0 kGy, and 4.0 kGy at a dose rate of 1.962 kGy. The irradiated samples were transported to the Food and Medical Laboratory for storage and analysis.

Storage conditions

The storage conditions used were 10.0 ± 1.0°C (low temperature) and 28.0 ± 1.0°C (ambient temperature). Samples were intended to be stored for an average of 10 days but lasted for 9 days and 23 days for those stored at 28.0 ± 1.0°C and 10.0 ± 1.0°C, respectively.

pH of the sample

The pH of the irradiated and the control homogenate samples was determined based on the AOAC (1992), a procedure using the Mettler Toledo pH meter (model T3KFTLH).

Total titratable acidity

In order to determine the total titratable acidity (TTA) of the samples, the procedure of Srivastava and Kumar (1993) was used. Ten millilitres of extracted tomato juice was thoroughly mixed with 50 ml of distilled water in a 100 ml conical flask and titrated against 0.1N NaOH with three drops of phenolphthalein as an indicator. This was continued until a pH of 8.1 was attained. Since citric acid is the most abundant organic acid in tomato, the titratable acidity was expressed in percentage of citric acid. The milli-equivalent weight of citric acid used was 0.06404. The acidity of the samples was calculated as follows:

\[
\% \text{Citric acid} = \frac{\text{Titre value} \times \text{Normality} \times \text{Milli-equivalent weight of acid} \times 100}{\text{Volume of sample}}
\]

Total soluble solids

The total soluble solids (TSS) of the fruits were determined by putting a drop of homogenate tomato juice on the Westover RHB-32ATC hand refractometer held at 20°C and expressed as °Brix (AOAC, 1992).

Moisture content

The MC of the variety used was determined based on the procedure used by Basoglu and Uylaser (2000). Five grams of the homogenate juice of each of the tomato was weighed into Petri dishes (pd) and dried overnight (16 h) in an oven at 105°C. The dishes were allowed to cool in a desiccator and final weight recorded with an AccuLab ALC-150.3. The MC was determined using the following equation:

\[
\% \text{Moisture content} = \frac{\text{(Wt of pd + sample)} - \text{(Wt of pd + dry sample)}}{\text{(Wt of pd + sample) - Wt of empty pd}} \times 100
\]

where wt = weight (with reference to the mass of the sample and pd as well)

Physiological weight loss

The weight loss of the tomato fruit sample was recorded to an accuracy of 0.01 g using a Scientech balance model SL5000. Percentage weight loss (PLW) was calculated by differences between initial weight and final weight (fruit weight on the final day of observation) divided by initial weight and expressed as a percentage (AOAC, 1992).
Results and Discussion

Physiological weight loss of tomato fruits stored at ambient temperature (28 ± 1°C) following gamma irradiation

Figure 1 indicates the impact of irradiation dose (kGy) on the physiological weight of tomato fruit stored at ambient temperature (28 ± 1°C). The weight loss of the unirradiated fruits was in the range of 2.80%–15.66% (with an average of 8.01%) whilst irradiated fruits were in the range of 2.48%–14.55% (mean of 6.24%) throughout the 9-day storage period.

From Figure 1, unirradiated fruits had the highest weight loss throughout the study period corresponding to the figure 15.66% on a ninth day. A general increase in weight loss for the unirradiated fruits with increasing storage days (P < 0.05) was observed. A general rise in weight loss as the doses of gamma irradiation increased as the storage days increased (which was significant, P < 0.05) was observed. The highest weight loss was observed in samples irradiated at 4 kGy throughout the storage period reaching 14.55% on the final day whilst fruits treated with 1 kGy showed the least weight loss (6.78%) on the final day of assessment which is similar to what was observed by Bhattarai and Gautam (2006). This may be due to the ability of climacteric fruits like tomato to generate heat that contributes to weight loss. The heat lost to the environment contributes to increased evaporation of water. Under ambient conditions, the heat generated is more rapid as a result of increased respiration rate. This leads to a rapid weight loss of the fruit characterized by excessive softness making the fruit no longer marketable (Davies and Hobson, 1981; Padmini, 2006).

Physiological weight loss of tomato fruit stored at low temperature (10 ± 1°C) following gamma irradiation

The physiological weight loss of tomato fruits treated with gamma radiation dose and stored at 10 ± 1°C is shown in Figure 2. Least weight loss is conspicuous in irradiated fruits as compared to the unirradiated fruits (control). Unirradiated samples recorded a mean weight loss of 22.93% whilst irradiated fruits recorded 1.85% mean weight loss throughout the 25-day storage period.

There was a general increase in the weight loss for the irradiated fruits throughout the storage period. Fruits irradiated at 1, 2, 3, and 4 kGy had a percentage weight loss of 2.34%, 2.76%, 2.73%, and 3.00% respectively from the initial day to Day 25 of storage period. Thus, weight loss increased with increasing dose of gamma radiation. The highest percentage mean weight loss of 22.93% with a significant increase (P < 0.05) in percentage weight loss throughout the storage period was observed in the control samples.

pH of tomato fruits stored at ambient temperature (28 ± 1°C) after exposure to gamma irradiation

Table 1 presents the effect of gamma irradiation on the pH of tomato fruit stored at ambient temperature (28 ± 1°C). The pH for the unirradiated fruits ranged from 4.35 to 4.38 whilst that of irradiated fruits ranged from 4.26 to 4.62. The pH of the unirradiated fruits reduced significantly after the third day but increased on the sixth day.

There was no significant difference (P > 0.05) between pH on the initial day and the final day of control fruits. However, there were significant differences (P < 0.05) in pH among storage days and irradiation doses.

From Table 1, irradiated fruits generally showed an increase in pH throughout the storage period. Fruits irradiated at 2 and 4 kGy had a significant (P < 0.05) increase in pH with the advancement of days reaching 2.43% and 7.80% respectively above the initial value by the final day (Day 9). As the fruits used in the study approached senescence or decay, the level of acidity reduced and this may be the reason why the pH increased after a few days of exposure to ambient conditions.

![Figure 1](https://academic.oup.com/fqs/advance-article-abstract/doi/10.1093/fqsafe/fyaa017/5856437) Effect of irradiation dose (kGy) on physiological weight loss of tomato fruit stored at ambient temperature (28 ± 1°C).

![Figure 2](https://academic.oup.com/fqs/advance-article-abstract/doi/10.1093/fqsafe/fyaa017/5856437) Effect of irradiation dose (kGy) on physiological weight loss of tomato fruit stored at low temperature (10 ± 1°C) stored for 25 days.

| Storage period (days) | pH            |
|-----------------------|---------------|
|                       | 0 kGy | 1 kGy | 2 kGy | 3 kGy | 4 kGy |
| 0                     | 4.39*<sub>a</sub> | 4.32*<sub>b</sub> | 4.40*<sub>c</sub> | 4.42*<sub>d</sub> | 4.26*<sub>e</sub> |
| 3                     | 4.35<sup>a</sup>  | 4.33<sup>b</sup>  | 4.43<sup>c</sup>  | 4.44<sup>d</sup>  | 4.37<sup>e</sup>  |
| 6                     | 4.38<sup>a</sup>  | 4.38<sup>b</sup>  | 4.47<sup>c</sup>  | 4.57<sup>d</sup>  | 4.59<sup>e</sup>  |
| 9                     | ** ND | 4.39<sup>a</sup>  | 4.51<sup>b</sup>  | 4.52<sup>c</sup>  | 4.62<sup>d</sup>  |

Least significant difference. Means with the same letters (upper cases, days) in the same column are not significantly (P > 0.05) different from each other and means with the same letters in the same row (lower case, doses) are not significantly different (P > 0.05) from each other.

*ND, not determined.
The observed phenomenon in the pH values of the samples used for the study agrees with the study of Padmini (2006) which indicated that pH increases with the advancement of storage days. Generally, there were significant differences \((P < 0.05)\) in the pH of tomato fruits exposed to gamma radiation doses used among each storage day. In terms of storage days, the pH of the unirradiated fruits varied significantly from the irradiated fruits.

**pH of tomato fruits stored at low temperature \((10 \pm 1^\circ C)\) after irradiation**

Table 2 presents the pH of tomato fruits subjected to increasing doses of gamma radiation and stored at \(10 \pm 1^\circ C\). The pH of unirradiated tomato fruits fluctuated between 4.22 and 4.49 throughout the storage period whilst that of irradiated fruits ranged between 4.23 and 4.49 but was not radiation dose-dependent. There were significant differences \((P < 0.05)\) in pH among storage days and irradiation doses.

By the final day, pH had increased in all doses throughout the storage period. There were significant differences \((P < 0.05)\) in pH among each storage day at different doses at which tomato fruits were irradiated.

The pH of the unirradiated fruits was significantly different \((P < 0.05)\) from irradiated fruits throughout the storage days. These results contradict those obtained by Youssef et al. (2011) who reported that irradiating tomato fruits at 1.5, 3.0, and 4.5 kGy had no significant \((P > 0.05)\) effect on the acidity (pH) of tomato juice, working at a storage temperature of 4°C. pH recorded for all irradiated fruits varied significantly but inconsistently during the storage period.

**TTA of tomato fruit stored at ambient temperature \((28 \pm 1^\circ C)\) after irradiation**

Table 3 presents the effect of radiation dose (kGy) on the TTA of tomato fruit stored at ambient temperature \((28 \pm 1^\circ C)\).

TTA in the unirradiated fruits reduced significantly \((P < 0.05)\) from 0.36% to 0.28% throughout the storage period which led to a 22.2% reduction. TTA of irradiated tomato fruits was in the range of 0.23%–0.46% resulting in a mean of 0.32%.

Generally, fruits treated with gamma radiation had a reduced TTA during the first 6 days but increased on the final day in all doses. The result confirms the findings of De Castro et al. (2006) who observed that titratable acidity decreased in the first 7 days of storage period. The rise in TTA after the sixth day could be related to the increase of gaseous conditions (elevation of CO₂ concentration and reduction of O₂) during the storage period as reported by De Souza et al. (1999). Fruits irradiated at 4 kGy had a significant reduction in TTA throughout the storage period. This confirms the fact that the amounts of organic acids usually decrease during maturity, because organic acids are substrates of respiration (Wills et al., 1981). Generally, TTA for the storage days differed significantly in both irradiated and unirradiated fruits.

**TTA of tomato fruit stored at low temperature \((10 \pm 1^\circ C)\) following irradiation**

Table 4 presents the effect of gamma radiation doses (kGy) on the TTA of tomato fruit stored at low temperature \((10 \pm 1^\circ C)\). Unirradiated fruits had a mean TTA of 0.33% throughout the storage period and displayed significant differences \((P < 0.05)\) among storage days. Samples irradiated had a mean TTA of 0.32% as given in Table 5.

Significant differences \((P < 0.05)\) were observed in %TTA of the irradiated samples as well as among the storage days which reduced %TTA at all levels. Unirradiated fruits represented a greater percentage of TTA as compared to irradiated fruits.

The observed phenomenon in terms of the %TTA for both irradiated and unirradiated samples (reduction in TTA during storage) was due to the amount of organic acids which usually decreases during maturity. This is because organic acids are substrates for respiration (Wills et al., 1981) and the acids are

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**Table 2. Effect of irradiation dose (kGy) on the pH of tomato fruit stored at low temperature \((10 \pm 1^\circ C)\).**

| Storage period (days) | pH       |
|----------------------|----------|
|                      | 0 kGy    | 1 kGy    | 2 kGy    | 3 kGy    | 4 kGy    |
| 0                    | 4.22ab   | 4.23b   | 4.30b   | 4.35bc   | 4.36bc   |
| 5                    | 4.40b    | 4.32bc  | 4.34b   | 4.44b    | 4.42b    |
| 10                   | 4.35c    | 4.40a   | 4.38ac  | 4.44a    | 4.43b    |
| 15                   | 4.49b    | 4.25c   | 4.34c   | 4.39b    | 4.31c    |
| 20                   | 4.39a    | 4.45ac  | 4.39b   | 4.42bc   | 4.47bc   |
| 25                   | 4.43bc   | 4.39bc  | 4.37bc  | 4.41bc   | 4.49bc   |

Least significant difference. Means with the same letters (upper cases, days) in the same column are not significantly \((P > 0.05)\) different from each other and means with the same letters in the same row (lower case, doses) are not significantly different \((P > 0.05)\) from each other.

**Table 3. Effect of irradiation dose (kGy) on the total titratable acidity of tomato fruit stored at ambient temperature \((28 \pm 1^\circ C)\).**

| Storage period (days) | Total titratable acidity (%) |
|----------------------|-----------------------------|
|                      | 0 kGy | 1 kGy | 2 kGy | 3 kGy | 4 kGy |
| 0                    | 0.36b | 0.38b | 0.33b | 0.33b | 0.46b |
| 5                    | 0.27a | 0.33a | 0.26a | 0.29ab | 0.32a |
| 10                   | 0.28a | 0.28h | 0.28h | 0.29h | 0.29h |
| 15                   |       |       |       |       |       |
| 20                   |       |       |       |       |       |
| 25                   |       |       |       |       |       |

Least significant difference. Means with the same letters (upper cases, days) in the same column are not significantly \((P > 0.05)\) different from each other and means with the same letters in the same row (lower case, doses) are not significantly different \((P > 0.05)\) from each other.

**Table 4. Effect of irradiation dose (kGy) on the total titratable acidity of tomato fruit stored at low temperature \((10 \pm 1^\circ C)\).**

| Storage period (days) | Total titratable acidity (%) |
|----------------------|-----------------------------|
|                      | 0 kGy | 1 kGy | 2 kGy | 3 kGy | 4 kGy |
| 0                    | 0.51bc | 0.47bc | 0.34bc | 0.36bc | 0.37bc |
| 5                    | 0.28bc | 0.28bc | 0.28bc | 0.28bc | 0.28bc |
| 10                   | 0.33bc | 0.28bc | 0.29bc | 0.31bc | 0.29bc |
| 15                   | 0.25bc | 0.38bc | 0.35bc | 0.32bc | 0.38bc |
| 20                   | 0.32bc | 0.26bc | 0.29bc | 0.31bc | 0.31bc |
| 25                   | 0.31bc | 0.32bc | 0.34bc | 0.32bc | 0.28bc |

Least significant difference. Means with the same letters (upper cases, days) in the same column are not significantly \((P > 0.05)\) different from each other and means with the same letters in the same row (lower case, doses) are not significantly different \((P > 0.05)\) from each other.
converted into salts and sugars by enzymes especially invertase (Deka, 2000).

**TSS (%)** of tomato fruit stored at ambient temperature (28 ± 1°C) following irradiation

Table 5 presents the effect of gamma radiation doses (kGy) on TSS of tomato fruits stored at ambient temperature (28 ± 1°C). Unirradiated fruits showed significant differences (P < 0.05) in TSS as storage days advanced. TSS reduced on the third day and increased on the sixth day in control fruits. In irradiated fruits, TSS ranged from 4.03% to 5.00%.

Tomato samples treated with gamma radiation showed no significant differences (P > 0.05) in TSS on Days 0 and 6, however, there were significant differences (P < 0.05) on Days 3 and 9. It was also observed that there were no significant differences (P > 0.05) within each dose during the storage period. Fruits treated with gamma radiation increased in TSS from Day 0 to Day 9 whilst from Day 3 to Day 6, TSS reduced in fruits treated with 1, 2, and 3 kGy. On Days 0 and 9, TSS increased with decreasing concentration radiation dose whilst on Days 3 and 6, it increased with increasing dose. Fruits treated with gamma radiation showed higher TSS content as compared to control (Table 5).

The increase in TSS agrees with results obtained by Salunkhe et al. (1974) who stated that the sugar content of tomato fruit juices increases after the first appearance of yellow colour in normal ripening. Also, TSS have been shown to increase during ripening then remain constant with over-maturity (Gautier et al., 2008).

**Table 5.** Effect of irradiation dose (kGy) on total soluble solids (%) of tomato fruit stored at ambient temperature (28 ± 1°C).

| Storage period (days) | Total soluble solids (%) of tomato fruits |
|-----------------------|------------------------------------------|
| 0 kGy                 | 4.10Aa 4.29Cb 4.37Ec 4.27Gb 4.27Ib       |
| 1 kGy                 | 3.50Cg 4.30Cgh 4.27Egh 4.40Hgh 4.40Jgh   |
| 2 kGy                 | 4.00Ba 4.33Cb 4.34Ec 4.41Hd 4.28Ie       |
| 3 kGy                 | 3.90Da 4.37Ca 4.37Ha 4.27La 4.27Pa       |
| 4 kGy                 | 3.93Cb 4.27Cc 4.23Hc 4.24Lc 4.12Qd       |
| 5 kGy                 | 3.90Cm 4.50Gq 4.50Iq 4.00Or 4.00Rr       |
| 6 kGy                 | 4.00Di 4.39Cn 4.25Eh 4.40Ih 4.40Jh       |
| 9 kGy                 | 4.00Ri 5.00Qh 4.17Oh 4.03Ni            |

Least significant difference. Means with the same letters (upper cases, days) in the same column are not significantly different (P > 0.05) within each dose, away from that of control fruits. On the third day, tomato fruits treated at 1 kGy showed a significantly higher % MC than those treated with 1 and 3 kGy both of which were different from that of control fruits. On the sixth day, irradiated tomato fruits treated at all doses did not differ from each other including unirradiated fruits. On a ninth day, tomato fruits treated

**Table 6.** Effect of irradiation dose (kGy) on total soluble solids (%) of tomato fruit stored at low temperature (10 ± 1°C).

| Storage period (days) | Total soluble solids (%) |
|-----------------------|----------------------------|
| 0 kGy                 | 4.33bc 4.29cd 4.37de 4.27ef 4.27gh |
| 1 kGy                 | 3.93cd 4.27de 4.23gh 4.24ij 4.12kl |
| 2 kGy                 | 4.13de 5.00ef 4.20fg 4.90hi 4.33ij |
| 3 kGy                 | 4.00ef 4.43gh 5.13ij 5.00kl 4.00mn |
| 4 kGy                 | 4.00ef 4.00ef 4.00ef 4.00ef 4.00ef |
| 5 kGy                 | 4.00ef 4.50gh 4.50hi 4.00ef 4.00ef |
| 6 kGy                 | 3.90ef 4.50gh 4.50hi 4.00ef 4.00ef |

Least significant difference. Means with the same letters (upper cases, days) in the same column are not significantly different (P > 0.05) different from each other.

The results confirm those of Akter and Khan (2012), Prakash et al. (2002), that there were no significant differences (P > 0.05) in TSS as a result of irradiation. The significant changes in TSS that were observed in the unirradiated samples, however, were different from the results by Akter and Khan (2012) in control tomato fruits stored at 25°C, this may be due to the slight changes in the temperature regimes used for this study.

**TSS (%)** of tomato fruit stored at low temperature (10 ± 1°C) following irradiation

Table 6 presents the effect of gamma radiation doses (kGy) on TSS (°Brix) of tomato fruit stored at low temperature (10 ± 1°C). TSS of ‘control fruits’ were between 3.90% and 4.33% whilst of irradiated fruits were between 4.00% and 5.13%.

There were no significant differences (P > 0.05) in TSS during the storage of the unirradiated fruits, however, TSS reduced slightly as storage progressed. There were no significant differences (P > 0.05) observed in the irradiated samples during the storage days.

Generally, there were no significant effects (P > 0.05) of storage and gamma radiation on the TSS in the samples. Similar results were found in tomato fruits stored at 12°C (Prakash et al., 2002; Akter and Khan, 2012) and dragon fruits stored at 10°C (Wall and Khan, 2008).

**MC of tomato fruit stored at ambient temperature (28 ± 1°C) following irradiation**

Figure 3 shows the MCs of tomato fruits stored at ambient temperature (28 ± 1°C) after gamma radiation of varying doses (kGy). The MC of the unirradiated fruits ranged between 94.49% and 95.45% and that of the irradiated tomato fruits ranged between 94.62% and 96.53%.

There was no significant difference (P < 0.05) in MC of the unirradiated fruits on Day 0 to Day 3. However, % MC decreased significantly (P < 0.05) on the sixth day in the unirradiated fruits. Generally, during storage, there were no significant differences (P > 0.05) in % MC within radiation doses. However, Days 0 and 9 differed significantly (P < 0.05) in fruits treated with 2 and 4 kGy.

From Figure 3, it can be observed that on Day 0, tomato fruits irradiated at 2 and 4 kGy resulted in significantly (P < 0.05) higher % MC than those treated with 1 and 3 kGy both of which were different from that of control fruits. On the third day, tomato fruits treated at 1 kGy showed a significantly higher % MC than the other doses including the control. On the sixth day, irradiated tomato fruits treated at all doses did not differ from each other including unirradiated fruits. On a ninth day, tomato fruits treated

**Figure 3.** Effect of irradiation dose (kGy) on the moisture content of tomato fruit stored at ambient temperature (28 ± 1°C).
at 1 and 2 kGy resulted in lower %MC than tomato fruits treated at 3 and 4 kGy.

The highest MC was recorded in the samples that were irradiated at 1 kGy on the third day whilst the least was observed in the samples that were irradiated at 2 kGy on Day 9.

**MC of tomato fruit stored at low temperature (10 ± 1°C) following irradiation**

Figure 4 shows the effect of gamma radiation doses on the MC of tomato fruit stored at low temperature (10 ± 1°C). MC of control fruits ranged between 94.49% and 95.60% which resulted in no significant differences during storage. MC of irradiated fruits ranged between 94.32% and 95.97%.

Within the samples that were irradiated there were no significant differences (P > 0.05) in the %MC throughout the storage period. On Day 0, tomato fruits that were irradiated at 3 kGy showed a significant difference (P < 0.05) in %MC. However, 2 and 4 kGy were not significantly different (P > 0.05) and this was the same case for 1 kGy and control fruits. On Day 5, fruits irradiated at 2, 3, and 4 kGy showed no significant differences (P > 0.05) in MC. On Day 10, fruits that were irradiated at 1, 2, and 3 kGy showed no significant (P > 0.05) changes and did not differ from 3 and 4 kGy and control fruits. On Day 15, fruits irradiated at 4 kGy were significantly different from all the other treatments including the control fruits. On Day 20, all treatments showed no significant differences (P > 0.05). On Day 25, 1 and 4 kGy were not significantly different (P > 0.5). Similarly, 2 and 3 kGy and unirradiated fruits were also not different.

**Conclusions**

Weight loss was greatest in unirradiated fruits (2.80%–15.66%) followed by those subjected to gamma irradiation (2.48%–14.55%) at ambient temperature storage (28 ± 1°C). At low-temperature storage, irradiated fruits weight loss ranged between 0.59% and 3.00% compared to 12.33% and 38.67% in untreated fruits. In general, weight loss was significantly low in all treated fruits at low-temperature storage compared to high-temperature storage. There was a lower weight loss in the samples irradiated than the unirradiated samples. Irradiated fruits had values in the range of 4.22%–4.49% and unirradiated fruits (4.23%–4.49%). Generally, fruits stored at 10 ± 1°C were more acidic (lower pH values) as compared to those stored at 28 ± 1°C in all treatments. TTA in irradiated tomato fruits (0.23%–0.46%) and fruits that were not irradiated (0.36%–0.28%) were lower throughout the storage period at ambient temperature storage (28 ± 1°C). At low-temperature storage (10 ± 1°C), fruits treated with gamma radiation had the least %TTA (0.26%–0.47%) compared to control fruits (0.25%–0.51%). Generally, TTA was larger in all treatments at low-temperature storage as compared to the ambient temperature storage. At ambient temperature (28 ± 1°C), unirradiated control fruits (3.50%–4.10%) exhibited lower TSS as compared to the irradiated fruits (4.03%–5.00%). Similarly, at low-temperature storage (10 ± 1°C), irradiated fruits displayed the largest TSS (4.00%–5.13%). Unirradiated (control) fruits displayed between 94.49% and 95.45% MC which was comparatively larger than that of irradiated tomato fruits (94.62%–96.53%) at ambient temperature storage (28 ± 1°C). In contrast, at low-temperature storage (10 ± 1°C), MC was greater in irradiated fruits (94.43%–95.87%). Storage of irradiated Burkina tomato fruits at low temperature should be encouraged instead of storing them at ambient temperature.

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**Conflict of interest**

The authors declare that there is no conflict of interest regarding the publication of this paper.

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**Figure 4.** Effect of radiation dose (kGy) on the moisture content of tomato fruit stored at low temperature (10 ± 1°C).
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