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Effect of Irradiation on Vitamin C, Acidity and Moisture Content of Mango Fruits with Gamma Ray from Cobalt-60 Source

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Authors' contributions

This work was carried out in collaboration between all authors. Author IM designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors AH, ABK and ED managed the analyses of the study. Author AH managed the literature searches. All authors read and approved the final manuscript.

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Original Research Article

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ABSTRACT

In this study four varieties of mango fruits were irradiated with Gamma ray from Cobalt-60 source at different dose points of 50 Gy, 100 Gy, 300 Gy and 800 Gy in order to investigate the effect of irradiation on vitamin C, titreable acidity and moisture content. Studies indicate that the dose point of 0.05 KGy (sample A) and 0.10 KGy (sample B) gained an average vitamin C content of 6.88% and 6.27% respectively while the dose point of 0.30 KGy showed no loss or gained of vitamin C content and the dose point of 0.80 KGy (sample D) loss 56.25% of vitamin C as compared to reference point (un-irradiated or control sample). The values of titreable acidity which was high on day 2 decreases at day 10 and later increases at day 17. This is attributed to an increase in pulp acidity which occurred as the ripening process proceeds. Also a study reveals that irradiation has no effect on moisture content of mango fruit but can delay the rate of respiration thus the ripening and shelf life.

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Keywords: Shelf life; gamma source; radiation dose; Irradiation; mango fruit.

1. INTRODUCTION

The king of the fruit "mango fruit is one the most popular, nutritionally rich fruit with unique flavor, fragrance, taste and health promoting qualities making it often called super fruit [1].

Mango fruit contain antioxidant compound namely quercetin**,** isoquercitrin, astragalin, fisetin, gallicacid and methylgallat, which help to protect against colon, bosom, leukemia and prostate cancer. It also contain low cholesterol with high level of fiber, pectin and vitamin C, iron which promotes good eyesight and prevents night blindness and aid digestion [2]. Mango fruit suffers considerable postharvest losses which can be high to 55% [3]. Food irradiation is the process of exposing food to ionizing radiation, energy that is transmitted to the food without direct contact capable of stripping electrons from the food [4]. Irradiation cannot make food radioactive, but it may reduce the nutritional content and change the flavor (much like cooking), produce radiolytic products, and increase the number of free radicals in the food. Food irradiation can also be defined as a preservation process of exposing foods to high-energy rays to improve product safety and shelf life [5]. Irradiation can also be defined as process involves in passing food through a radiation field at a set speed to control the amount of the energy or dose absorbed by the food [3]. Irradiation does not cook food only causes the temperature to increase by 2.5ºC at time of irradiation. Under controlled conditions, the food itself does not come into direct contact with the radiation source [6]. Studies carried out by International Atomic Energy Agency (IAEA) [7] showed that increase in radiation dose from consumption of food irradiated to an average dose below 60 KGy with Gamma rays (**γ**) from cobalt-60 or Cesium -137 with 10MeV or with X-rays produced by electrons beams with energy below 5MeV are insignificant, and best characterized as zero [6]. Based on the experimental findings of WHO, FAO, and IAEA, CODEX Alimentarius commission has set out the absorbed dose delivered to a food should not exceed 10 KGy and the energy level of X-rays and electrons generated from machine source operated at or below 5 MeV and 10 MeV respectively, in part, to prevent radioactivity in the irradiated food [8].

When food is irradiated, ionizing radiation reacts with water in the food, causing the release of electrons and the formation of highly reactive free radicals. The free radicals interact with vitamins in ways that can alter and degrade their structure and/or activity [9]. The extent to which vitamin loss occurs can vary based on a number of factors, including the type of food, temperature of irradiation, and availability of oxygen. Nonetheless, vitamin loss almost always increases with increasing doses of radiation. The destruction of vitamins continues beyond the time of irradiation. Therefore, when irradiated food is stored, it will experience greater vitamin loss than food that has not been irradiated. Cooking further accelerates vitamin destruction in irradiated food more than in non-irradiated food [10]. The very fact that irradiation is used to extend the shelf life of food compounds the issue of vitamin loss should be checked, it is for no good in eating mango without nutrient. For example, an irradiated mango can sit in a crate for a longer time without rotting, but it will continue losing vitamins for the period after which a non-irradiated mango would have been discarded [11].

This research work intends to employ different doses of gamma radiation to study Effect of Irradiation on Vitamin C, Acidity and Moisture Content of Mango Fruits.

2. MATERIALS AND METHODS

Mango fruits (Flat mangoes, Binta sugar mangoes, Barki Akus mangoes and Cameron mangoes) were harvested at matured green stage from GIF orchard located at SHEDA and were immediately and carefully transported to the laboratory. They were selected and washed with distill water to remove stain and to help in the detection of wounds. The samples were dried at average temperature of 28.2°C and relative humidity (RH) of 50±5%. The mango fruits were packed in four pairs per group, containing 20 fruits at which 10 were used for both sensory and physiochemical analysis.

The groupings was done carefully by picking ten fruits from each variety and without mix–up, pack them in an air conditional room where they are labeled as follows A, B, C, D and E as in Fig. 1.

Sample –A

Sample –B

Sample –C

Sample –D

Sample –E (Control)

Fig. 1. Showing grouping of different variety of mango fruits

The sample A, B, C and D, were irradiated with 0.05, 0.10, 0.30 and 0.8 KGy respectively while the sample E which contained no irradiation served as the bench mark for comparism.

The mango fruits were then put into a container covered with carton ready and transported to irradiation room containing C0-60 source of current activity of about 5.5 x 10^{15} Bq (=170KCi) as shown in Fig. 2.

After irradiation, both the control and irradiated mangoes were stored at room temperature at low humid environment so that it last up to 21 days where they are subjected to further analysis such as titreable acidity (TA), vitamin C contents and percentage of moisture contents.

Fig. 2. Showing mango fruits ready for irradiation

2.1 Measurement of Absorbed Dose

Irradiation was carried out in the stationary mode of operation using C0-60 source of current activity of about 5.5 x 10^{15} Bq (=170KCi) with the dose rate 2 Gy/min. The Bruker e-scan Alanine dosimetry reader system, Model SC0205, manufactured by Bruker Biospin Corporation, USA, provides a reliable means of measuring the absorbed dose, based on the generation of specific stable radicals in the crystalline alanine. It was also certify that the mango fruits (samples) were checked for absorbed dose and the following findings were deduced as shown in Table 1.

2.2 Measurement of Titreable Acidity (T.A.)

The titreable acidity (TA) of the mango fruits were performed at three different times to include day 2, day 10 and day 17 after irradiation using a standard solution of 0.1 M of sodium hydroxide (NaOH). The fruits were first pick from each group and peel with knife and then blend with 100 ml distill water.

The NaOH solution of base of volume 25 mL was titred over 200 ml of mango fruits juice using phenolphthalein as indicator. The indicator was chosen because it's a titration between a strong base (NaOH) and weak acid (mango fruits acid). The colour changed from yellow to colourless (Fig. 3).

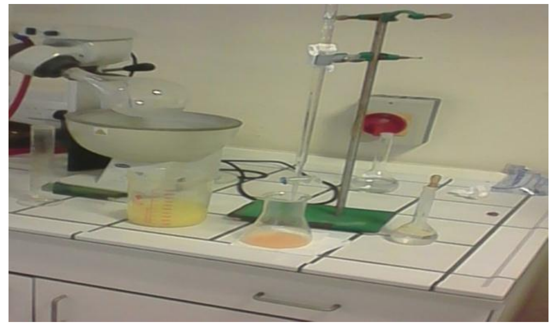

Fig. 3. Showing the stand and result of the Titration

2.3 Measurement of Vitamin C

The determination of vitamin C content of the mango fruits using redox iodine titration were also performed in three different stages; 2 days after irradiation, 10 days after irradiation and 17 days after irradiation. 50 g of the mango fruits is blend with an electric blender in 100 ml of distill water adding up to 200 ml titrated over 25 ml volume of redox iodine and then the results were compared with 0.25 g/250 ml (0.4 M) of a standard solution of vitamin C. The titration was done on pipette with tri-iodide over 25 ml of mango fruits juice on the conical flask. The end point of the reaction is the blue-black colouration of the starch (cellulose) showing the end of vitamin C in the juice as demonstrated in Fig. 4.

Table 1. Showing dose points result for required dose and actual dose detected

Sample	Required dose (Gy)	Actual dose		
		Minimum	Maximum	Average
Batch A	50	47	62	54.50
Batch B	100	100	106	103.00
Batch C	300	286	305	295.50
Batch D	800	792	810	801.00

Fig. 4. Showing the blended mango juice and their titration with I_3^-

2.4 Measurement of Moisture Content

The percentage of the moisture in the mango fruits was determined to ascertain the rate of loss of moisture before and after irradiation. The hot air oven, evapourating dish, desiccators and analytical balance were the apparatus used to analyzed moisture content of fruit juice. The evapourating dishes were first washed and air dried in oven at 105ºC for about 20 minutes, then removed and cooled in the desiccators for 20 minutes.

The evapourating dishes are then labeled and weigh as W_1. The piece of mango fruits is then cut out which normally 2-5 g from the sample specimen of group A-E, and weighed accurately as W_2 in triplicate and quickly transferred to the oven for about 4 hours at temperature of 80°C. After 4 hours the samples were removed from hot air oven and quickly transfer to desiccator to cool for 20 minutes and weigh as W_3. The procedure is repeated for 2 hours for each subsequent time until a constant mass was obtained.

The moisture content in % for each sampling group is calculated using the formula below:

$$\text{Moisture} = \frac{\text{loss in weight due to drying}}{\text{weight of sample taken}}\ \% \quad (1)$$

$$= \frac{W_2 - W_3}{W_2 - W_1} \times 100\% \quad (2)$$

3. RESULTS AND DISCUSSION

3.1 Vitamin C Content of Mango Friuts

Vitamin C (Ascorbic Acid) is an antioxidant that is essential for human nutrition. Vitamin C deficiency can lead to a disease called Scurvy, which is characterized by abnormalities in the bone and teeth. The best way of determining the amount of vitamin C in the fruit juice is by the used of redox titration which is better than acid-base titration since there are additional acids in juice. But few of them interfere with the oxidation of ascorbic acid by iodine.

Iodine is relatively insoluble, but this was be improved by complexion the iodine with iodide to form tri-iodide;

$$I_2 + I^{-1} \rightarrow I_3^- \quad (3)$$

Tri-iodide oxidizes vitamin C to form dehydroascorbic acid:

$$C_6H_8O_6 + I_3^- + H_2O \rightarrow C_6H_6O_6 + 3I^- + 4H^+ \quad (4)$$

As long as vitamin C is present in the solution, the tri-iodide is converted to the iodide ion very quickly. However, when all the vitamin C is oxidized, iodide and tri-iodide will be present, which react with starch to form a blue-black complex which is the end point of the titration.

The values of the PH of mango fruits fall on day 2 and increased on day 10 and later fall on day 17 for dose points of 0.05 KGy, 0.10 KGy, 0.30 KGy and even the control or un-irradiated sample. The dose point of 0.80 KGy showed a steady rate of increment from 3.96 to 5.12 and finally to 5.77, for day 2, day 10 and day 17 respectively. The un-irradiated mango fruit has the highest values of PH on day 2, day 10 and day 17 than the irradiated samples (A-D) but the sample D has PH value (5.77) which is slightly higher than the sample E (control = 5.21) as showed in Table 2.

Both the PH of samples irradiated with 0.05, 0.10, 0.30 kGy and the control respectively increases and decreases slightly but the sample irradiated with 0.80 KGy increased at steady rate. The concentration of the vitamins C as shown in Table 4 indicated that the value of vitamin C content of mango fruits decreased from day 2 to day 10 and later increased at day 17 after irradiation for dose points of 0.30 KGy and 0.80 KGy while the rest of vitamin C content increases at a steady rate. The vitamin C content of dose point 0.80 KGy is lost by a 56.25 percentage.

This will be difficult to draw a conclusion, it will be better to take the average of Vitamin C content of the mango fruits and the average PH for each of the dose points for the period of three weeks. The average vitamin C content of mango fruits, the average PH value and percentage loss of vitamin C content for the period of 21 days was obtained as tabulated in Table 3.

The values of PH were similar to those reported by Thomas et al. [12], who irradiated mangos with doses of 0.3-1.0 kGy and found no significant changes in PH values, even when the

Table 2. Shows the sample of mango fruits, the average volume of mango fruits juice used, concentration in mg/L and the potential hydrogen (PH)

Sample	Used volume(ml)			Conc (mg//L			PH		
	Day 2	Day 10	Day 17	Day 2	Day 10	Day 17	Day 2	Day 10	Day 17
A	0.40	0.40	0.80	29.19	29.19	50.37	3.92	5.80	4.21
B	0.40	0.40	0.70	29.19	29.19	51.10	3.87	5.02	5.00
C	0.70	0.30	0.60	51.10	21.90	43.80	3.63	4.85	5.07
D	1.30	0.40	0.80	94.90	29.19	58.40	3.96	5.12	5.77
E	0.50	0.30	0.80	36.50	21.90	58.40	4.27	5.99	5.21

Table 3. Shows the average vitamin C content, % loss of vitamin C and the average PH

Sample	Average vitamin C	Average PH	% loss Vitamin C
A	36.25	4.64	-6.88
B	36.49	4.63	-6.27
C	38.93	4.52	0.00
D	60.83	4.95	56.25
E	38.93	5.16	Nil

ripening of the fruit was slowed. Lima et al. 2001 [13] also stressed the importance of evaluating PH as an intrinsic factor that exerts the greatest selective effect on the micro-flora likely to develop on fruits and vegetables.

The dose point of 0.05 KGy, (sample A) and 0.10 KGy (sample B) gained an average vitamin C content of 6.88% and 6.27% respectively while the dose point of 0.30 KGy showed no loss or gained of vitamin C content and the dose point of 0.80 KGy (sample D) loss 56.25% of vitamin C as compared to reference point (un-irradiated or control sample).

This is in agreement with the findings of Mitchell, et al. [14] that showed that at the low doses of 0.3 to 0.75 kGy, food irradiation has been found to destroy up to 11 percent of vitamin C in fruit before storage, and up to 79 percent of vitamin C after three weeks of storage. But this is small compared to vitamins lost in process food and rot food.

On regard to the ascorbic acid content, we found no interaction between dose and valuation day and between the different gamma radiations doses except for highest dose point 0.80 KGy. These findings agreed with those reported by Youssef et al. [15], who observed that gamma irradiation of mango fruits at doses of 0.5 and 2.0 kGy led to an increase in the ascorbic acid content, which may have been influenced by the combination of the radiation and quality of the fruit. In this present study, the ascorbic acid curve demonstrated that the mango fruits exhibited a reduction in some substance during the ripening process, which is a common finding in most fruits [16].

3.2 Titreable Acidity (TA) of Mango Fruits

The titreable acidity of mango fruits result is shown in Table 4 performed at day 2, day 10 and day 17 after irradiation.

The values of titreable acidity which was high on the day 2 decrease at day 10 and later increase at day 17. This is due to an increase in pulp acidity which occurred as the ripening process proceeds. Although few exceptions occurred, the organic acid content is diminished during maturation owing to either respiration or the conservation of sugars [17].

Table 4. Showing concentration of T.A of mango fruits juice in Mol/dm^3

Sample	Day 2	Day 10	Day 17
A	0.0118	0.0046	0.0080
B	0.0101	0.0028	0.0048
C	0.0109	0.0032	0.0050
D	0.0125	0.0044	0.0034
E	0.0093	0.0022	0.0042

3.3 Moisture Content of Mango Fruits

The moisture content of the fruits were done at four good different time, before irradiation, two (2) days after irradiation, 10 days after irradiation, 17 days after irradiation. The analyses of the moisture content were performed three times for each group sample and the mean or average results in % of each sample dose points are tabulate in Table 5.

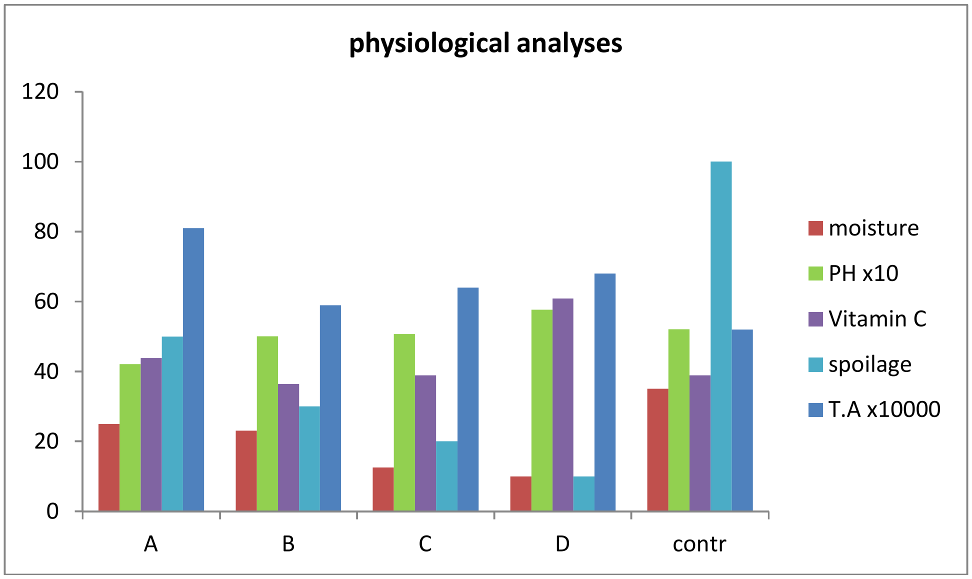

Fig. 5. Physiological analysis of mango fruits

Table 5. Showing mean moisture content of mango fruits in percentages (%)

Sample	2 days	10 days	15days	Average %
A	79.7	78.9	81.4	80.0
B	79.5	81.9	79.7	80.4
C	81.2	81.8	77.9	80.3
D	80.6	82.7	73.0	78.7
E	75.3	75.9	78.0	76.4

Fig. 6. Showing the samples at the end of 21 days

This result is in accordance with findings from FAO source of nutritional value of mango fruits which state that the moisture content of mango fruits is 80% $\pm$ 2%. (FAO source). And irradiation has no effect on moisture content of mango fruit but can delay the rate of respiration thus the ripening and shelf life.

The summary of all the physiological analysis such as moisture content, mass/weight loss, titreable acidity, vitamin C content, rotting/ spoilage observation and the PH value of mango fruits are shown below for both irradiated samples and control sample.

4. CONCLUSION

Four varieties of mango fruits were irradiated with Gamma ray from Cobalt-60 source at different dose points of 50 Gy, 100 Gy, 300 Gy and 800 Gy to investigate effect of irradiation on vitamin C, titreable acidity and moisture contents. The observations were made at three different days, namely day 2, day 10 and day 17 after irradiation. We noticed that sample of mango fruits irradiated with 800 Gy lost 56.25% of vitamin C, which delay the ripening and preserved the firmness up to 14 days after harvesting. We also found out that at low dose point like 0.05 KGy to 0.10 KGy dose points there were gain in vitamin C but 0.30 KGy dose point has no effect.

On regard to titreable acidity, an increase in pulp acidity occurred during the ripening process.

With few exceptions, the organic acid content is diminished during maturation owing to either respiration or the conservation of sugars.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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