

# Effect of Gamma Irradiation, Packaging and Storage on Vitamin C Content of Garden Eggs

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**Abstract:** Garden eggs are important economic vegetable crops which serve as excellent source of food with high Vitamin C content. The effect of gamma radiation (0, 1, 2, 3 kGy), packaging (polyethylene) and storage (0,1,2,3,4 weeks at 29±1°C) on the Vitamin C content of three varieties of garden eggs (*Solanum aethiopicum* GH 8772 and *Solanum aethiopicum* GH 8773, and *Solanum torvum*) were studied. Irradiation was done using a cobalt-60 source and the Vitamin C content of the samples were determined by the method of Ciancaglini *et al* (2001). The effect of gamma irradiation (1 - 3 kGy) on Vitamin C content of the three varieties of garden eggs was not uniform. Packaging with polythene decreased the content of Vitamin C in fruits of *Solanum torvum* but not those of *Solanum aethiopicum* L. [GH 8772 and GH 8773]. Storage period decreased the Vitamin C content of packaged samples of all three varieties of garden eggs.

**Keywords:** Gamma Irradiation, Vitamin C, Packaging, Storage, Garden Eggs

## 1. Introduction

Garden eggs (*Solanum* spp.) is a woody perennial herb of the Family Solanaceae. Consumption of its fruits is widespread in the tropics and temperate parts of the world [1]. When matured, fruits may be eaten raw or boiled, fried and sautéed for soup and stew [2, 3]. The fruits are used as food in addition to serving as rich sources of vitamins A, B and C, potassium, magnesium, calcium, phosphorus and sodium. These vitamins and minerals are useful for the prevention or treatment of diseases such as asthma, bronchitis, cholera and dysuria [1, 4]. [5] reported that extracts from garden egg suppress the development of blood vessels required for tumor growth and metastasis, and also inhibit protein-activated receptor 2 inflammation that causes atherosclerosis [6].

Garden egg was ranked in the top 10 species for superoxide scavenging (SOS) activity [7] of 120 vegetables species evaluated for antioxidant activity using four different assays (2,2'-azino-bis-3-ethylbenzthiazoline-6-sulphonic acid

[ABTS], 2, 2-diphenyl-1-picrylhydrazyl radical [DPPH], inhibition of lipid peroxidation [ILP], and superoxide scavenging [SOS]). Antioxidant activity has been linked to ascorbic acid and high phenolic content in the leaves, calyx and fleshy portions of the fruit [8, 9, 10].

Garden eggs have limited shelf-life for freshness mainly due to their high evapo-transpiration rate resulting in rapid water loss. Poor post-harvest handling, shoot and fruit borers, and the lack of quality standards contribute greatly to yield losses in Ghana. In addition, garden egg plants are also prone to infection by pests, fungi, bacteria and viruses at all stages of growth on field and after harvest [11].

In spite of the beneficial uses of garden eggs, research into extending the shelf-life of garden eggs using gamma irradiation has received little attention in most developing countries. Refrigeration, modified atmosphere storage, freezing and drying represent some of the technologies utilized in shelf-life extension of garden eggs [12, 13, 14, 15]. Irradiation is a proven technology which has been endorsed by notable international health and food authorities. As a

process it has the capacity to eliminate insect pests and microbial pathogens from fresh fruits and vegetables. It also delays ripening and senescence thereby extending the shelf-life of fresh fruits and vegetables without adverse effect on the quality [16].

Phytosanitary doses of irradiation (0.15 to 1 kGy) in general have no effect on macronutrients or minerals in fruits and vegetables [17, 18]. There is medium to high sensitivity of Vitamin C to irradiation in most fresh produce [19]. Most vegetables continue to ripen after harvest and therefore post harvest handling and storage can also affect nutrient composition of vegetable vitamin levels [20, 21]. Although packaging protects fresh produce from mechanical damage and poor environmental conditions, information on its impact on nutrients is very limited. Therefore the objective of this study was to determine the effect of gamma radiation, packaging and storage on the Vitamin C content of three varieties of garden eggs (*Solanum aethiopicum* L. [GH 8772 and GH 8773] and *S. torvum*).

## 2. Materials and Methods

### 2.1. Sampling

Three varieties of garden eggs (*Solanum aethiopicum* GH 8772; GH8773 and *S. torvum*) were obtained from a market in Accra, Ghana. The samples were obtained 2 days after harvest and sorted to remove bruised, pitted, riped fruits as well as fruits without stalk (calyx). For the purpose of easy referencing, fruits of GH8772 and GH8773 were coded "A" and "C" while those of *S. torvum* were coded "B".

### 2.2. Packaging of Samples

The fruits were surface-sterilised with 70% alcohol. Packaging was done by placing 10 fruits (approximately 400 – 500 g of A and C) and 300 g of B in perforated polyethylene zip – lock pouches (density = 0.18 g/cm<sup>3</sup>).

### 2.3. Irradiation of Samples

The samples were irradiated under ambient conditions using a Cobalt-60 source at the Gamma Irradiation Facility (GIF) of the Radiation Technology Centre (RTC) in Ghana Atomic Energy Commission (GAEC) at doses of 0, 1, 2 and 3 kGy. The dose rate during the irradiation process was 1.962 kGy/hr and ferrous sulphate (Fricke) dosimeter was used to measure absorbed dose.

### 2.4. Storage of Samples

The packaged sample (perforated zip – lock pouches) and the unpackaged control sample were stored at 29±1 °C under two packaging conditions.

### 2.5. Determination of Vitamin C content

The ascorbic acid content in the samples was determined by the method outlined by [22]. A 0.005M of iodine solution was prepared by weighing 2 g of potassium iodide and 1.3 g

of iodine into a beaker. Few drops of distilled water were added and swirled until all the iodine had dissolved. The solution formed was made up to 1 litre in a volumetric flask. Fruits (two fruits per variety, dose and package) were picked at random from the lot, chopped into pieces and 10 g of the samples were taken and homogenized with a laboratory Waring blender. The slurry was put into Eppendorf centrifuge tubes. They were centrifuged using Extra Merlin 505 Centrifuge (UK). Twenty millilitres of the supernatant was poured into a 250 ml conical flask. The iodine solution was titrated against the supernatant. 1 % (w/v) starch solution prepared by weighing 1 g of powdered starch and dissolving it in 100 ml of distilled water served as an indicator. One millilitre of starch solution indicator was added to the supernatant of the homogenized pulp to serve as an indicator to a blue-black colour end point. The titration was done in triplicate at the Physicochemical Laboratory of RTC, GAEC. The titre values were used to calculate the ascorbic acid content of the fruits.

### 2.6. Statistical Analysis

The results obtained from the experiments were analyzed using Statgraphics Centurion software (XVI.I edition). One-way and two-way analyses of variance were used to determine significant differences at 95% confidence interval.

## 3. Results

### 3.1. Effect of Irradiation on Vitamin C Content of Garden Eggs

As shown in Tables 1 and 3, significant differences ( $P < 0.05$ ) were observed in the effect of gamma irradiation on the Vitamin C content of the three varieties of garden eggs. While irradiation dose of 3kGy reduced the Vitamin C content of samples of Variety B and the packaged samples of Varieties A and C, it increased the Vitamin C content of unpackaged samples of Variety A and C. However, doses of 1 and 2 kGy decreased the Vitamin C content in varieties A and B but increased that of Variety C.

### 3.2. Effect of Packaging on Vitamin C Content of Garden Eggs

Figure 1 shows the effect of packaging on the Vitamin C content of the three varieties of garden eggs. There were significant differences ( $P < 0.05$ ) between the packaged and unpackaged samples of Variety B but not those of samples A and C. Among both the packaged and unpackaged samples, Variety B had significantly higher Vitamin C content compared to Varieties A and C.

### 3.3. Effect of Storage on Vitamin C Content of Garden Eggs

There were significant differences ( $P < 0.05$ ) within the samples of all three varieties during the storage period with respect to their Vitamin C content (Table 2). As storage period progressed, there were decreases in Vitamin C content

for the packaged samples of all three varieties compared to unpackaged samples. In the case of unpackaged samples of Variety B, there was a clear pattern of decline in Vitamin C content as storage period progressed.

**Table 1.** Effect of irradiation on the vitamin C content of three varieties of garden eggs stored under two packaging conditions.

Dose (kGy)	Varieties					
	<i>S. aethiopicum</i> – [A]		<i>S. torvum</i> – [B]		<i>S. aethiopicum</i> – [C]	
	Unpack	Pack	Unpack	Pack	Unpack	Pack
0	1.43 <sup>a</sup>	1.34 <sup>a</sup>	23.82 <sup>b</sup>	8.19 <sup>b</sup>	1.78 <sup>a</sup>	1.23 <sup>b</sup>
1	2.05 <sup>bc</sup>	1.23 <sup>a</sup>	13.65 <sup>ab</sup>	2.73 <sup>a</sup>	2.05 <sup>ab</sup>	1.41 <sup>b</sup>
2	2.28 <sup>c</sup>	0.82 <sup>a</sup>	13.65 <sup>ab</sup>	2.73 <sup>a</sup>	2.23 <sup>b</sup>	1.50 <sup>b</sup>
3	1.68 <sup>ab</sup>	0.96 <sup>a</sup>	8.19 <sup>a</sup>	2.73 <sup>a</sup>	2.05 <sup>ab</sup>	0.73 <sup>a</sup>

Values are means of 15 determinations - (3 replicates by 5 storage weeks) Mean values in the same column with different letters (a – c) were significantly different ( $P < 0.05$ ); Vitamin C content in mg/100g

**Table 2.** Effect of storage on the vitamin C content of three varieties of garden eggs stored under two packaging conditions.

Storage Week	Varieties					
	<i>S. aethiopicum</i> – [A]		<i>S. torvum</i> – [B]		<i>S. aethiopicum</i> – [C]	
	Unpack	Pack	Unpack	Pack	Unpack	Pack
0	1.08 <sup>a</sup>	1.71 <sup>d</sup>	37.54 <sup>c</sup>	13.65 <sup>c</sup>	1.25 <sup>a</sup>	1.54 <sup>bc</sup>
1	2.62 <sup>c</sup>	1.48 <sup>cd</sup>	23.89 <sup>b</sup>	3.41 <sup>b</sup>	2.28 <sup>ab</sup>	1.08 <sup>ab</sup>
2	1.54 <sup>b</sup>	1.00 <sup>bc</sup>	5.69 <sup>a</sup>	0.00 <sup>a</sup>	2.05 <sup>b</sup>	1.02 <sup>a</sup>
3	1.76 <sup>b</sup>	0.91 <sup>b</sup>	6.83 <sup>a</sup>	3.41 <sup>b</sup>	2.16 <sup>ab</sup>	1.59 <sup>c</sup>

**Table 3.** Interactive effect of irradiation and storage on Vitamin C content of three varieties of garden eggs under two packaging conditions at room temperature.

Dose (kGy)	Storage Week	Varieties					
		<i>S. aethiopicum</i> – [A]		<i>S. torvum</i> – [B]		<i>S. aethiopicum</i> – [C]	
		Unpack	Pack	Unpack	Pack	Unpack	Pack
0	0	0.68 <sup>c</sup> <sub>A</sub>	2.05 <sup>w</sup> <sub>K</sub>	27.30 <sup>b</sup> <sub>B</sub>	13.65 <sup>z</sup> <sub>L</sub>	1.37 <sup>ab</sup> <sub>A</sub>	2.05 <sup>w</sup> <sub>K</sub>
	1	2.05 <sup>abc</sup> <sub>A</sub>	1.37 <sup>y</sup> <sub>K</sub>	40.96 <sup>a</sup> <sub>C</sub>	13.65 <sup>z</sup> <sub>L</sub>	2.28 <sup>ab</sup> <sub>A</sub>	1.37 <sup>x</sup> <sub>K</sub>
	2	1.37 <sup>bc</sup> <sub>A</sub>	1.25 <sup>yz</sup> <sub>K</sub>	22.75 <sup>c</sup> <sub>B</sub>	-	1.37 <sup>ab</sup> <sub>A</sub>	1.37 <sup>x</sup> <sub>K</sub>
	3	1.37 <sup>bc</sup> <sub>A</sub>	2.05 <sup>w</sup> <sub>K</sub>	27.30 <sup>b</sup> <sub>B</sub>	13.65 <sup>z</sup> <sub>L</sub>	1.82 <sup>ab</sup> <sub>A</sub>	1.37 <sup>x</sup> <sub>K</sub>
1	0	1.71 <sup>bc</sup> <sub>A</sub>	-	0.80 <sup>d</sup> <sub>A</sub>	-	2.05 <sup>ab</sup> <sub>A</sub>	-
	1	1.37 <sup>a</sup> <sub>A</sub>	2.05 <sup>w</sup> <sub>K</sub>	40.96 <sup>a</sup> <sub>C</sub>	13.65 <sup>z</sup> <sub>L</sub>	0.68 <sup>b</sup> <sub>A</sub>	1.37 <sup>x</sup> <sub>K</sub>
	2	2.73 <sup>a</sup> <sub>A</sub>	1.14 <sup>z</sup> <sub>K</sub>	27.30 <sup>b</sup> <sub>B</sub>	-	2.05 <sup>ab</sup> <sub>A</sub>	1.37 <sup>x</sup> <sub>K</sub>
	3	1.37 <sup>bc</sup> <sub>A</sub>	-	-	-	2.73 <sup>a</sup> <sub>A</sub>	0.68 <sup>z</sup> <sub>K</sub>
2	0	2.05 <sup>abc</sup> <sub>A</sub>	1.59 <sup>x</sup> <sub>K</sub>	-	-	2.05 <sup>ab</sup> <sub>A</sub>	2.28 <sup>y</sup> <sub>K</sub>
	1	2.73 <sup>a</sup> <sub>A</sub>	1.37 <sup>y</sup> <sub>K</sub>	-	-	2.73 <sup>a</sup> <sub>A</sub>	1.37 <sup>x</sup> <sub>K</sub>
	2	2.73 <sup>a</sup> <sub>A</sub>	1.37 <sup>y</sup> <sub>K</sub>	-	-	2.73 <sup>a</sup> <sub>A</sub>	1.37 <sup>x</sup> <sub>K</sub>
	3	2.73 <sup>a</sup> <sub>A</sub>	1.37 <sup>y</sup> <sub>K</sub>	-	-	2.73 <sup>a</sup> <sub>A</sub>	1.37 <sup>x</sup> <sub>K</sub>
3	0	0.91 <sup>c</sup> <sub>A</sub>	1.37 <sup>y</sup> <sub>K</sub>	40.96 <sup>a</sup> <sub>C</sub>	13.65 <sup>z</sup> <sub>L</sub>	1.59 <sup>ab</sup> <sub>A</sub>	1.37 <sup>x</sup> <sub>K</sub>
	1	3.64 <sup>a</sup> <sub>A</sub>	1.37 <sup>y</sup> <sub>K</sub>	27.30 <sup>b</sup> <sub>B</sub>	-	2.05 <sup>ab</sup> <sub>A</sub>	0.68 <sup>z</sup> <sub>K</sub>
	2	2.05 <sup>a</sup> <sub>A</sub>	1.37 <sup>y</sup> <sub>K</sub>	-	-	2.05 <sup>ab</sup> <sub>A</sub>	2.05 <sup>w</sup> <sub>K</sub>
	3	2.05 <sup>abc</sup> <sub>A</sub>	-	-	-	2.73 <sup>a</sup> <sub>A</sub>	1.37 <sup>x</sup> <sub>K</sub>
4	0	2.73 <sup>a</sup> <sub>A</sub>	-	-	-	2.73 <sup>a</sup> <sub>A</sub>	2.05 <sup>w</sup> <sub>K</sub>
	1	1.37 <sup>bc</sup> <sub>A</sub>	1.37 <sup>y</sup> <sub>K</sub>	40.96 <sup>a</sup> <sub>C</sub>	13.65 <sup>z</sup>	1.37 <sup>ab</sup> <sub>A</sub>	1.37 <sup>x</sup> <sub>K</sub>
	2	2.05 <sup>abc</sup> <sub>A</sub>	2.05 <sup>w</sup> <sub>K</sub>	-	-	2.73 <sup>a</sup> <sub>A</sub>	0.91 <sup>y</sup> <sub>K</sub>
	3	1.37 <sup>bc</sup> <sub>A</sub>	1.37 <sup>y</sup> <sub>K</sub>	-	-	2.05 <sup>ab</sup> <sub>A</sub>	-
4	3	1.59 <sup>bc</sup> <sub>A</sub>	-	-	-	2.05 <sup>ab</sup> <sub>A</sub>	1.37 <sup>x</sup> <sub>K</sub>
	4	2.05 <sup>abc</sup> <sub>A</sub>	-	-	-	2.05 <sup>ab</sup> <sub>A</sub>	-

Values are means of 3 determinations, Vitamin C content in mg/100g; - = no data due to spoilage a-d (unpack), w-z (pack) = Mean values in the same column with different letters were significantly different ( $P < 0.05$ ) A-C (unpack), K-M (pack) = Mean values in the same row with different letters were significantly different ( $P < 0.05$ ) A = *Solanum aethiopicum* (GH 8772) B = *Solanum torvum* C = *Solanum aethiopicum* (GH 8773)

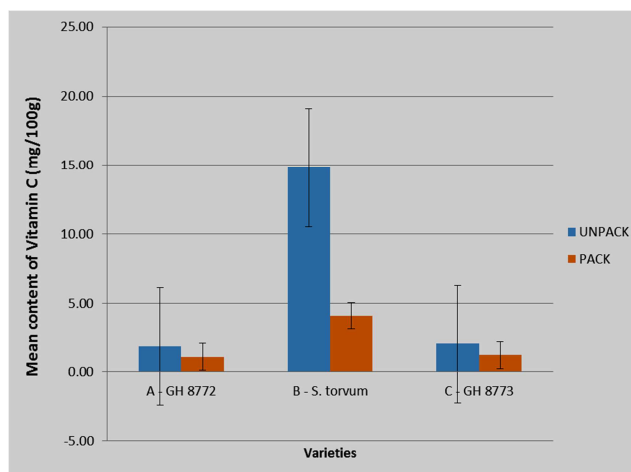
## 4. Discussion

### 4.1. Effect of Irradiation on Vitamin C Content of Garden Eggs

Vitamin C is a water-soluble vitamin which is inherently

Storage Week	Varieties					
	<i>S. aethiopicum</i> – [A]		<i>S. torvum</i> – [B]		<i>S. aethiopicum</i> – [C]	
	Unpack	Pack	Unpack	Pack	Unpack	Pack
4	2.30 <sup>c</sup>	0.34 <sup>a</sup>	0.20 <sup>a</sup>	0.00 <sup>a</sup>	2.39 <sup>b</sup>	0.85 <sup>a</sup>

Values are means of 12 determinations - (3 replicates by 4 storage weeks) Mean values in the same column with different letters (a – d) were significantly different ( $P < 0.05$ ); Vitamin C content in mg/100g



**Figure 1.** Effect of two packaging conditions on the population of aerobic mesophiles for three varieties of garden eggs.

unstable in solution with its destruction affected by temperature, light and pH [23]. As a result of this observation, Vitamin C has been identified as one of the most sensitive vitamins to irradiation, with the effect of irradiation influenced by exposure to oxygen, storage and temperature as well as the pH of the food matrix or storage medium [19].

The effect of radiation dose on the Vitamin C content of varieties A and C did not follow a clear pattern (Tables 1 and 3). This observation might be due to differences in maturity of the samples within each variety in this study. Samples of variety B had the highest Vitamin C content (14.83 mg/100g) among the three varieties of garden eggs. According to a study by [24], irradiation can reduce Vitamin C content in some vegetables but the decrease is inconsequential and does not exceed the decline seen during storage. Other studies have shown radiation dose of 1 kGy significantly reduced Vitamin C levels in fresh-cut lettuce [25] and 3 kGy also led to 20.4% loss in tomatoes [26]. In this study also, the Vitamin C content of samples of variety B decreased after irradiation. Minimal changes were also observed in Vitamin C levels in capsicums irradiated with 1, 2 and 3 kGy [27]. In some curcubit vegetables (cucumber, carrot), irradiation with dose up to 2 kGy did not significantly affect Vitamin C levels [28].

#### 4.2. Effect of Packaging on Vitamin C Content of Garden Eggs

In this study, samples of garden eggs under packaged condition (polythene) of storage had significantly lower Vitamin C content for variety B compared to samples under unpackaged condition of storage. In the case of varieties A and C, the differences between package and unpackaged samples were not significant. In a related study, garden eggs stored in a perforated plastic container had higher Vitamin C content compared to those stored in sisal sack and a passive evaporative cooler [29]. However, there was no difference in loss of Vitamin C of ready-to-use broccoli and green pepper under different packaging systems [30]. The reduction in Vitamin C content of samples under packaged storage conditions might be due to a build-up of heat as a result of respiration. Vitamin C has been shown to be unstable at high temperatures [29, 31].

#### 4.3. Effect of Storage on Vitamin C Content of Garden Eggs

Vitamin C has been shown to be unstable during storage at room temperature because of oxidation [32]. This might explain the results of this study which have revealed a decline in Vitamin C content of all the irradiated samples of the varieties of garden eggs during storage at ambient conditions. [33] similarly reported decrease in Vitamin C content of tomato and orange after 21 days of storage. The significance of storage conditions was well illustrated in the study where Vitamin C content increased in tomatoes stored for 15 days at cool temperatures, but there were losses of 15% of Vitamin C during storage at 25 °C [21]. It has been reported that varietal differences, metabolic changes in plant tissue, and storage conditions have greater impact on Vitamin C content in fruits and vegetables than irradiation treatment during storage [19, 34]. This might explain the non-uniform decline in Vitamin C content of the samples of variety A and C compared to variety B as observed in this study.

## 5. Conclusion

The effect of gamma irradiation (1 - 3 kGy) on Vitamin C content of the three varieties of garden eggs was not uniform. While there were decreases in Vitamin C content in *Solanum torvum*, decreases in *Solanum aethiopicum* L. [GH 8772 and GH 8773] did not have any pattern. Packaging with polythene decreased the content of Vitamin C in fruits of *Solanum torvum* but not those of *Solanum aethiopicum* L. [GH 8772 and GH 8773]. Storage period decreased the Vitamin C content of packaged samples of all varieties and in the case of *Solanum torvum* there was also a clear pattern of decline in Vitamin C content under unpackaged conditions.

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