

Effect of Irradiation and Storage on the Physico-chemical Properties of Tomato (*Solanum lycopersicon* L.) Powder under Solar and Freeze-Dried Conditions in Ghana

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Abstract

A study was conducted to assess the effect of irradiation and storage on the physico-chemical properties of tomato (*Solanum lycopersicon* L.) powder under solar dried and freeze-dried conditions in Ghana. Forty kilogrammes (40 kg) of tomato fruits were obtained for the study. The fruits were solar and freeze dried and tomato powder obtained from them. These were exposed to gamma radiation from 1-3 kGy, with 0 kGy as control. The parameters investigated in the study for the two-month period include; moisture content, total soluble solids, total titratable acidity, pH and colour. The pH of the samples ranged from 4.02 to 6.18, moisture content from 12.55% to 23.47%, total titratable acidity from 0.11% to 0.99%, total soluble solids from 4.80% to 5.06%, L*(colour) from 32.71 to 36.97, a* (colour) from 6.69 to 22.02 and b*(colour) from 14.38 to 22.91. Gamma radiation did not affect moisture content of the samples, total soluble solids, total titratable acidity and pH ($p>0.05$). Gamma irradiation affected the colour of the samples significantly ($p<0.05$).

Key words: irradiation, storage, moisture content, pH, total soluble solids, solar dried, freeze dried, Akoma, month.

1. Introduction

Tomato is an important fruit vegetable cultivated all over the world. It is a seasonal and highly perishable vegetable, deteriorating few days after harvest, affecting their nutritional and qualitative characteristics (Nakhasi *et al*., 1991). The shelf life of tomato is within 4 to 6 days after harvest, and this is dependent on the variety and storage conditions (Ellis *et al*., 1998). The short shelf-life of tomato, coupled with improper packaging and storage equipment, as well as lack of effective transport means has been one of the bottlenecks affecting the tomato industry (Babalola *et al*., 2010; Idah *et al*., 2007).

To extend the shelf life of tomatoes, they are processed into puree, ketchup, paste, powder, juice and canned whole (Alam *et al*., 2009). These processing methods preserve the nutritional qualities of fresh tomatoes although some may be lost during processing. The predominant method of preservation of fresh tomato in most homes is by storing at low temperatures. This however, often results in poor and uneven ripening, and in some instances, high fungal spoilage (Ryall and Lipton, 1972; Tomkins, 1963).

Dehydration is one of the most widely used methods for fruits and vegetables preservation. It is well known that during drying, vegetables undergo physical, structural, chemical and nutritional changes that can affect quality indicators like texture, colour, flavour, and nutritional value (Di Scala & Crapiste, 2008). Increasing demand for dehydrated tomato in domestic and international markets is growing, with greater portion of it being used in the catering industry (Ghavidel and Davoodi, 2010). It is therefore important to develop suitable technology for drying and preservation of this valuable crop to reduce the losses, provide food security and increase productivity.

Like other fruits and vegetables, tomato can be dried using several drying methods such as sun, solar, spray and freeze drying techniques. The quality of the dehydrated product depends on factors such as tomato variety, the total soluble solid content of the fresh product, air humidity, air temperature and velocity, the size of the tomato segments and the efficiency of the drying system. The rate of drying also affects the quality of the dehydrated product (Ghavidel and Davoodi, 2010). The objective of the study was to determine the effect of radiation and storage on the physico-chemical properties of solar dried and freeze dried tomato powder.

2. Materials and Methods

2.1. Sample collection and preparation

Forty kilogrammes (40 kg) of fresh and matured fruits of tomato (*Solanum lycopersicon* L. (var. Akoma)) were purchased from Akomadan in the Offinso North District of the Ashanti Region of Ghana, and transported in plastic crates to the laboratory. Sorting was done to eliminate injured and damaged fruits. The fruits were washed in clean water, rinsed in brine and further distilled water, after which they were divided into two parts for solar and freeze drying. For solar drying samples, the fruits were cut into two, the seeds were removed, each half was further chopped into four with an alcohol-sterilized stainless knife, arranged on alcohol-sterilized aluminium sheets and placed in a Solar dryer (2.78m x 5.45m x 16.46 m) for five days after which the dried samples (Plate a) were ground into powder with a blender (Philips Pengisar HR 2021 model) with stainless steel blades.

Samples for freeze drying were also cut into two, the seeds were removed and each half further chopped into four with an alcohol-sterilized stainless knife, blended and kept in new plain polyethylene bags and packed in a freezer till they were frozen. After freezing, samples were dried in a freeze-dryer (Vertis Consul 24 model).

Plate: (a) Solar dried tomato

Plate: (b) Freeze dried tomato powder

2.2 Irradiation of samples

Twenty grams each of solar dried and freeze dried powdered (plate b) samples was weighed into polyethylene Zip lock bags for irradiation and storage. For each dose, samples were bagged in triplicates and each set was further kept in a large zip lock bag for storage. Samples of the solar and freeze dried tomato powder were then irradiated in air at doses of 0, 1, 2 and 3 kGy at a dose rate of 2.6 kGy/h using Cobalt-60 source at the Gamma

Irradiation Facility of the Ghana Atomic Energy Commission. The Lithium fluoride photo-flourescent film (SUNNA Dosimeter System, UK) was used to determine the absorbed dose.

2.3 Storage of tomato powder

The irradiated tomato powder and their controls were kept in zip lock plastic bag and further stored in a clean box at (30±2ºC) room temperature. Solar dried and freeze dried samples were stored for 60 days. A laboratory thermometer was kept in the box to observe the temperature throughout the storage period.

2.4 Determination of moisture content of irradiated tomato powder

The moisture contents of the irradiated and non-irradiated (control) tomato powder were determined according to the method of AOAC (2000) on monthly basis. 2g of the powder were weighed into petri dishes in triplicates. The samples were dried for 2 hours at 130º C in an oven (Gallenkamp, United Kingdom). The dish, covered while still in the oven, was transferred into a desiccator and allowed to cool to room temperature before being weighed. The percentage moisture content was calculated using the formula:

$$\% \text{ Moisture} = \frac{(W_2 - W_3)}{(W_2 - W_1)} \times 100$$

Where W_1 is the weight of the empty petri dish, W_2 is the weight of petri glass and wet sample and W_3 is the weight of the petri dish and dry sample respectively (Neilson, 2010).

2.5 Determination of total soluble solids (TSS) of irradiated tomato powder

The total soluble solids of the tomato powder were determined every month using the method described in AOAC (2000). 5g each of the irradiated and unirradiated tomato powder were weighed and mixed with 50 ml of distilled water in a clean beaker. Each was filtered through a sieve of 1mm pore size. The TSS was measured using a Westover Model RHB-32ATC Hand Held Brix Refractometer. Readings were taken in triplicates after the refractometer had been calibrated (Neilson, 2010).

2.6 Determination of total titratable acidity (TTA) of the irradiated tomato powder

The titratable acidity of the tomato powder was determined every month using the method described in AOAC (2000). 10g of the irradiated and unirradiated powder was mixed with 100ml of distilled water and filtered. 10 ml of the extract was pipetted into a 25ml conical flask. The aliquot was diluted with 50 ml distilled water to minimize interference from colour. 3 drops of 1% phenolphthalein was added and titrated with 0.1M NaOH to the end point (pH=8.1±0.1). TTA was analysed in triplicate and expressed as citric acid equivalent. Acidity was computed and expressed as percent citric acid (Neilson, 2010)

$$\% \text{ acid} = \frac{\text{Titre value} \times \text{Normality} \times \text{M.eq.wt of Acid} \times 100}{\text{Volume of Sample}} \times 100$$

Milli-equivalent weight of citric acid = 0.06404

2.7 Determination of pH of irradiated tomato powder

The pH of the tomato powder was determined every month according to the AOAC (2000). 10 g of irradiated and unirradiated powder were weighed and mixed with 100ml distilled water and filtered. The pH of the filtrate was measured using a standard pH meter (Mettler Toledo Model) after it had been calibrated.

2.8 Determination of colour changes of irradiated tomato powder

Colour changes were measured every month. It was done using a Minolta Camera (CR-300 with a D65 light source; Minolta Camera Co., Osaka Japan) based on the CIELAB color parameters L*, a* and b* where L* defines the lightness and a* and b* are the chromatic components, a* defines the redness and b* defines yellowness respectively. A standard white calibration curve plate was used to calibrate the calorimeter before taking the measurements in triplicates.

2.9 Data analysis

Data were analyzed using STATGRAPHICS Centurion software and GenStat version 12. Means were separated using the least significant difference and the chosen level of significance was $p < 0.05$.

3. RESULTS AND DISCUSSION

3.1 Effect of gamma radiation and storage on the Moisture Content (%) of solar dried and freeze dried tomato powder

The moisture contents of the solar dried and freeze dried tomato powders used for the study are shown in Table 1. Significant differences ($p<0.05$) were observed between and within all factors and their interactions. Freeze dried powder recorded higher values compared to the solar dried powder. The moisture content of the solar dried samples varied between 12.55% at 0 kGy in month 0 and 14.31% at 3 kGy in month 1, while the freeze dried samples recorded values between 23.47% at 1 kGy in month 0 and 25.36% at 0 kGy in month 2. There were no significant differences ($p>0.05$) between the control and irradiated samples in the solar dried and freeze dried powder at the various doses used. The moisture content of the solar and freeze dried tomato powder increased significantly ($p<0.05$) with increasing storage period. Gamma radiation treatment did not significantly ($p>0.05$) affect moisture content however storage had a significant effect on the moisture content. This was due to difference in drying methods since the freeze dried samples were porous in nature (Abascal *et al*., 2005). This permitted the intake of moisture from the environment. Immediately after irradiation, the moisture contents of the treated and control were not significantly different in both drying methods. Upon 2 months storage, the moisture contents increased significantly in the solar and freeze dried samples. The findings in this study is similar to previous studies (Hussain *et al*., 2011; Hossain and Gottschalk, 2009; Latapi and Barret, 2006). These authors documented that moisture content in a sample increases with storage due to changes in the environment which leads to changes in the relative humidity in the packaging material.

Table 1: Effect of gamma radiation and storage on the Moisture Content (%) and Total Soluble Solids of solar and freeze dried tomato powder

Month	Doses (kGy)	Moisture Content (%)		Total Soluble Solids (%)	
		Solar dried	Freeze dried	Solar dried	Freeze dried
0	0	12.55^{aA}	23.57^{aB}	5.06^{aA}	7.33^{bcB}
	1	12.65^{abA}	23.47^{aB}	5.00^{aA}	7.73^{dB}
	2	12.54^{aA}	23.94^{abB}	5.00^{aA}	6.80^{aB}
	3	12.63^{abA}	23.78^{abB}	5.00^{aA}	7.40^{cdB}
1	0	13.22^{bA}	23.73^{abB}	5.00^{aA}	7.13^{abcB}
	1	13.84^{cA}	23.89^{abB}	5.00^{aA}	7.07^{abcB}
	2	14.23^{cA}	24.18^{bB}	5.00^{aA}	7.00^{abB}
	3	14.31^{cA}	23.88^{abB}	5.00^{aA}	7.07^{abcB}
2	0	12.94^{abA}	25.36^{cB}	4.80^{aA}	7.07^{abcB}
	1	12.79^{abA}	25.24^{cB}	5.00^{aA}	7.00^{abB}
	2	12.98^{abA}	25.07^{cB}	5.00^{aA}	7.00^{abB}
	3	12.94^{abA}	25.38^{cB}	5.00^{aA}	7.00^{abB}

LSD: Means with the different letters (within the same variety) are significantly different ($p<0.05$) from each other for each month and dose (column). Means with different letters (between different methods) are significantly different ($p<0.05$) from each other for each month and dose (row).

3.2 Effect of gamma radiation and storage on the Total Soluble Solids (TSS, %) of solar dried and freeze dried tomato powder

The total soluble solids of the freeze dried and solar dried tomato powders are shown in Table 1. Generally, significant differences ($p<0.05$) were observed between and within the drying methods and months. Solar dried powder recorded lower total soluble solids as compared to the freeze dried powder. The solar dried powder recorded total soluble solids varying between 4.80% at 0 kGy in month 2 and 5.06% at 0 kGy in month 0. There were no significant differences ($p>0.05$) between the control and irradiated solar dried powders however a sinusoidal pattern was observed in the freeze dried powder as radiation dose increased. No significant difference ($p>0.05$) was observed between the control and irradiated solar dried and freeze dried powders as storage months increased. Radiation treatment had no effect on the total soluble solids in this study. This observation was in accordance with literature (Prakash *et al*., 2002; Miller and McDonald, 1996). Low gamma radiation doses are reported not to affect total soluble solids (Patil *et al*., 2004; Hallman and Martinez, 2001).

Table 2: Effect of gamma radiation dose and storage on the pH and Total Titratable Acidity (%) of solar and freeze dried tomato powder

Month	Doses(kGy)	pH		Total Titratable Acidity	
		Solar dried	Freeze dried	Solar dried	Freeze dried
0	0	6.09^{gB}	4.18^{cA}	0.12^{abA}	0.74^{bB}
	1	6.15^{hB}	4.23^{eA}	0.11^{aA}	0.72^{aB}
	2	6.18^{iB}	4.19^{cdA}	0.11^{aA}	0.71^{aB}
	3	6.03^{fB}	4.18^{cA}	0.13^{bcA}	0.72^{aB}
1	0	5.74^{cB}	4.22^{eA}	0.14^{cA}	0.81^{cB}
	1	5.88^{eB}	4.22^{eA}	0.12^{abA}	0.84^{dB}
	2	5.79^{dB}	4.21^{deA}	0.13^{cA}	0.82^{cB}
	3	5.81^{dB}	4.19^{cdA}	0.13^{bcA}	0.71^{aB}
2	0	5.56^{aB}	4.10^{bA}	0.24^{eA}	0.99^{eB}
	1	5.64^{bB}	4.08^{bA}	0.24^{deA}	0.98^{eB}
	2	6.18^{iB}	4.02^{aA}	0.24^{deA}	0.98^{eB}
	3	6.03^{fB}	4.02^{aA}	0.23^{deA}	0.98^{eB}

LSD: Means with the different letters (within the same drying method) are significantly different ($p<0.05$) from each other for each month and dose (column). Means with different letters (between different methods) are significantly different ($p<0.05$) from each other for each month and dose (row).

3.3 Effect of gamma radiation and storage on the pH and total titratable acidity of solar dried and freeze dried tomato powder

The pH of the solar dried and freeze dried tomato powders are shown in Table 2. Significant differences ($p<0.05$) were observed in all parameters and their interactions. The solar dried powder recorded high pH values varying between 5.56 at 0 kGy in the second month and 6.18 at 2 kGy in months 0 and 2 compared to the freeze dried samples which recorded lower values between 4.02 at 2 and 3 kGy in month 2 and 4.22 at 0 and 1 kGy in month 1. The pH reduced significantly ($p<0.05$) in both drying methods as storage months increased. Total titratable acidity of the freeze dried and solar dried tomato powders are also shown in Table 2. Significant differences ($p<0.05$) were also observed within and between all the factors and their interactions. The total titratable acidity in the solar dried powders were low, varying between 0.11% at 1 and 2 kGy in month 0 and 0.24% at 0, 1 and 2 kGy in month 2; whereas the freeze dried powder recorded higher values, between 0.71 at 2 and 3 kGy in months 0 and 1 and 0.99 at 0 kGy in the second month. The TTA in the freeze dried powder decreased significantly ($p<0.05$) with increasing dose and the solar dried powder exhibited sinusoidal trends as radiation dose increased. TTA increased significantly ($p<0.05$) in the solar dried and freeze dried powder as storage months increased. Freeze dried powder recorded lower pH and higher total titratable acidity values compared to solar dried powder although they belong to the same variety. Two months after storage, the pH of the solar and freeze dried samples reduced significantly while the total titratable acidity increased significantly. This observation was in accordance with previous findings which revealed that total titratable acidity and pH were inversely related, thus as pH increases, TTA decreases and viceversa (Ajayi and Oderinde, 2013; Lui *et al*., 2010; Beck *et al*., 1990). Radiation treatment had no effect on the total titratable acidity and pH as reported by Prakash *et al*. (2002).

3.4 Effect of gamma radiation and storage on the colour of solar and freeze dried tomato powder

The colour changes detected in the solar dried and freeze dried powders after irradiation and storage are shown in Table 3. There were significant differences ($p<0.05$) between and within all the factors. L* a* and b* values are used to denote the colour changes in a sample. The L* values in the powders ranged from 32.71 at 0 kGy in month 2 to 35.87 at 3 kGy in month 1 in the solar dried powder and 31.02 at 1 kGy in month 1 to 36.97 at 3 kGy in month 0 in the freeze dried powder. Thus freeze dried samples recorded higher L* values compared to solar dried samples.

The a* values of the tomato powder varied between 6.69 and 22.02. The freeze dried powder recorded higher a* values between 15.00 at 0 kGy in month 2 and 22.02 at 3 kGy in month 0 whereas the solar dried samples recorded lower values of 6.69 at 3 kGy in month 2 to 8.95 at 1 kGy in month 0. The b* values recorded in the tomato powder ranged from 14.38 at 2 kGy in month 1 to 22.91 at 3 kGy in month 0 in the solar dried sample and 19.25 at 1 kGy in month 1 to 24.83 at 3 kGy in month 2 in the freeze dried samples. The L*, a* and b* values of the freeze dried samples were higher and significantly different from the solar dried samples. Similar observation was made by Nindo, (2008) who observed that freeze dried samples had better retention of colour in dried vegetables than solar dried samples. Immediately after radiation treatment, the L* (brightness) and a* (redness) values recorded did not follow a definite pattern; hence was not dose dependent. Two months after storage, there were significant decreases within and between L*, a* and b* values in both drying methods. The behaviour of the two drying methods were similar to earlier reports (Abano *et al*., 2012; Akdeniz *et al*., 2012; Lui *et al*., 2010; Contreras *et al*., 2008; Sharma and Le Maguer, 1996). The freeze dried samples recorded higher a* values but this did not reflect in the lycopene content because solar dried powder recorded higher lycopene values compared to the freeze dried powder. This implies that lycopene is not the only carotenoid responsible for the red colour observed in tomatoes (Zeb and Mehmood, 2004). The reduction in yellowness, b*, of solar and freeze dried samples was due to isomerization (Anguelova and Warthesen, 2000) and biochemical changes within the dried powder.

Table 3: Effect of gamma radiation and storage on the colour of solar and freeze dried tomato powder

Month	Dose (kGy)	L		a		b	
		Solar dried	Freeze dried	Solar dried	Freeze dried	Solar dried	Freeze dried
0	0	34.60^{fA}	36.52^{iB}	8.70^{hA}	21.4^{hB}	21.58^{bcA}	24.46^{cdA}
	1	35.07^{haA}	35.17^{hB}	8.95^{iA}	20.64^{gB}	22.42^{bcA}	22.79^{bcdA}
	2	35.64^{kA}	36.49^{iB}	7.88^{eA}	20.51^{gB}	22.62^{bcA}	24.00^{bcdA}
	3	35.49^{jA}	36.97^{jB}	7.91^{efA}	22.02^{iB}	22.91^{cA}	25.70^{dA}
1	0	33.91^{dA}	34.94^{gB}	8.25^{gA}	19.35^{fB}	20.09^{bcA}	22.81^{bcdA}
	1	33.52^{bB}	31.02^{aA}	8.08^{fgA}	18.47^{dB}	19.22^{bA}	19.25^{aA}
	2	34.83^{gB}	32.70^{bA}	7.97^{efA}	18.91^{eB}	14.38^{aA}	20.72^{abB}
	3	35.87^{lB}	33.72^{dA}	7.46^{dA}	18.60^{dB}	21.81^{bcA}	22.14^{abcA}
2	0	32.71^{aA}	32.70^{bA}	7.12^{cA}	15.00^{aB}	19.55^{dcA}	22.79^{bcdA}
	1	33.86^{cB}	33.03^{cA}	7.60^{dA}	15.01^{aB}	21.12^{bcA}	23.85^{bcdA}
	2	35.20^{iB}	33.86^{eB}	6.94^{bA}	16.04^{cB}	22.73^{cA}	24.63^{cdA}
	3	34.03^{eA}	34.86^{fB}	6.69^{aA}	15.23^{bB}	21.11^{bcA}	24.83^{cdB}

LSD: Means with the different letters (within the same drying method) are significantly different (p<0.05) from each other for each month and dose (column). Means with different letters (between different varieties) are significantly different (p<0.05) from each other for each month and dose (row).

4. Conclusion

The physico-chemical analysis indicated that the method of drying had a significant effect ($p<0.05$) on each parameter; nonetheless irradiation has little effect on the physicochemical properties of tomato notwithstanding the method of drying used. Irradiation had no effect on the moisture content of tomato powder during storage. Control and irradiated powder were not significantly different ($p<0.05$) during storage. The moisture content increased significantly in the control and irradiated powders with increasing storage period. Therefore irradiation had no effect on the moisture content of solar dried and freeze dried tomato powder. Freeze dried powder recorded higher colour values than the solar dried powder hence it looked very attractive and more appealing than the solar dried powder. Irradiation significantly ($p<0.05$) affected the colour but it was not dose dependent. The colour of both powders reduced significantly with storage.

Acknowledgement

The authors wish to express their appreciation to Mr. John Apatey of Radiation Technology Centre of BNARI, GAEC for allowing them to use the laboratory within his jurisdiction for the physicochemical analysis, Mr. Quarco and the technologists at the RTC (GAEC) for conducting the dosimetry and irradiation of the samples and Elder Bismark of Akomadan for providing tomatoes for the experiment.

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