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Effect of Gamma Irradiation Treatment and Storage on Physico-chemical, Microbial and Sensory Quality of Minimally Processed Pineapple (*Ananas comosus*)

Mavis Owureku-Asare[1*], Abraham Adu-Gyamfi[1], Joyce Agyei-Amponsah[1], Wisdom Selorm K. Agbemavor[1], John Bosco Adom-Mensah[1], Stanley Acquah[1], Enoch Quayson[2] and Firibu Saalia[3]

[1]Radiation Technology Centre, Biotechnology and Nuclear Agriculture Research Institute, Ghana.
[2]Department of Biochemistry, School of Biological Sciences, University of Cape-Coast, Ghana.
[3]Department of Nutrition and Food Science, University of Ghana, Accra, Ghana.

Authors' contributions

This work was carried out in collaboration between all authors. Authors MOA designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript and managed literature searches. Authors AAG, JAA, WSKA, JBAM, SA, EQ and FS managed the analyses of the study and literature searches. All authors read and approved the final manuscript.

Original Research Article

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ABSTRACT

Aims: The aim of the study was to assess the effect of gamma irradiation dose on quality attributes of minimally processed pineapple.
Study Design: Physico-chemical quality parameters such as Total Soluble Solids (TSS), Titratable Acidity (TA), pH, Total Sugars (TS), Reducing Sugars (RS), Vitamin C, as well as Sensory and microbial quality of irradiated cut pineapples were studied over a period of 12 days at 5ºC.
Place and Duration of Study: This study was carried out at the Radiation Technology Center of Biotechnology and Nuclear Agriculture Research Institute, between May and

**Corresponding author: E-mail: mowureku.asare@gmail.com;*

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Methodology: Smooth cayenne pineapples were cut into cubes and irradiated at three doses; 0, 2 and 3 kGy. Irradiated samples were stored at 5ºC for 12 days and analysed every 4th day during storage. Physicochemical analyses were also carried out according to Analysis of the Association of Official Analytical Chemists (AOAC 1990) methods. Microbial counts including total plate count, total coliform count, total yeast and moulds count and Salmonella were assessed. Sensory attributes including sweetness, colour, flavour, texture and overall preference for the cut pineapples were assessed using 30 semi trained panelists.
Results: Results showed that irradiation treatment had no significant effect (P = 0.13) on Vitamin C, TSS, TS and RS, but significantly (P = 0.03) caused changes in pH and TA. Significant decreases (P = 0.02) in vitamin C was observed during the storage period in both control and irradiated samples. Sensory evaluation revealed that irradiation at 2kGy and 3kGy did not significantly affect (P = 0.15) the ratings of any of the sensory attributes assessed.
Conclusion: Gamma irradiation was effective in reducing the overall microbial load of minimally processed pineapple. Irradiation treatments at 2 and 3kGy and storage at 5ºC for up to 8 days could enhance hygienic quality of minimally processed pineapple.

Keywords: Gamma irradiation; cut pineapples; storage; microbial quality; sensory attributes.

1. INTRODUCTION

Pineapple is the highest non-traditional export commodity for Ghana and the country produces 62,200 MTs per year, 65% of which is exported [1]. Ghana's pineapple export sector has grown rapidly between 1986 and 2002, with production increasing from 2,600 to 42,000 metric tonnes [2]. A sizable domestic market exists in addition to the export market and it absorbs a large quantity of pineapples when there is excess supply or when the produce does not meet export quality. A number of processing companies are active in producing cut pineapple and juice for urban consumers. It has become a major business for processors to minimally process pineapples and sell openly on major streets, markets, supermarkets and other public places in major cities. The rising public awareness of their health benefits of fruits has also led to this increased production and consumption in recent years [3].

Minimal processing of fruits is an alternative technology to reduce post-harvest losses and can contribute to the further development of agribusiness in Ghana. This processing helps to firstly keep the produce fresh and supply it in a convenient form, and secondly, extend shelf life and to facilitate its distribution to consumers [4]. Minimally processed pineapples (MPP) are subjected to these operations: washing, peeling, cutting, packaging and storage, and have similar quality to the fresh product. However processing the fruit also facilitates deterioration processes such as tissue softening, oxidative browning and production of undesirable flavour and odours [5], microbial spoilage [6] and requires specific storage conditions.

Concerns have also been raised about the quality of these MPP and how they are processed and marketed for consumption. A number of reports on microbiological quality of cut fruits are available, demonstrating contamination of these products with pathogenic organisms [7]. Various methods have been suggested for the surface decontamination of cut fruits which include surface treatment with chlorine water; but these have proved ineffective in complete elimination of pathogens [8,9,10].

Application of ionizing radiation for preservation of fruits and vegetables has proved effective in improving the shelf-life of fruits [11,12], and reducing spoilage. In a study conducted by [13], radiation treatment of cut pineapple with 2.0kGy did not significantly ($p<0.05$) affect its nutritional as well as sensory quality. Studies done by [13], on cut pineapple indicated that microbiological quality of fresh cut pineapple was poor (unpublished data). It was suggested that further studies with other varieties from different geographical locations be done as well. [14,15] reported that, irradiation of pre-packaged vegetables and ready to eat meals at 2.0 kGy and 3.0 kGy reduced the total viable cells to levels below the detection limit of 100 cells/g. A study by [16] revealed irradiation was more effective and ideal compared to the use of chemical preservatives in improving the microbiological quality and therefore extending the shelf life of refrigerated fresh-cut mango.

In Ghana, studies have not been conducted on the use of irradiation technology to improve hygienic quality of cut pineapple. However, due to the increasing patronage of minimally processed pineapples in the country, there is the need to conduct studies on the effective use of gamma irradiation technology as a means of preserving and enhancing the quality of freshly cut pineapples. The purpose of this work was to study the effect of Gamma irradiation treatment on the physico-chemical, microbial and sensory qualities of minimally processed smooth cayenne variety of pineapple during refrigerated storage.

2. MATERIALS AND METHODS

2.1 Sample Collection and Preparation

Smooth cayenne pineapples were purchased from a farm in the Eastern region of Ghana. The samples were transported to the laboratory; washed, peeled, and cut into identical pieces of about 3cm by 3cm. Samples were packaged in polyethylene terephthalate (PET) packs 300g each and subjected to irradiation treatment.

2.2 Gamma Irradiation of Samples

Gamma irradiation of pineapple samples was carried out in a Cobalt-60 Food Package Gamma Irradiator Facility at Radiation Technology Center of Ghana Atomic Energy Commission. Irradiation treatment from a Cobalt-60 gamma source with dose rate of 0.376Gy/s and specific activity of 7419Ci was done at two levels (2 and 3 kGy) and non-irradiated, (0kGy) as the control. Dose rate was determined using a standard Fricke dosimeter.

2.3 Storage of Irradiated Samples

The irradiated samples (2 and 3kGy) and the controls (0kGy) were stored in a refrigerator (IGNIS Model: RWN130) set at 5ºC and evaluated on the day of irradiation and at 4days interval over a total of 12 days storage period. A portable laboratory thermometer was kept in the refrigerators to monitor the temperatures throughout the storage period.

2.4 Physico-Chemical Analyses

Three hundred (300) grams of cut pieces of pineapple was blended in a warring blender and strained to obtain the juice. Vitamin C was determined by the Dichloroindophenol method AOAC [17]. The pH of the juices was evaluated using an electronic TOA pH meter (HM 305

Model, Japan). Titratable acidity (TA) was assessed as outlined in 942.15 of [17]. Total Soluble Solids (TSS) was determined using an Abbe refractometer. Total sugars (TS) and Reducing sugars (RS) were carried out according to methods outlined in [17]. All the tests were carried out in triplicates.

2.5 Microbial Analyses

Twenty five grams of sliced pineapple was aseptically homogenized in 225 ml of sterile 1% peptone water in a stomacher. Serial dilutions were made from 10^{-1} to 10^{-6} and the pour plate method was used to determine total viable count on Plate count agar (PCA), total coliform count on Violet Red Bile Agar (VRBA), total yeast and moulds count on Oxytetracycline-Glucose Yeast Extract Agar (OGYEA) and detection of Salmonella using Xylose Lysine Desoxycholate Agar (XLDA). Plating was done in triplicates and bacteria were incubated at 36±1ºC and estimated within 24hrs and 48hrs. The number of cfu/g was calculated by multiplying the number of bacteria by dilution factor. Yeast and moulds were incubated at room temperature (25ºC). Total yeast counts was estimated within 48hrs and total moulds count was estimated within 3 to 5 days. The horizontal method for detecting Salmonella sp. (ISO 6579-2002) was used for detecting *Salmonella* Typhimurium and *Salmonella* Paratyphi. Microbial analysis was done on the 1st, 4th, 8th and 12th day of storage.

2.6 Sensory Analyses

Organoleptic analysis of the pineapple samples was carried out with thirty panelists who were randomly assigned irradiated and non-irradiated samples to evaluate sweetness, colour, flavour, texture and overall preference [18]. Difference, preference and acceptability test was carried out using a 7 point hedonic scale [19].

2.7 Data Analysis

Data obtained was analyzed using STATGRAPHICS Plus, version 3.0 (Statistical Graphics Corporation, STSC Inc, U.S.A). One factor Analysis of variance (ANOVA) procedures was used to determine differences in treatment means. Fisher's least significant difference (LSD at $p < 0.05$) was used for mean separation. The mean count of total viable cells were calculated and transformed into logarithms. The mean $\log_{10}$ values and standard deviations (SD) were calculated on the assumption of a $\log_{10}$ normal distribution.

3. RESULTS AND DISCUSSION

3.1 Effect of Irradiation on Physico-Chemical Quality of Cut Pineapples during Refrigerated Storage

TSS is the amount of dissolved sugars in the fruit and it is a better indicator of sweetness level than the TS in a fruit [20]. In Table 1, the differences in TSS were not statistically significant ($P = .08$) among the treatment over the storage period and under the temperature conditions (5ºC). The highest TS were recorded by samples irradiated at 3 kGy at the end of storage. The breakdown of polysaccharides into water soluble sugars during storage might be the reason for the increase in the sugar content. However the increases in TS were not significantly ($P = .09$) caused by irradiation treatment. No significant ($P = .07$) differences in TS and RS were observed for control and irradiated samples (2kGy and 3kGy) over the storage period.

Table 1. Effect of Gamma Irradiation and storage at 5ºC on physicochemical quality of cut pineapple

Dose (kGy)	Storage day	TSS (%)	RS (g/100ml)	TS (g/100ml)	pH	TAA (%)	Vit. C (g/100ml)
0	1	13.00^{a}±0.00	3.70^{b}±3.64	9.64^{c}±4.23	3.69^{a}±0.06	0.52^{a}±0.01	34.07^{a}±4.55
	4	12.50^{a}±0.25	3.82^{b}±4.56	9.45^{c}±4.42	3.61^{b}±0.12	0.57^{b}±0.07	29.33^{ab}±3.08
	8	12.50^{a}±0.50	3.57^{b}±5.43	9.14^{c}±8.55	3.38^{c}±0.07	0.61^{c}±0.05	24.19^{b}±6.56
	12	12.00^{a}±0.02	3.72^{b}±6.47	9.10^{c}±5.66	3.30^{d}±0.02	0.64^{d}±0.03	18.63^{c}±4.65
2	1	12.00^{a}±0.0	3.64^{b}±5.77	8.74^{c}±6.23	3.71^{e}±0.23	0.45^{e}±0.02	33.95^{a}±4.29
	4	12.50^{a}±0.25	3.81^{b}±3.87	9.48^{c}±5.88	3.53^{f}±0.07	0.50^{f}±0.00	30.95^{ab}±6.65
	8	12.50^{a}±0.20	3.62^{b}±4.57	9.16^{c}±4.33	3.44^{g}±0.05	0.55^{g}±0.02	28.46^{b}±4.75
	12	12.00^{a}±0.20	3.59^{b}±3.24	9.15^{c}±6.55	3.32^{h}±0.03	0.61^{h}±0.05	24.54^{c}±4.07
3	1	12.00^{a}±0.00	3.63^{b}±5.98	8.91^{c}±5.22	3.96^{i}±0.21	0.39^{i}±0.06	33.84^{a}±4.80
	4	12.50^{a}±0.50	3.56^{b}±5.76	8.80^{c}±4.77	3.91^{j}±0.11	0.49^{j}±0.07	31.29^{ab}±4.59
	8	12.50^{a}±0.00	3.72^{b}±4.47	9.21^{c}±6.87	3.79^{k}±0.04	0.50^{k}±0.04	30.07^{b}±4.85
	12	12.00^{a}±0.25	3.65^{b}±5.08	9.07^{c}±4.66	3.64^{l}±0.02	0.55^{l}±0.03	25.00^{c}±5.32

Values are means of triplicates with a standard deviation. Mean values in a column with same superscript are not significantly different (P<.05) from each other

There was a general decrease in pH and increase in TA for irradiated and non-irradiated samples, over the storage period. The highest TA and lowest pH after 12 days of storage was 0.64±0.03% and 3.30±0.02 recorded for non- irradiated samples. Irradiation dose and storage time had significant effect (P = .07) on TA and pH of pineapple samples. Significant (P = .02) decreases in pH was observed in the non-irradiated and irradiated (2kGy) samples by 4th day of storage. However, the non-irradiated samples and samples irradiated at 2 kGy recorded higher TA and lower pH during storage, compared to samples irradiated at 3kGy. During storage of fresh fruits, senescence is enhanced by the breakdown of sugars during fermentation processes into chemical components like alcohol and carbon dioxide that contribute to reduced pH and increased acidity of the samples. The increase in acidity is an indication that spoilage and the presence of microbes like yeast are capable of metabolizing a variety of sugars through aerobic and anaerobic fermentation to increase acidity. Irradiation dose of 3kGy was most effective for preserving the quality of pineapple samples as indicated by the relatively low acidity recorded over the storage period.

There were decreases in vitamin C in both irradiated and non-irradiated samples over the storage period. Non-irradiated samples recorded the lowest vitamin C of 18.63±4.65mg/100ml at the end of the storage period. This means that samples irradiated at 2 and 3kGy retained higher vitamin C over the 12 days of storage than control samples. Samples irradiated at 3kGy recorded the highest vitamin C of 25.0 ± 5.32mg/100ml by the end of 12 day storage at 5ºC. It was found that irradiation dose did not significantly affect (P = .21) vitamin C content of the samples but storage days significantly reduced (P = .01) vitamin C of both the control and irradiated samples. [13] also observed that irradiation treatment at 2kGy had no significant effect (P> .05) on vitamin C content of cut pineapple; however storage at 8º to 10ºC significantly reduced (P< .05) vitamin C in both irradiated and non-irradiated samples. Vitamin C of pineapples ranges between 20 - 34.44mg/100ml [21]; vitamin C of pineapple samples irradiated at 2kGy and 3kGy at 12 days of storage fell within this range, but vitamin C for control (0kGy) sample fell below this range.

3.2 Effect of Irradiation on Microbial Quality of Cut Pineapples during Refrigerated Storage (5ºC)

Control samples and samples irradiated at 2kGy recorded total viable count (TVC) of 5.97 and 5.85 log10 cfu/g respectively on 12th day of storage (Table 2). These values are unsatisfactory according to microbiological guidelines published by Gilbert et al. [22] which states that TVC of ≥ 5.0 $\log_{10}$cfu/g is unsatisfactory. TVC of 3.34 - 2.46 $\log_{10}$cfu/g was recorded for samples irradiated at 3kGy on day 1 to 12th day of storage at 5ºC.Thus irradiation at 3 kGy reduced TVC in samples to nationally and internationally accepted levels of 10^4cfu/g (1.0 - 4.0 $\log_{10}$cfu/g).There was a general reduction in TCC for the control and irradiated samples over the storage period (Table 2). All MPP samples recorded coliforms counts, although the lowest was seen in cut pineapples treated with the highest dose of 3 kGY. After 12 days of storage, non-irradiated (0kGy) and 2kGy treated samples showed marginal decreases in coliform counts whereas 3 kGy treated samples recorded no coliforms. It is possible that the refrigeration condition and the low pH of pineapples prevented the growth of the coliforms that were initially present. Irradiation of samples at a dose of 3 kGy eliminated the coliforms that were initially present in the sample though the initial counts were low 3.28 $\log_{10}$cfu/g and within acceptable limits. The coliform counts reduced in all samples and decreased to marginal levels by the 12th day of storage. *Salmonella typhimurium* and moulds were not detected in both control and irradiated samples throughout the storage period. [23] reported rapid increases in both the total

microbial and yeast and mould counts in the control experiment of mango cubes after 4 days of storage at 5ºC.

Table 2. Effect of Gamma Irradiation and storage at 5ºC on Microbial quality of cut pineapple

Microbial profile	Dose	Day 1	Day 4	Day 8	Day 12
Total viable count	0	5.0±0.038	5.71±0.050	4.95±0.014	5.97±0.013
	2	4.84±0.018	4.46±0.042	4.32±0.082	5.85±0.016
	3	3.34±0.051	3.04±0.024	3.04±0.040	2.46±1.134
Total coliform count	0	4.80±0.021	4.23±0.042	3.71±0.013	2.45±0.054
	2	4.62±0.019	3.89±0.026	2.45±0.016	3.49±0.028
	3	3.28±0.307	3.43±0.619	2.00±0.275	--
Total yeast count	0	--	2.46±0.043	3.26±0.423	3.78±0.516
	2	--	2.43±0.034	3.28±0.453	3.77±0.355
	3	--	2.43±0.323	3.32±0.234	3.79±0.563
Total mould count	0	--	--	--	--
	2	--	--	--	--
	3	--	--	--	--
Salmonella	0	--	--	--	--
	2	--	--	--	--
	3	--	--	--	--

(--) micorganisms were not detected. Colony Counts were expressed as log_{10}cfu/g and each value is a mean ± standard deviation of three replicates

Generally, samples irradiated at 3 kGy over all showed appreciable decreases in microbial load over 12 day storage compared to samples irradiated at 2 kGy and the control. Total yeast count recorded was 3.78, 3.77 and 3.79 log_{10}cfu/g. The presence of yeast was characterized by slight fermentative aroma from the control samples and samples irradiated at 2 kGy. Inoculated pack studies with *Salmonella typhimurium* by [13] indicated that a dose of 2 kGy was sufficient to eliminate 5 log_{10}cfu/g of this bacterial pathogen [13]. Kent mango samples irradiated at 2.5 kGy and stored at 6ºC recorded no viable cells beyond the first day of storage [16].

3.3 Effect of Irradiation on Sensory Quality of Cut Pineapples during Refrigerated Storage (5ºC)

Sensory evaluation of both non-irradiated and irradiated pineapple samples was done over 12 days of storage at 5ºC. It was observed that the panelists could not differentiate between the control and irradiated samples (Table 3). Sensory evaluation studies revealed that irradiation dose had no significant effect (P = 0.12) on the ratings of all the sensory attributes of the samples. However storage days significantly affected the ratings of texture, taste and aroma of pineapple samples.

There were significant differences (P= 0.03) in texture, taste, colour and aroma of the irradiated samples and non-irradiated samples on the 4th and 8th day of storage. This could be attributed to the onset of senescence by the 8th day of storage. Overall acceptability scores of irradiated and non-irradiated samples on day 12 was 4.2, for control samples and 4.8, 4.1 for samples irradiated at 2kGy and 3kGy respectively; which did not represent a good product on day 12. Subjects were not allowed to score for taste and texture (by mouth feel) on day 12 because some of the samples had undergone some browning and did not

have good visual appeal. The overall general score for all sensory attributes at 8 days of storage was above 5.3 (Table 3). Comparing 5.3 on the 7 point hedonic scale, sensory quality of control and irradiated samples at 2kGy and 3kGy stored for 8 days were acceptable by the panelists. Low scores were recorded for colour and aroma on day 12 reducing the acceptability of both irradiated and non-irradiated minimally processed pineapples.

Table 3. Sensory evaluation of colour, texture, taste and aroma of cut pineapples

Dose/kG	Storage days	Colour	Texture	Taste	Aroma	Acceptability
0	1	1	5.2	5.1	4.2	5.0
	4	4	5.5	5.0	4.2	4.9
	8	8	5.0	5.5	5.3	5.7
	12	12	4.3	–	–	4.4
2	1	1	5.2	5.4	5.0	5.1
	4	4	5.3	5.2	5.1	5.1
	8	8	5.8	5.5	5.3	5.4
	12	12	4.1	–	–	4.6
3	1	1	5.0	4.6	5.0	4.8
	4	4	4.9	4.7	4.8	4.6
	8	8	5.3	5.1	5.6	5.1
	12	12	4.3	–	–	4.8

Data represents mean rank of organoleptic profile of cut pineapple samples 1–Dislike very much, 2–Dislike much, 3–Dislike moderately, 4–Neither like nor dislike, 5–Like moderately , 6–Like much, 7–Like very much. (–) Subjects did not score for taste and texture on 12th day of storage.

4. CONCLUSION

Radiation processing of minimally processed smooth cayenne pineapples at 2kGy and 3kGy did not change its physico-chemical and sensory quality. Storage days of up to 12 days at 5ºC reduced the sensory quality of both irradiated and non-irradiated samples. The microbial quality of pineapple was enhanced by irradiation as there was an overall reduction in microbial load for irradiated samples. Samples irradiated at 3kGy recorded the most reduction in microbial load (low TVC and TCC), than samples irradiated at 2kGy and control (0kGy), hence enhancing the hygienic quality of cut pineapples. However microbial quality of irradiated pineapple (2 and 3kGy) was within acceptable limits and safe for consumption for up to 8days of storage at 5ºC.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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