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Effect of γ-Irradiation on microbial and chemical composition and organoleptic qualities of fresh Zingiber officinale rhizomes

Amal N. Al-Kuraieef MSc, PhD and Amal H.Al-shawi MSc, PhD
Asst.Professor,Department of Nutrition and Food Science ,Princess NourabintAbdulrahman University, Riyadh, Kingdom of Saudi Arabia

Abstract: *A study was conducted to assess the effect of radiation on Microbiological quality , chemical composition and organoleptic qualities of fresh Zingiberofficinalerhizomes or ginger. Fresh ZingiberofficinaleRhizomes were treated by using three doses of gamma radiation, 5.0, 10.0, 15.0 KGy. The results showed that radioactive transactions have led to a significant reduction in total number of bacteria; yeast and fungi. The results also revealed that Fresh Zingiberofficinalerhizomes weresensitive to irradiation. At high doses of 10.0 KGy, moderate changes were detected at chemical composition. However, a significant difference in the texture with the dose of 15.0 KGy was observed compared with control.*
Key words: *Irradiation, Zingiberofficinalerhizomes, microbial quality, chemical composition ,organoleptic qualities.*

I. Introduction

Irradiation has the potential to enhance food safety for both fresh foods that will be consumed raw and for raw foods that will be further processed. Radiation processing of food is one of the latest methods developed for this purpose. Exposure of food material to radiation has strong advantages over conventional methods of preservation such as cold storage, fumigation, salting and drying because it does not lead to loss of flavour, odour, texture or quality. In addition, irradiation is a direct, simple and efficient one-time process (Manrique*et al*., 2005). Gamma radiation inactivates bacteria, molds, and yeasts and controls some of the biochemical and physiological changes associated with ripening, maturation, and sprouting (Urbain(1986), Diehl (1990), Diehl and Josephson (1994)). Irradiation, being a cold process, has many advantages. It is used in a very regulated manner to treat a variety of food commodities. Nine countries including India have cleared the radiation processing of *Zingiberofficinale*for sprout inhibition (ICGFI , 2004).

Ginger is the underground stem or rhizome of the plant *Zingiberofficinaleroscoe* , has been used as an important cooking spice around the world over 2000 years (Bartey and Jacobs 2000).According to McGee (2004) and Conley (1997) fresh *Zingiberofficinale*or ginger powder may be added to soups, stew and juices and in meat and vegetable dishes. The taste imparted to a dish depends upon when *Zingiberofficinale*is added during cooking. It is a more subtle flavour when added at the beginning and a more pungent taste if added at the near end.

Roots of *Zingiberofficinale*and extracts from *Zingiberofficinale*contain polyphenol compounds((6-Zingiber officinaleol and its derivatives),which have high antioxidant activity(Chen, *et al*(1986) and Herman (1994)).There are more than 50 antioxidants isolated from rhizomes of Zingiberofficinale(Masuda ,et al 2004).

Antioxidants isolated from *Zingiberofficinale*are categorised into two groups ; Zingiberofficinaleol related compounds and diarylheptanoids. Kikuzaki and Nakatani (2006)observed that the nonvolatile fraction of the dichloromethane extract of *Zingiberofficinale*rhizomes exhibited a strong antioxidant activity which was purified by chromatographic techniques to provide five Zingiberofficinaleol related compounds and eight diaryheptanoids .

The effect of gamma radiation on inhibition of sprouting in fresh*Zingiberofficinale*has been studied previously (Thomas , 1988; Yusuf, 1990; Mukherjee and Thomas , 1995; Quairel and others 2002). These reports suggested a dose of 0.12 kGy to achieve sprout inhibition and control fungal rot.

Mishre*et al*(2004) conducted radiation treatment of fresh *Zingiberofficinale*and found that radiation dose of 5 kGy and storage temperature of 10 °C are best suited for the shelf life extension of fresh peeled and packed *Zingiberofficinale*for a period of more than 2 months with superior microbiological quality. The 5-kGy irradiated samples remained free from residual microflora during storage.

There are many reports with respect to the effect of gamma radiation on dry *Zingiberofficinale*and the chemical changes associated with it (Farag and others 1995; Variyar and others 1997; Onyenekwe 2000).However, there is little information on the effect of gamma radiation at higher doses (1 to 15 kGy) on fresh raw Zingiberofficinale.

II. Materials And Methods

Selection of*Zingiberofficinale*rhizomesamples

The samples of fresh *Zingiberofficinale*Rhizomes were purchased from local market in Riyadh, Saudi Arabia .Then the *Zingiberofficinale*were washed and dried well by exposing them to air and then placed in polyethylene bags (250 grams in each bag).The bags were divided into groups to conductmicrobial qualities, chemical analysis and organoleptic qualities(five replicates for each group).

Irradiation process

Irradiation process was achieved using cobalt -60 at gamma call-220 at King Abudl Aziz City for Science and Technology (KACST) in Riyadh. The *Zingiberofficinale*samples except control were exposed to different doses of gamma radiation 5.0, 10.0, 15.0 kGy.

Assay of microbial content

Microbial content of Fresh *Zingiberofficinale*Rhizomes samples was evaluated(A.P.H.A,1985) through total plate count (TPC) of the microbial content of bacteria, yeasts, and fungi. The estimation was done by taking 10 gm of mint and applying 90 ml of sterilized physiological substance (saline) to obtain a dilution of 1/10.The required dilution was prepared and the Agar Media culture was prepared as following: agar (15g), Trypone (5g), dextrose as glucose (1g) and yeast extract (2.5g). The pH value was adjusted to 7±0.2. The Agar Media was placed in Petri dishes which have been prepared in advance, then sterilized and incubated at degrees of 35ºC for 48 hours. Five replicates after each test analysis was made and the total count was calculated for each (1 g) of the samples of radiated and non-radiated Zingiberofficinale.

Chemical analysis

The essential oils were extracted from treated samples of *Zingiberofficinale*rhizomes and then injected into the gas liquid chromatograph (GlC).

Extraction of essential oils

Fresh *Zingiberofficinale*Rhizomes samples were cleaned, cut and chopped were placed in a flask with double – distilled water. A continuous steam distillation was performed for 3h , after which the oil was isolated from the steam distillate and dried over anhydrous sodium sulphate (AOAC, 1975)

GIC analysis of volatile oils

Authentic volatile compounds were obtained from Dragoc (Holzminden , Germany) .Essential oil was analyzed by a GC pye – unicam gas chromatogramph with dual flame ionization detectors (FID) with chromate – graph fitted with a coiled glass column (1.5 mx 4 mm) and packed with diatomitec 100 – 120 mesh and coated with 10% PEGA .

The oven temperature was programmed to rise at a rate of 4° C per minute from 60°C to 180°C and the isothermal operation was held at 180°C for 15 min .

Detector and injector temperatures were 220°C and 30°C respectively. Gas flow rates for nitrogen , hydrogen and air were 30,33,30 ml/min ,respectively. The essential oils extracted were into the GLC to verify the under the peak were calculated (Farag*etal*,1989).

Assessment of Organoleptic Qualities

Organoleptic Test: Fresh *Zingiberofficinale*Rhizomes was submitted to 10 panelists for evaluation. The ranking method was used in combination with scoring based on the hedonic scale with 9 scores ranging from "dislike extremely" to "like extremely". The results were analyzed using analysis of variance (WHO ,1999 and Resurreccion*et al.*, 1995).

Data analysis

The experimental data were subjected to analysis of variance ANOVA) for the completely randomized block design that was used. Averages and least significant differences were calculated using the SAS system version 9.1.3. (Cary, NC). Results were expressed as mean ± SD (standard deviation) . The P value of <0.05 was considered significant (Ott, 1984).

III. Results And Discussion

Table 1 indicatesmicrobiological quality offresh *Zingiberofficinale*Rhizomes irradiated with various doses of γ-irradiation.

Table 1. Microbiological quality ofFresh*Zingiberofficinale*rhizomes irradiated with various doses of γ-irradiation.

Radiation Dose (kGy)	*Total Aerobic Count*	*Total yeast & mold count*
Control	4.1×10^7	75
5.0	1.2×10^3	< 10
10.0	< 10	< 10
15.0	< 10	< 10

It was observed that microbial counts were higher for fresh samples (control) than that of irradiated ones. The use of irradiation treatment might affect the microbial counts. It was noticed that gamma irradiation caused a great reduction in the tested microorganisms and this reduction was proportional to irradiation doses. The lowest irradiation dose of 5.0kGy decreased the total aerobic bacterial counts of fresh *Zingiberofficinale*rhizomes by 93%, whereas , it decreased the total aerobic bacterial counts at the dose of 10.0 and 15.0kGy to 99%. The higher reduction in total aerobic bacterial counts of*Zingiberofficinale*samples might be due to the direct effect of radiation as well as the indirect effect resulting from radiolysis which is greater in fresh samples than irradiated one.

Irradiation at doses of 1 to 10 kGy has been found to achieve a 5-log reduction of pathogenic bacteria and prolong the shelf life of fresh produce without compromising its sensory attributes (Prakash *et al*.,2000; *Foleyd et al*., 2004; Bari *et al*,. 2005). More importantly, irradiation was found to be effective in reducing viable *E coli* 0157:H7 internalized in fresh lettuce leaves and baby spinach significantly (Niemira, 2007 – 2008).

Appropriate- dose irradiation was observed to inactivate*Listeria monocytogenes*on broccoli, cabbage ,tomatoes, mung bean sprouts, *Zingiberofficinale*and diced celery (Prakash *et al*., 2000; Bariet *et al*., 2005); *Salmonella* on radish and mung bean sprous and minimally processed pineapple (Shashidhar*et al*., 2007); Listeria and Yersinia on minimally processed capsicum (Ramamurthy *et al*,. 2004). Fresh coriander (cilantro) leaves and sliced carrots (Kamat*et al*,. 2005); and total aerobic count on fresh cilantro leaves (Fan *et al*,. 2003) and diced Roma tomatoes (Prakash *et al* ,. 2002). Irradiation is a non-thermal process that can be used to improve the microbiological safety of these foods(Landgraf*et al*., 2006).

Table 2 details dose response of γ-irradiation on volatile oilsof Fresh *Zingiberofficinale*Rhizomes .It was found that the volatile oils are sensitive to irradiation.Irradiation reduces the major terpenes such aszingiberenewhich decreased from 7.00% in control to 6.05% , 5.98%and 5.43% in samples dose treated with 5,10 and 15 KGy respectively. The same trend was also observed with D,3-Corne$, β- caryophyllene,β-sesquiphellandre and α– Pinene ,as shown in table 2 . The total concentrations of identified compounds decreased gradually with increasing irradiation dose. The concentration was 99.50% in control and decreased to 90.72% ,98.46% and 97.33% after irradiation with 5,10 and 15 KGy, respectively . The results demonstrated that *Zingiberofficinale*volatile oils are radio sensitive, especially at high doses .Earlier studies showed that *Zingiberofficinale*essential oils are heat sensitive ,especially on temperatures above 90°C (Suchada,etal,2005).

Table 2 . Dose response of γ-irradiation on volatile oilsof fresh *Zingiberofficinale*rhizomes

Compounds in Zingiber officinale %	**Control**	**Doseresponse of irradiation on volatile oils (mean ± SD)**			
		5.0kGy	***10.0kGy***	***15.0kGy***	***LSD***
D, 3- Corne$	**1.49±0.24 [a]**	**1.2± 0.14 [a]**	**1.26±0.89 [a]**	**1.28±0.16 [a]**	0.36
α– Pinene	**16.09±1.17 [a]**	**14.06±1.66 [ab]**	**14.00±2.03 [a]**	**13.63±1.60 [ab]**	1.66
Camphene	**44.16±1.19 [a]**	**45.44±1.89 [a]**	**46.05±2.53 [a]**	**47.03±2.03 [ab]**	1.91
β-Pinene	**2.46±0.13 [a]**	**2.81±0.19[ab]**	**2.43±0.16 [ab]**	**2.46±0.12 [a]**	0.15
α - Phellandrene	**1.60±0.33 [a]**	**1.84±0.41 [ab]**	**1.55±0.31 [a]**	**1.28±0.22[b]**	0.32
Limonene$	**5.82±1.08 [a]**	**4.44±1.03 [a]**	**5.75±1.6 [ab]**	**4.67±1.10[b]**	1.20
β- Phellandrene	**11.33±2.71 [a]**	**12.7±2.90[b]**	**11.8±2.55 [a]**	**12.00±2.77 [a]**	2.73
Eucalyptol$$ Cineole	**7.03±1.89 [a]**	**5.68±1.44 [a]**	**6.98±1.76 [a]**	**6.66±1.45 [a]**	1.63
Isoborneol, acetate	**0.58±0.30 [a]**	**0.42±0.43 [a]**	**0.70±0.68 [ab]**	**0.75±0.63 [a]**	0.51
β- caryophyllene	**0.72±0.23 [a]**	**0.17±0.13 [ab]**	**0.99±0.45 [a]**	**1.01±0.98[b]**	0.44
Zingiberene	**7.00±1.09 [a]**	**6.05±1.12 [a]**	**5.98±1.43 [ab]**	**5.43±1.55[b]**	1.29
β- sesquiphellandre	**1.29±0.90 [a]**	**0.88±0.76 [ab]**	**1.00±0.99[b]**	**1.11±0.85 [ab]**	0.87
Total	**99.50±11.26**	**90.72±12.1**	**98.46±15.38**	**97.33±13.46**	13.05

Values having different letters in the same column are significantly different(P <0.05)

The irradiation process at low doses is considered to be a cold , physical treatment for food ,because no significant heating occurred as a result of treating the samples .Therefore , irradiation has no effect on flavour

compounds directly. However it can affect the flavour indirectly by oxidation or hydroxylation of the terpene aromatic ring with the production of free radicals from the water present infood(Urbain,1986).These radicals can react with terpenes to produce terpene alcohols as indicated in the study with γ-irradiation of Zingiberofficinale. On the other hand , terpenes,which were incorporated in most of the essential oils, had the same skeleton structure but differed in their functional groups , such as -OH,-CHO or -COOH .therefore, configurational changes can occur ,following high dose irradiation, including changes in the position of the double bond and the functional group to produce different compounds (Farkas, et al,1983).

The organoleptic qualities(appearance, color, odor, taste, texture, overall quality) of the irradiated *Zingiberofficinale*rhizome samples were assessed by the trained panelists on *Zingiberofficinale*irradiation. The score of hedonic scale test were analyzed by analysis of variance as shown in Table 3.

Table 3 Organoleptic qualities of fresh *Zingiberofficinale*rhizomes irradiated with various doses of γ-irradiation(n=5)

Dose kGy	*Mean Organoleptic scores(*±SD)					
	Appearance	*Color*	*Odor*	*Taste*	*Texture*	*Overall quality*
Control	9.0± 0.10 [a]	9.0± 1.01[a]	9.0± 1.41[a]	9.0± 1.31[a]	9.0± 1.10[a]	9.0± 1.20[a]
5.0	9.0± 0.20 [a]	8.25±1.60[ab]	8.95±1.10[ab]	8.75± 1.80[a]	8.25± 1.60[ab]	8.50± 1.22[ab]
10.0	9.0± 1.20 [a]	8.50± 1.20[ab]	8.75± 1.70[ab]	8.95± 1.20[a]	8.50± 0.60[ab]	8.75± 1.18[ab]
15.0	8.75± 1.0 [b]	8.0± 1.8[b]	8.50± 1.30[ab]	8.50± 1.50[a]	7.50± 2.20[b]	8.25± 1.58[ab]
LSD	0.65	1.15	1.37	1.25	1.35	1.39

Values having different letters in the same column are significantly different (P < 0.05)

From Table 3 it was observed that doses of 5.0 and 10.0 kGy indicated no effect on the organoleptic qualities of *Zingiberofficinale*Rhizomes. However, a significant reduction in the texture with the dose of 15.0 KGy was observed.Therefore, beyond this dose of irradiation,treatment may not be suitable for *Zingiberofficinale*Rhizomes.

Earlier studies indicated that Gamma radiation could cause injury to succulent vegetables which are sensitive to irradiation(Bandekar*et al*., 2003; Suchada*et al*., 2005). Hagenmaier and Baker (1997) . Gunes*et al*., (2001) observed changes in the texture of vegetables and fruits exposed to various doses of irradiation.This could be due to biological variations among the samples. Irradiation has been associated with softening of plant tissues, specificallywith degradation of polymers such as pectin and cellulose(Prakash *et al*.,2002).

Horak*et al*(2006) found that the disinfection doses were effective in fresh pre-cut vegetables during storage time and they did not affect the sensorial properties.

IV. Conclusion

To sum up, Gamma irradiation caused a great reduction in microorganisms and this reduction was proportional with irradiation dose.moderate changes were detected at doses (5 and 10 KGy) for volatile oil *Zingiberofficinale*but was sensitive to irradiation especially at 15.0 KGy dose.

The results of the present study indicated that the use of irradiation is a suitable method for food preservation without changes in sensory qualities.However it was also observed that dose level above 15.0KGy can affect the texture and freshness adversely.

Accordingly, the present study recommends utilizing γ-irradiation for preservation of *Zingiberofficinale*Rhizome and other vegetables. Further, work is needed to evaluate the in vivo assays after feeding the experimental animals on the irradiated food stuff.

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