Effects of γ Irradiation on the Volatile Compounds of Ginger Rhizome (*Zingiber officinale* Roscoe)

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Gingers were irradiated at a dose of 0.05 kGy to inhibit sprouting and conserve quality. Effects of γ irradiation on the flavor compounds of ginger were studied. After 3 months of storage after irradiation, the quantities of some major volatile compounds such as α-zingiberene, α-bergamotene, neral, geranial, and α-curcumene were significantly lower in irradiated than in unirradiated ginger, although no difference was found immediately after irradiation. A triangle test showed no difference between irradiated and unirradiated gingers stored for 1 month at ambient temperature but showed significant difference after 5 months of storage.

Keywords: *γ irradiation; volatile compound; ginger rhizome*

INTRODUCTION

Nutrition and weight loss occur in stored ginger rhizome due mostly to sprouting. Irradiation with a dose of 0.08 kGy could inhibit sprouting (Yang et al., 1979). Yusof (1990) found that gingers irradiated with 0.05 kGy and stored at 25–28 °C, 76–96% relative humidity (RH), could be maintained at good quality for 4 months. Gingers harvested in December in Taiwan and wrapped in net packages could be stored for 4 months at 13 °C, 75–80% RH (Liu et al., 1982). Cold storage (15 °C, 78–85% RH) could delay sprouting and weight loss of ginger (Shukor et al., 1986). However, after irradiation, gingers would be economically stored at ambient temperature. We found that the flavor of dried shiitake mushroom was affected by irradiation (Lia et al., 1994). The volatile components were decreased after medium-dose (5–10 kGy) irradiation. On the other hand, recently we found that some volatile compounds of fresh shiitakes were increased after low-dose (1 kGy) irradiation (unpublished data, 1994). The data seemed to show that the flavor compounds (small molecules) were induced or produced from some precursors (large molecules) decomposed by low-dose irradiation. Although the volatile compounds of gingers have been reported (Sheen et al., 1990), we thought it of interest to study the effects of irradiation on ginger flavor in this work.

EXPERIMENTAL PROCEDURES

Ginger Irradiation. Gingers (*Zingiber officinale* Roscoe Da-mor) were harvested by and purchased from a farmer in Taidon, Taiwan, in December. After curing for 1 month at ambient temperature, a total of 23 kg of gingers in paper cases (25 × 100 cm) were irradiated with 0.05 kGy irradiation at the Institute of Chemistry Industry, Hsinchu, by a ^{60}Co source with 152 000 Ci (2.6 × 10^5 rad/h). The gingers, irradiated and unirradiated, were then stored at ambient temperature (25 °C) for examining the quality and flavor.

Analysis of Volatile Compounds. One hundred fifty grams of ginger, unirradiated and irradiated, were extracted in 150 mL of phosphate buffer (0.1 M, pH 7.0) and blended for 5 min with a homogenizer. Volatile compounds of ginger were collected by a Likens–Nickerson apparatus (Romer et al., 1974) for 2 h with extracting solvent (70 mL of pentane and ether, 1:1). The extracts were dried with anhydrous Na_2SO_4 and concentrated by a spinning-band distillation apparatus. A GC-9A (Shimadzu) with Chrompack fused silica capillary column CP-Wax 52CB (0.32 mm × 50 m) was used with hydrogen as carrier gas in combination with an FID detector with a flow rate of 1.5 mL/min. Injector temperature was 250 °C. The column was maintained at 50 °C for 10 min and then heated to 200 °C at a rate of 1.5 °C/min. The final temperature was held for 40 min. An aliquot of 3 μL of *n*-nonane (2.22 mg/1.5 mL of pentane–ether = 1:1) was added to extracts of ginger as an internal standard. The volatile compounds were further examined by Finnigan-MAT PSQ-70 GC–MS. Operational parameters were as follows: carrier gas, He; electron energy, 70 eV; electron multiplier voltage, 1500 V; ion source temperature, 120 °C. Analysis of volatile compounds was performed after 1 and 3 months of storage after irradiation.

Triangle Test. Slices of ginger (100 g) were boiled with 20 g of sucrose and 1500 mL of water for 20 min for making a traditional Chinese ginger soup for panel triangle test. The test was performed according to perfume, taste, pungency, and color of the ginger soup by a panel of 14 persons. A triangle panel test was performed as described by James (1986). The results show a significant difference at a 1% level when 10 or more of 14 persons can recognize the difference between the irradiated and unirradiated gingers.

RESULTS AND DISCUSSION

The major volatile components of ginger (*Z. officinale* Roscoe Da-mor) were α-terpinene (12%), α-bergamotene (12%), geranial (11%), 1,8-cineole (9%), neral (7%), farnesene (6%), β-sesquiphellandrene (6%), β-phellandrene (5%), α-curcumene (4%), α-pinene (4%), myrcene (3%), nerol (2%), and α-zingiberene (1%) (Table 1). Volatile compounds such as neral, geranial, β-sesquiphellandrene, α-curcumene, and geranyl acetate offered the most contribution to ginger flavor (Sheen et al., 1990). Although the ginger quality was not very homogeneous, the sampling was relatively difficult, and the standard errors were high, the actual chemical changes instead of experimental errors were considered. The volatile compounds of irradiated gingers sampled immediately or 1 month after irradiation had the same GC profile (Figure 1) as unirradiated gingers. However, after 3 months of storage, the quantity of the volatile

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0021-8561/94/1442-2574$04.50/0

Table 1. Effects of 0.05 kGy γ Irradiation on Volatile Components (Micrograms per Kilogram of Ginger) of Gingers

				storage		
peak no.[a]	compound	Kovats index[b]	treatment[c]	0 months	1 month	3 months
1	nonane	904	unirr	I.S.[d]	I.S.	I.S.
			irr	I.S.	I.S.	I.S.
2	α-thujene	1016	unirr	1 ± 1[e]	2 ± 1	3 ± 0
			irr	2 ± 1	3 ± 1	2 ± 0
3	α-pinene	1034	unirr	25 ± 17	45 ± 14	56 ± 7
			irr	40 ± 21	62 ± 20	53 ± 6
4	α-terpinene	1080	unirr	83 ± 45	136 ± 40	170 ± 1
			irr	116 ± 37	186 ± 60	160 ± 3
5	camphene	1115	unirr	5 ± 3	9 ± 2	10 ± 1
			irr	9 ± 3	12 ± 4	10 ± 1
6	myrcene	1171	unirr	23 ± 9	38 ± 10	42 ± 2
			irr	37 ± 13	46 ± 17	46 ± 6
7	limonene	1187	unirr	21 ± 3	22 ± 7	31 ± 2
			irr	25 ± 8	29 ± 13	28 ± 3
8	β-phellandrene	1219	unirr	68 ± 4	59 ± 6	81 ± 8
			irr	92 ± 13	76 ± 21	97 ± 34
9	1,8-cineol	1221	unirr	85 ± 36	126 ± 31	134 ± 1
			irr	148 ± 38	163 ± 59	136 ± 7
10	terpinolene	1290	unirr	4 ± 2	6 ± 1	6 ± 0
			irr	5 ± 1	7 ± 3	6 ± 1
11	2-heptanol	1303	unirr	7 ± 2	9 ± 4	19 ± 10
			irr	10 ± 8	18 ± 3	25 ± 7
12	6-methylhept-5-en-2-one	1332	unirr	18 ± 9	21 ± 3	19 ± 7
			irr	33 ± 11	16 ± 6	20 ± 0
13	2-nonanone	1384	unirr	3 ± 1	2 ± 0	3 ± 0
			irr	2 ± 1	2 ± 0	3 ± 1
14	citronellal + α-copaene	1475	unirr	4 ± 1	8 ± 6	5 ± 0
			irr	7 ± 4	6 ± 3	7 ± 1
15	unknown	1500	unirr	6 ± 2	3 ± 1	5 ± 1
			irr	4 ± 1	5 ± 1	6 ± 2
16	linalool	1530	unirr	16 ± 2	13 ± 1	14 ± 2
			irr	26 ± 9	14 ± 4	16 ± 4
17	caryophyllene	1593	unirr	7 ± 6	7 ± 2	7 ± 0
			irr	8 ± 1	7 ± 2	9 ± 3
18	citronellyl acetate	1660	unirr	32 ± 5	24 ± 4	11 ± 1
			irr	14 ± 11	17 ± 7	19 ± 3
19	neral	1679	unirr	155 ± 10	135 ± 19	140 ± 14
			irr	204 ± 48	113 ± 47	81 ± 13
20	α-zingiberene	1683	unirr	31 ± 5	20 ± 3	23 ± 1
			irr	29 ± 5	21 ± 9	14 ± 0
21	α-bergamotene	1734	unirr	270 ± 16	227 ± 35	234 ± 44
			irr	374 ± 65	212 ± 88	115 ± 6
22	geranial	1745	unirr	216 ± 12	147 ± 38	117 ± 19
			irr	151 ± 86	160 ± 80	106 ± 13
23	α-curcumene	1746	unirr	95 ± 20	66 ± 22	47 ± 16
			irr	45 ± 15	57 ± 28	27 ± 1
24	farnesene	1760	unirr	109 ± 10	67 ± 22	57 ± 15
			irr	105 ± 61	81 ± 37	46 ± 22
25	geranyl acetate	1766	unirr	8 ± 1	5 ± 0	4 ± 1
			irr	4 ± 2	5 ± 2	5 ± 0
26	β-sesquiphellandrene	1789	unirr	233 ± 110	88 ± 28	86 ± 19
			irr	94 ± 47	88 ± 40	75 ± 17
27	nerol	1826	unirr	35 ± 14	30 ± 6	38 ± 21
			irr	90 ± 20	38 ± 19	35 ± 8
28	geranyl 2-methylpropanoate	2018	unirr	11 ± 4	6 ± 3	3 ± 0
			irr	7 ± 3	6 ± 3	3 ± 1
29	unknown	2098	unirr	10 ± 4	5 ± 2	2 ± 0
			irr	5 ± 3	4 ± 2	4 ± 0
30	elemol	2211	unirr	7 ± 3	3 ± 1	2 ± 1
			irr	4 ± 1	3 ± 2	3 ± 1

[a] Peak numbers refer to Figure 1. [b] Linear retention index determined on CP-Wax 52CB column by using *n*-paraffin (C_6–C_{25}) as references. [c] Irr, irradiated; unirr, unirradiated. [d] I.S., internal standard. [e] The values are shown as mean ± standard error.

compounds of irradiated gingers such as α-zingiberene, α-bergamotene, neral, geranial, and α-curcumene were significantly decreased (Table 1). In our previous studies the total volatile compounds of dry shiitake (*Lentinus edodes* Sing) were also decreased by more than 50% after irradiation with a dose of 5 or 10 kGy (Lai et al., 1994). This suggested that irradiation affected the stability of volatile compounds during storage. The unstable compounds were easily decomposed and became other small compounds. An optimal dose of irradiation increased the levels of volatile compounds, but decreases resulted from high (5 or 10 kGy) doses (Lai et al., 1994). During storage after irradiation, neral was the most unstable of the key compounds of ginger flavor. However, according to the results of the triangle test, the perfume, taste, pungency, and color of ginger soup were not different from those of unirradiated ginger after 1 month of storage after irradiation (Table 2), although 5 months after irradiation, the ginger soup showed a significant difference in flavor, taste, and color

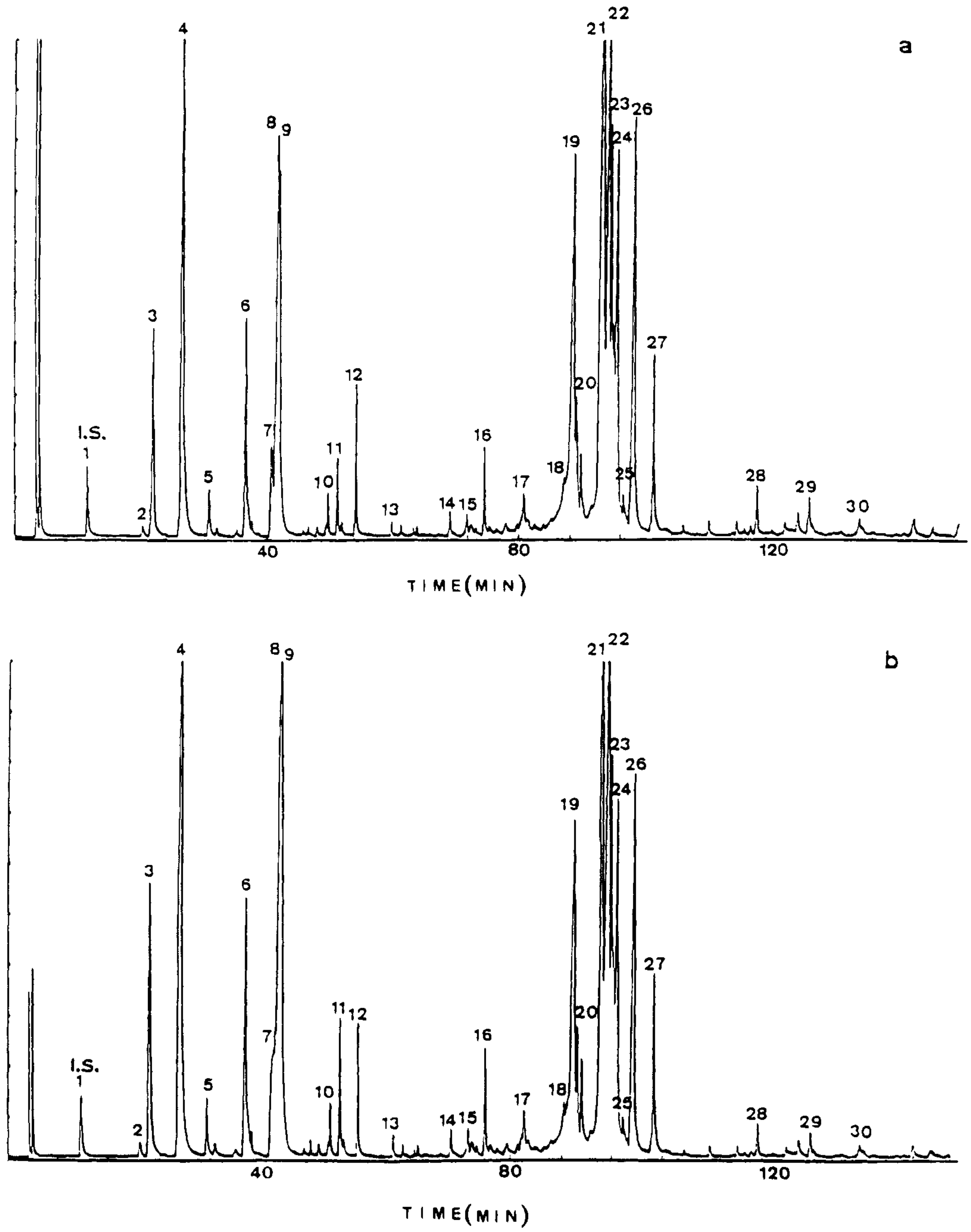

Figure 1. Capillary gas chromatograms of the volatile components of gingers unirradiated (a) and irradiated (0.05 kGy) (b). Peak numbers refer to Table 1.

Table 2. Sensory Evaluation of Soup of Gingers Irradiated (0.05 kGy) and Unirradiated

sensory evaluation	storage (months)	flavor	taste	pungent	color
triangle test[a]	1	5/14	4/14	5/14	4/14
	5	10/14[b]	10/14[b]	7/14	14/14[b]

[a] Fourteen panelists performed the test. [b] Means significantly different at the 1% level, when 10 or more of 14 panelists could tell the difference between the gingers irradiated and unirradiated.

between the unirradiated and irradiated samples. After irradiation, the volatile compounds became unstable and a loss of flavor occurred during storage. One or three months after irradiation, the change (decrease) of the volatile components was successfully detected by chemical analysis (GC−MS) but not by triangle test. Five months after irradiation, the change of the flavor quality was noted as a significant difference by the panel of the triangle test. The data of the panel test could show the difference between irradiated and unirradiated samples but could not indicate if the flavor of the irradiated sample was of a higher or lower flavor quality. According to the data from the chemical analysis (Table 1), the volatile components decreased after irradiation; therefore, the gingers should provide a lower flavor quality 5 months after irradiation. In ginger, irradiation in a low dose of 0.05 kGy did not offer a benefit for flavor, taste, and color after long-term storage but instead induced the loss of flavor, taste, and color, although the treatment could inhibit sprouting.

ACKNOWLEDGMENT

This work was supported by a grant from the Atomic Energy Council of the Republic of China. We thank Dr. Chung-May Wu, Ms. Shu-Er Liou, and Mr. Ming-Chin Wang, FIRDI, for technical assistance and Mr. Yih-

Tsann Chen, Institute of Chemistry Industry, for performing irradiation.

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Received for review April 26, 1994. Revised manuscript received August 18, 1994. Accepted September 2, 1994.[⊗]

[⊗] Abstract published in *Advance ACS Abstracts*, October 15, 1994.