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Effect of Gamma Irradiation and Fumigation on the Biological Qualities of Green, Black, and Oolong Teas

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Abstract The biological qualities of green, black, and oolong teas were monitored by observing their microbial decontamination and insect disinfestation following gamma irradiation (0-10 kGy) and fumigation (MeBr or PH_3) during 6-month storage at room temperature. *Plodia interpunctella* Hubner was found as an important quarantine pest in teas used. In a comparative study, both treatments were found to be effective in disinfecting the stored samples. An irradiation dose of 5 kGy was sufficient to control all microorganisms related to the quality of teas, while fumigation with methyl bromide and phosphine showed no appreciable decontamination effect on the microorganisms. As a result, irradiation was found an effective alternative to fumigants for the improvement of biological tea qualities during storage.

Keywords: teas, irradiation, fumigation, decontamination, disinfestation

Introduction

Of the various kinds of tea widely consumed all over the world, most are produced from the same plant species, *Camellia sinensis* L. According to the manufacturing process, most teas are classified into three major categories, non-fermented green tea, partially fermented oolong tea, and fully fermented black tea (1). Numerous studies have demonstrated that aqueous extract or the major polyphenols of tea possess antimutagenic, antidiabetic, antioxidant, antibacterial, anti-inflammatory, antitumor, hypocholesterolemic, and above all, cancer-preventive activities in a variety of experimental animal model systems (2, 3). In spite of all the beneficial effects, teas, like other plant materials, are prone to microbial contamination and insect infestation during storage and marketing, resulting in quality deterioration and trade barriers. Some decontamination methods are, therefore, of considerable concern in terms of economic, public health, and environmental aspects (4).

Teas contaminated with microorganisms and infested with *Plodia interpunctella* (Hubner) may be controlled with methyl bromide (MeBr) or hydrogen phosphide (phosphine, PH_3) (4, 5). Despite low residues, however, fumigation may not be desirable from the viewpoint of human health and environmental concerns. More importantly, MeBr can deplete the ozone layer and will therefore be phased out for most uses by 2005 in developed countries (4). Phosphine is the only fumigant, other than methyl bromide, which is widely registered and permitted for disinfestation of most durable commodities. Nevertheless, as it ranks as one of the current most toxic fumigants, an alternative is required (5). In this regard, irradiation is recommended as the possible alternative in controlling microorganisms and insects in teas. Different countries including Yugoslavia, Brazil, South Africa, Croatia, Ghana, and Mexico have approved the use of irradiation at a dosage of between 1 and 10 kGy for the disinfestation and microbial control of herbal teas and tea extracts (6). The present work investigated the comparative effects of gamma irradiation and fumigation on the microbial and pest control of green, black, and oolong teas after 6 month storage at room temperature.

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Materials and Methods

Irradiation and fumigation of teas Green (Korea), black (Sri Lanka), and oolong (China) tea samples, containing 3.62, 6.07, and 2.22% moisture content, respectively, were purchased from H. Tea Co., Gwangju, Korea. Samples were packed in commercial polyethylene film (0.08 mm) prior to irradiation. Gamma irradiation was carried out in a ^{60}Co irradiator (AECL, IR-79, MDS Nordion International Co. Ltd., Ottawa, ON, Canada) at Korea Atomic Energy Research Institute (KAERI), Daejon, Korea. The applied dose levels were 0 to 10 kGy and the target doses were assured by ceric/cerous dosimeter (±5.6%). Chemical fumigation was performed under commercial conditions at 27°C for 48 hr at 15 g/m^3 for MeBr and 27°C for 96 hr at 3 g/m^3 for PH_3, before packaging (4). All treated tea samples were stored at room conditions (15±12 °C) for 6 months.

Microbiological analysis All microbiological media used in this study were purchased from Difco Laboratories (Detroit, MI, USA). Total aerobic bacteria were enumerated by the spread plate method using standard plate count agar and incubated at 37°C for 20 hr. Yeasts

and molds were enumerated by the spread plate method using potato dextrose agar and incubated at 30°C for 2 days. Coliforms were enumerated by the pour plate method using desoxycholate agar and incubation at 37°C for 48 hr (7). All samples were used at 0 and 6 month of storage counts were recorded as colony-forming units (CFU)/g sample.

Pest identification and survey on mortality Pest identification and survey on mortality were performed based on the Checklist of Insects from Korea (8). The teas were infested with *Plodia interpunctella* Hubner and the larvae of this pest were reared on the teas for 3 weeks at 25°C and 60-70% RH. The disinfecting effects of irradiation and fumigation were observed for the treated samples during storage (n=30).

Results and Discussion

Microbiological qualities The results of the microbiological survey for green, black, and oolong teas are shown in Table 1. The total bacterial count was 5.0×10^2, 2.0×10^2, and 2.8×10 CFU/g in untreated green, black, and oolong teas, respectively. The low bacterial contamination in the tea samples may have arisen because of the antibacterial (9) and antimicrobial (10, 11) properties, as well as the lower water activity (12). The number of yeasts and molds was 1.2×10, 2.2×10^2, and 1.0×10 CFU/g in untreated green, black, and oolong teas, respectively. Regardless of the tea variety (fully fermented black tea, partially fermented oolong tea or non fermented green tea), the moisture content of the tea leaves was dramatically reduced from about 75% at the beginning of the tea making process to 5% in the finished tea. The final water activity of less than 0.1 in the freshly made tea (12) is not favorable for the growth of microorganisms. Due to the hygroscopic nature of the tea samples (13) during 6 month storage, the increased microbial loads were enumerated in the tea samples (Table 1). However, coliforms were not detected in any of the tea samples.

In comparing the effects on microorganisms, irradiation at 5 kGy was sufficient to destroy total bacterial count and yeasts and molds, whereas fumigation with methyl bromide or phosphine exhibited only a small influence on the changes in the microbial population of green, black, and oolong teas. Kwon *et al.* (14) reported that 5 kGy gamma irradiation was enough to destroy the yeasts and molds and coliforms contaminated in ginseng products. In another study on the comparative effects of irradiation and PH_3 fumigation on white ginseng, 5 kGy irradiation was demonstrated to be sufficient to control coliforms, as well as yeasts and molds, and to reduce total bacterial count by more than 3 orders of magnitude whereas fumigation showed little effect on microbial population (15). Chun *et al.* (16) reported that gamma irradiation was effective for growth inhibition or destruction of yeasts and molds in *kochujang*. Kwon *et al.* (17) also found a similar result for electron-beam irradiated *meju* and soybean paste.

Pest identification and mortality *Plodia interpunctella* Hubner, Indian meal moth, was identified as a major target pest in teas, and is well recognized as one of the most important pests for stored products. It is a cosmopolitan pest that not only attacks a wide range of stored cereal products (18-20), but also other food products including dried vegetables (21), groundnuts (22), dried fruits and almonds (23), pistachios and walnuts (24), raisins and prunes (25), processed foods (26), and white ginseng (27). Teas were exposed to fumigation with MeBr and PH_3, as well as gamma irradiation at low doses (0-0.5 kGy) or relatively high doses (1-3 kGy), to determine their inactivation effect on *P. interpunctella*. The comparative

Table 1. Comparative effects of gamma irradiation and fumigation on the microbial population of dried teas after 6 month storage at room temperature

Microorganism[1)]	Sample	Storage period (month)	Treatment				
			Control	5 kGy	10 kGy	MeBr	PH_3
Total bacterial count	Green tea	0	5.0×10^2	0	0	2.1×10^2	3.0×10^2
		6	2.3×10^3	0	0	3.3×10^2	1.3×10^3
	Black tea	0	2.0×10^2	0	0	2.8×10^2	3.1×10^2
		6	3.8×10^2	0	0	3.3×10^2	6.1×10^2
	Oolong tea	0	2.8×10	0	0	3.0×10	2.6×10
		6	3.5×10^3	0	0	1.9×10^2	1.6×10^2
Yeasts and molds	Green tea	0	1.2×10	0	0	1.8×10	2.2×10
		6	3.0×10^2	0	0	6.3×10^2	1.3×10^3
	Black tea	0	2.2×10^2	0	0	3.1×10	2.6×10^1
		6	2.5×10^2	0	0	3.3×10^2	1.0×10^2
	Oolong tea	0	1.0×10	0	0	N.D[2)]	N.D
		6	2.7×10^3	0	0	1.2×10	1.5×10

[1)]Microbial count is expressed as colony forming unit (CFU) per g of sample.
[2)]Not detected (the minimum detection level was 10 CFU/g of the sample).

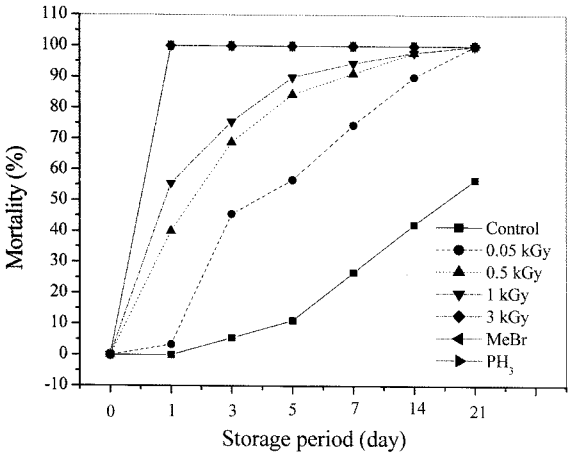

Fig. 1. Mortality of *P. interpunctella* adult by gamma irradiation and fumigation after 6 month storage at room temperature (n=30).

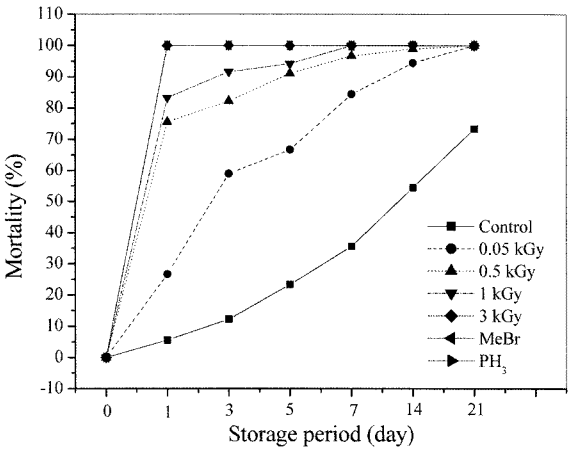

Fig. 3. Mortality of *P. interpunctella* deutolarva by gamma irradiation and fumigation after 6 month storage at room temperature (n=30).

effects of fumigation and irradiation on adult insect are presented in Fig. 1. At a dose of 0.5 kGy, all insects survived after irradiation but a mortality rate was approximately 40% when observed after 24 hr. A mortality rate of 90% was observed at the 14th day and the insects were totally eliminated by the 21st day. In the case of pupa (Fig. 2), an irradiation dose of 0.5 or 1 kGy resulted in a mortality rate of 40 or 60%, respectively, after 24 hr of treatment. Deutolarva and protolarva were more sensitive to gamma irradiation than adult and pupa were, resulting in 75 and 60% mortalities after 24 hr and 100% mortality after 7 and 5 days, respectively (Fig. 3 and 4). Fumigation with MeBr and PH_3 resulted in 100% mortality of *P. interpunctella* after treatment in tea, while irradiation at 0.5 kGy or less showed the same mortality after 3 weeks of storage. The total mortality rate remarkably increased at higher irradiation doses, reaching 100% immediately after irradiation at 3 kGy, which is a very high dose compared to the typical doses required for sexual sterility (28, 29). There are three concepts for using

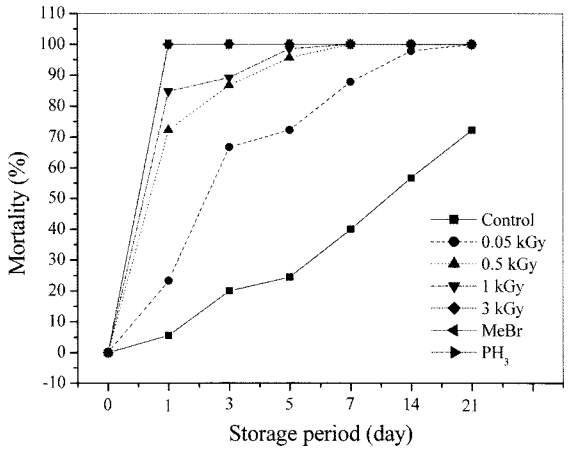

Fig. 4. Mortality of *P. interpunctella* protolarva by gamma irradiation and fumigation after 6 month storage at room temperature (n=30).

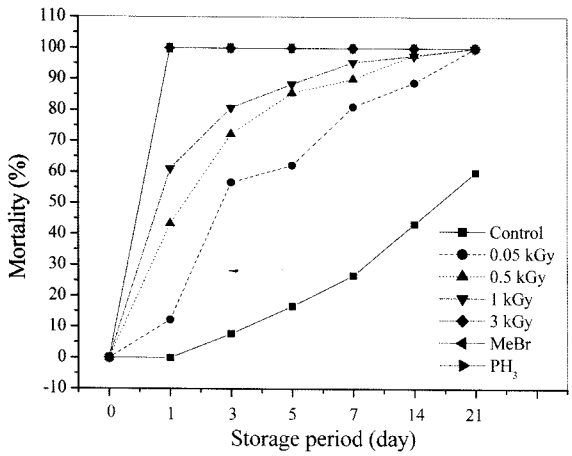

Fig. 2. Mortality of *P. interpunctella* pupa by gamma irradiation and fumigation after 6 month storage at room temperature (n=30).

irradiation as a quarantine treatment for controlling pests: sexual sterility reproductively, "Probit-9" security, and total mortality (28-30). Since "Probit-9" security, however, is being applied in the current quarantine regulation for the export or import of products, the concept of total mortality was used in this work. These results were in good agreement with the report on the quarantine and quality security of chestnuts exposed to gamma irradiation and chemical fumigation (31).

In conclusion, gamma irradiation at a level of 5 kGy was found to be effective in improving the hygienic quality of dried teas. Therefore, irradiation shows promise as a potential alternative (32) to MeBr or PH_3 fumigation for both disinfection and microbial decontamination of green, black, and oolong teas while still retaining their overall qualities.

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