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Changes in the Components of Red Ginseng after Irradiation and the Korean Consumer's Perception of Irradiated Food

Yoon-Seok Choi[1], Jung-Min Kim[1], Eun-Ok Han[2]

[1]Department of Bio-convergence Engineering, Korea University, Seoul, Korea; [2]Department of Education and Research, Korea Academy of Nuclear Safety, Seoul, Korea

ABSTRACT

Background: We examined changes in red ginseng components after different doses of irradiation were applied. We also evaluated what housewives and teachers know about irradiated food, as well as their perceptions of and attitudes toward it.

Materials and Methods: General nutrients and unique components of irradiated ginseng were then analyzed. Education on irradiated foods and red ginseng was provided to teachers and housewives on two occasions, and changes in their behaviors were evaluated via a qualitative survey.

Results and Discussion: The ideal radiation dose to reduce the number of bacteria without changing the unique components of red ginseng is 7.5 kGy. Notably, after educational seminars on this topic, consumers' knowledge, attitudes toward, and perceptions of irradiated ginseng compared to non-irradiated red ginseng changed significantly.

Conclusion: It is necessary to provide consumers with information on irradiated foods to promote the growth of the domestic food industry, and to improve public knowledge of the safety and effects associated with the irradiation of food.

Keywords: Red Ginseng, Irradiated Food, Education, Consumer, Perception

Original Research

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Corresponding author: Eun-Ok Han

Department of Education & Research,
Korea Academy of Nuclear Safety,
260 Songpa-daero, Songpa-gu,
Seoul 05719, Korea
Tel: +82-2-554-7336
Fax: +82-2-508-7941
E-mail: haneunok@gmail.com

Introduction

The oldest pharmacological work, entitled "Shinnongbonchogyeong (神農本草經)", was written about 4,500 years ago and states that ginseng is innocuous, protects the five viscera, and invigorates the body [1]. The bioactive effects of ginseng include its effects on the cardiovascular, immune, and nervous systems as well as other clinical effects, such as detoxification, antitumor activity, and antidiabetic activity [2-7]. The primary bioactive substances of ginseng include ginseng saponins (ginsenosides), polyacetylenes, acidic polysaccharides, ginseng proteins, and phenolic substances [8-10]. When fresh ginseng is steamed for 2 hours and then dried, it becomes red ginseng; the heat generated during this process produces the unique components of red ginseng, including saponin components, such as ginsenosides Rg2, Rg3, Rh1, and Rh2. The unique saponin components of red ginseng are effective for preventing cancer, inhibiting cancer cell growth, decreasing blood pressure, protecting brain cells, enhancing learning ability, and inducing antithrombotic activity and sulfation [11-24]. Based on

these characteristics, red ginseng is a major export product and is well known among consumers as an effective natural medicine with few adverse side-effects [25].

The quality of red ginseng products is relatively uniform because these products are produced mostly by the Korea Tobacco and Ginseng Corporation. However, long-term storage or distribution of raw red ginseng materials may result in deterioration of their biological quality due to the presence of insecticides or microbes. To address this problem, chemical fumigants are typically used. Alternatively, irradiation may be used to improve the safety of storage, distribution, and consumption of red ginseng, assuming consumers accept this method of this treatment. In Korea, irradiation with 7 kGy or less has been legally approved for the sterilization of ginseng (including red ginseng) products since 2004 [26]. The World Health Organization views the irradiation of food products as the safest and most effective food processing method and as an acceptable approach to decrease the spread of foodborne illnesses worldwide [27]. Food irradiation technology has been proven to display outstanding food sterilization, insecticide, germination inhibition, maturity regulation, and property improvement effects, since the early 20th century, when this parasite extermination method was first patented. Later the safety of irradiated food products was officially recognized by various international organizations, including the Food and Agriculture Organization, the International Atomic Energy Agency, and the World Health Organization. After irradiation with 10 kGy or less, the processed food products do not exhibit toxicological or biological problems [28-30]. Since the safety of irradiated food was officially recognized, irradiation of more than 250 types of foods has been approved in 52 countries. Within Korea, two gamma-radiation facilities are currently successfully operating.

Although irradiation technology has been utilized for the safe storage and distribution of foods around the globe, its utilization within the domestic sector has not grown as expected due to strict regulations regarding food irradiation programs. Additionally, consumers often have misperceptions and experience feelings of anxiety with regard to irradiated food. Thus, to change the general misperceptions surrounding irradiated foods, it is necessary to develop existing and additional policies and conduct more studies of all food products [31]. Without accurate information on irradiated foods, consumers are uncertain about the safety of these foods and may be reluctant to purchase such foods [32]. Consumers' acceptability of irradiated foods is relatively low, mainly because of concerns regarding general safety [33]. However, regardless of how scientifically outstanding, economical, and safe a technology may be, the distribution and utilization of irradiated food products faces challenges which the general public does not appear to willingly accept [34]. Thus, various approaches must be applied in order to improve consumers' understanding of food irradiation.

Therefore, in this study, the researchers have aimed to analyze changes in red ginseng components after the irradiation process according to legally approved radiation dosages, in order to provide an objective analysis of component changes in the experimental samples. In addition, a survey was conducted among housewives, who are major consumers of red ginseng, and teachers, who are viewed as having a high level of scientific understanding on this topic, in order to observe changes in their knowledge and perceptions of irradiated red ginseng and their subsequent attitudes toward this irradiated product. This study was designed to evaluate whether irradiated foods could be accepted and adopted favorably by the general public following sufficient educational awareness on this topic.

Materials and Methods

1. Study Design

Red ginseng powder samples (6-year-old, Punggi Ginseng products of high preference among consumers; verified by the Korea Tobacco and Ginseng Corporation) were purchased. The expiration date of these products was April 25, 2019. Red ginseng powder was then irradiated at five doses (0, 2.5, 5, 7.5, 10 kGy) to produce red ginseng powder using the ^{60}Co gamma radiation facility at Greenpia Technology Inc., Yeoju, Korea. The components of the red ginseng powder were then analyzed based on the radiation dosage after storage at room temperature. The powder was visually inspected and analyzed considering the following factors: heat quantity, carbohydrates, crude proteins, crude fats, sodium, sugars, saturated fatty acids, trans fats, cholesterol, and bacterial numbers. To ensure a high level of reliability, the Korea Advanced Food Research Institute performed the major component analysis. The 10 components analyzed in this study are included on the labels of most food products. The unique components and characteristics of red ginseng (stored at room temperature) were analyzed as follows: ginsenosides Rg1, Rb1, and Rg3; saponins; humidity; particle size; foreign substances; lead; cadmium; tin; bacterial num-

bers; and coliform bacteria. This analysis was also performed by the Korea Ginseng Product Corporation.

Educational seminars were conducted on irradiated foods and red ginseng on two occasions for teachers, who are considered to be highly educated, and housewives, who are evidently the major consumers of red ginseng. Educational content included the principles, legal basis, and history of irradiated foods; nutrients and components of red ginseng; advantages and disadvantages of the irradiation process; and changes in the experimental food components depending upon the irradiation dosage. To examine changes in consumers' knowledge, perceptions, and attitudes toward irradiated red ginseng following educational seminars, a survey and statistical analysis were conducted. Additionally, changes in consumers' behaviors following educational awareness were observed.

2. Participants

A survey was conducted among 70 individuals, including 20 men (28.6%) and 50 women (71.4%), and changes in their behaviors were observed thereafter. Between July and November 2017, four educational seminars were provided for the participants in addition to a survey, and observations of participant behavioral changes were documented. The participants included 37 teachers (46.8%) and 42 housewives (53.1%). For 85% of participants, their monthly incomes ranged from 2 million to 8 million Korean won. Questionnaire items included their intake and purchasing of ordinary red ginseng and irradiated red ginseng, consumption patterns, knowledge of red ginseng effects and safety, and general attitudes.

As part of the educational process, data regarding changes in red ginseng components depending on radiation dose were presented. The participants were then asked to choose from red ginseng samples exposed to 0–10 kGy irradiation, and then informed to consume the samples provided. In this experiment, participants who consumed irradiated red ginseng were given 1 point for each step; 2 points were considered as a perfect score for this experiment.

3. Statistical Analysis

SPSS version 15.0 for Windows (SPSS Inc., Chicago, IL, USA) was used to analyze the data. Data are presented as frequencies and percentages or means and standard deviations. Statistical analyses were carried out using Pearson correlation coefficients, *t*-tests, and multiple regression.

Results and Discussion

1. Changes in Unique Components of Red Ginseng Powder following Irradiation

Firstly, analyzed changes in the unique components of red ginseng powder after irradiation were documented. Notably, there were no significant changes in the major components of red ginseng, regardless of the radiation dosage. In contrast, bacterial numbers decreased dramatically as the radiation

Table 1. Changes in Unique Components of Red Ginseng Powder following Irradiation

Classification	Irradiation				
	0 kGy	2.5 kGy	5 kGy	7.5 kGy	10 kGy
Sum of ginsenosides Rg1, Rb1, and Rg3 (mg/g)	6.94	6.14	7.38	6.58	6.5
Ginsenoside Rg1 (mg/g)	2.53	2.18	2.61	2.44	2.26
Ginsenoside Rb1 (mg/g)	4.16	3.74	4.55	3.94	4.05
Ginsenoside Rg3 (mg/g)	0.25	0.22	0.22	0.21	0.2
Saponin (mg/g)	75.4	76.4	74.8	70.3	75.9
Red ginseng components	Detected	Detected	Detected	Detected	Detected
Moisture (%)	2.9	2.7	2	2.7	2.3
Particle size (%)	74.8	79.3	80	79.9	75.9
Foreign substance	None	None	None	None	None
Lead (mg/kg)	0.2	0.2	0.2	0.2	0.4
Cadmium (mg/kg)	0.1	0.1	0.1	0.1	0.1
Tin (mg/kg)	9	12.4	13.6	9.5	11.3
Bacterial number* (CFU/g)	14,000	65	45	0	10
Coliform bacteria	Negative	Negative	Negative	Negative	Negative

Unique components of red ginseng are the major components of ginseng suggested by the Korea Ginseng Product Corporation.
*In microbiology, colony-forming units (CFUs) are a measure of the number of visible bacteria or fungi. Unlike counting all living or dying cells directly under a microscope, measuring CFU is measuring visible cells. In solids it is given in CFU/g (colonized units per gram).

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dosage increased. Without irradiation, the number of bacteria was quite high; however, after irradiation at the legally approved dose of 7.5 kGy, the number of bacteria was significantly reduced, without changes in the unique components of ginseng (Table 1).

2. Changes in the General Nutrient Components of Red Ginseng Powder following Irradiation at Different Doses

Upon visual inspection, the yellowish brown powder of irradiated ginseng maintained a constant level of chromaticity, regardless of the irradiation dose. Nine components showed no significant differences following irradiation. In contrast, changes in bacterial contents were observed after irradiation with doses of more than 2.5 kGy (Table 2).

3. Changes in Participants' Knowledge, Perceptions, and Attitudes towards Irradiated Red Ginseng following Educational Awareness

Following educational awareness, there were no significant changes in the participants' perception regarding the safety of non-irradiated red ginseng. However, in relation to

Table 2. Changes in the General Nutrient Components of Red Ginseng Powder following Irradiation at Different Doses

Classification	Irradiation				
	0 kGy	2.5 kGy	5 kGy	7.5 kGy	10 kGy
Calories (per 100 g)	374.1	373.6	374.3	372.8	371.9
Carbohydrates	77.4	77.5	77.7	77.3	77.1
Crude protein (nitrogen factor = 6.25)	13.2	13.2	13.4	13.2	13.4
Crude fat	1.3	1.2	1.1	1.2	1.1
Sodium	73.01	63.42	70.18	66.18	62.51
Sugars	20.3	20.3	20.4	20.3	20.2
Saturated fatty acids	0.2	0.2	0.2	0.2	0.2
Trans fats	0.01	0.01	0.01	0.01	0.01
Cholesterol	Not detected	Not detected	Not detected	Not detected	Not detected
Bacterial number (/g)	570	20	0	0	0

General nutrient components of red ginseng powder are the major nutrient components of all types of foods for consumers suggested by the Korea Advanced Food Research Institute. There is no absolute standard for the normal range of each measurement.

Table 3. Changes in Participants' Knowledge, Perceptions, and Attitudes towards Irradiated Red Ginseng following Educational Awareness

Classification	Education	Knowledge of irradiated red ginseng		Perception of ordinary red ginseng safety		Perception of irradiated red ginseng safety	
		Score	*t* (*p*-value)	Score	*t* (*p*-value)	Score	*t* (*p*-value)
Sex							
Male	Before	2.26 ± 1.88	-4.800 (0.000)**	3.95 ± 0.76	-1.165 (0.258)	3.40 ± 0.99	-4.273 (0.000)**
	After	4.37 ± 1.16		4.15 ± 0.75		4.10 ± 0.64	
Female	Before	1.27 ± 1.48	-8.782 (0.000)**	3.79 ± 0.74	0.819 (0.417)	3.32 ± 0.78	-3.675 (0.001)**
	After	3.29 ± 1.60		3.69 ± 0.88		3.83 ± 0.73	
Occupation							
Teacher	Before	2.18 ± 1.72	-7.694 (0.000)**	3.91 ± 0.71	-1.559 (0.128)	3.29 ± 0.87	-5.725 (0.000)**
	After	4.36 ± 1.03		4.12 ± 0.69		4.00 ± 0.60	
Housewife	Before	0.90 ± 1.33	-6.306 (0.000)**	3.76 ± 0.78	1.542 (0.133)	3.39 ± 0.83	-2.362 (0.024)*
	After	2.81 ± 1.64		3.53 ± 0.93		3.82 ± 0.81	
Married							
Single	Before	1.80 ± 1.30	-5.880 (0.004)*	3.83 ± 0.75	-1.581 (0.175)	3.50 ± 0.55	-2.000 (0.102)
	After	4.00 ± 1.22		4.17 ± 0.41		4.17 ± 0.41	
Married	Before	1.47 ± 1.66	-9.088 (0.000)**	3.83 ± 0.74	0.760 (0.450)	3.29 ± 0.85	-4.845 (0.000)**
	After	3.53 ± 1.59		3.75 ± 0.88		3.86 ± 0.73	
Ordinary red ginseng intake experience							
Yes	Before	1.51 ± 1.62	-9.715 (0.000)**	3.82 ± 0.75	0.287 (0.775)	3.30 ± 0.83	-5.110 (0.000)**
	After	3.56 ± 1.58		3.78 ± 0.86		3.88 ± 0.70	
No	Before	2.67 ± 2.52	-1.732 (0.225)	4.33 ± 0.58	-1.000 (0.423)	4.33 ± 0.58	-1.000 (0.423)
	After	4.67 ± 0.58		4.67 ± 0.58		4.67 ± 0.58	
Irradiated red ginseng intake experience							
Yes	Before	4.00 ± 1.41	-1.000 (0.374)	4.20 ± 0.84	0.000 (1.000)	3.60 ± 1.52	-1.500 (0.208)
	After	4.40 ± 0.89		4.20 ± 0.84		4.20 ± 0.84	
No	Before	1.36 ± 1.52	-10.342 (0.000)**	3.81 ± 0.74	0.145 (0.885)	3.32 ± 0.78	-4.947 (0.000)**
	After	3.54 ± 1.59		3.79 ± 0.86		3.89 ± 0.70	

Values are presented as mean ± standard deviation.
The questionnaire included five knowledge-related questions; 5 points was considered a perfect score.
*$p < 0.05$, **$p < 0.01$.

irradiated red ginseng, participants' knowledge and perceptions of food safety measures improved after education depending on sex, occupation, marital status, and whether participants had experience with the consumption of non-irradiated or irradiated red ginseng. Thus, this study suggests that participants who previously had little knowledge of irradiation showed significant changes in their knowledge and perception after educational awareness on the topic of the irradiation of food products (Table 3).

4. Changes in the Participants' Attitudes towards Choosing Red Ginseng Products after Educational Seminars

Regarding non-irradiated red ginseng, there were no significant changes in participants' attitudes towards choosing red ginseng products after education, although the number of individuals stating that they would choose ordinary red ginseng increased after educational awareness. In contrast, for irradiated red ginseng, the participants' perception of safety improved after education on the topic depending on sex, occupation, marriage status, and whether they had experience with the intake of non-irradiated red ginseng or irradiated red ginseng. Thus, participants who had inadequate knowledge of the effects of irradiation prior to educational seminars, showed significant changes in their attitudes towards irradiated red ginseng following educational awareness (Table 4).

5. Correlations among the Perceptions, Knowledge, and Attitudes toward Red Ginseng

Following educational seminars, attitudes towards choosing both non-irradiates and irradiated red ginseng were correlated with a perception of safety of ($\rho = 0.387$, $\rho = 0.462$), a perception of necessity of ($\rho = 0.483$, $\rho = 0.530$), and knowledge variable of ($\rho = 0.303$, $\rho = 0.245$). The level of correlation was statistically significant. Among these factors, attitudes

Table 4. Changes in the Participants' Attitudes towards Choosing Red Ginseng Products after Educational Seminars

Classification	Education	Attitudes towards ordinary red ginseng		Attitudes toward irradiated red ginseng	
		Score	*t* (*p*-value)	Score	*t* (*p*-value)
Sex					
Male	Before	1.70±0.73	1.453 (0.163)	0.84±1.01	-1.756 (0.096)
	After	1.50±0.89		1.37±0.96	
Female	Before	1.20±0.97	-1.124 (0.267)	0.34±0.76	-5.152 (0.000)**
	After	1.36±0.93		1.29±0.96	
Occupation					
Teacher	Before	1.64±0.78	0.000 (1.000)	0.65±0.95	-3.230 (0.003)*
	After	1.64±0.78		1.42±0.92	
Housewife	Before	1.06±0.98	-0.533 (0.598)	0.34±0.77	-4.126 (0.000)**
	After	1.16±0.99		1.21±0.98	
Married					
Single	Before	0.34±0.77	-4.126 (0.000)**	0.67±1.03	-0.542 (0.611)
	After	1.21±0.98		1.00±1.10	
Married	Before	1.33±0.93	-0.477 (0.635)	0.50±0.87	-4.969 (0.000)**
	After	1.39±0.92		1.33±0.94	
Ordinary red ginseng intake experience					
Yes	Before	1.35±0.93	-0.435 (0.665)	0.42±0.82	-5.674 (0.000)**
	After	1.40±0.91		1.32±0.95	
No	Before	1.33±1.15	-	2.00±0.00	1.000 (0.423)
	After	1.33±1.15		1.33±1.15	
Irradiated red ginseng intake experience					
Yes	Before	1.60±0.89	-	1.20±1.10	-1.000 (0.374)
	After	1.60±0.89		1.60±0.89	
No	Before	1.33±0.93	-0.435 (0.665)	0.44±0.83	-5.056 (0.000)**
	After	1.38±0.92		1.29±0.96	

Values are presented as mean±standard deviation.
Attitudes toward choosing red ginseng were measured based on the sum of participants' attitudes toward choosing ordinary or irradiated red ginseng. A high score indicated that the participant was more likely to choose red ginseng.
*$p<0.05$, **$p<0.01$.

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towards choosing non-irradiated red ginseng and irradiated red ginseng were highly correlated with the perception of necessity, and the perception of necessity for both non-irradiated and irradiated red ginseng were highly correlated with the perception of safety ($\rho = 0.917$, $\rho = 0.844$). Thus, when individuals were aware of the necessity of buying irradiated red ginseng, they were likely to choose irradiated red ginseng and were more likely to be concerned about food product safety (Table 5).

6. Factors Affecting Attitudes towards Red Ginseng

In multiple linear regression analysis, attitudes towards choosing non-irradiated and irradiated red ginseng after education were the dependent variable, and perception of safety, perception of necessity, and knowledge, were the independent variables. The results showed significant differences before and after education. In particular, the perception of necessity of both non-irradiated and irradiated red ginseng significantly affected attitudes towards choosing red ginseng following education on the topic. In other words, those who were aware of the necessity of red ginseng were likely to purchase either non-irradiated or irradiated red ginseng, indicating that education on this topic influenced consumers' tendencies to choose irradiated red ginseng (Table 6).

Conclusion

Food irradiation technology has been developed through various studies conducted by developed countries and has been shown to be more effective than any other sanitation treatment to improve food product safety in terms of microbiology, toxicology, dietetics, and genetics. However, the use of irradiated foods in Korea still remains low, potentially because of the low level of understanding and acceptability of irradiated foods among consumers and food producers [35]. To promote a safe domestic food industry and to improve general public health, it is necessary to provide consumers with information on irradiated foods to facilitate decision making. Due to the fact that negative views regarding nuclear energy and irradiation are prevalent, it is necessary to provide accurate information on the use of nuclear energy usages and irradiated foods. Accordingly, in this study, we evaluated the components of red ginseng and then assessed changes in consumers' knowledge and attitudes towards red

Table 5. Correlations among the Perceptions, Knowledge, and Attitudes toward Red Ginseng

Classification	Ordinary red ginseng intake				Irradiated red ginseng safety			
	Attitudes toward choosing red ginseng	Safety perception	Necessity perception	Knowledge	Attitudes toward choosing red ginseng	Safety perception	Necessity perception	Knowledge
Attitudes toward choosing red ginseng	1				1			
Safety perception	0.387**	1			0.462**	1		
Necessity perception	0.483**	0.917**	1		0.530**	0.844**	1	
Knowledge	0.303*	0.497**	0.450**	1	0.245*	0.517**	0.493**	1

*$p < 0.05$, **$p < 0.01$.

Table 6. Factors Affecting Attitudes towards Red Ginseng

Classification	Item	Unstandardized coefficient		Standardized coefficient	t
		B	Standard error	Beta	
Ordinary red ginseng	(constant)	-0.642	0.473		-1.358
	Perception of safety	-0.357	0.285	-0.347	-1.252
	Perception of necessity	0.840	0.308	0.735	2.732**
	Knowledge	0.083	0.071	0.144	1.165
		$F = 7.486^{**}$, $R^2 = 0.260$			
Irradiated red ginseng	(constant)	-1.364	0.570		-2.392
	Perception of safety	0.079	0.263	0.061	0.302
	Perception of necessity	0.680	0.274	0.493	2.481*
	Knowledge	-0.018	0.075	-0.030	-0.241
		$F = 8.404^{**}$, $R^2 = 0.283$			

*$p < 0.05$, **$p < 0.01$.

ginseng.

The major saponin components of fresh ginseng and white ginseng are Rb1, Rb2, Re, and Rg1 [36, 37]. During the thermal treatment of red ginseng, new unique saponin components of red ginseng, including ginsenosides Rg2, Rg3, Rh1, and Rh2, were produced. These saponin elements are known to have effects in preventing cancer, inhibiting cancer cell growth, protecting brain cells, enhancing learning ability, and inducing antioxidant activity [11, 17, 20, 21, 23]. Rg3 is generated upon Rb1 hydrolysis. This is a unique compound that exists only in red ginseng, and the quantity of this element increases in high-temperature steaming conditions [11, 17, 20, 38]. Our results showed that there were no changes in the levels of these compounds following irradiation, suggesting that irradiated red ginseng maintained its efficacy. Several studies have demonstrated that food irradiation yields safe food products by extending the effective storage period and deactivating germs [39]. Moreover, irradiation has not been shown to affect nutrients in comparison with other technologies used for food processing and preservation. Major nutrients, such as proteins, carbohydrates, and fats, are stable up to an irradiation level of 10 kGy [40]. The patterns observed in this study were consistent with those observed in previous studies.

Many respondents are concerned that irradiated food products may become radioactive following treatments, and essentially the central purpose and benefits of food irradiation may be ignored. Consumers may believe that irradiation may change the organic qualities of the product, such as flavor and smell, and cause a significant loss of nutrients [41]. It has been noted that such negative perceptions have persisted for more than 10 years in Korea. This is a serious problem that must be overcome through the development of advanced educational programs [42]. In this study, the participants showed significant changes in their knowledge, perception, and attitudes after being educated on the changes in components of irradiated red ginseng. This indicates that even consumers who lack knowledge of the irradiation process, or have negative views on irradiation, may change their attitudes and accept irradiated foods as they learn more about irradiation methods and the advantages of irradiation. Hence, education is of great importance to general acceptability of irradiated foods [33], and it is necessary to provide consumers with more information on irradiated foods and future educational opportunities. As reported previously [43], differences in perceptions surrounding the level of risk among everyday consumer's results not from the mistaken recognition of statistical data regarding risks, but from the different levels of exposure to vernacular related to risk factors experienced by individuals and their meanings in a typical living environment [43]. People often face situations in which they have to choose among various behaviors in daily life. They are likely to make decisions after considering the benefits and disadvantages of each behavior [44]. This is why science educators and researchers emphasize the importance of developing the ability to judge values and make decisions rationally based on an accurate understanding of scientific technologies [45-48]. Accordingly, it is necessary to provide accurate information on red ginseng and other foods for which irradiation is permitted, in order to familiarize consumers with the benefits associated with irradiated foods. Furthermore, experts must develop strategies to help consumers make informed decisions and increase their acceptability of such food products.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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