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Analysis of food irradiation education for elementary, middle, and high school students for three years in South Korea

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BACKGROUND/OBJECTIVES: The current South Korean government policy on food irradiation technology should be reformed based on an in-depth investigation of the communications aspect, because the issue is no longer of a technological nature, given the proven safety and efficacy of the processes.

SUBJECTS/METHODS: The target population of the education program consisted of elementary, middle, and high school students attending 310 schools in South Korea (2013: 63 schools, 2014: 104 schools, 2015: 143 schools). Data subjected to analysis were 13,327 pre-education and 12,641 post-education questionnaires received from 7,582 elementary, 2,671 middle, and 3,249 high school students who participated in the education program from May 2012 to April 2015 (n = 12,831), after the exclusion of inadequately filled-in questionnaires.

RESULTS: Analysis of the three-year educational effect trend was conducted by comparing levels of variables before and after food radiation education. The analysis yielded the finding that the post-education levels were significantly higher for all variables. That is, for interest in education, perception (necessity, safety, subjective knowledge, and information acquisition), objective knowledge, and attitude, with the sole exception of objective knowledge in 2013.

CONCLUSIONS: Given that post-education levels of perception, knowledge, and attitude concerning irradiated foods increased considerably compared to pre-education levels, behavior change should be induced by providing continuous education to enhance, these primary variables.

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INTRODUCTION

Food irradiation has been strongly recommended and asserted to be the most effective technology with the potential to replace chemical preservatives and fumigants. Its safety has been proved over the past decades by important international organizations, such as WHO, FAO, and WTO, and relevant international academic societies [1]. Irradiated foods are foods processed by exposing them to pre-determined doses of ionizing radiation depending on the purpose (germination inhibition, insecticide degradation, sterilization, or maturity control) [2,3]. Given the current situation of international trade, in which the food irradiation standards specified by the Codex Alimentarius Commission are not merely recommended, but mandatory for all foodstuffs traded in the OECD countries, there is a need for more aggressive promotional consumer education on the use of food irradiation technology in some countries, including South Korea [4,5].

However, despite the obvious advantages of food irradiation, this method has not yet found wide applications in the domestic Korean food industry. One of the reasons is the uncertainty about its acceptability to consumers, which is ascribable to the tepidity of the government commitment to raising awareness and encouraging a positive perception of irradiated foods among consumers [5,6]. For lack of opportunity to become accurately informed about irradiated foods, consumers cannot make informed choices; coupled with concerns about health-related safety, this means that they face difficulties making food selection and purchase decisions [7-11]. One survey estimated the percentage of Korean consumers who are uninformed about food irradiation at 90% [12], which implies that the general public is largely not familiar with irradiated foods [13]. Furthermore, although food contamination caused by radioactive materials and food irradiation are based on two fundamentally different principles [14], irradiated foods are still perceived negatively among the public [15], influenced by negative media coverage on the occasion of the Fukushima nuclear power plant accident in Japan about radioactive pollution of marine products, radioactivity concentrations in the atmosphere, and the consequences for food security for future generations [16].

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These circumstances have made it irrational to blithely predict progress in industrial society, since human actions and reactions in relation to these issues are quite uncertain [17]. Tomas & Durant [18] noted that enhancement of the scientific understanding of the public leads to consolidation of positive attitudes towards science and a supportive frame for leading in turn not only to the development of scientific research, growth of the national economy, and expansion of national power, but also contributing to social integrity and individual benefit via more rational, evidence-based - consumer behavior and decision-making. This also applies to the issue of food irradiation, because accurate perception of health risks related to irradiated food is a determinant factor for the future of food irradiation technology and related industries. Futurology is an academic discipline that predicts events in the near and far future, ranging from 50-100 years to 1,000 years or more [19]. The current South Korean government policy on food irradiation technology should be reformed based on an in-depth investigation of the communications aspect, because the issue is no longer of a technological nature, given the proven safety and efficacy of the processes. From the futurological perspective, if future generations of Koreans experience food supply problems due to a current lack of consumer education, it will be a loss at a national level. In this context, the present study was designed as part of a large-scale communication strategy for the enhancement of public understanding through the creation of a national consensus about irradiated foodstuffs. In order to provide basic data required to formulate such a strategy, elementary, middle, and high school students were selected as the research population in this study, in consideration of the high ripple effects expected in this population group. Analyzed were differences in perception, knowledge, and attitude regarding irradiated foods as a result of the implementation of an education program designed to enhance the understanding of food irradiation, between the baseline (pre-education) level and the post-education level.

SUBJECTS AND METHODS

Research procedure

The research was carried out in the following steps: Step 1) research and education program design, Step 2) official announcement of education program via the Departments of Education of each municipal or provincial government, Step 3) selection of final program participants from elementary, middle, and high school interested in participation, Step 4) pre-education survey, Step 5) implementation of the education program (theory and practice; 45 min each), and Step 6) post-education survey. The education program consists of theory and practice parts. The theory part included watching a video clip explaining the concepts of radiation application, including food irradiation (10 min), and heard a subsequent lecture on the topic (25 min). In the practice part, the participants formed teams and measured natural radioactivity (Fig. 1). The educational content of the video and lecture included the history, principles, and current status of food irradiation.

Research tool

As a research tool, we used a questionnaire with items covering perceptions of, knowledge of, and attitude toward food irradiation; these are major variables influencing behavior in a traditional learning paradigm (Fig. 2). The category "perception" was divided into subcategories covering necessity, safety, information acquisition, and subjective knowledge of food irradiation and irradiated foods; these variables are understood to exert direct influence on human actions and reactions. The category "objective knowledge" included items on the principles of food irradiation and on the difference between irradiated foods and foods contaminated by radioactivity. Finally, the category "attitude" contained items on intention regarding irradiated food purchase and consumption.

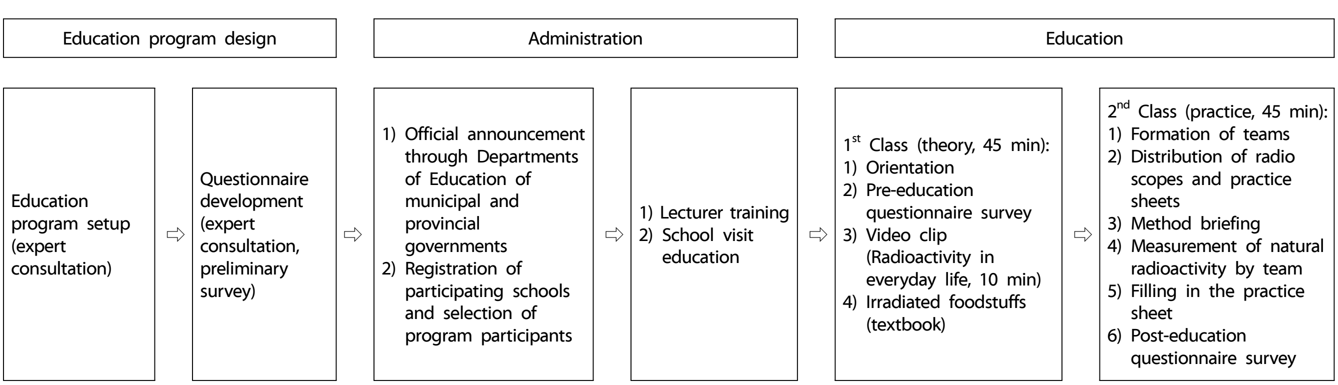

Fig. 1. Research procedure and education program elements

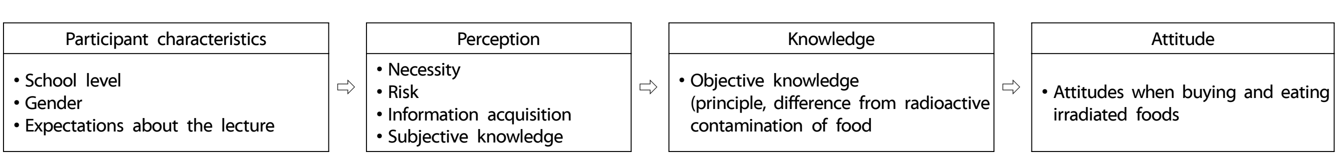

Fig. 2. Composition of the questionnaire

Research participants

The target population of the education program consisted of elementary, middle, and high school students attending 310 schools in South Korea (2013: 63 schools, 2014: 104 schools, 2015: 143 schools). Data subjected to analysis were 13,327 pre-education and 12,641 post-education questionnaires received from 7,582 elementary (from fourth-grade to sixth-grade students), 2,671 middle (from first-grade to third-grade students), and 3,249 high school students (from first-grade to third-grade students) who participated in the education program from May 2012 to April 2015 (n = 12,831), after the exclusion of inadequately filled-in questionnaires (Table 1) from first-year to third-year students. Limitations of the study is not the same as a follow-up students for three years.

Statistical analysis

SPSS/WIN 15.0 was used to analyze the data in terms of frequency and percentage, mean and standard deviation, Pearson's correlation coefficient, t-test, one-way ANOVA, and multiple regression.

RESULTS

Educational effect trend analysis

Analysis of the three-year educational effect trend was conducted by comparing levels of variables before and after food radiation education. The analysis yielded the finding that the post-education levels were significantly higher for all variables, that is, for interest in education, perception (necessity, safety, subjective knowledge, and information acquisition), objective knowledge, and attitude, with the sole exception of objective knowledge in 2013. This implies that perception of and attitude towards irradiated foods can change through education. The lack of change in the level of objective knowledge in 2013 was attributed to the excessive difficulty of the theory part, which was understood to have failed to enhance students' theoretical knowledge as a result. Subsequent to that, the educational content was modified to facilitate understanding, and the level of objective knowledge was found to have improved after the implementation of the education program in 2014 and 2015 (Table 2). There was no significant difference each year.

Table 1. Grade and gender of the participants in the education program for three years

Category		2013		2014		2015	
		Pre-education n (%)	Post-education n (%)	Pre-education n (%)	Post-education n (%)	Pre-education n (%)	Post-education n (%)
Grade	Elementary	2,029 (59.7)	1,827 (57.9)	2,107 (52.7)	2,057 (52.5)	3,328 (56.0)	3,102 (55.7)
	Middle	430 (12.7)	419 (13.3)	777 (19.4)	793 (20.3)	1,421 (24.0)	1,332 (23.9)
	High	940 (27.7)	911 (28.9)	1,114 (27.9)	1,064 (27.2)	1,181 (20.0)	1,136 (20.4)
	Total	3,399 (100.0)	3,157 (100.0)	3,998 (100.0)	3,914 (100.0)	5,930 (100.0)	5,570 (100.0)
Gender	Male	1,785 (52.5)	1,652 (52.3)	2,147 (53.7)	2,072 (52.9)	2,902 (48.9)	2,665 (47.8)
	Female	1,537 (45.2)	1,390 (44.0)	1,832 (45.8)	1,822 (46.5)	3,028 (51.1)	2,905 (52.2)
	No response	77 (2.3)	115 (3.6)	19 (0.4)	20 (0.5)	0 (0.00)	0 (0.00)

NB: The periods covered by "2013," "2014," and "2015" are May 2012–April 2013, May 2013–April 2014, and May 2014–April 2015, respectively.

Table 2. Analysis of trends in educational effects for three years

Category		2013						2014						2015					
		Elementary		Middle		High		Elementary		Middle		High		Elementary		Middle		High	
		(Mean ± SD)	t (*P*-value)	(Mean ± SD)	t (*P*-value)	(Mean ± SD)	t (*P*-value)	(Mean ± SD)	t (*P*-value)	(Mean ± SD)	t (*P*-value)	(Mean ± SD)	t (*P*-value)	(Mean ± SD)	t (*P*-value)	(Mean ± SD)	t (*P*-value)	(Mean ± SD)	t (*P*-value)
Interest in edu.	Pre	1.81 ± .39	.893	1.79 ± .41	-3.166	1.83 ± .38	-3.352	1.81 ± .39	-2.130	1.78 ± .42	-4.931	1.83 ± .38	-2.502	1.75 ± .43	-9.208	1.68 ± .47	-8.206	1.82 ± .39	-4.462
	Post	1.82 ± .38	(0.372)	1.87 ± .34	(0.002)	1.88 ± .32	(<.001)	1.84 ± .37	(0.033)	1.87 ± .33	(<.001)	1.87 ± .34	(0.012)	1.85 ± .36	(<.001)	1.81 ± .39	(<.001)	1.89 ± .32	(<.001)
Perception																			
Necessity	Pre	3.73 ± 1.02	10.054	3.70 ± 1.03	5.285	3.75 ± .95	6.343	3.81 ± 1.05	11.356	3.58 ± 1.06	7.571	3.70 ± 1.01	5.579	3.90 ± 1.03	11.700	3.78 ± 1.02	6.851	3.74 ± .95	6.228
	Post	4.05 ± .91	(<.001)	4.05 ± .90	(<.001)	4.01 ± .82	(<.001)	4.15 ± .87	(<.001)	3.96 ± .92	(<.001)	3.92 ± .85	(<.001)	4.17 ± .82	(<.001)	4.02 ± .87	(<.001)	3.96 ± .79	(<.001)
Safety	Pre	3.34 ± .98	-10.108	2.96 ± .98	-10.112	2.85 ± .99	-14.689	3.31 ± 1.01	-14.726	2.85 ± 1.02	-12.259	2.83 ± .98	-12.904	3.30 ± 1.03	-17.997	2.96 ± 1.02	-13.783	2.78 ± .97	-15.151
	Post	3.66 ± .94	(<.001)	3.61 ± .91	(<.001)	3.50 ± .91	(<.001)	3.75 ± .92	(<.001)	3.46 ± .96	(<.001)	3.35 ± .90	(<.001)	3.73 ± .89	(<.001)	3.47 ± .94	(<.001)	3.37 ± .91	(<.001)
Info. acq.	Pre	2.27 ± 1.12	19.120	2.15 ± 1.02	14.513	2.31 ± 1.01	15.312	2.24 ± 1.15	23.819	2.24 ± 1.04	17.244	2.32 ± 1.01	17.192	2.17 ± 1.12	-32.225	2.19 ± 1.05	24.078	2.32 ± .98	21.256
	Post	2.95 ± 1.10	(<.001)	3.11 ± .88	(<.001)	2.98 ± .84	(<.001)	3.04 ± 1.02	(<.001)	3.06 ± .84	(<.001)	3.00 ± .83	(<.001)	3.00 ± .96	(<.001)	3.08 ± .90	(<.001)	3.09 ± .75	(<.001)
Subj. kn.	Pre	2.47 ± 1.01	20.299	2.45 ± .91	12.981	2.43 ± .84	18.842	2.49 ± 1.03	27.026	2.43 ± .91	17.854	2.40 ± .84	20.114	2.45 ± 1.01	-35.855	2.40 ± .93	23.906	2.42 ± .85	23.192
	Post	3.15 ± 1.02	(<.001)	3.25 ± .87	(<.001)	3.15 ± .79	(<.001)	3.31 ± .95	(<.001)	3.22 ± .84	(<.001)	3.11 ± .82	(<.001)	3.31 ± .90	(<.001)	3.21 ± .86	(<.001)	3.20 ± .77	(<.001)
Obj. kn.	Pre	23 ± 4.20	1.323	28 ± 4.50	-.389	27 ± 4.50	-1.301	25 ± 4.30	24.176	25 ± 4.40	11.663	27 ± 4.50	13.333	19 ± 3.90	30.576	22 ± 4.20	12.760	22 ± 4.20	13.825
	Post	21 ± 4.10	(0.186)	29 ± 4.50	(0.697)	30 ± 4.60	(0.193)	59 ± 4.90	(<.001)	53 ± 5.00	(<.001)	54 ± 5.00	(<.001)	53 ± 5.00	(<.001)	44 ± 5.00	(<.001)	48 ± 5.00	(<.001)
Attitude	Pre	3.20 ± 1.02	-15.217	2.95 ± 1.00	-9.935	2.84 ± .95	15.941	3.19 ± 1.11	-19.886	2.81 ± 1.06	-12.299	2.85 ± .99	-14.813	3.12 ± 1.11	26.832	2.86 ± 1.04	-15.914	2.81 ± .94	-14.529
	Post	3.71 ± 1.44	(<.001)	3.63 ± .99	(<.001)	3.56 ± .98	(<.001)	3.84 ± 1.00	(<.001)	3.46 ± 1.05	(<.001)	3.47 ± .98	(<.001)	3.82 ± .98	(<.001)	3.49 ± 1.07	(<.001)	3.39 ± .96	(<.001)

NB: * Interest in education, perception of irradiated foods (necessity, safety, information acquisition, subjective knowledge), and attitude toward irradiated foods are assessed on a scale of 1–5. Objective knowledge of irradiated foods is assessed on a scale of 1–100.

* Higher scores on perception of necessity and of safety, information acquisition, and subjective knowledge respectively mean higher levels of perception that irradiated foods are necessary and safe, acquired information about irradiated foods, and information status. Higher scores on attitude mean more positive attitudes towards the purchase and consumption of irradiated foods.

Educational effect trend analysis by school level

In all three years of implementation of the program, elementary school students scored higher than middle and high school students in terms of safety perception and attitude, with statistical significance, while the highest degree of interest in education and information acquisition was demonstrated by

Table 3. Educational effect trend analysis by school level

Category		2013				2014				2015			
		Pre-education		Post-education		Pre-education		Post-education		Pre-education		Post-education	
		(Mean ± SD)	F (*P*-value)	(Mean ± SD)	F (*P*-value)	(Mean ± SD)	F (*P*-value)	(Mean ± SD)	F (*P*-value)	(Mean ± SD)	F (*P*-value)	(Mean ± SD)	F (*P*-value)
Interest in education	Elementary	1.81 ± .39		1.82 ± .38		1.81 ± .39		1.84 ± .37		1.75 ± .43		1.85 ± .36	
	Middle	1.79 ± .41	1.953 (0.142)	1.87 ± .34	10.427 (<.001)	1.78 ± .42	4.002 (0.018)	1.87 ± .33	3.648 (0.026)	1.68 ± .47	36.701 (<.001)	1.81 ± .39	13.102 (<.001)
	High	1.83 ± .38		1.88 ± .32		1.83 ± .38		1.87 ± .34		1.82 ± .38		1.89 ± .32	
Perception Necessity	Elementary	3.73 ± 1.02		4.05 ± .91		3.81 ± 1.05		4.15 ± .87		3.90 ± 1.03		4.17 ± .82	
	Middle	3.70 ± 1.03	.369 (0.692)	4.05 ± .90	.557 (0.573)	3.58 ± 1.06	15.002 (<.001)	3.96 ± .92	29.658 (<.001)	3.78 ± 1.02	14.762 (<.001)	4.02 ± .87	32.637 (<.001)
	High	3.75 ± .95		4.01 ± .82		3.70 ± 1.01		3.92 ± .85		3.74 ± .95		3.96 ± .79	
Safety	Elementary	3.34 ± .98		3.66 ± .94		3.31 ± 1.01		3.75 ± .92		3.30 ± 1.03		3.73 ± .89	
	Middle	2.96 ± .98	89.901 (<.001)	3.61 ± .91	8.683 (<.001)	2.85 ± 1.02	112.452 (<.001)	3.46 ± .96	76.603 (<.001)	2.96 ± 1.02	136.981 (<.001)	3.47 ± .94	83.093 (<.001)
	High	2.85 ± .99		3.50 ± .91		2.83 ± .98		3.35 ± .90		2.78 ± .97		3.37 ± .91	
Info. acq.	Elementary	2.27 ± 1.12		2.95 ± 1.10		2.24 ± 1.15		3.04 ± 1.02		2.17 ± 1.12		3.00 ± .96	
	Middle	2.15 ± 1.02	3.217 (0.040)	3.11 ± .88	4.086 (0.017)	2.24 ± 1.04	2.266 (0.104)	3.06 ± .84	1.215 (0.297)	2.19 ± 1.05	9.064 (<.001)	3.08 ± .90	5.971 (0.003)
	High	2.31 ± 1.01		2.98 ± .84		2.32 ± 1.01		3.00 ± .83		2.32 ± .98		3.09 ± .75	
Subj. kn.	Elementary	2.47 ± 1.01		3.15 ± 1.02		2.49 ± 1.03		3.31 ± .95		2.45 ± 1.01		3.31 ± .90	
	Middle	2.45 ± .91	.769 (0.463)	3.25 ± .87	2.036 (0.131)	2.43 ± .91	2.909 (0.055)	3.22 ± .84	17.846 (<.001)	2.40 ± .93	1.745 (0.175)	3.21 ± .86	9.327 (<.001)
	High	2.43 ± .84		3.15 ± .79		2.40 ± .84		3.11 ± .82		2.42 ± .85		3.20 ± .77	
Objective knowledge	Elementary	23 ± 4.20		21 ± 4.10		25 ± 4.30		59 ± 4.90		19 ± 3.90		53 ± 5.00	
	Middle	28 ± 4.50	4.902 (0.007)	29 ± 4.50	16.006 (<.001)	25 ± 4.40	1.433 (0.239)	53 ± 5.00	6.207 (0.002)	22 ± 4.20	4.147 (0.016)	44 ± 5.00	15.095 (<.001)
	High	27 ± 4.50		30 ± 4.60		27 ± 4.50		54 ± 5.00		22 ± 4.20		48 ± 5.00	
Attitude	Elementary	3.20 ± 1.02		3.71 ± 1.04		3.19 ± 1.11		3.84 ± 1.00		3.12 ± 1.11		3.82 ± .98	
	Middle	2.95 ± 1.00	46.171 (<.001)	3.63 ± .99	7.106 (<.001)	2.81 ± 1.06	58.824 (<.001)	3.46 ± 1.05	69.721 (<.001)	2.86 ± 1.04	54.947 (<.001)	3.49 ± 1.07	104.285 (<.001)
	High	2.84 ± .95		3.56 ± .98		2.85 ± .99		3.47 ± .98		2.81 ± .94		3.39 ± .96	

* Interest in education, perception of irradiated foods (necessity, safety, information acquisition, subjective knowledge), and attitude toward irradiated foods are assessed on a scale of 1–5. Objective knowledge of irradiated foods is assessed on a scale of 1–100.
* Higher scores on perception of necessity and of safety, information acquisition, and subjective knowledge respectively mean higher levels of perception that irradiated foods are necessary and safe, acquired information about irradiated foods, and information status. Higher scores on attitude mean more positive attitudes towards the purchase and consumption of irradiated foods.

Table 4. Analysis of trends of educational effects by gender for three years

Category		2013				2014				2015			
		Pre-education		Post-education		Pre-education		Post-education		Pre-education		Post-education	
		(Mean ± SD)	t (*P*-value)	(Mean ± SD)	t (*P*-value)	(Mean ± SD)	t (*P*-value)	(Mean ± SD)	t (*P*-value)	(Mean ± SD)	t (*P*-value)	(Mean ± SD)	t (*P*-value)
Interest in education	Male	1.83 ± .38	3.212 (<.001)	1.87 ± .34	3.924 (<.001)	1.83 ± .38	2.876 (0.004)	1.86 ± .35	1.185 (0.236)	1.76 ± .42	2.708 (0.007)	1.87 ± .34	4.557 (<.001)
	Female	1.79 ± .41		1.82 ± .39		1.79 ± .41		1.85 ± .36		1.73 ± .44		1.83 ± .38	
Perception Necessity	Male	3.75 ± 1.03	1.039 (0.299)	4.08 ± .89	2.699 (0.007)	3.75 ± 1.10	1.085 (0.278)	4.08 ± .92	2.598 (0.009)	3.85 ± 1.06	.671 (0.502)	4.15 ± .85	5.134 (<.001)
	Female	3.71 ± .97		4.00 ± .85		3.72 ± .97		4.01 ± .83		3.83 ± .97		4.04 ± .80	
Safety	Male	3.16 ± 1.05	.807 (0.420)	3.67 ± .96	4.137 (<.001)	3.10 ± 1.09	.707 (0.480)	3.59 ± .98	.280 (0.780)	3.20 ± 1.09	6.157 (<.001)	3.67 ± .96	5.781 (<.001)
	Female	3.13 ± .96		3.53 ± .88		3.07 ± .96		3.58 ± .89		3.03 ± .98		3.52 ± .88	
	Male	2.30 ± 1.10	2.356 (0.019)	3.06 ± 1.02	4.390 (<.001)	2.32 ± 1.13	3.564 (<.001)	3.04 ± .97	.831 (0.406)	2.28 ± 1.13	5.380 (<.001)	3.09 ± .98	4.131 (<.001)
	Female	2.21 ± 1.05		2.90 ± .97		2.20 ± 1.04		3.02 ± .89		2.13 ± 1.03		2.99 ± .84	
Info. acq.	Male	2.50 ± .97	2.910 (0.004)	3.21 ± .97	3.287 (<.001)	2.51 ± .98	3.735 (<.001)	3.27 ± .94	2.345 (0.019)	2.53 ± 1.01	8.157 (<.001)	3.33 ± .92	5.753 (<.001)
	Female	2.40 ± .93		3.10 ± .89		2.39 ± .92		3.20 ± .85		2.33 ± .91		3.20 ± .82	
Objective knowledge	Male	26 ± 4.40	2.285 (0.022)	26 ± 4.40	2.002 (0.045)	27 ± 4.50	2.378 (0.017)	57 ± 5.00	.495 (0.621)	22 ± 4.10	2.183 (0.029)	50 ± 5.00	.538 (0.591)
	Female	23 ± 4.20		23 ± 4.20		24 ± 4.30		56 ± 5.00		19 ± 4.00		50 ± 5.00	
	Male	3.10 ± 1.07	1.889 (0.059)	3.72 ± 1.04	3.534 (<.001)	3.04 ± 1.15	1.402 (0.161)	3.72 ± 1.05	3.946 (<.001)	3.05 ± 1.11	3.887 (<.001)	3.75 ± 1.07	6.655 (<.001)
	Female	3.03 ± .95		3.59 ± .96		3.00 ± 1.00		3.60 ± .99		2.94 ± 1.03		3.57 ± .96	

NB: * Interest in education, perception of irradiated foods (necessity, safety, information acquisition, subjective knowledge), and attitude toward irradiated foods are assessed on a scale of 1–5. Objective knowledge of irradiated foods is assessed on a scale of 1–100.
* Higher scores on perception of necessity and of safety, information acquisition, and subjective knowledge respectively mean higher levels of perception that irradiated foods are necessary and safe, acquired information about irradiated foods, and information status. Higher scores on attitude mean more positive attitudes towards the purchase and consumption of irradiated foods.

high school students after the education in 2015. This implies that the educational effect on safety perception and attitude towards the purchase and consumption of irradiated foods is greatest when the education is given in the elementary school years indeed, high school students scored significantly lower than elementary school students on these variables (Table 3). However, there was no significant difference each year. In The Theory of Reasoned Action, Ajzen [20] argued that humans weigh the profits and losses of an action by means of maximum use of available information, prior to proceeding to that action. In applying this view to the high school students in the present study, it can be understood that their low scores in safety perception and attitude arose from their judgment that the purchase and consumption of irradiated foods may have harmful effects. Van der Linden [21] stated that risk perception is influenced not merely by cognitive factors, but also by empirical (emotion, personal experience) and sociocultural (social norms, pursuit of values) factors. Viewed in this light, it can be assumed that the atmosphere created by negative media coverage of various irradiated foodstuffs exercised influence on the risk perception of high school students.

Educational effect trend analysis by gender

Throughout the three years of the program, boys scored higher than girls subjective knowledge. Additionally, compared to girls, boys showed higher post-education necessity perception toward irradiated foods and more positive attitudes toward the purchase and consumption of irradiated foods. This implies that food irradiation education needs to put more focus on female students. This is consistent with the results of a study by Han *et al*. [22] (Table 4).

Inter-variable correlations

Throughout the three school years, all variables for perception and attitude, with the exception of objective knowledge, were shown to be positively correlated with one another. Before the education program, high correlations were demonstrated between levels of information acquisition and objective knowledge, safety perception and attitudes towards the purchase and consumption of irradiated foods, information acquisition and objective knowledge, and necessity perception and attitude. Here, it is noteworthy that safety perception was closely associated with attitude towards the purchase and consumption of irradiated foods before receiving the education. However, there was no significant difference each year.

In a study conducted by Oh *et al*. [23], risk perception for nuclear power was found to be significantly associated with risk perceptions for radioactivity and radioactivity-based products, which is consistent with the finding of a study by Choi *et al*. [12] that consumers show the greatest interest in safety as opposed to other factors when buying food. This result reflects the principle that risk perception is a determinant factor for risk acceptability [24]. On the other hand, given that post-education necessity perception and attitude change are closely

Table 5. Correlation among major variables for three years

Category	2013							2014							2015						
	Int. in Edu.	Nec.	Safety	Info. acq.	Subj. kn.	Obj. kn.	Att.	Int. in Edu.	Nec.	Safety	Info. acq.	Subj. kn.	Obj. kn.	Att.	Int. in Edu.	Nec.	Safety	Info. acq.	Subj. kn.	Obj. kn.	Att.
Pre-																					
Int. in Edu.	1							1							1						
Necessity	.090 (**)	1						.092 (**)	1						.067 (**)	1					
Safety	.060 (**)	.377 (**)	1					.076 (**)	.423 (**)	1					.053 (**)	.443 (**)	1				
Info. acq.	.036 (*)	.129 (**)	.166 (**)	1				.051 (**)	.120 (**)	.115 (**)	1				.049**	.102 (**)	.147 (**)	1			
Sub. kn.	.066 (**)	.124 (**)	.149 (**)	.539 (**)	1			.094 (**)	.155 (**)	.153 (**)	.545 (**)	1			.070 (**)	.110 (**)	.178 (**)	.559 (**)	1		
Obj. kn.	.092 (**)	.044 (*)	-.015	.057 (**)	.059 (**)	1		.034 (*)	.038 (*)	.048 (**)	.070 (**)	.087 (**)	1		.010	-.010	-.010	.064 (**)	.065 (**)	1	
Attitude	.093 (**)	.271 (**)	.347 (**)	.099 (**)	.131 (**)	.004	1	.062 (**)	.344 (**)	.364 (**)	.125 (**)	.135 (**)	.022	1	.093 (**)	.320 (**)	.352 (**)	.112 (**)	.132 (**)	.000	1
Post-																					
Int. in Edu.	1							1							1						
Necessity	.181 (**)	1						.179 (**)	1						.156 (**)	1					
Safety	.127 (**)	.452 (**)	1					.154 (**)	.473 (**)	1					.131 (**)	.448 (**)	1				
Info. acq.	.107 (**)	.236 (**)	.224 (**)	1				.104 (**)	.187 (**)	.186 (**)	1				.095 (**)	.168 (**)	.146 (**)	1			
Sub. kn.	.121 (**)	.311 (**)	.309 (**)	.532 (**)	1			.200 (**)	.285 (**)	.309 (**)	.529 (**)	1			.155 (**)	.237 (**)	.281 (**)	.495 (**)	1		
Obj. kn.	.048 (**)	-.006	.001	.025	.046 (*)	1		.080 (**)	.119 (**)	.098 (**)	.074 (**)	.097 (**)	1		.017	.068 (**)	.038 (**)	.041 (**)	.033 (*)	1	
Attitude	.175 (**)	.471 (**)	.447 (**)	.191 (**)	.269 (**)	.005	1	.169 (**)	.495 (**)	.446 (**)	.182 (**)	.272 (**)	.149 (**)	1	.149 (**)	.451 (**)	.447 (**)	.165 (**)	.261 (**)	.027 (*)	1

NB: In all three school years, all variables except for objective knowledge showed inter-variable correlations.
NB: * $P < 0.05$, ** $P < 0.01$

related, it seems that attitude change may be induced by providing information on the necessity of irradiated foods in materials for food irradiation education. This point is also reflected in the research finding that personal risk perception is not necessarily associated with the real severity of the risk [25,26]. Furthermore, cases where the level of objective knowledge is not correlated with the attitude towards the purchase and consumption of irradiated foods reflect the findings of evidence-based studies that the role of knowledge in the perception process is not as important as surmised, and that a complex mixture of factors plays the more important role [27,28]. (Table 5).

Factors influencing attitudes toward the purchase and consumption of irradiated foods

Multiple linear regression was performed with attitudes towards irradiated foods as a dependent variable and interest in education, perception (necessity, safety, information acquisition, and subjective knowledge), objective knowledge as independent variables. In all three years of the program, safety perception

Table 6. Factors influencing the attitude towards purchase chose of irradiated foods

Category				B	St. error	β	t	*P*-value	F	*P*-value	R^2
2013	Pre-education	(Constant)		1.151	.104		11.013	<.001			
		Interest in education		.147	.043	.057	3.416	<.001			
		Perception	Necessity	.158	.018	.155	8.687	<.001			
			Safety	.280	.018	.277	15.443	<.001	96.236	<.001	.155
			Info. acq.	.004	.019	.004	.215	0.830			
			Subj. kn.	.080	.021	.075	3.849	<.001			
		Objective knowledge		.045	.039	.019	1.155	0.248			
	Post-education	(Constant)		.466	.106		4.377	<.001			
		Interest in education		.223	.044	.080	5.099	<.001			
		Perception	Necessity	.351	.020	.304	17.270	<.001			
			Safety	.298	.019	.273	15.609	<.001	214.936	<.001	.300
			Info. acq.	.007	.018	.007	.402	0.688			
			Subj. kn.	.083	.020	.077	4.084	<.001			
		Objective knowledge		.020	.036	.008	.548	0.583			
2014	Pre-education	(Constant)		1.064	.096		11.049	<.001			
		Interest in education		.044	.040	.016	1.079	0.280			
		Perception	Necessity	.226	.017	.220	13.538	<.001			
			Safety	.272	.017	.260	16.053	<.001	141.017	<.001	.180
			Info. acq.	.047	.017	.047	2.721	0.007			
			Subj. kn.	.037	.020	.033	1.862	0.063			
		Objective knowledge		.026	.036	.011	.717	0.474			
	Post-education	(Constant)		.382	.096		3.999	<.001			
		Interest in education		.147	.040	.050	3.671	<.001			
		Perception	Necessity	.398	.018	.341	22.194	<.001			
			Safety	.272	.017	.248	16.123	<.001	307.165	<.001	.325
			Info. acq.	.029	.017	.027	1.707	0.088			
			Subj. kn.	.079	.019	.069	4.208	<.001			
		Objective knowledge		.145	.028	.070	5.200	<.001			
2015	Pre-education	(Constant)		.957	.076		12.661	<.001			
		Interest in education		.149	.030	.060	5.025	<.001			
		Perception	Necessity	.208	.014	.197	14.749	<.001			
			Safety	.256	.014	.249	18.423	<.001	191.970	<.001	.165
			Info. acq.	.029	.014	.029	2.011	0.044			
			Subj. kn.	.048	.016	.043	2.958	0.003			
		Objective knowledge		.008	.032	.003	.263	0.792			
	Post-education	(Constant)		.377	.083		4.522	<.001			
		Interest in education		.137	.032	.048	4.214	<.001			
		Perception	Necessity	.361	.016	.295	23.010	<.001			
			Safety	.308	.014	.279	21.645	<.001	386.931	<.001	.295
			Info. acq.	.027	.015	.024	1.881	0.060			
			Subj. kn.	.111	.016	.095	7.036	<.001			
		Objective knowledge		.017	.023	.009	.760	0.447			

NB: In all three school years, the variable exerting the greatest influence on attitude towards purchase and consumption of irradiated foods was perception of safety before the education, but changed to perception of necessity after the education.

exerted the greatest influence among the variables influencing pre-education attitude towards the purchase and consumption of irradiated foods; post-education, the same position was taken by necessity perception. Further, post-education explanatory power was higher than the pre-education explanatory power (2013: from 15.5% to 30.0%, 2014: from 18.0% to 32.5%, 2015: from 16.5% to 29.5%). Flynn *et al*. [29] evaluated health risks as perceived by the public from two dimensions: "dread risk" and "unknown risk." An unknown risk is a risk that is improperly understood, and the perception of irradiated foods may correspond to this category of risk (Table 6).

DISCUSSION

As the result of a 45-min education session given to elementary, middle, and high school students in schools across South Korea, with content covering the principles, state of application, and pros and cons of food irradiation, students' post-education perceptions, knowledge, and attitudes regarding irradiated foods improved significantly compared to pre-education levels. Bruhn *et al*. [30] reported that even consumers with little knowledge or negative views of irradiation show favorable attitudes towards irradiated foodstuffs after being exposed to promotional materials or campaigns on processing techniques using food irradiation and their advantages. Furthermore, Fox *et al*. [31] verified in a general sense that receivers of positive information on a technology are motivated to purchase related products, while negative information leads to decrease in purchase intentions. This was also true for purchase intention for irradiated foods [32]. In the long run, positive change of attitudes towards the purchase and consumption of irradiated foods can be efficiently induced by providing education on their necessity and safety.

When a new technology for food production or processing becomes available, government, business, and food experts should make great efforts to provide the public with correct information so as to prevent the spread of unfounded concerns and anxiety. For its part, the public should view safety issues regarding novel technologies from a scientific, rational perspective instead of adopting an emotional approach [14]. In general, the public does not have sufficient scientific or technological knowledge to allow such a perspective, and thus rely more heavily on emotional perceptions and/or personal experiences instead of making rational decisions [33]. Therefore, change of attitude may be more efficiently induced by providing information on safety and necessity of irradiated foods that incorporates an emotionally affective perspective.

Based on the results of this study, we would like to put forward the following proposals with the intent to help future generations make adequate judgments concerning the choice and purchase of irradiated foods. First, given that post-education levels of perception, knowledge, and attitude concerning irradiated foods increased considerably compared to pre-education levels, behavior change should be induced by providing continuous education to enhance, these primary variables. Second, given the high correlations between irradiated food related necessity and safety perceptions and levels of information acquisition and attitude, improvement of attitude should be sought through improvement of necessity and safety perception of irradiated foods. Third, elementary and middle school students are suitable as a target population for this kind of education because of the greater educational effects found among younger persons in this, also from the futurological point of view. Fourth, considering that necessity and safety perceptions are important variables influencing attitudes towards the purchase and consumption of irradiated foods, the content of education programs of this sorts should focus on the necessity and safety of irradiated foods so as to induce positive attitudes. In particular, perception of irradiated foods as safe exerts the greatest influence on attitude change and should be the main focus. In order to induce positive attitude change, which is the ultimate goal of the proposed educational program, it appears to be equally important to choose an optimal target population and to apply an appropriate strategy to the selection of educational contents.

REFERENCES

1. Health Canada, Health Products and Food Branch; Canadian Food Inspection Agency. Recommended Canadian Code of Practice for Food Irradiation. Ottawa: Canadian Food Inspection Agency; 2002 Nov 19.
2. Korea Food and Drug Administration. Guidebook on Food Labeling Standards. 1st ed. Cheongju: Korea Food and Drug Administration; 2010.
3. Korea Food and Drug Administration. Guidebook on Food Labeling Standards. 2nd ed. Cheongju: Korea Food and Drug Administration; 2012.
4. Lee JW. Application and prospect of food irradiation for providing the safe food materials. Food Ind Nutr 2006;11:12-20.
5. Nam HS, Kim KE, Yang JS, Ly SY. Effect of food irradiation education on food majoring college students' knowledge and acceptance of irradiated food. Korean J Diet Cult 2000;15:279-85.
6. Yoon Y, Byun MW, Kim WJ, Kwon JH, Lee JW. Current status of food irradiation technology on quarantine of agricultural commodities. Food Sci Ind 2009;42:19-26.
7. Han EO, Choi YS. Relation of self-efficacy and cognition of irradiated food among high school students. J Radiat Prot 2013;38:106-18.
8. Kim MR. Study on the Management Trend of Domestic and Foreign Countries toward Food Irradiation. Cheongju: Korea Food and Drug Administration; 2004.
9. Kim H, Kim M. Consumer attitudes towards irradiated foods. J Korean Home Econ Assoc 2003;41:119-30.
10. Malone JW Jr. Consumer willingness to purchase and to pay more for potential benefits of irradiated fresh food products. Agribusiness 1990;6:163-78.
11. Foster A. The impact of consumer acceptance on trade in irradiated foods. Br Food J 1990;92:28-34.
12. Choi MH, Youn SJ, Ahn YS, Seo KJ, Park KH, Kim GH. A survey on the consumer's recognition of food labeling in Seoul area. J Korean Soc Food Sci Nutr 2010;39:1555-64.
13. Lee JS. The effect of media modality and the valence of the risk messages on affective risk perception and behavioral intention. Korean. J Cogn Sci 2012;23:457-85.
14. Lee JE, Lee CH. The effects of consumer compaign to boycott certain food produce on national economy and food security. Food

Sci Ind 2011;44:43-9.
15. Seo HJ. Fukushima nuclear accident and negative perceptions. J Gov Stud 2013;19:321-61.
16. Han E, Kim J, Choi Y. Using education on irradiated foods to change behavior of Korean elementary, middle, and high school students. Nutr Res Pract 2014;8:595-601.
17. Park JW. The status and role of the precautionary principle in international environmental law. Hanyang Law Rev 2007;24:405-27.
18. Tomas G, Durant J. Why should we promote the public understanding of science? In: Shortland M, editor. Scientific Literacy Papers. Oxford: Rewley House; 1987. p.1-14.
19. Lee TJ, Ki BJ, Kim IS. A national survey of the policy customers' perceptions and beliefs of nuclear energy issues and agenda. Korean J Advert 2015;26:299-323.
20. Ajzen I. The theory of planned behavior. Organ Behav Hum Decis Process 1991;50:179-211.
21. Van der Linden S. Towards a new model for communicating climate change. In: Cohen SA, Higham JE, Peeters P, Gössling S, editors. Understanding and Governing Sustainable Tourism Mobility: Psychological and Behavioural Approaches. New York (NY): Routledge; 2014. p.243-275.
22. Han EO, Kim JR, Choi YS. Different perceptions, knowledge, and attitudes of elementary, middle, and high school students regarding irradiated food, nuclear power generation, and medical Radiation. J Radiat Prot 2014;39:118-26.
23. Oh MY, Choi JM, Kim HS. Stigma effect of technology with risk: the impact of stigma on nuclear power on the perception and acceptance of products based on radiation technology. Korean J Journal Commun Stud 2008;52:467-500.
24. Cho SK, Oh SK. A theoretical approach to derive perception indicators influencing the acceptability on nuclear energy facilities & policies. J Energy Eng 2002;11:332-41.
25. Weinstein N. Unrealistic optimism about future life events. J Pers Soc Psychol 1980;19:30-53.
26. Lee JS. The effect of media modality and the valence of risk messages on affective risk perception and behavioral intention. Korean J Cogn Sci 2012;23:457-85.
27. Krimsky S. The role of theory in risk studies. In: Krimsky S, Golding D, editors. Social Theories of Risk. New York (NY): Praeger; 1992. p.3-22.
28. Honkanen P, Verplanken B. Understanding attitudes towards genetically modified food: The role of values and attitude strength. J Consum Policy 2004;27:401-20.
29. Flynn J, Perter E, Mertz CK, Slovic P. Risk, media, and stigma at rocky flats. In: Flynn J, Slovic P, Kunreuther H, editors. Risk, Media and Stigma: Understanding Public Challenges to Modern Science and Technology. London: Earthscan Publication Ltd; 2001. p.309-327.
30. Bruhn CM, Schutz HG, Sommer R. Attitude change toward food irradiation among conventional and alternative consumers. Food Technol 1986;40:86-91.
31. Fox JA, Hayes DJ, Shogren JF. Consumer preferences for food irradiation: how favorable and unfavorable descriptions affect preferences for irradiated pork in experimental auctions. J Risk Uncertain 2002;24:75-95.
32. Rodriguez L. The impact of risk communication on the acceptance of irradiated food. Sci Commun 2007;28:476-500.
33. Epstein S. Integration of the cognitive and the psychodynamic unconscious. Am Psychol 1994;49:709-24.