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-Review-

Status and Prospects of Food Irradiation Technology in Korea

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Abstract

In Korea, the health authorities and food industry emphasize the need of sanitary food production, which is mainly resulted from the recent growing of consumer's interest in the safety of food. For the reason, development of a new alternative technology to chemicals, currently used for decontamination and disinfestation, has become an urgent task in the domestic and worldwide food industry. Furthermore, the improvement of quality and manufacturing process of processed foods is a requisite for winning the competition in export fields. Irradiation technology being practically applicable in the food industry has been well established on the basis of more than 40 years of R & D work in the fields of the increasing availability of food-stuffs, sanitary food production and quarantine treatment in the food trade. The wholesomeness of irradiated foods has been officially approved in 38 countries, of which 30 countries are commercially utilizing food irradiation technology. The first commercial irradiator in Korea(18.5 PBq: 500 kCi ^{60}Co, max. cap; 4 MCi) was established at Yeoju-gur, Kyung Ki-do with the technical assistance of Korea Atomic Energy Research Institute in June 1987. As of 1996, thirteen irradiated food groups(over 25 items) have been domestically approved for human consumption and an industrial irradiation facility is also available. However, the promotion of consumer acceptance toward ir-radiated foods is considered as a confronted subject to be studied for a commercial utilization.

Key words: food irradiation, commercial utilization, consumer acceptance

INTRODUCTION

In every part of the world, people wage a constant battle against the spoilage of food caused by infestation, contamination, and deterioration. There are no exact data on how much of the world's food supply is spoiled, but losses are enormous, especially in developing countries. In such countries, the estimated storage loss of cereal grains and legumes is at least 10%. With non-grain staples, vegetables, and fruits, the losses due to microbial contamination and spoilage are believed to be as high as 50%. In commodities such as dried fish, insect infestation is reported to result in the loss of 25 % of the product, plus an additional 10% loss due to spoilage. With a rapidly expanding world population, any preventable loss of food is intolerable.

However, the loss of edible food is only part of a larger problem. A Joint FAO/WHO Expert Committee on Food Safety(1) concluded that foodborne disease, while not well documented, was one of the most widespread threats to human health and is an important cause of reduced economic productivity. For example, it is conservatively estimated that the cost of medical care and lost productivity resulting from major diseases spread by contaminated meat and poultry amounts to at least US$ 1,000 million a year in the United States.

Efforts to reduce the devastating consequences of food wastage and foodborne disease started before the first written records. In the course of tens of thousands of years, people have discovered many other methods of preserving food such as salting, cooking, smoking, canning, freezing and chemical preservation. The most recent addition to this list is irradiation, i.e., the exposure of foods to carefully measured amounts of ionizing radiation.

Food irradiation, along with pasteurization, canning, freezing and drying, is simply a physical method of treating food in order to make it safe to eat and longer lasting. Therefore, it has been used to achieve a variety of desirable objectives and offered consumers many advantages, the most important of which is improved sanitary level of foods. From the development of this technique, food irradiation has been classified into three

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Table 1. Dose requirement in various applications of food irradiation

Purpose	Dose(kGy)	Products
Low dose(up to 1 kGy)		
(a) Inhibition of sprouting	0.05~0.15	Potatoes, onions, garlic, ginger-root, etc.
(b) Insect disinfestation and parasite disinfection	0.15~0.50	Cereals and pulses, fresh and dried fruits, dried fish and meat, fresh pork, etc.
(c) Delay of physiological process(e.g. ripening)	0.50~1.0	Fresh fruits and vegetables
Medium dose(1~10 kGy)		
(a) Extension of shelf-life	1.0~3.0	Fresh fish, strawberries, etc.
(b) Elimination of spoilage and pathogenic microorganisms	1.0~7.0	Fresh and frozen seafood, raw or frozen poultry and meat, etc.
(c) Improving technological properties of food	2.0~7.0	Grapes (increasing juice yield), dehydrated vegetables and cereals(reduced cooking time)
High dose(10~50 kGy)		
(a) Industrial sterilization (in combination with mild heat)	30~50	Meat, poultry, seafood, prepared foods, sterilized hospital diets
(b) Decontamination of certain food additives and ingredients	10~50	Spices, enzyme preparations, natural gum, etc.

categories according to the average irradiation dose required(Table 1).

Low dose applications(up to about 1 kGy) give inhibition of sprouting, insect disinfestation and parasite disinfection, and delay of ripening. Medium dose applications(1~10 kGy) cause extension of shelf-life according to reduction of microbial load, reduction in the number of nonsporing pathogenic microorganisms, and improvement of physicochemical properties of foods. High dose applications(10~50 kGy) give industrial sterilization and elimination of viruses(2,3).

Commercial application of food irradiation, though small in number, has been steadily increased in recent years. Health and safety authorities in 38 countries have approved irradiation of more than 50 different kinds of foods and 30 of these countries are commercially utilizing the irradiation process(4).

In Korea, the potential utilization of food irradiation is gradually recognized by the food industry and authorities concerned as a viable technology to solve or supplement the limitation of traditional methods for food preservation and processing, and furthermore to meet the stiff standards for quality and quarantine confronted with in ever-increasing international trade of food products. Because of this practical importance, this paper is focused on the status and development of food irradiation technology in Korea.

RESEARCH ACTIVITIES AND LEGISLATIONS ON FOOD IRRADIATION IN KOREA

In the late 1960's, a few Korean scientists showed interest in the use of radioisotopes for food preservation. At that time, those who were engaged in research work had difficulties in using the limited radiation sources so that research was implemented only in the national institutes. This early research provided a foundation for food irradiation in Korea. Especially, since the early 1980's, under the national co-ordinated and regional co-operative research programs, irradiation techniques have been applied to various foods for preserving and improving their quality safety. Most of these researches have dealt with the efficacy and feasibility of irradiation processing over conventional methods, such as chemical treatment, refrigeration, etc.

In Korea, the last three decades of R & D in the field of food irradiation, which extended its scale from an experimental basis to a semi-industrial study on different kinds of foods, have provided the extensive knowledge necessary to provided with its utilization along with the publication of more than 200 papers as shown in Table 2.

With respect to the wholesomeness of irradiated food, the Korean government has accepted the recommendations of international organizations concerned(FAO, WHO, IAEA, FDA, CAC, etc.)(5~7). In recent years, the wholesomeness of irradiated foods has been investigated by Korea National Institute of Safety Research and Korea Atomic Energy Research Institute. Especially, in the case of γ-irradiated ginseng products, wholesomeness, focusing on microbiological, physicochemical, physiological and genotoxicological points of view, was already recognized(8). The wholesomeness of other food items were also investigated recently.

Table 2. Status of food research using ionizing radiation in Korea

Group	Item	Research content	No. of paper
Fresh vegetable	potato, onion, garlic, sweet potato, tomato, etc.	sprout inhibition, delay of ripening	16
Fruit	chestnut, strawberry, apple, pear, grape, peach, mandarin orange, etc.	sprout inhibition, delay of ripening	12
Mushroom	fresh and dried mushrooms	growth inhibition disinfestation	8
Ginseng product	white and red ginseng products fresh ginseng	decontamination, improvement of quality, extension of shelf-life	21
Grain and legumes	rice, corn, soybean, etc.	disinfestation, wholesomeness	18
Spice, herb and dried vegetable	pepper, ginger, garlic, onion, green onion, spinach, carrot, etc.	decontamination	20
Fish and fishhery product	fresh and dried fish, dried laver, fried fish paste, etc.	radurization, decontamination	29
Meat and its product	chicken, beef, pork, ham, sausage, etc.	radurization	8
Fermented foods	kimchi, soybean paste powder, etc.	extension of shelf-life, decontamination	14
Quality evaluation	irradiated food, oil, malt, enzymes, etc.	physical, chemical and organoleptic properties	28
Quality improvement	soybean, corn starch	reduction of soaking and cooking time, modified starch process	8
Microorganism	bacteria, molds, yeasts, insect, parasite	radiosensitivity	14
Animal feeds	poultry feed, etc.	decontamination	4

On the basis of these studies, food irradiation has been recognized by the government and food industry as a viable alternative method for food processing and preservation, having a greater potential than that of conventional methods. Also, the recommendations of the FAO/IAEA/WHO and the Codex Alimentarius Commission were based upon the legislations for the implementation of food irradiation(9,10).

The Korea Ministry of Health and Welfare(MOHW) is responsible for clearances and regulations of irradiated foods, MOHW consults with the Committee of Food Sanitation Deliberation and the National Health Institute concerned. Korea Institute of Nuclear Safety, which is a government-funded organization under the Ministry of Science and Technology, inspects periodically irradiators according to the Atomic Energy Law to ensure compliance with regulations.

The Presidential decree(No. 11, 717 of 29 June 1985) and MOHW decree(No. 767 of 1 July 1985) were a legal basis for newly-established food irradiation business. The general standard and regulations for irradiation of foodstuffs were enforced in September 1987, and amended in 19 May, 1995.

The type of ionizing radiation for food irradiation maybe used gamma rays from the radionuclides ^{60}Co. Regulations prohibit re-irradiation of food under any circumstances. The irradiated foods should be packaged using a proper container or appropriate materials before going to markets. The regulations also require that prepackaged irradiated foods should be labeled with the international symbol(above Φ5cm) for food irradiation. Gamma radiation from ^{60}Co source is authorized to be used for food irradiation on 13 food groups as shown in Table 3(11).

TECHNOLOGY TRANSFER AND COMMERCIALIZATION OF FOOD IRRADIATION IN KOREA

The Korean government authorized food irradiation in 1985 as a new physical process for food preservation which would be beneficial to relevant industries and consumers. The decision was made based upon the results of research that were mainly accomplished by the Korea Atomic Energy Research Institute(KAERI), encouraged by the recommendations of the 1980 joint FAO/IAEA/WHO Expert Committee on the Wholesomeness of Irradiated Food and by the adoption of Codex General Standard for Irradiated Food by the Codex Alimentarius Commission in 1983(9,10).

Table 3. List of authorized applications of food irradiation for human consumption in Korea

Product	Type of clearance	Dose permitted	Date of approval	Note
Potato, onion, garlic	Unconditional	0.15max.	16 Oct. 1987	
Chestnut	Unconditional	0.25max.	16 Oct. 1987	
Fresh mushrooms	Unconditional	1.00max.	16 Oct. 1987	
Dried mushrooms	Unconditional	1.00max.	16 Oct. 1987	
Dried meats, powdered-fish and shellfish	Unconditional	7.00max.	14 Dec. 1991	Only for the processing food
Soybean paste powder, hot pepper powder, soy sauce powder	Unconditional	7.00max.	14 Dec. 1991	
Starch	Unconditional	5.00max.	14 Dec. 1991	Only for the condimental product
Dried spices and their preparations	Unconditional	10.00max.	19 May 1995	
Dried vegetables	Unconditional	7.00max.	19 May 1995	Only for the Processing food
Yeast and enzyme foods	Unconditional	7.00max.	19 May 1995	
Powdered aloe	Unconditional	7.00max.	19 May 1995	
Ginseng products including red ginseng	Unconditional	7.00max.	19 May 1995	
Second sterile meals for patient	Unconditional	10.00max.	19 May 1995	

According to the government policy of technical transfer to small and medium-sized industries, KAERI has assisted a private firm(Greenpia Tech. Inc.) in the field of food irradiation for five years. Greenpia Tech. Inc. proposed the construction of a 500 kCi ^{60}Co commercial irradiator(maximum capacity: 4 MCi) to the MOST in 1984, and the facility was established at Yeoju-gun, Kyungki-do in June 19, 1987 on the financial basis of 80% borrowed by the Government sector and 20% by the private sector. From the beginning of its operation, it has been used for food irradiation and medical sterilization. Now, the irradiation facility is loaded with 540 kCi of ^{60}Co and its operating rate is about 100% which is composed of 70% in food irradiation, 20% in medical sterilization and 10% others. In recent years, companies using irradiation technology have recognized that food irradiation is often the only possible alternative to fulfill the strict quality requirements of their customers. Therefore, the number of companies using this technology has remarkably increased(Fig. 1).

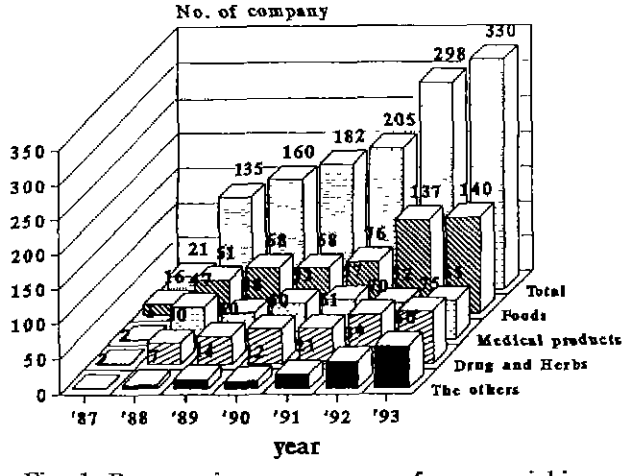

Fig. 1. Progress in user company of commercial irradiator in Korea.

The patent license contracts to related food irradiation(12 kinds with term validity of 10 years) and the agreement of technical assistance were established by KAERI and Greenpia Tech. Inc. on 20 July, 1992. These activities are gradually influencing the increase in number of food items and their quantity for food irradiation(Table 4). Especially, spices and dried vegetable seasonings are the most common products to be commercially irradiated since the ban of ethylene oxide fumigation on foods by MOHW on 1 July, 1991. The trend in the practical application is likely to increase in the coming year in view of the recent prohibition or restriction on the use of other fumigants on foods. In view of increasing the operating rate of irradiation facility, however, consumer acceptance along with transporting expenses is considered as the most important factor of all.

Table 4. Yearly quantity of gamma-irradiated materials in Korea (unit : ton)

Product	Year								
	'87	'88	'89	'90	'91	'92	'93	'94	'95
Foods									
Sprouting foods	142	559	–	–	–	–	–	–	–
Spices	–	–	1101	765	1469	2112	1995	1966	1983
Soybean paste powder	–	–	–	–	–	38	112	105	90
Soybean sauce powder	–	–	–	–	–	131	170	110	96
Condimented dried-meat	–	–	–	–	–	52	20	62	68
Powdered fish & shellfish	–	–	–	–	–	333	483	305	280
Corn starch	–	–	–	–	–	70	52	107	96
Dried mushroom	–	–	–	–	–	245	150	178	185
Ginseng products	–	–	–	–	–	–	–	–	21
Yeast & enzyme foods	–	–	–	–	–	–	–	–	4
Medical products	9	865	846	335	469	403	425	480	440
Others	27	62	62	72	96	234	270	295	490
Total	178	1486	2018	1192	2034	3618	3677	3608	3753

Table 5. The subjects perceptions toward food irradiation (n=700)

Questions		Responses N(%)	Frequency	
			Radiation worker N(%)	General public N(%)
Have you ever heard of food irradiation?	Yes	574(82.0)	303(93.5)	271(72.1)
	No	126(18.0)	21(6.5)	105(27.9)
Do you know food irradiation has been approved by the Korean Government and International Organizations?	Yes	307(43.9)	188(58.0)	119(31.7)
	No	390(55.7)	135(41.7)	255(67.8)
	Uncertain	3(0.4)	1(0.3)	2(0.5)
Are irradiated foods the same as contaminated foods by radioactivity?	Yes	45(6.4)	11(3.4)	34(9.0)
	No	522(74.6)	290(89.4)	232(61.0)
	Uncertain	133(19.0)	110(7.1)	110(29.3)

CONSUMER'S PERCEPTIONS AND ATTITUDES TOWARD FOOD IRRADIATION IN KOREA

Irradiation of foods offers consumers many advantages, the most important one of which is the improvement in sanitation of foods. Decrease in foodborne illness could be resulted by irradiation, which inhibit the survival of bacteria and parasites, resulting in reduction of healthcare costs. Other advantages include replacement of chemical fumigants, extended food shelf-life, reduction of mold, and safe transport of food from insect quarantine areas.

Although food irradiation had been approved in Korea for 13 food groups from 1987 to 1995, labeled irradiated products are not marketed at the consumer level. The food industry is also reluctant to use this technology due to uncertain consumer responses on the irradiated foods. Few studies have been done to estimate consumers' perceptions and attitudes toward irradiated foods in Korea. In 1988, the Korean Women's Association reported that 41% of consumers were aware of food irradiation; nevertheless, the majority of the respondents showed a negative attitude toward irradiated foods, especially in relation to safety(12). This result was most likely derived from their preconceptions concerning the safety of nuclear technology, although demographic features of the consumer groups were not reported in the survey.

The most recently, the basic perceptions and attitudes toward irradiated food was investigated in order to shed further light on food irradiation areas(13). In basic perceptions toward food irradiation, radiation workers, males, the well-educated, and older respondents showed

a higher level of awareness and understanding of food irradiation than the general public, females, the less-educated, and younger respondents(Table 5, Fig. 2). On purchasing intent for irradiated foods in general, 37.4% of the subjects were readily willing to buy irradiated foods while 57.2% of the subjects wanted more information about irradiation(Fig. 3). Although consumers preferred irradiated foods over chemically treated

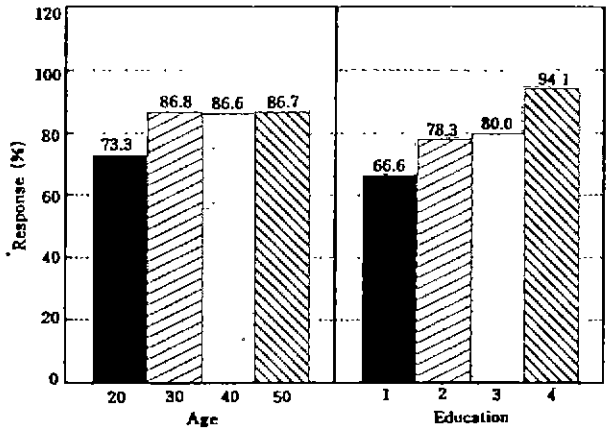

Fig. 2. Percentage of the subjects who have heard of food irradiation previously according to their age and education level(n=700).
1: Junior high school 2: high school
3: University 4: Graduate school

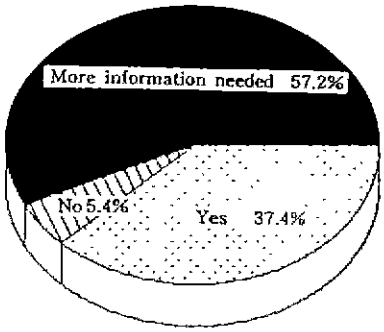

Fig. 3. Willingness of the subjects to buy irradiated foods(n=700).

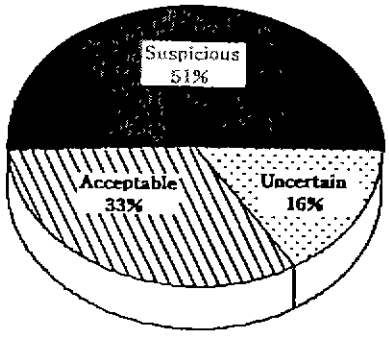

Fig. 4. Opinions on the wholesomeness of irradiated foods(n=700).

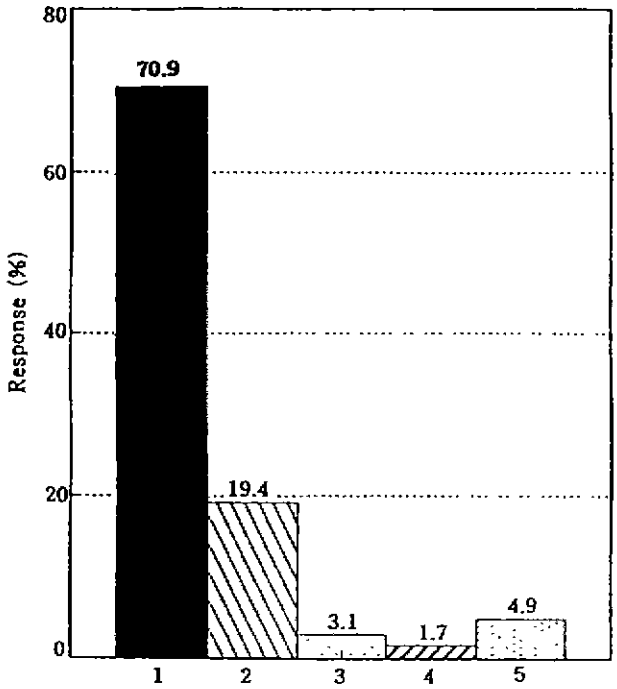

Fig. 5. The reason for delay of food irradiation commercialization(n=700).
1: Lack of public information, 2: Distrust of the authorities, 3: Due to new method, 4: Due to added expense, 5: Other.

food, about half of the subjects(51%) were concerned about the safety of irradiated foods(Fig. 4). The survey indicated that the majority of respondents(70.9%) had insufficient public information and incorrect understanding of food irradiation, which was a major reason for the delay of the utilization of this technology in foods(Fig. 5). Therefore, nationwide education of the characteristics and safety of food irradiation technology should be undertaken in order to increase public understanding and acceptance of irradiated foods.

CONCLUSION

Taken as a whole, the most critical impediment to the commercial application of food irradiation has been the general consumers' low acceptance. However, the positive attitude toward irradiated foods was easily found among the consumers when they understood the safety and advantages of this technology. In this respect, further efforts were required to educate the consumers with valid information on the beneficial aspects of food irradiation compared with conventional methods.

The Korean government and most of the food industries have recognized the benefits and advantages

of irradiation processing over the existing conventional methods. The most important task in food irradiation could be to overcome consumers' psychological resistance and transportation matters of the products to be irradiated.

In conclusion, all the successful commercialization of food irradiation has been associated with the careful provision of well thought-out information for the consumers. There are certain essential elements that need to be included if the information provided is to change the consumers' perception of why irradiation is being used and what it is doing to the particular food. Also, the key to the acceptance of irradiated food lies in having high quality products readily available for the consumers to try.

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