기획특집

Current Status of Food Irradiation: Benefits, Regulations and Acceptance

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I. Introduction

Irradiation has been in every part of our lives, and human experience it every day in the natural circumstances (Fan et al., 2008). Radiation of gamma rays, electron beam, and X-rays transfer their energies to target materials by emitting atomic electrons, which ionize other atoms (Cleland, 2006). Irradiation with ionizing energy is widely used to improve the physical, chemical, and biological properties of materials in various industries (Cleland, 2006), and it is used in food industry. Of radiation types, gamma irradiation is suggested as the most effective method because it destroys pathogenic microorganisms in the final products after packaging because of its high permeability (Fan et al., 2008).

Food irradiation has been known as alternatives to the chemical fumigants or preservatives usually used for a sanitation treatment for international trade for controlling pathogenic microorganisms (WHO 1999). Use of gamma irradiation can prevent decay by destroying spoilage flora and by improving food safety and quality of foods without compromising the nutritional or sensory quality (Abu-Tarboush et al., 1996). Hence, use of gamma irradiation technology has been gradually increasing up to 404,804 tons of irradiated foods worldwide (Fan et al., 2008).

Accepted scientific tests indicated that irradiated foods are safe, and Satin (1996) concluded that food irradiation is one of the safest methods of food preservation ever developed. Use of irradiation technology on foods has been officially adopted by international organizations and experts (WHO, 1999) because of its effectiveness in food, wholesomeness and economic benefits. In addition, use of gamma irradiation has positive effects in preventing decay by destroying microorganisms and by improving

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the food safety and quality of foods without compromising the nutritional or sensory quality (Abu-Tarboush et al., 1996).

II. Why do we irradiate foods?

Food irradiation can provide a wide range of benefits to consumers as well as food industry. In a practical point of view, there are three general applications and dose categories that are referred to when foods are treated with ionizing radiation (ICFGI, 1999)

Low-dose irradiation-up to 1 kGy: sprout inhibition, delay of ripening, insect disinfection, parasite inactivation.

Medium-dose irradiation-1 to 10 kGy: reduction in numbers of spoilage microorganisms, reduction in numbers or elimination of non-spore-forming pathogens, i.g. disease causing microorganisms.

High-dose irradiation-above 10 kGy: reduction in numbers of microorganisms to the point of sterility

III. Food irradiation clearance

1. Codex (Codex 1983)

1) Radioactive source and facility structure

To irradiate foods, either a radionuclide source (^{60}Co or ^{137}Cs) or X-rays and electrons generated from machine sources can be used. Average beam power should also be properly recorded, and the irradiation facility for food irradiation should be of two designs, either "continuous" or "batch type".

2) Dosimetry and average absorbed dose

Before the irradiation of any foods, dosimetry measurements should be performed to demonstrate that the radiation process satisfy the regulatory requirements. Dosimetry measurement is required for new food, irradiation process and whenever modifications are made. In order to calculate the overall average absorbed dose, the doses for homogeneous products or bulk products of homogeneous bulk density can be measured by distributing an adequate number of dose meters and at random throughout the volume of the goods. From the dose distribution, an

Table 1. Food irradiation applications (ICGFI, 1999)

Benefit	Dose (kGy)	Products
Low dose (up to 1 kGy)		
(i) Inhibition of sprouting	0.05-0.15	Potatoes, onions, garlic, root ginger, yam etc.
(ii) Insect disinfestations and parasite disinfection and meat, fresh pork, etc.	0.15-0.5	Cereals and pulses, fresh and dried fruits, dried fish
(iii) Delay of physiological process (e.g. ripening)	0.25-1.0	Fresh fruits and vegetables
Medium-dose (1-10 kGy)		
(i) Extension of shelf-life	1.0-3.0	Fresh fish, strawberries, mushrooms etc.
(ii) Elimination of spoilage and pathogenic microorganisms	1.0-7.0	Fresh and frozen seafood, raw or frozen poultry and meat, etc.
(iii) Improving technological properties of food	2.0-7.0	Grapes (increasing juice yield), dehydrated vegetables (reduced cooking time), etc.
High-dose (10-50 kGy)		
(i) Industrial sterilization (in combination with mild heat)	30-50	Meat, poultry, seafood, prepared foods, sterilized hospital diets
(ii) Decontamination of certain food additives and ingredients	10-50	Spices, enzyme preparations, natural gum, etc.

average absorbed dose can be calculated.

3) Conditions for irradiated foods

Since 1980' s, international agencies prepared regulations and Codex also cited the reports of the Joint FAO/IAEA/WHO Expert committees on Food Irradiation (WHO Technical Report Series, 604, 1977 and 659, 1981) as Table 1.

2. International clearance

Irradiation technology is used to produce high quality products in medical products, cosmetics, animal feeds and herbal medicines, especially in foods for various benefits. In regard to pathogenic microbial contamination of foods, the frequency of foodborne illness outbreaks attributable to fresh produce and other agricultural produces has been increased (Bryan 1988; Golden et al., 1993).

In addition, food irradiation was also recommended by FAO/IAEA/WHO expert committee on the wholesomeness of irradiated food (FAO/IAEA/WHO, 1999) and Codex General Standard for irradiated food (Codex, 2003). Besides decontamination efficiency, the other reason for irradiation to be used in food industry is cost effective. For instance, irradiation on fruits for disinfestations only costs 10-20% of the cost of the vapor-heat treatment (FAO/IAEA, 1999).

To control foodborne illness and prolong shelf-life, 56 countries approved food irradiation for human consumption (Table 4).

Table 3. Conditions for the irradiation of some individual food items specifically examined by the Joint FAO/IAEA/WHO Expert Committee (Codex 1983)

Food	Purpose of the process	Average dose
Chicken	To improve storage life	< 7 kGy
	To reduce the levels of pathogenic bacteria	< 7 kGy
Cocoa beans	To control insect infestation	< 1 kGy
	To decrease microbial load in fermented beans	< 5 kGy
Dates	To control insect infestation during storage	< 1 kGy
Mangoes	To control insect infestation	< 1 kGy
	To delay ripening	< 1 kGy
	To decrease microbial populations	< 1 kGy
Strawberry	To prolong the shelf life	< 3 kGy
Onions	To inhibit sprouting during storage	< 0.15 kGy
Papaya	To control insect infestation	< 1 kGy
	To delay ripening	< 1 kGy
Potatoes	To inhibit sprouting during storage	< 0.15 kGy
Pulses	To control insect infestation	< 1 kGy
Rice	To control insect infestation	< 1 kGy
Spices	To control insect infestation	< 1 kGy
	To reduce microbial load	< 10 kGy
	To reduce the number of pathogenic microorganisms	< 10 kGy
Teleost fish and fish products	To control insect infestation	< 1.0 kGy
	To decrease levels of natural flora	< 2.2 kGy
	To reduce the number of pathogenic bacteria	< 2.2 kGy
Wheat and ground wheat	To control insect infestation	< 1 kGy

Recently, food irradiation also emerged as a viable sanitary and phytosanitary treatment to meet requirement among governments. Thus, food irradiation faced with new facts and developments in the international trade, health, environmental, quarantine, and legislative areas (Molins, 2001).

3. Clearance in Korea

In Korea, gamma irradiation from a ^{60}Co source is authorized for use in food irradiation for 26 food items (Table 4). However, in 2010 the food labeling regulation has been initiated to all processed foods, and domestic and imported ingredients, which may rapidly decrease industrial use of irradiation. Therefore, the consumer acceptance will be the barrier, if the practical management system is not established.

Table 3. Current status of food irradiation clearance in the world

Country	Food class	Food item	Country	Food class	Food item
Algeria	8	16	Italy	2	6
Argentina	5	11	Japan	1	1
Australia	3	15	Korea	6	24
Austria	1	3	Libya	4	7
Bangladesh	7	15	Luxembourg	1	3
Belgium	8	25	Mexico	8	17
Brazil	8	16	Netherland	5	19
Bulgaria	1	3	New Zealand	3	18
Canada	3	4	Norway	1	3
Chile	6	18	Paraguay8	15	
China	6	11	Peru	8	19
Costa Rica	6	18	Philippine	8	22
Croatia	8	19	Poland	3	7
Cuba	8	16	Portugal	1	3
Czech Republic	8	26	Russia	6	16
Denmark	1	3	Saudi Arabia	8	17
Egypt	2	7	South Africa	8	21
Finland	3	4	Spain	1	2
France	7	17	Sweden	1	2
Germany	2	4	Syria	7	18
Ghana	8	20	Thailand	6	25
Greece	1	3	Tunisia	3	7
Hungary	1	3	Turkey	8	18
India	6	16	Ukraine	6	16
Indonesia	4	8	USA	8	18
Iran	1	1	Uruguay	1	1
Ireland	1	3	Vietnam	7	19
Israel	6	13	Zambia	8	16

Table 4. Food irradiation clearance in Korea (KFDA, 2008)

Food	Approved absorbed dose (kGy)
Potato, onion, garlic	< 0.15
Chestnut	< 0.25
Fresh mushroom, dried mushroom	< 1
Egg powder, cereals or legumes and their powder as ingredients of a food products, starch for processed food	< 5
Dried seafood products or dried meat products for processed food, Powdered soybean paste, Kochujang, soy sauce, yeast or enzyme food, algae food, aloe powder, ginseng products	<7
Dried spices or their products, composite seasoning products, sauces, tea (extracted or powdered), patient food	<10

IV. Safety issues of irradiated foods

Safety concerns for irradiated foods always have been issued for many years, but distinguished international agencies such as IAEA, WHO, and FAO have conducted many researches to prove the safety of irradiated foods. In addition, many other studies showed that irradiation on foods is toxicologically safe and nutrients were not changed (USFDA, 1997; Mazur, 2003). Whereas Steele (2001) suggested that criticism about irradiation is originated from incorrect information.

V. Acceptance of consumer and industry

Although safety of irradiated foods has been proved by international agencies and scientists, consumers still misunderstand that irradiated foods are radioactive. In the USA, 72% of consumers were aware of irradiation, but 87.5% of them were not much sure about the technology (Recurreccion et al., 1995). It was also found that 30% of American consumers believed that irradiated food is radioactive (Recurreccion et al., 1995). In Korea, 35.6% of consumer responded "I heard of irradiated foods, but I don't know about irradiated foods" (Byun et al., 2009).

The low level of awareness and knowledge of the benefit may result in low acceptance of irradiated foods (Gunnes and Tekin, 2006), and this low consumer acceptance may cause low industry acceptance because industry may not want to use irradiation technology if they cannot make more benefits than other decontamination technology. With this low consumer acceptance, food industry may also not see the necessity to use irradiation technology if other technologies are still available. Food industry would use radiation technology only for the products that can be treated only with irradiation. Hence, food irradiation could be still limited to spice, grain, and fruits and vegetables (Kume et al., 2009).

VIII. Conclusion

Currently, food irradiation technology is used to improve food safety and food security, and this technology is very closely related to cost benefits and international trade because radiation technology has been considered to replace harmful fumigants for human health and environmental protection. However, consumer and industry acceptance has been barrier to expand this technology because consumers may misunderstand that irradiated foods are radioactive, and industry do not challenge themselves to the condition they are not sure if they can make more benefits than other decontamination technology. Therefore, multilater promotion efforts are needed rather than research not to make the useful technology faded.

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