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ABSTRACT

Irradiation has been recognized as a safe and effective method for reducing food losses and increasing hygienic quality of food which can contribute positively to food security, safety and global food trade. This paper deals with the application of irradiation to decontaminate food for safety reasons, either for pasteurization or sterilization purposes. Foodborne disease is the most widespread health problem, and represents the main cause of death, particularly in developing countries. Elimination of specific types of spoilage and nonspore-forming pathogenic bacteria in foods especially those of animal origin using irradiation up to 10 kGy maximum dose has been developed successfully, and legally approved in a number of countries. Irradiation of food using doses above 10 kGy for sterilization purpose has also been developed in some countries with good results, but its application is still hampered by lack of national regulations. This technology can be used for decontaminating hospital foods, such as for eliminating pathogenic bacteria in raw foods of animal origin, spices, ready-to-eat shelf-stable food, etc., and for sterilizing foods intended for patients with reduced immuno-responses.

INTRODUCTION

Food irradiation is a physical method for processing food which consists of exposing food to gamma rays, X-rays or electrons over a limited period of time. It has been recognized as a safe and effective method for treating food for various purposes. This technology can be used as an additional powerful weapon to

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combat high food losses and foodborne diseases, as well as to wider trade of many food commodities which in turn can contribute positively to food security, safety and global food trade.

At present, 38 countries have approved the use of irradiation for treating certain food items, and 27 countries including Indonesia are using this technology for commercial purpose (1). In Indonesia, commercial application of food irradiation was approved by the health authority in 1987 for 3 groups of food, namely grains, spices, and tuber and root crops. In early 1992, a commercial irradiator called Indogamma went into operation at Cibitung, about 60 km away from Jakarta. The first commercial food irradiator in the USA was also operated in early 1992 by Vindicator Company at Mulberry, Florida. Currently, there are over 160 commercial irradiation facilities treating mainly medical supplies, and about 50 of these facilities are used for treating food in various countries (2).

The Codex Alimentarius Commission, which is the Executive Organ of the Joint FAO/WHO Food Standard Programme, adopted in 1983 a General Standard for Irradiated Food and its associated Code of Practice. The Standard recognized that the process of food irradiation has been established as safe for general application to an overall average dose of 10 kGy. This upper limit does not mean that food irradiated above 10 kGy become unsafe, but it is simply the level at or below which safety has been established.

Currently, a large quantity of scientific data concerning toxicity, nutritional and wholesomenes, chemistry and microbiology of food irradiated with doses above 10 kGy has been generated and reviewed (3). These data will be evaluated by a group of expert appointed by the FAO/IAEA/WHO International Consultative Group on Food Irradiation (ICGFI). Application of food irradiation at dose level greater than 10 kGy will be one of the topics to be discussed at the 11th ICGFI Meeting held in Denpasar, Bali, on 2-4 November this year.

Irradiation of food above 10 kGy can be directed to the production of shelf-stable food, and to sterilize or pasteurize foods for individuals in severe immuno-suppressed or immuno-deficient states.

This paper will focus on the application of irradiation for preparation of safe food products especially for high risk individual, such as hospital patients.

FOODBORNE DISEASES

Food contamination by biological agents of disease is a major public health problem all over the world. Food poisoning caused by microorganisms can be divided into 2 main categories, i.e. foodborne infections and foodborne intoxications. Foodborne infections from eating contaminated food or drinking contaminated water cause illness by microbial invasion of the host, or by release of toxins produced when the foodborne bacteria have grown in the intestinal tract or some other organ. The genera of bacteria causing foodborne infections are : Salmonella, Shigella, certain strains of E. coli, Vibrio parahaemolyticus, Yersinia enterocolitica, Campylobacter jejuni, Clostridium perfringens and

Bacillus cereus. Normally, about 10^6 organisms per gram of food are required to cause bacterial enteritis symptoms in people. However, in certain circustances the minimum infective dose may be as low as 1 to 10 organisms, as the infectious dose can be affected by many factors, such as the diet, physical condition, and immune status of the consumer (4).

Food intoxications cause illness when toxins synthesized in a food by the multiplication and metabolism of certain microorganisms are absorbed via the intestinal tract of the consumer. Organisms which are responsible for foodborne intoxications are : Clostridium botulinum, Staphylococcus aureus, Bacillus cereus, Pseudomonas cocovenenans, several species of bacteria which metabolize amino acids to form histamine, tyramine or phenyle thylamine, and many types of moulds synthesizing mycotoxins. Generally, 10^4-10^5 viable cells per gram or ml of food are needed for exotoxins to be released into the food, but as with foodborne infections, other factors may influence the minimum infectious dose.

The number of reported cases of foodborne illness continues to rise not only in developing countries, but also in developed ones, although the means for control of pathogens in foods are already well-known. Contamination of food, especially of animal origin with pathogenic nonspore-forming bacteria, as well as infection with parasitic helminths and protozoa are important public health problems and causes of human suffering and malnutrition. According to WHO, infectious and parasitic diseases represented the most frequent cause of death worldwide (35%) in

1990, with the majoriry of deaths occurring in developing countries (1). Diarrhoeal disease caused about 25% of deaths in developing countries, and it is estimated that in possibly, up to 70% of cases, food is the vehicle for transmission of diarrhoeal diseases.

Foodborne diseases are particularly serious for infants and young children, pregnant women, the immuno-compromised, the hospitalized, and the elderly. Therefore, special attention should be given to food products intended for these groups.

DECONTAMINATION OF FOOD BY IRRADIATION

Application of irradiation for the purpose of food safety can be divided into 2 categories, namely radiation-pasteurization (radurization) and radiation-sterilization (radappertization).

Radiation-pasteurization is comparable to heat pasteurization which is intended for eliminating all of specific type of organisms which can cause spoilage or food poisoning, thereby reducing the risk of consuming food pathogens. Radiation-sterilization is comparable to canning which eliminates all organisms from foods.

Biological contaminants of foods vary in resistance to the lethal effects of radiation. Resistance increases inversely with size from parasites, moulds, bacteria (excluding spores), yeast, bacterial spores, with viruses generally being the most resistant. However, within these classes, exceptions and overlapping occur.

The sensitivity of organisms to radiation can be identified from its D_{10} value. The D_{10} value is the amount of absorbed radiation dose needed to reduce the population by 90%, or to achieve a 10% survival level of the organisms initially present. Table 1 shows comparative radiation resistance of food organisms (5). The sensitivity of an organism may change, as its D_{10} value varies with various factors, such as growth phase, gaseous atmosphere, temperature, water activity, dose rate, radiosensitizers and radioprotectants. Therefore, it is understood that irradiation dose needed to pasteurize or to sterilize certain food products is specific to each product. Compatibility of food to irradiation treatment should also be considered, since many food items undergo undesirable changes in their organoleptic properties after irradiation.

Application of irradiation to eliminate foodborne pathogens especially from food of animal origin has been developed and legally approved in many countries (Table 2) (6). Irradiation of fresh food of animal origin should be done in chilled or frozen condition to avoid organoleptic changes, while for dry products, irradiation can be done at ambient conditions.

Radiation-sterilization of food using high dose level has also been developed in some countries. This kind of application can be directed to the production of shelf-stable food intended for certain groups, such as yachtsmen, campers, hikers, mountain climbers, and those who receive food through emergency relief operations. Such foods have been successfully used by astronauts and armed forces personnel in some countries. Successful radiation-sterilized shelf-stable foods consisting of meat and seafood products of high quality have been produced in the USA and South Africa (Table 3) (7). The use of these foods has been limited by lack of national regulation. For example, no general clearance on radiation-sterilized food has been given by the US-FDA. In South Africa, the use by military does not require special regulations, but use by other specific groups such as yachtsmen on the basis of need, requires permission from national authorities.

Another target is radiation-sterilized meals intended mainly for medical use, such as for immunocompromised bone marrow and organ transplant or AIDS patients. A few countries (Finland, Netherlands and United Kingdom) have already approved radiation-sterilized meals for medical use. At one US hospital, the Fred Hutchinson Cancer Research Centre, Seattle, a variety of radiation-sterilized food items were consumed by bone marrow transplant and other immunosuppressed patients with much success over the period from 1974 to 1988. In 1988, the hospital discontinued their use, as a small research irradiator used for their sterilization at a nearby university became too weak to deliver the required high dose in a reasonable period of time (7). The types of radiation-sterilized food given to the patients in the US hospital were : breads, noodles, pastry products, cereals, drybeverages, snacks, candies, nutritional supplements and condiments in individual serving packets (8).

RADIATION-STERILIZATION STUDIES IN INDONESIA

Radiation-sterilization of foods intended for hospital patients have also been developed in Indonesia since 1990 at the

Centre for Application of Isotopes and Radiation, National Atomic Energy Agency, Jakarta. The types of food products which has been studied successfully are shown in Table 4. The foods were vacuum packaged in nylon laminate or PVDC laminate pouches, and irradiated at the prescribed doses at liquid nitrogen temperature. Sterilization dose of each food item was determined according to the AAMI (Association for the Advancement of Medical Instrumentation) or ISO/DIS 11137.2 (1993) methods based on its bioburden (9).

Biscuits, cakes, dry beverages, condiments, candies and chocolates gave good results from palatability point of view. The colour of salt, sugar, and milk powder turned yellowish, but still acceptable. The crispiness of chips and crackers decreased after irradiation, but still palatable (10-13). Nuts and foods containing oil developed a specific irradiation odour and flavour due to radiolysis of fatty acids after radiation-sterilization. However, the off-odour tends to decrease after prolonged storage (13).

Radiation-sterilization of bread is now under investigation, and collaboration with certain hospitals to test the palatability of radiation-sterilized foods either by patients or hospital's staff will be done soon.

A study conducted at the Centre indicated that biscuit irradiated at 17.5 kGy dose in vacuum at liquid nitrogen temperature did not undergo changes in total lipid and protein contents, as well as its niasin content. Thiamine, the most radiation sensitive of the vitamin B group decreased only 8.77% at such dose level in biscuit (14).

Radiation-sterilized food is developed for giving more food choices for patients who are being nursed under strictly sterile conditions in a laminar air flow room. The safety and wholesomeness of radiation-sterilized food has been proved in some countries as experienced by the astronauts, armed forces personels, and hospital patients.

CONCLUSIONS

Foodborne disease is still the main cause of death worldwide, primarily in developing countries. Decontamination of food by irradiation for safety purpose has been developed and legally approved in a number of countries with an overall average dose not exceeding 10 kGy. Irradiation of food using doses above 10 kGy for sterilization purpose has also been developed in some countries with good results, but its application is still limited by lack of national regulation.

This technology will be very beneficial for decontaminating hospital foods, such as for eliminating pathogenic bacteria in raw foods of animal origin, spices, ready-to-eat shelf-stable foods, etc., and for sterilizing foods intended for patients with reduced immuno-responses.

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Table 1. Comparative radiation resistance of food organisms

Organism	D_{10} range (kGy)			
	0.03-0.25 Sensitive	0.25-0.80 Mod-sens.	0.80-1.70 Mod-Res.	1.7-8.0 Resistant
Vibrio				
Yersinia				
Campylobacter				
Pseudomonas				
E. coli				
Salmonella				
Staphylococcus				
Penicillium				
Aspergillus				
Micrococcus				
Sacharomyces				
B. coagulans				
B. stearothermophilus				
B. cereus				
Cl. sporogenes				
Cl. perfringens				
Cl. botulinum				
Viruses				

Source : Ref. (5).

Table 2. Types of food legalized to be irradiated for decontaminatio[n] purpose in various countries

Food	Dose range (kGy)	Number of countries approved
Chicken	1.5-10.0	15
Fish	1-3	7
Shrimp	3-7	6
Frogleg	4-8	6
Pork	0.3-1.0	1
Red meat	10	1
Sausage	5-8	2
Camembert	2.25-3.50	1
Egg powder	up to 10	1
Spices	up to 10	26
Dehydrated vegetables	up to 10	10
Herbal tea	10	3
Arabic gum	up to 10	2
Dried fruits	6	1
Cocoa beans	5	3

Source : Ref. (6).

Table 3. Radiation-sterilized shelf-stable food developed in South Africa and USA

South Africa	USA (dose range, kGy)*	
Meat loaf	Roast beef	(37-43)
Smoked viennas	Beef steak	(37-43)
Roast chicken	Ham	(37-43)
Country sausage	Corned beef	(25-29)
Beef curry	Turkey slices	(37-43)
Chicken and tomato	Pork sausages	(27-33)
Chicken casserole	Chicken	(45-54)
Bobotie	Cooked salami	(25-27)
Beef steak in gravy	Shrimp	(38-49)
Chicken stew	Codfish cake	(32 min)
Smoked chicken	Bacon	(25.2 min)
Boerewors	Pork shop	(43.7 min)
Steak		
Meat balls		
Chicken curry		
Beef stew		
Roast beef		
Hamburgers		

* Developed by US Army Natick Laboratories, Natick, MA
Source : Ref. (8).

Table 4. Radiation-sterilized foods developed at the CAIR, Jakarta

Food Group	Food Items	Irrad. dose (kGy) (Dm_{in})
Biscuits and Cakes	Biscuit, assorted	17.5
	Cup cakes Mariza	20.0
	Ordinary cake	25.0
Dry beverages	Tea	17.5
	Coffee	17.5
	Milk powder	20.0
	Cacao powder	15.0
	Nutrisari	15.0
	Instant coffee + sugar	17.5
Condiments	Sugar	17.5
	Salt	17.6
	Soya sauce	15.7
Meat dishes	Abon (beef)	25.0
	Empal	25.0
	Rendang	25.0
	Paru goreng	22.0
Snacks and Candies	Cassava chips, tempe cracker, emping (sweet and salty)	23.5
	Nuts, assorted	16.5
	Candies, assorted	15.5
	Chocolates	16.8

Source : Ref. (10-13).