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# Review on Radiation as a Means of Food Preservation and its Challenge

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**Abstract:** Food irradiation is a process of exposing food to ionizing radiation for the purpose of food safety and preservation. Ionizing radiation has advantages and disadvantages from some advantages point of view it use to destroy harmful biological microorganisms in food, to extend shelf life of food and to facilitates trade (food) exportation(i.e. it prevent trade barrier).The disadvantages of food irradiation is, it requires so expensive and sophisticated material(machine), negative perception of the consumer about irradiated food, this is because of lack of knowledge and awareness, people think that as if irradiated food becomes radio actives, but food irradiation is recognized by FAO/WHO label by radura, international symbol for irradiated food. So irradiated food is not radioactive because no contact between food and radiation sources, but it has an effect on public health when the processor's not follow the appropriate procedure(eg. over dosage of the radiation). There for the processors should follow an appropriate procedure, rules and principles. Properly radiated food does not have any health impact on consumer.

**Key words:** Food irradiation · Consumer health and perception · Review

## INTRODUCTION

Food irradiation is a preservation process of exposing food to high energy rays to improve product safety and shelf life. It could be used to replace chemical preservatives as well as thermal treatment. It is considered as cold pasteurization of food and currently permitted in 35 countries worldwide for 40 different food products [1, 2]. The use of gamma irradiation in dairy product is considered as one of the most important peaceful application [3]. There was no hazard caused by irradiation up to 10 kilo grey which could not cause cancer, genetic mutation or tumors [4]. Therefore, hospitals use irradiated food for patients with severely impaired immune system [5].

Giving science based information on food irradiation leads to positive consumer approaches [6]. Many consumers are primarily hostile to irradiation. By other means, "People think the irradiated product is radioactive," but when the process is made clear to them they will become more in favor [7, 8]. Fox (2002) reported that, consumer awareness of food irradiation was 29%. Also, 80% of consumers were unsure about the safety of irradiated foods, this is because of lack of understand and awareness of irradiated food.

There for the objective of this review is to highlight on:

- hygienic and safety status of irradiated food
- Consumer health and perception on irradiated food
- Shelf life status of irradiated food

**Radiation Source:** Three principal types of radiation source can be used in food irradiation according to the Codex Alimentations General Standard [9]: Gamma radiation from radio nuclides such as 60Co (copper) or 137Cs (cesium), Machine sources of electron beams with energies up to 10 MeV, Machine sources of bremsstrahlung (X rays) with electron energies up to 5 MeV. Because of their greater penetrating capability, ã rays and X rays may be used for processing of relatively thick or dense products. Ionizing radiation for food processing is limited to high energy photons (gamma rays) of radio nuclides 60Co or CS, X-rays from machine sources with energies up to 5 MeV and accelerated electrons with energies up to 10 MeV generated by electron accelerating machines [10]. These kinds of Ionizing radiation are preferred due to: the suitable food preservative effects do not generate radioactivity in foods or packaging materials and available at costs as commercial use of the irradiation process [11].

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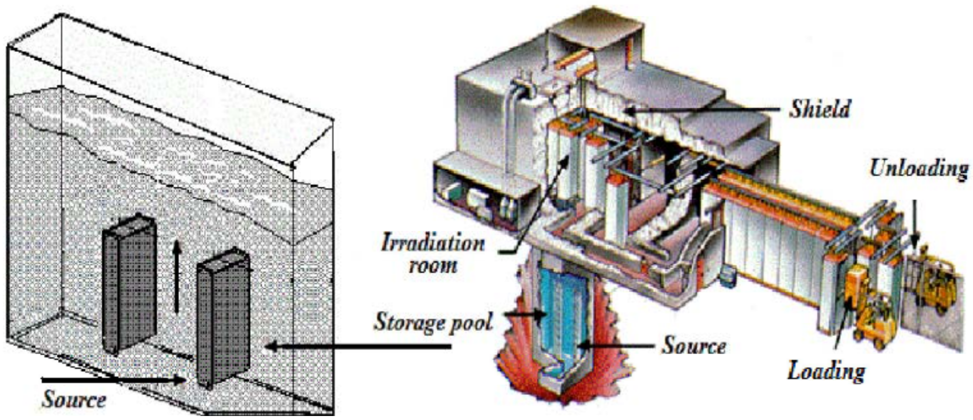


Fig. 1: *Commercial gamma irradiator*: Source: [14].

**Gamma Ray:** The use of gamma irradiation in dairy product is considered as one of the most important peaceful application of nuclear energy [3].In 1983; Becker stated that food cannot become radioactive through exposure to gamma rays from 60Co, 137Cs, X-rays of 5 MeV electrons with energy levels below 10 MeV [12].

Irradiation treatment with controlled doses of gamma irradiation is a safe and suitable technique for decontamination of foods. Few commercial gamma facilities use cesium-137 (Cs-137) as a gamma ray source. Because, Cs-137 emits gamma rays that are approximately half the energy of those emitted by C o-60 [13].

**E-Beam Ray:** The effects of irradiation by electron beam on the color and the contents of volatile oils in five-spice powder (prickly ash, star aniseed, cinnamon, clove and fennel) and chili were assessed by Lianzhong *et al*. [15]. Irradiation enhanced the UV absorption of aqueous extracts of spices, but the darkening phenomenon of spices due to irradiation was temporary, E-beam radiation offers three distinct advantages compared with gamma: first, the need to carry radioactive materials around the country is eliminated. Second, it can be turned off when not in use and the last, E-beam characterized by its low penetration a high dosage rates. It performs best when on low-density, uniformly packaged products. Therefore, it can effectively inactivate food borne pathogens on the surface of the slices, with the least negative effect [2010].
X-Ray

Another machine source of ionizing radiation is the X-ray generator. An X-ray is a wave-form of energy similar to light. Unlike accelerated electrons, X-rays have great power to penetrate some materials. But as the early experimenters found, converting electricity into X-rays is a very inefficient, hence expensive, operation. The X-ray machines available for food processing have generally been adapted from those used in medical and industrial radiography and are not well suited to supply the power needed for food processing. Recent developments suggest that these problems of cost and power output may be solved by a new type of X-ray generator [16].

**Irradiation as Food Preservation:** In some parts of Africa, insect's infestation is responsible for most losses from production to marketing. Irradiation is an effective physical treatment for disinfesting insects in dried fish a small dose of 0.3KGYwould be sufficient to destroy insects in the products [17].

Developing countries export large quantities of frozen sea food which may be contaminated with salmonella. In most cases; the level of salmonella contamination in frozen food is low. Irradiation can be effectively eliminating this residual contamination of food while the food is in frozen state. Developing countries should not adopt technologies which consume large amount of energy. Irradiation is much superior in terms of energy requirements when compare with heat treatment [18].

Radiation in developed countries: United States food and drug administration have approved the following foods, Packaged frozen red meat to control pathogen and to extend shelf life, Herbs and spices [19] to control insects, Wheat and Wheat flavor to control insects.

Radiation processing has also been shown to decrease the anti-nutritional components in some proteinaceius leguminous seeds, thereby helping to provide food security. Augmentation in international trade of tropical fruits and vegetables is considered to be one of the important modules for the economic development strategy of many underdeveloped countries [20].

**Consumer Acceptability of Irradiated Food:** Consumers have concerns about the effects of irradiation on the intrinsic quality of food, the effects of long term consumption of irradiated food on health, health risk to employees and environmental pollution [21]. However, 55.8% of people expressed that they would buy irradiated food because of the Radura symbol. Consumer surveys have revealed the acceptability rates ranging from 45% to more than 90%, depending on the food commodity and the way of presentation. Nowadays, other authors [22] reported that consumers would purchase irradiated foods, depending on their level of concern and awareness and the provision of sufficient background information.

**Advantages of Irradiation:** A method to ensure hygienic quality of food: the use of ethylene oxide fumigation for decontaminating the ingredients has been increasing restricted in recent years. The European community is used a directive which prohibited the use of ethylene oxide on food starting from January 1991 [23]. Reducing food loss :most microorganisms and all insects which cause damage to fresh commodities such as fish, meat, fruit, vegetable, etc. and their products are sensitive to low dose irradiation. Thus, irradiating the food with dose between one and five KGY results in insect's disinfestations and a several fold reduction of spoilage microorganisms, there by extending the shelf life of the food [24].

**Limitation of Irradiation:** Infrastructure and economic of food irradiated: food treatment adds cost to the product, like other physical food processes, irradiation has high capital costs and requires a critical capacity and product volume for economic operation. A number of market tests of irradiated food have been carried out in the past five years with interesting result [25], by consumer critical education.

**Safety and Effect of Irradiation:** Irradiation as a means of food preservation offers many benefits, including killing disease causing bacteria and parasites in food, extending shelf life of food, reducing post-harvest losses and reducing food allergy. It is an effective way to improve food safety and reduce the incidence of diseases. Further, it is safe and environment friendly. Processing and preparing foods can make them safer to eat by destroying toxins and eliminating or inhibiting pathogens. Because these techniques help protect consumers, most cases of food borne illness involve raw animal products, fruits and vegetables that have been contaminated by pathogens [26].

In general, food macronutrients (carbohydrates, proteins and lipids) and most micronutrients (mainly water soluble and fat-soluble vitamins) are not appreciably affected by 10 KGY-range ionizing dose with regard to their nutrient contents. However, with higher radiation doses (above 10KGY exceeding permitted limit in the EU), the structural properties of the fibrous carbohydrates can be degraded and lipids can become somewhat rancid, leading to a loss of food quality [27]. Moreover, the irradiation of lipids at high doses and especially in the presence of oxygen, can lead to the formation of liquid hydrogen peroxides. The oxidation products formed often have undesirable odors and flavors (rancidity). Lipid oxidation can be significantly reduced by freezing and/or by oxygen removal prior to irradiation. Of the micronutrients, thiamine is of concern because of its relatively high sensitivity to the effects of radiation. Foods that contain thiamine (e.g. pork) are suitable as indicators of food safety regarding the irradiation treatment [27].

Besides the nutritional and sensory values, the wholesomeness (lack of mutagenicity, teratogenicity and toxicity) of irradiated foods has been studied extensively [28]. Radio lytic changes in foods are minimal and are predictable from the radiation chemistry of principal food components.

**Effects on Food Products:** Ionizing radiation produces chemical changes by primary and secondary radiolysis effects.

The effect of chemical reactions depends on the absorbed dose, dose rate and facility type, presence or absence of oxygen and temperature. The physical status of food (frozen or fresh, solid, liquid or powder) and also its composition influence the reactions induced by the radiation [29].

**Effects of Ionizing Radiation on Public Health:** There is no plethora of international committees to discuss the significant danger sun bath ("UV" sun, 2013) – just gentle public education from doctors and pharmacists pressing families to use blocking agents and to restrict their exposure periods, especially at the start of abaci, Irradiation can be effect direct, caused by reactive oxygen centered (•OH) radicals originating from the radiolysis of water or indirect on organisms and food products. An indirect effect (the damage to the nucleic acids) occurs when radiation ionizes a neighboring molecule, which in turn reacts with the genetic material. Since, water is a major component of most foods and microbes; it is often ends up producing a lethal product [30].

Table 1: Dose requirement in various applications of food irradiation

| Purpose | Dose | Product |
|---|---|---|
| Low dose (up to 1 kGy) | 0.05-0.15 | Potatoes, onions, garlic, gingerroot, etc. |
| (a)Inhibitionof sprouting | | |
| (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,pathogenic microorganisms | 1.0-7.0 | Fresh and frozen seafood, raw or Frozen poultry and meat, etc. |
| (c) Improving technological property of food. | 2.o-7.0 | Grapes (increasing juice yield), dehydrated vegetables (reduced cooking time), etc. |
| High dose (10-50 kGy) | | |
| (a) Industrial sterilization (in combination with mild heat) | 30-50 | Meat, poultry, seafood, prepared foods, sterilized hospital diets, etc. |
| (b) Decontamination of Certain food additives. | 10-50 | Spices, enzyme preparations, natural gum, etc. |

Source: [16]

**Process of Irradiation:** During the irradiation process food is exposed to the energy source in such a way that a precise and specific dose is absorbed. To do that it is necessary to know the energy output of the source per unit of time, to have a defined spatial relationship between the source and the target and to expose the target material for a specific time. The radiation dose ordinarily used in food processing ranges from 50 Gy to 10 kGy and depends on the kind of food being processed and the desired effect [31].

The actual dose of radiation employed in any food processing application represents a balance between the amount needed to produce a desired result and the amount the product can tolerate without suffering unwanted change. High radiation doses can cause organoleptic changes (off-flavors or changes in texture), especially in foods of animal origin, such as dairy products. In fresh fruits and vegetables, radiation may cause softening and increase the permeability of tissue [16].

The success of food irradiation depends on: Calculations of the absorbed dose delivered to the food product; in radiation processing, the absorbed dose is a key quantity in the processing of food. Therefore, Dosimetry is a fundamental affair in radiation processing. Since the radiation absorbed dose is related to the desired effect in a particular food, the need for appropriate and precise dose measurement techniques must not be underestimated [32].

Determination of the dose distribution patterns in the product package (process qualification).Process load geometries are commonly limited to conventional shapes and sizes of packaging. The importance of Dosimetry in process qualification is to ensure that the absorbed dose requirements for a specific product can be satisfied. This process (dose mapping) verifies the scale and regions of the maximum and minimum doses and helps set up all the parameters required to achieve the absorbed dose [33].

Control of the routine radiation process (control procedures); routine dosimeters are used in radiation processing facilities, traceable to national or international standards are important and necessary in process control of food irradiation [34].

**Degrees of Food Processing:** Not all foods undergo the same degree of processing. In this review, processed foods are classified in three categories: minimally processed food, processed food ingredients and highly processed food [35].

**Minimally Processed Food:** Fruit, vegetables, legumes, nuts, meat and milk are often sold in minimally processed forms. Foods sold as such are not substantially changed from their raw, unprocessed form and retain most of their nutritional properties. Minimal forms of processing include washing, peeling, slicing, juicing and removing inedible parts [36].

**Processed Food Ingredients:** This group includes flours, oils, fats, sugars, sweeteners, starches and other ingredients. High fructose corn syrup, margarine and vegetable oil are common examples. Processed food ingredients are rarely eaten alone; they are typically used in cooking or in the manufacture of highly processed foods [37].

**Highly Processed Foods:** Highly processed foods are made from combinations of unprocessed food, minimally processed food and processed food ingredients. They are often portable, can be eaten anywhere (while driving, working at the office and watching TV and require little or no preparation. Highly processed foods include snacks and desserts, such as cereal bars, biscuits, chips, cakes and pastries, ice cream and soft drinks; as well as breads, pasta, breakfast cereals and infant formula [38].

Given the wide variety of foods that could qualify as highly processed and the lack of any clear, widely accepted criteria for defining them as such, it is difficult to make any generalizations about the nutritional value of highly processed foods. Some health professionals, however, have expressed concern over the growing popularity of certain highly processed foods in diets [39].

**Packaging for Irradiate Food:** Food packaging can offer numerous benefits, such as making products easier to store and transport, preserving them and making them easier to prepare. It also allows for the display of marketing, labels, recipes and other information [40].

Irradiation in combination with other treatments may suppress the growth of surviving microorganisms during storage [41]. For example, the effect of irradiation was increased by packaging vegetables in atmospheres enriched with carbon dioxide or containing essential oils. Sensory changes on high-fat products can be reduced by vacuum packaging associated to refrigeration and depend on the type of products [42].

Some studies have shown, Irradiation can change some physical and chemical properties of polymeric packaging materials and the changes depend on the type of polymer, irradiation conditions and processing exposure [43]. For this reason any packaging materials must be confirmed by FDA before use in food irradiation [44].

**Physical Effects of Irradiation:** Solid waste from food packaging, however, poses an environmental concern. Food packaging accounts for roughly two-thirds (by volume) of total packaging waste in the United States. Discarding packaging materials in landfills has the potential to pollute air and water, while combusting them for energy can emit greenhouse gases, dioxins and other pollutants (depending on the materials used) that are harmful to health and the environment [40].Recycling, composting and reusing containers offer more environmentally sound alternatives. Manufacturers can also reduce the amount of materials used in food packaging, ideally without compromising benefits to consumers [45].

Physical effects include changes in crystallinity, permeability, surface structures and post irradiation aging effects. Radiation changes in the physical properties of a packaging material should not delay its function [46].

**Chemical Effects:** Bisphenol A (BPA) is a chemical commonly used in the linings of metal cans and in the manufacture of hard plastics, such as some bottles and food storage containers [47].Some reviews have found links between BPA exposure and cardiovascular disease, diabetes, male sexual dysfunction, certain cancers and changes to immune function. Products packaged in metal cans and plastic wrap, including soups, vegetables and infant formula, detected low levels of BPA in those foods [47]. As a precautionary measure, some manufacturers have stopped using BPA in bottles and packages.

Most food packaging materials are originated from polymers. They may be susceptible to chemical changes (after ionizing radiation) that are the result of two reactions, cross-linking (polymerization) and chain scission (degradation). Both reactions are generally relative to dose and depend on dose rate and the oxygen content of the atmosphere in which the polymer is irradiated. Chemical effects include evolution of radiolysis products, migration of radiolytic products of the polymers and degradation of antioxidants [48]. The vacuum condition or an inert atmosphere prevents radiation cross-linking of polymers. During irradiation, ions and free radicals are produced. These highly reactive materials are responsible for the color changes in irradiated polymers and could migrate into food and affect taste, odor and safety (. Therefore, Radiation resistant of polystyrene, polyester and Polyamide is due to the high energy requirement to form cross-links [44].

**Product Release and Certification:** Proper facility operation and adherence to process control entail records and documentation, such records are necessary for the purpose of auditing by a customer or of inspection by an authority. Typically, these records should include: Information about the maintenance of the equipment and instrumentation used to control or measure the dose delivered to the product, All dosimetry data for facility qualification, product absorbed dose mapping and routine product processing, Values of all the process parameters affecting the absorbed dose in the product, Product description and loading pattern in the process load, Date the product was processed and the name of the operator of irradiation [49].

## CONCLUSION AND RECOMMENDATIONS

Food Irradiation is types of modern food preservation, which is safer and proper preservation method, but it has an effect on public health when the processor/professional could not carried out food irradiation properly. On the other hand People think that irradiated food becomes radioactive and causes cancer, but there is no radiation risk related diseases instead, the risk is greater by consuming non irradiated food.

Based on the above fact the following points are recommended:

- The consumer should not worry about health risk with that properly processed food during irradiation.
- The consumer should look for the symbol" Radura" during purchasing irradiated food.

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