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# Food Irradiation - An Effective Technology for Food Safety and Security

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## Abstract

This review will look at the irradiation-based food preservation method. A country's ability to successfully adopt new technologies hinges on the availability of a suitable infrastructure. Irradiation has a low operating cost and utilizes minimal energy, but it requires significant capital investments and a minimum output volume to be economical. Over a specific threshold concentration, off tastes might develop and organoleptic changes can occur. At low quantities, however, not all pathogens and their poisons will be eliminated. Radiation therapy can be difficult to standardize because the results vary. How effectively the therapy works depends on several factors, including the commodity and cultivar, radiation dose, level of maturity, physiological status, temperature and environment before and after treatment, pre-and post-harvest treatments, and the sensitivity of the microorganisms to be controlled. Tolerance varies with the maturity level. Depending on public perception, regulatory actions, economics, and logistics associated with specific conditions, irradiation as a method of reducing foodborne diseases will be used. Not all foods can be irradiated in all situations due to technological and financial restrictions. Irradiation cannot indefinitely extend the shelf life of fresh food because the enzymes in foods like fruits, vegetables, fish, shellfish, meat, and poultry are still active and resistant to even high-dose radiation. If foods are exposed to too much radiation, they may lose flavor, especially if they are high in fat. Irradiated grains and legumes must be packaged carefully to prevent insect infestations because irradiation does not leave behind any harmful residue that would deter insects. Irradiation produces very little chemical changes in food, and the changes are similar to those by other preservation methods like heat. The application of irradiation technology will benefit farmers whose post-harvest grain lost value as a result of food spoilage, consumers who experience health problems as a result of virus exposure, exporters of such cereals, and ultimately the government, which gains economically from the hard cash generated. It will also benefit firms that package food, extension agents, technical assistants, and researchers. Radiation processing of food has been approved by various international statutory bodies and organizations to ensure 'Food Security & Safety', and overcome 'Technical barrier to International Trade' and currently is being practiced in more than 60 countries worldwide.

**Keywords:** Irradiation Technology; Food Preservation; Microorganisms; Shelf Life; Food Spoilage; Health Problems

**Abbreviations:** EM: Electromagnetic

## Introduction

During the food irradiation process, ionizing radiation is applied to food and food packaging [1- 6]. It is a technique for physically preparing food in which prepared or bulk food is exposed to gamma, x, or electron radiation [7].

Ionizing radiation can only be used to irradiate food using electrons with a maximum energy of 10 MeV and electromagnetic (EM) radiation with a maximum energy of 5 MeV. The procedure getsrid of the bacteria, insects, molds, and fungus that cause foodborne illnesses or food spoilage. Food must be exposed to an effective dosage of ionizing radiation for a predetermined period of time inorder to irradiate it. Irradiation preserves the food's flavor, texture, aroma, and nutritional value while also making it safer and less likely to spoil. Foods cannot always be radioactively sterilized.For instance, a number of fruits, like some cucumbers, tomatoes, and grapes, are radiation- sensitive [1].

Food irradiation technology is gaining popularity across the globe. In comparison to heat or chemical treatment, irradiation is a more effective and acceptable method of getting rid of food- borne bacteria. The method, which is quite similar to pasteurization, makes food safer to eat by getting rid of microorganisms. For two seasons, radiation-exposed food products are not radioactive. First off, when cobalt-60 is subjected to the gamma rays used in food radiation, it does not become radioactive. Second, because it never comes into contact with the source directly, the meal cannot become radioactively polluted [8].

Ethiopia's economy is mostly based on agriculture, making about 38.8% of its GDP (National Planning Commission, 2016). The majority of this contribution is made by the agriculture and livestock subsectors, with crops contributing almost 30% of the GDP and 67.3 percent of export earnings (National Bank of Ethiopia, 2015) [9]. According to data from the Central Statistical Agency (CSA), sorghum accounted for 14.6 percent of Ethiopia's total grain crop area in the 2014–2015 cropping season, placing it third after teff (24.0 percent) and maize (16.8 percent) [10].

Pests and spoilage take between one-third and fifty percent of the food produced worldwide. Nuclear (radiation) technology can halt a significant percentage of these losses by postponing spoilage. Irradiation can lessen food post-harvest losses brought on by bugs, germs, mold (fungus),sprouting, or over ripeness. These losses are estimated to account for between 25 and 40 percent ofthe output in many developing countries [1].

According to numerous data sources from published, unpublished, and other scientific studies, aflatoxin is easily contaminated by peanuts, red pepper, maize, malt barely, sorghum, and other types of crop commodities [11].

Millions of cases of foodborne illness are reported each year, according to the US Centers for Disease Control and Prevention (CDC), the World Health Organization (WHO), and the Food andAgriculture Organization of the United Nations (FAO). Due to food recalls and medical expenses,these food poisonings have a significant financial impact. It has also been reported that the availability, abundance, and safety of food are in jeopardy; that by 2050, the global production of wholesome food must rise by 70%; that a significant amount of food—about 40%, or 1.3 billion tons annually—is lost between production and consumption, representing a lost investment for farmers; and that this loss adds to consumer costs and burdens on the environment. New solutions are required to address these issues with health, the economy, and the environment [12].

Man has always been quite concerned about food preservation. Due to insect and microbial contamination, foods lose a sizable portion of their nutritious content during storage, transportation, and marketing (15 percent for cereals, 20 percent for fish and dairy products and up to 40 percent for fruits and vegetables). Particularly, pathogenic bacteria are one of the most significant global public health problems and a major cause of human suffering. In 1992, the World Health Organization (WHO) reported that infectious and parasitic diseases were the primary cause of death worldwide (35 percent), with the majority of deaths taking place in underdeveloped countries [13,14].

Post-harvest losses for a few crops in Ethiopia have been estimated to be between 10 and 50 percent, with losses for maize, barley, and sorghum being respectively 17.4 percent, 10 percent, and 12.5 percent [15-17]. Pakistan reportedly banned all supplies of red kidney beans from Ethiopia in 2017 [18]. Ethiopian beans are said to contain significant levels of phytohemagglutinin, which might make them hazardous if they were to change. Pakistan is one of the major importers of food from Ethiopia. The ban will be a fatal blow to regional exporters and the reputation of locally cultivated beans.

For a few crops in Ethiopia, post-harvest losses have been reported to range from 10 to 50 percent,with maize, barley, and sorghum each suffering losses of 17.4 percent, 10 percent, and 12.5 percent [15-17]. According to a report Getachew S [18], Pakistan outlawed in 2017 all shipments of red kidney beans from Ethiopia. According to reports, Ethiopian beans have high phytohemagglutinin concentrations, which might make them poisonous if they were to change. One of the main countries that imports food from Ethiopia is Pakistan. The restriction will be a devastating blow tolocal exporters and the standing of homegrown beans.

## Discussion

Consumed for their nutritional worth, foods are organic materials. Foods are organic substances like moisture, protein, fat, carbohydrate, and minerals that are derived from either plants or animals. Foods turn perishable due to physical, chemical, or microbial factors. The nutritional value, color, texture, and flavor of food can all be impacted by food rotting. So as to maintain theirquality over an extended length of time, foods must be preserved. The processes or strategies usedto manage both internal and external factors that could cause food to spoil are referred to as food preservation. The main goal of food preservation is to prolong the shelf life of food while maintaining its original nutritional content, color, texture, and flavor [19].

The benefits and hazards of eating particular foods for health are known to consumers. The food industry puts a lot of effort, resources, and knowledge into producing products that are safe and meet consumer expectations. Food contamination can be prevented by examining raw materials prior to their entry into the food chain, storing the food at a cooling temperature, processing the food to lessen or eliminate the microbial burden, and avoiding contamination after processing [7]. A safe and helpful process for the environment is irradiation. Irradiation of food can also have a direct influence on a country's capacity to export food.

Irradiation truly offers the same advantages as heating, cooling, drying, or chemically treating with the further benefits that [1]:

- It does not affect taste, smell or texture of the food
- It does not leave potentially harmful residues, unlike chemical treatments
- It can be used to treat packaged foods, protecting them from subsequent microbialcontamination or pest reinfestation

Food irradiation is a technique that can be used safely to reduce food losses due to deterioration and to control contamination that may cause illness and even death. Irradiating food using high- energy electron beams, gamma rays, or x-rays kills undesired microorganisms, insects, fungi, and other pests while also postponing rotting. It does not make food radioactive. Irradiation renders pathogens sterile and destroys them [8].

All foods change in composition after being harvested, whether it be fruit ripening, cellular or chemical structure breakdown by enzymes or bacteria, or bacterial toxin production. If food is notconsumed right after harvest, it will start to deteriorate enzymatically or microbially [20].

Food is exposed to radiation at very low temperatures. Food irradiation can be used on frozen foods or other heat-sensitive foods instead of heat treatment (e.g., fruits). Food irradiation, whichuses powerful penetrating gamma rays to treat food of various sizes, eliminates the serious problemof cross-contamination during transport and handling. Food can be irradiated without using as much energy as more conventional methods like freezing or heating [20].

Whether they are fresh or prepared, foods all deteriorate when they are exposed to heat, light, or oxygen. Numerous breakdown products are known to be produced as a result of thermal denaturation and oxidation. The first stage of degradation is the creation of "free radicals." All diets contain free radicals, which are unstable and commonly present. The breakdown byproductsproduced when an item of food is exposed to ionizing radiation are known as radiolytic products.Food contains extremely low amounts (in the ppm range) of radiolysis products, which are now impossible to quantify. The major components of food—water, protein, lipids (fatty substances), and carbohydrates (starches, sugar, and cellulose)—are all vulnerable to radiolytic attack. Fats are the materials that are most vulnerable to oxidation and free-radical damage. The identified products primarily appear to result from the breakdown of smaller molecules into smaller fragments or from the combining of these fragments [20].

### Ionizing Radiation Interaction Mechanism

The primary target of ionizing radiation is the DNA present in chromosomes, also referred to as deoxyribonucleic acid (DNA). Effects on the cytoplasmic membrane appear to substantially aggravate radiation-induced cell damage. Despite the fact that radiation alters cells, the impact on different microorganisms vary. By altering the DNA molecules, radiation can damage cells directly or indirectly. Radiation that strikes a DNA molecule directly damages or kills cells by upsetting its molecular structure. If injured ells are still alive, further abnormalities like cancer maydevelop [7].

Radiation has an indirect impact on organic molecules such as water molecules, which make up the majority of a cell. As a result, extremely reactive free radicals with an unpaired electron, such hydroxyl (HO) and alkoxy (RO2), are created. These free radicals interact with DNA molecules and harm the structural integrity of the molecules. Hydrogen peroxide, or H2O2, is also believed to be damaging to the DNA molecule. A cell's capacity to operate is weakened, and free radical damage to DNA molecules can result in cell death. The quantity of them created depends on the entire dose. It has been found that the indirect effect accounts for the majority of radiation-induceddamage because water makes up over 70% of a cell. In addition to the damage caused by the byproducts of water radiolysis, cellular injury can be caused by ionization of atoms on constitutiveessential components including DNA, reactive nitrogen species (RNS), and other species. The final result of direct and indirect effects, which may manifest immediately or decades later, is theformation of biochemical and physiological changes, as well as genetic and epigenetic changes [6,7].

### Irradiation Facilities

There are three main common food irradiation technologies [1,3,6,21]:

- Gamma Rays ( Co - 60 and Cs -137)
- Machine-Generated Electrons (EB), or
- Machine-Generated X-rays.

The two main elements of the irradiation process are the radiation source and the facilities neededto expose food to the radiation source [20,22]. The most common type of radiation source is a granule or pellet of radioactive cobalt, also known as Cobalt-60 or Cesium-137, that is packed inside stainless-steel tubes.

Electron accelerators use electric and magnetic fields to produce a stream of negative electric charge, fast electrons. The top limit is frequently maintained at 10 MeV for energy produced by gamma rays and at 5 MeV for electron and x-ray radiation in order to avoid the problem of radioactivity being induced while radiating food [20]. A gamma ray source is identified by its highpenetration power. Therefore, food that is radioactive and is contained in larger packaging units will be consumed. Because any problems will only be mechanical in nature and simple trained staff can fix them, it has a high level of reliability.

The penetrating power of electrons is considerably less than that of gamma radiation. Larger food containers can be irradiated with gamma rays, although electron ray penetration is only effective up to 5-8 cm. A high throughput is feasible due to the dose rate (e.g. irradiation of grain). The dose can be altered for every style of packing unit. Additionally, the machinery can be shut off and added to the production line in smaller pieces. A gamma ray source is much lessprone to problems than an accelerator, which calls for the use of personnel who have undergoneparticular training [20].

The organism's susceptibility to radiation, the speed at which it can repair damaged DNA, and most importantly the amount of DNA in the target organism all affect how efficient the processis [23].

- Parasites and insect pests (have large number of DNA) are rapidly killed byextremely low dose.
- It take more irradiation to kill bacteria (because they have less DNA).
- Viruses are the smallest pathogens that have nucleic acid, and they are, in general, resistant to irradiation doses approved for foods.

If the food contains live cells, they will be harmed or destroyed in the same way as microorganisms are. This is a beneficial impact since it prevents sprouting and slows ripening, which can be utilizedto extend the shelf life of fruits and vegetables.

Live cells present in the food will be damaged or destroyed in the same way as microbes are. Thishas a positive effect since it delays ripening and reduces sprouting, which can be used to increasethe shelf life of fruits and vegetables.

| Cobalt -60 | Electron beams | X-rays |
|---|---|---|
| High penetrating power | Low penetrating power | High penetrating power |
| Permanent radioactive source | Switch on–switch off capability | Switch on–switch off capability |
| High efficiency | High efficiency | Low efficiency |
| Source replenishment needed | High throughput | High throughput |
| Low throughput | Power and cooling needed | Power and cooling needed |
| - | Technically complex | Technically complex |

Characteristics of irradiation sources [5] are depicted as shown in the table below.

The practical process requirements, such as: the minimum and maximum absorbed dose (Dmin, Dmax); dose uniformity (DUR = Dmin/Dmax); and dose rate; material thickness, density, and shape; production rate; capital and operating costs; ease of use; and the nature of the foods to be treated, usually determine the preferred type of radiation source.

### Radiation Dose

The amount of radiation absorbed by the substance determines the radiation's effect [20]. The radiation energy absorbed in a volume is divided by the volume's mass to determine the dose. In the SI unit system, the energy is expressed as a Joule, the dose as a J/kg, or a Gray.

1J/kg Equals 1 Gy, and 1000J/kg = 1 kGy.

The three main categories of food irradiation doses are low (less than 1 kGy), medium (1–10 kGy),and high (greater than 10 kGy). To get the intended effects from the goods, different dose levels are needed [1,5,20].

The regulation and monitoring of the adsorbed radiation dosage absorbed by a food product are ofgreatest importance in order to guarantee the quality of the irradiated product and to assure regulatory compliance. Dosimetry is the only objective method that can guarantee the dependability and quality of the procedure. Dosimetry provides the basis for documentation and satisfies all technical, legal, and regulatory requirements [20,22,24].

| Effect of Treatment | Radiation Dose (kGy) | Type of Food | Remark |
|---|---|---|---|
| Inhibition of sprouting | 0.05-0.15 | Potatoes, onions, garlic, gingerroot etc. | Low dose |
| Insect disinfestation and parasite disinfestation | 0.15-0.50 | Cereals and pulses, fresh and dried fruits, dried fish and meat, fresh pork etc. | (up to 1 kGvJ) |
| Delay of physiological process | 0.50-1.0 | Fresh fruits and vegetables | |
| Extension of food shelf life by delaying mould growth | 1.5-3.0 | Fresh fish, strawberries and some other fruits, vegetables and sliced bread | Medium dose (1-10 kGyJ) |
| Decontamination of spoilage | 2.0-5.0 | Fresh and frozen seafood, poultry and meat in raw or frozen state, eggs and egg powder etc. | |
| Improvement of technological properties of food | 2.0-7.0 | Grapes (increasing juice yield), dehydrated vegetables (reduced cooking time) etc. | |
| Commercial sterilization | 30-50 | Meat, poultry, seafood (shellfish), some vegetables, baked foods, prepared foods, sterilized hospital diets | High dose (10-50 kGvJ) |
| Decontamination of certain food additives and ingredients | Oct-50 | Seasonings, spices, nuts, dried vegetables, enzymes preparations, natural gum, etc. | |
| (Replacement of chemicals) | | | |

## Conclusion

Food is processed and preserved with irradiation, which yields results similar to pasteurization or freezing. During this process, the food is subjected to doses of radiation or ionizing radiation. At modest doses, irradiation lengthens a product's shelf life. At higher doses, this mechanism kills insects, mold, bacteria, and other potentially harmful germs [20,24].

Irradiation has the potential to be employed for pest control, product quality improvement, shelf- life extension, and decontamination [5]. De-infestation is one of the most important postharvest steps in food processing. One way to increase shelf life is to prevent sprouting. Another technique is to postpone the ripening and senescence of tropical fruits. Irradiation extends the shelf life of perishable commodities by getting rid of spoiling bacteria. As fruits ripen, they normally gradually lose their capacity to fend off phytopathogens. When ripening is delayed using a low dose, a higherlevel of resistance is maintained in the fruit, and as an added benefit, microbial development is delayed. Irradiation has the power to eradicate diseases and reduce microbial load.

Irradiation can greatly extend the shelf life of many fruits and vegetables, meat, poultry, fish, and sea food [25]. Additionally, it may be possible to reduce the spread of illness, pests, and bugs through international trade. This will help us improve overall public health. Food irradiation can raise the caliber and acceptance of Ethiopian food exports on global markets.

To increase food safety, quality, and commerce, irradiation, a relatively new technology, has just been introduced to this arsenal of food security techniques. Irradiation can be used to kill bacteriathat cause illness and food deterioration in solid foods like meat, poultry, seafood, and spices because it is a cold approach. Without altering the food's nutritional value or sensory qualities, bug eggs and larvae can also be killed off in fresh fruits and vegetables. It is remarkable at rendering dangerous microorganisms in frozen food dormant. Foods that were frozen or uncooked before irradiation stay that way afterward, and volatile aromatic components are preserved, as irradiationis a type of cold pasteurization [24].

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