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Innovative Food Preservation Techniques: The Rise of Irradiation

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Introduction:

Food preservation is critical for maintaining safety, reducing waste, and preserving nutritional value. Food irradiation is a novel technique that employs ionizing radiation to extend the shelf life of foodstuffs while successfully removing hazardous germs. This non-thermal approach improves food safety without compromising nutritional content or sensory attributesOne of the most essential basic necessities for human survival is food. Food that has been kept for an extended period of time could spoil or decay. Thus, preservation is required to increase the amount of time that these foods may be stored while maintaining their nutritional value. In the past, food was often preserved by blanching, smoking, salting and other methods. The advancement of modern technology has led to the creation of numerous novel food preservation technologies, one of which involves irradiation. Food irradiation is a method of nonthermal food preservation. Food irradiation is a physical procedure whereby prepackaged or bulk food items are subjected to regulated levels of ionizing radiation, such as electron beams, gamma rays, or X-rays. Ionizing radiation has the potential to be used in food processing, primarily because it can damage DNA very effectively, rendering living cells inactive. As a result, microorganisms, insect gametes and plant meristems are unable to reproduce, which can have a variety of preservative effects depending on the radiation dose that is absorbed (Farkas L, 2006). However, there are few additional chemical changes in food caused by radiation (Thayer, 1990). The irradiation of foods is an approved food processing method that uses electron beams or ionizing radiation to increase food safety. Like pasteurization, but without heat, the irradiation process alters texture and freshness. The radiation process stops shoot development and obstructs biological processes that cause decay. Food products that have been exposed to radiation have longer shelf lives, become inactive to microbes and insects and have a delay in ripening and sprouting in tubers. Low-

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energy radiation is used in food irradiation. Food irradiation causes modifications that are typically acceptable in terms of appearance and nutritional impact. The irradiation of food was not widely accepted until recent research revealed its advantages and safety. By eradicating harmful microbes, radiation attempts to make food safer to eat. However, problems like as public perception, regulatory issues and expensive initial expenditures may impede its widespread adoption. Recognizing these aspects is critical in determining the role of food irradiation in modern food preservation and its potential contribution to a sustainable food supply.

Irradiation principles

Ionizing radiation, a high-energy source, is used in the food preservation process. It does so because materials in its path have the potential to ionize. These food constituents are excited, ionized and changed when exposed to radiation sources, including electron beams, gamma rays and X-rays. A situation known as excitation occurs when living cells become susceptible to outside stimuli. Free radicals are created by the process of ionization, which breaks down macromolecules. Modifications to the components of live cells prevent DNA synthesis, preventing microbial cell proliferation and its biological consequences. In food, this action prevents microbial development (Zhao L *et al*., 2017).

Radiation sources

Three radiation sources are used in food irradiation facilities: electron beams (≤10 MeV), X-rays (≤7.5 MeV in certain countries and < 5 MeV in others) and gamma radiation. Radionuclides such as ^{60}Co and ^{137}Cs are used to produce gamma radiation. The use of ^{137}Cs for food processing is strongly advised because of the high solubility of isotopes in water. Similar effects of applying an electron beam to atoms and molecules include the production of extremely reactive free radicals and the breaking of double-stranded structures, such as microbial DNA (Lung *et al.,* 2015). To create X-rays, the electrons at the target metal, such as gold or tungsten, accelerate. Energy from electric rays is released as heat during this process. However, X-ray efficiency may be increased by increasing the electron beam and target material atomic number (Petwal V C 2007).

Advantages of Food Irradiation

- The procedure extends food's shelf life by inactivating spoiling germs, reducing waste, and increasing availability.
- It inhibits ripening in fruits and sprouting in vegetables, allowing for longer storage shelf life.

Table: Different doses of food irradiation				
Sl.No.	**Level of Dose**	**Range**	**Definition**	**Food items**
1	Low dose	0-1kGy	Irradiation of tubers seeks to inhibit the germination process. In cereals or nuts and seeds aims to eliminate insects. Meanwhile, irradiation of dry vegetables and dry derived from animals, spices, or dry herbs and tea herbs is intended to eradicate insects	Tubers, fresh produce, grains, nuts, and seeds, dried seasonings, and dry goods derived from animals
2	Moderate dose	1-1-kGy	Extend the self- life, decrease number of microorganisms, minimize certain infections, manage parasite infection and get rid of dangerous organisms like salmonella	Fresh fruits and vegetables, some kinds of cereals and nuts and seeds, fresh seafood, poultry, and other fresh meat, dried fruits, spices, dried herbs, some herbal products, and dried animal products can be applied
3	High dose	>10kGy	The purpose of dried herbs is to lessen some harmful microbes. Animal-based ready-to-eat processed food items, on the other hand, aim to prolong shelf life by sterilizing and eliminating harmful bacteria, particularly those that contain spores. Dried spices with a 10.0 kGy minimum dosage. The dosage for animal-based ready-to-eat food items is 65.0 kGy	Dried spices and prepared foods made from animals

- Irradiation effectively eliminates harmful microorganisms like Salmonella and E. coli, lowering the risk of foodborne illness.
- Irradiated foods can be sterilized, making them safe for people with weakened immune systems and extending their shelf life even without refrigeration.

- These advantages make food irradiation an important technology for improving food safety and sustainability.
- Studies reveal that food preserved by radiation often retains its nutritional value more effectively than conventional techniques.

Impact of Irradiation on Food Quality

Food irradiation has a diverse impact on quality, including nutritional, sensory, and safety elements. In terms of nutritional quality, irradiation generally preserves the bulk of macronutrients such as proteins, lipids, and carbs even at high dosages. Some sensitive micronutrients, particularly vitamins A, B_1, C, and E, may see modest declines at higher radiation levels. Overall, irradiation has nutritional effects similar to typical food processing procedures like heating or pasteurization. In terms of sensory features, irradiation usually does not dramatically alter the flavour, texture and colour of food, as long as proper radiation dosages are utilized. Low amounts can even improve specific attributes, such as meat softness, however high levels can cause negative changes, such as protein denaturation and off-flavors.

One of the key advantages of food irradiation is its ability to reduce or eradicate pathogenic microbes and rotting organisms. This not only improves food safety but also increases the shelf life of many products, making them safer to consume while maintaining their quality. Irradiation can cause physical changes in meat, such as better texture and water-holding capacity, but the effects are dose-dependent. While low dosages may improve quality, excessive levels can harm the structural integrity of food. Chemical changes can also occur, such as the creation of free radicals, which can lead to lipid oxidation if not controlled effectively. However, these effects are often minor and can be mitigated with correct dose selection and packing practices.

Challenges and Limitations of Irradiation

Food irradiation presents various barriers to wider adoption, mostly owing to public perception and regulatory constraints. Many customers are ignorant of its advantages and can misconstrue it for safety issues, while differing legislation across nations hamper international trade. Smaller businesses may also find the initial investment in irradiation technology too expensive. Although irradiation typically retains nutritional quality, there is worry that excessive doses may degrade particular vitamins and sensory qualities. Overcoming these obstacles requires improved consumer education, consistent laws, and technical developments to increase the acceptance and efficacy of food irradiation in preservation.

Conclusions

The use of radiation in food has several advantages, including minimal or no heating, so the material properties remain unaffected. Irradiation can reduce microorganisms and insects and prolong the shelf-life of food products. Foods that are packed, frozen and fresh may all be irradiated in one step without the need for chemical addition. Gamma, X-ray and electron beams are the radiation types most frequently employed to irradiate food items, and each has benefits and drawbacks. In recent years, the popularity of food irradiation as a processing technology has increased, with an increasing number of nations using it to disinfect and control pests in agricultural goods. Additionally, the nutritional value and sensory appeal of foods are not greatly diminished. Compared with other processing techniques, such as heat and chemical processes, it is a more suitable and effective way to improve food stability and safety.

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