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A Critical Review on the Effect of Gamma Irradiation on Microbiological Activity, Quality, and Safety of Food

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Review Article

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Abstract

There is an increasing demand to guarantee the safety of the food supply due to the public's growing concerns about food safety and foodborne illnesses. It has been demonstrated that gamma irradiation is a potential technique for safely eliminating a variety of common pathogens. The extra advantage of gamma irradiation technology is that it prolongs the shelf life of irradiated food items. The irradiation process has been demonstrated to be reliable; it is widely applied to medical supplies, spices, and other products in numerous nations across the world. Convincing the public that this technology is helpful and even essential for ensuring their safety is the major task at hand. Studies on the market have revealed that while a large number of consumers are eager to buy irradiated food, a large number are not. The aim of the current paper was to highlight the significant effect of gamma irradiation on food quality and safety, in order to correct the wrong believes about gamma irradiation by large number of consumers to comply with the right scientific evidence supported by regulations and control of the Food and Drug Authority (FDA). Well-structured research papers and official documents were reviewed thoroughly to extract official updated information about the characterization and safety with versatile applications of gamma irradiation in food sector.

Keywords: Food Irradiation; Gamma Irradiation Facility; Sterilization; Pathogen Inactivation; Food Quality And Safety; Microbiological Activity; Shelf-Life

Abbreviations: ABTS: 2,2'-azino-bis (3-ethylbenzo thiazoline-6-sulphonic Acid); BSC: *Bacillus* Species Count; CDC: Centers for Disease Control and Prevention; DILs: Derived Intervention Levels; DPPH: 2,2-Diphenyl-1-picrylhydrazyl; EPA: Environmental Protection Agency; FCMs: Food Contact Materials; FDA: Food and Drug Administration; FRAP: Ferric Reducing Antioxidant Power; GIF: Gamma Irradiation Facility; HPH: High Pressure Homogenization; HPP: High Pressure Processing; IF: Infant Formula; kGy: Kilogray; 4,4'-MDA: 4,4′-methylenedianiline; MIC: Metal Ion Chelating; 3-MCPD: 3-monochloropropanediol; NRC: Nuclear Regulatory Commission; PAAs: Primary Aromatic Amines; RBH: Rice

Bran Hydrolysate; RBP: Rice Bran Protein; RBPH: Rice Bran Protein Hydrolysate; SAC: *Staphylococcus Aureus* Count; SAL: Sterilization Assurance Level; SC: *Salmonella* Count; TCC: Total Coliform Count; 2,4-TDA: 2,4-diaminotoluene; TVC: Total Viable Count; USDA: United States Department of Agriculture; WHO: World Health Organization; YMC: Yeast and Mold Count.

Introduction

Food irradiation was first approved in the 1980's. Since then, there have been concerns about a number of issues. However, none of these have altered the scientific agreement on food irradiation's safety and sufficiency. In particular, nutritional sufficiency has been confirmed for the nutritional value of irradiated fresh produce, which has been irradiated in order to improve the health of the plant. The use of food irradiation in the international trade of fresh food is growing rapidly. Although irradiation is still a relatively small food processing technology, the risks of underutilizing it need to be recognized more widely [1]. Internationally, gamma irradiation is recognized as a method for processing and preserving food. Disinfestation, sprout inhibition, delayed ripening, microbial reduction, and starch modification of different grains, fruits, and vegetables are only a few of its numerous applications.

The structure of the food's macro components may be changed by irradiation, which impacts the food's numerous physicochemical, functional, thermal, and rheological properties. The irradiation dose must be calibrated to reduce any negative effects and to prevent irradiation from having an unintended impact on the organoleptic qualities of foods [2].

Healthy diet is crucial in lowering the severity of infectious diseases [3]. Nutritional treatment is also involved in food processing technologies to ensure that therapeutically effective meals with micro- and macronutrients are supplied in high-quality, safe, nutritionally packed formulations without contaminants [4].

Radiation is used in the food irradiation process to eradicate pests like insects and bacteria and stop food from spoiling. Similar to pasteurizing milk and preserving fruits and vegetables, food irradiation can make food safer to consume. Irradiation neither renders food radioactive nor alters its flavor, consistency, or appearance. Gamma rays, x-rays, or high-energy electrons are used to irradiate food, which kills or inactivates the bacteria and viruses that are responsible for foodborne illness [5].

Definition of Gamma Irradiation

A gamma ray, sometimes referred to as gamma radiation (sign γ), is a kind of electromagnetic radiation (Figure 1) penetrating and produced when atomic nuclei decay radioactively. It is made up of electromagnetic waves with the smallest wavelengths, which are usually shorter than X-rays with frequencies more than 30 exahertz (3×10^{19} Hz). In 1900, French scientist and physicist Paul Villard discovered gamma radiation while researching the radiation released by radium. Ernest Rutherford first identified two less invasive forms of decay radiation (discovered by Henri Becquerel) in 1900, naming them alpha (sign α) and beta (sign β) rays in increasing order of penetrating power. In 1903, he named this radiation "gamma rays" due to its comparatively high penetration of matter following alpha and beta rays [6].

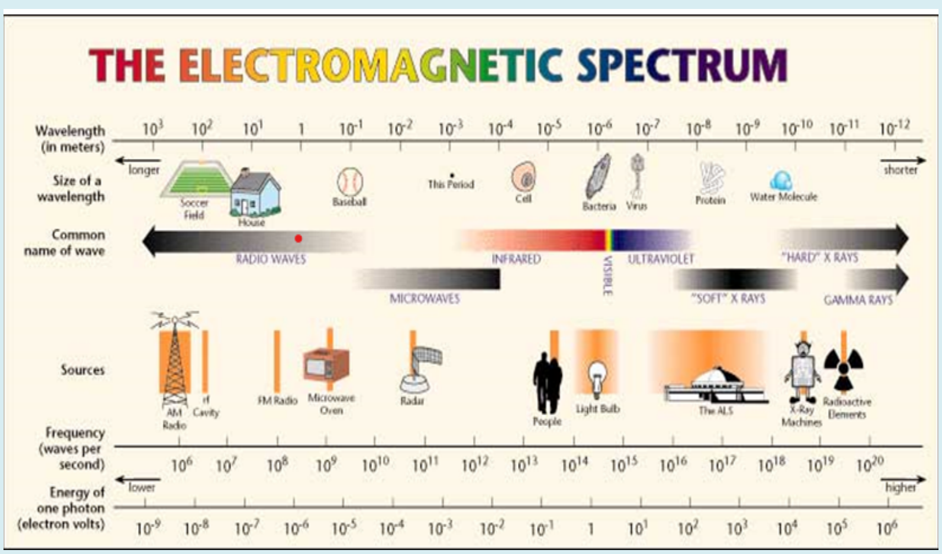

Figure 1: The Electromagnetic Spectrum [6].

Safety of Food Irradiation

The Food and Drug Administration (FDA), the World Health Organization (WHO), the Centers for Disease Control and Prevention (CDC), and the United States Department of Agriculture (USDA) all see irradiated food as safe. A maximum overall average dose of 10 kGy was considered adequate for the majority of food applications [5].

Regulation of Food Irradiation

The FDA is in charge of controlling food radiation. Standards for radioactivity in food are regulated by the U.S. Food and Drug Administration (FDA). When deciding whether domestic food in interstate commerce or imported food poses a safety risk, the FDA establishes derived intervention levels (DILs), amounts of radioactivity in food. FDA evaluates each situation to see if preventative measures are required [5].

Labeling of Food Irradiation

In fact, the alterations brought about by irradiation are so slight that it is difficult to determine if a food has been exposed to radiation. Only after concluding that irradiating food is safe can the FDA approve a source of radiation for use on food. The FDA mandates that goods that have undergone radiation must display the global radiation sign. On the food label (Figure 2), look for the Radura symbol next to the words “Treated with radiation” or “Treated by irradiation”. Bulk items like fruits and vegetables must either have a label next to the selling container or be individually labeled. Keep in mind that proper food handling techniques used by producers, processors, and consumers are not replaced by irradiation. Foods that have been irradiated must be handled, stored, and prepared in the same way as foods that have not been irradiated since, if fundamental food safety precautions are not taken, they may still become contaminated with pathogens following irradiation [7].

Figure 2: Food Irradiation Symbol [7].

Food Irradiation Procedure

Food items are exposed to ionizing radiation in order for food irradiation to occur. Since food irradiation does not use heat to kill bacteria, it is referred to as a “cold” approach. Heat is used in other food safety procedures like pasteurization and canning. After food is made and packed, the irradiation procedure takes place. Food is put into a chamber and given a certain level of radiation exposure. The radiation enters the food and either destroys or stops the growth of microorganisms; it does not stay in the food. Although it is an additional precaution, radiation does not take the place of other food safety protocols [8].

Unit of Irradiation Absorbed Dose

The dose in radiation processing refers to the quantity of energy that the target material absorbs. This is reported in units of kiloGray, where 1 kGy = 1,000 J/kg, or Gray, where 1 Gy is equal to 1 Joule per kilogram, as per the SI system. Dose Level. One joule of energy is equal to one gray (Gy) per kilogram of product (1 gray = 100 rads). 1000 Joules per kilogram is one kilogray. This is calculated by dividing the average energy applied to a unit of matter by its mass. The international unit of absorbed dosage is kGy.

The Allowable Amount of Gamma Radiation in Food Irradiation

International health and safety authorities have endorsed the safety of irradiation for all foods up to a dose level of 10 kGy.

Molecular Mechanism of Gamma Irradiation-Induced Cell Damage

The absorption of energy generated by gamma irradiation causes morphological and functional changes in pathogens seen in exposed items. A number of theories were put out in an attempt to explain the mechanisms underlying the infections’ gamma-ray-induced cell harm, including enhanced cellular membrane permeability, enzyme malfunction, and radiotoxic production. Although there is a sufficient evidence to support these theories, the general consensus today is that gamma radiation harm mostly results from damage to deoxyribonucleic acid (DNA), as demonstrated by several experimental findings. Gamma rays can either directly break the DNA helix or produce free radicals that cause the chemical links in DNA to break [9].

Gamma Irradiation Facility

- **Irradiation Room**: When the cobalt is in the water, people can safely enter the irradiation room.
- **Radiation Source**: Cobalt is shielded under water in an underground tank when not in use.
- **Control Console**: Treatment is controlled by the speed of the conveyer belt. Amount of energy needed varies by the density of the load.

- **Loading**: Packaged food is loaded onto a conveyer belt for treatment.
- **Unloading Processed Product**: Treated food can be handled immediately. The fence keeps treated and untreated food separate.
- **Radiation Shield**: Concrete walls prevent gamma rays from escaping into the environment.
- **Cobalt 60 in Gamma Facility:** Cobalt 60 is the most prevalent source of ionizing radiation. The radioactive material is housed in "source pencils" which are two sealed stainless steel tubes with one inside the other and double encapsulated. When not in use, these are arranged in a rack, which is submerged in an underground water room. The rack is lifted during the radiation process. Packaged food items travel on a conveyer belt into an interior space where they come into contact with the rack holding the source pencils. Gamma rays, often known as photons, are forms of energy that penetrate the food's encapsulation and cure it.
- **Gamma Irradiation Facility Safety:** When not in use, water is utilized to protect the cobalt. It is not radioactive in the water. In order to protect workers and the environment from radiation, several safety measures must be included in radiation facilities. The Department of Transportation, state agencies, and the Nuclear Regulatory Commission (NRC) all keep a close eye on the use and transportation of radioactive materials, as well as the facilities and equipment that are used in them.

Some Applications of Gamma Irradiation in Food Sector

Applications of Gamma Irradiation in Food Processing

Prior to protein extraction, defatted rice bran underwent gamma irradiation pre-treatment. Rice bran protein (RBP), rice bran protein hydrolysate (RBPH), and rice bran hydrolysate (RBH) were all included in the extracted content. For all extracts, but particularly RBH, where the yield and protein recovery improved by 21.2% and 13.8%, respectively, the extraction yields and protein recovery increased with irradiation. The irradiation-processed extracts were found to have a higher total phenolic content of RBP and RBH. The structure of rice bran may be altered by gamma radiation, resulting in a greater release of bioactive substances. In extracts treated by irradiation, antioxidant activity (ABTS, DPPH, FRAP, and MIC tests) dramatically increased [10].

Effect of Gamma Irradiation in Sterilization of Packaging Materials

Primary aromatic amines (PAAs), which include 2,4-diaminotoluene (2,4-TDA) and 4,4′-methylenedianiline (4,4'-MDA), are a class of organic compounds that the International Agency for Research on Cancer has classified as "possibly carcinogenic to humans". Food contact materials (FCMs), which include laminated food packaging materials, colorful kitchen utensils, and colored napkins, have been found to contain residual monomers, isocyanate hydrolysis compounds or azo dyes contaminants. As ^{60}Co-γ irradiation dose increased (5, 10 and 25 kGy), MDAs migration considerably decreased. For MDAs migration, high pressure processing (HPP) treatment (400 MPa/25 °C/15 min) reduced or preserved the same findings as the control. In terms of PAAs migration, ^{60}Co-γ irradiation and HPP were generally considered to be safe sterilization techniques [11]. This result agreed with the previous publication about the effect of high pressure homogenization (HPH) for optimization of food processing, quality, and safety [12].

Effect of Gamma Irradiation on Microbial Decontamination of Food

Gamma irradiation as a non-thermal physical treatment has the potential to be effective at microbial decontamination. In this investigation, different gamma radiation dosages (2, 4, 6, 8 and 10 kGy) were applied to flour and grain of common buckwheat (Fagopyrum esculentum Moench). The control sample is the non-irradiated sample. All samples were tested for antioxidant activity (AOA), total phenolic content (TPC), total flavonoid content (TFC), rutin, and quercetin levels. In contrast to control samples, the values in the irradiation samples were greater. AOA, TPC, TFC, and rutin levels were increased in grain samples irradiated at 10 and in flour samples irradiated at 8, respectively. There was little change in the amount of quercetin. All test results were lower after 2 kGy of radiation. For buckwheat, gamma irradiation could be successfully applied as a novel preservation treatment [13].

Gamma radiation was applied to dried cassava chips at a dosage rate of 0.75 kGy/h with goal doses of 2.5, 5.0, 7.5, and 10.0 kGy. As a control, un irradiated chips were employed. Using established techniques, the dried cassava chips' total viable count (TVC), total coliform count (TCC), yeast and mold count (YMC), *Staphylococcus aureus* count (SAC), *Bacillus* species count (BSC), and *Salmonella* count (SC) were all calculated. The dried cassava chips included coliform, *Staphylococcus aureus*, *Bacillus* spp., yeast, and molds, but not *Salmonella*. The bacteria found on the surfaces of the dried cassava chips were dramatically and dose-dependently decreased by gamma irradiation. The microbiological quality of dried cassava chips may be improved by radiation decontamination [14].

The impact of gamma irradiation on the microbiological stability of calyx powder from *Hibiscus sabdariffa* (Roselle) was identified. Samples of roselle calyx powder were placed in high-density polyethylene bags, irradiated at 0, 2, 4, 6, 8 and 10 kGy, and then left unattended for three months at room temperature (27 ± 3 °C). For microbiological analysis, samples were obtained at 0, 1, 2, and 3 months. The microbial load of the dried calyx powder was dramatically decreased by gamma irradiation dosages of (2, 4 and 6 kGy). In samples exposed to radiation at dose rates of 8 and 10 kGy, no microbial counts were found. This suggests that bacteria in the samples were entirely killed by gamma radiation doses of 8 and 10 kGy. Roselle calyx powder's microbiological shelf life is increased by gamma irradiation-based decontamination [15].

The goal of another study was to determine how gamma irradiation (0, 2, 4, 6, 8 and 10 kGy) affected the physical-chemical, antinutritional, functional, microbiological and sensory characteristics of weaning food made with brown rice. With higher dosage, irradiated weaning food's rehydration ratio (3.60-1.30%) and swelling power (2.59-1.08 g/g) both significantly decreased. With higher irradiation doses, the solubility index (1.32-6.18%) significantly rose. Increased radiation doses resulted in significantly lower moisture content (8.82-7.85%) and browning index (0.611-0.0.998). Irradiation dosages enhanced antioxidant activity, total phenol, β-carotene, iron, and calcium levels. With an increase in irradiation dose, the total plate count, sensory qualities, phytate, and oxalate contents all reduced [16].

All pathogens tested (*B. cereus, L. monocytogenes, S. aureus, E. coli O157: H7, and S. Typhimurium*) were more sensitive to radiosensitization when exposed to γ-irradiation in the frozen form of infant formula (IF) than in its powdered form, with a higher effect against *B. cereus, S. Typhimurium, and L. monocytogenes* [17].

Limitation on the Effect of Gamma Irradiation in Food Sector

It is noteworthy to mention that the gamma irradiation sterilization technique is merely based on biological effect on the living pathogens and it has no effect on the hazardous materials emerging as food processing contaminants such as 3-monocholoropropanediol (3-MCPD) emerging from the thermal processing of refined edible oils [18]. Gamma irradiation cannot destroy the chemical pesticides and toxins present in the food.

Conclusion

The current review successfully achieved its aim by highlighting the significant effect of gamma irradiation on food quality and safety. Because it breaks down bacterial DNA and prevents bacterial growth. Gamma irradiation is a physical and chemical method of sterilizing. Food deterioration is decreased by radiation, an efficient method of food preservation that increases food's shelf life. Additionally, the process helps the consumer by lowering the chance of contracting foodborne illnesses brought on by pathogens. It is recommended to increase the awareness of consumers about the safety of gamma irradiation helping in making safe food.

References

1. Roberts PB (2023) The Safety and Nutritional Adequacy of Irradiated Foods. In: Smithers GW (Ed.), Encyclopedia of Food and Safety. 2nd(Edn.), Academic Press, pp: 612-620.

2. Jan K, Bashir K, Maurya VK (2021) 2.04 Gamma Irradiation and Food Properties. In: Knoerzer K, et al. (Eds.), Innovative Food Processing Technologies. Elsevier, pp: 41-60.

3. Almoselhy RIM (2021) Extra virgin olive oil as nutritional therapeutic immuno-enhancer. International Journal of Family Studies, Food Science and Nutrition Health 4(2): 26-45.

4. Almoselhy, Rania IM (2023) Formulation and evaluation of novel nutraceuticals rich in protein, vitamins, minerals, natural flavors, and steviol glycosides for improving quality of life. Food Science and Applied Biotechnology 6(2): 357-371.

5. EPA (2022) what is food irradiation? United States Environmental Protection Agency.

6. Wikipedia (2023) Gamma ray.

7. FDA (2022) Food Irradiation: What You Need to Know. US Food and Drug Administration.

8. CDC (2022) Food Irradiation: How does food irradiation work?

9. Harrell CR, Djonov V, Fellabaum C, Volarevic V (2018) Risks of Using Sterilization by Gamma Radiation: The Other Side of the Coin. International Journal of Medical Sciences 15(3): 274-279.

10. Masamran S, Chookaew S, Tepsongkroh B, Supawong S (2023) Impact of gamma irradiation pre-treatment before subcritical water extraction on recovery yields and antioxidant properties of rice bran extract. Radiation Physics and Chemistry 207: 110834.

11. Ma JJ, Wang ZW, Xu J, Hu CY, Qiu TC, et al. (2022) Effect of autoclave sterilization, gamma irradiation and high-pressure processing on the migration of 4,4'-MDA and

its isomers in laminated food packaging bags. Food Packaging and Shelf Life 33: 100875.

12. Almoselhy RIM (2022) High-Speed and High-Pressure Homogenization Techniques for Optimization of Food Processing, Quality, and Safety. Open Access Journal of Microbiology & Biotechnology 7(4): 000243.

13. Amiri M, Arab M, Sadrabad EK, Meybodi N, Fallahzadeh H (2023) Effect of gamma irradiation treatment on the antioxidant activity, phenolic compounds and flavonoid content of common buckwheat. Radiation Physics and Chemistry 212: 111127.

14. Armah JO, Ocloo FCK, Appiah V (2023) Microbial decontamination of dried cassava (Manihot esculenta) chips using gamma irradiation. Radiation Physics and Chemistry 212: 111173.

15. Ocloo FCK, Appiah V, Asantewaa B, Quayson ET (2023) Microbial quality of gamma-irradiated dried Roselle calyx powder. Radiation Physics and Chemistry 202: 110519.

16. Jan A, Sood M, Younis K, Islam RU (2020) Brown rice based weaning food treated with gamma irradiation evaluated during storage. Radiation Physics and Chemistry 177: 109158

17. Robichaud V, Bagheri L, Salmieri S, Uscanga BR, Millette M, et al. (2021) Effect of γ-irradiation and food additives on the microbial inactivation of foodborne pathogens in infant formula. LWT 139: 110547.

18. Almoselhy RIM (2021) A review of emerging health risks with 3-mcpd processing contaminant in refined edible oils. Journal of Microbiology and Biotechnology 6(3): 000202.