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Review Article

Functions of Irradiation and Its effects on the Food safety and Quality

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Abstract

The Food irradiation is a tried-and-true technique that's frequently used to improve the quality and the safety of the meat. With the application of this technique, the growth of bacteria, viruses, and parasites is successfully inhibited. By postponing spoiling and inhibiting the growth of the germs, it also extends the shelf life and improves the quality of the items. Provided that the right dosage is applied, the radiation has no effect on the colour, the taste, or the texture of the meats. Its impact on the chemical and the nutritional properties of the meat is more complicated, though, as it may change the vitamins, the fatty acids, the amino acids, and produce the free radicals that oxidise the fat. The impact of these modifications is dependent on a number of factors, such as the kind of the meat, the storage conditions, and the radiation exposure. The Meat's physical characteristics, such as its softness, the texture, and the dose-dependent ability to retain the water, can also be impacted by the radiation. Low amounts of the radiation may enhance texture and softness, while excessive doses cause protein denaturation, which adversely affects these characteristics. The regulatory and the public perception elements of the food irradiation are also examined in this study. Although the radiation is permitted and regulated in many nations, its use is debatable and causes anxiety in the public. The Food irradiation is a dependable method of enhancing the safety and the quality of the meat; nevertheless, it is important to take into account the effects it may have on the chemical, physical, and nutritional characteristics of the product when selecting the right dosage and application. To better understand the long-term effects of the radiation on the meat and allay consumer worries, further study is thus required.

Keywords: food irradiation; quality; safety; meat

Introduction

The Meat is a valuable element of the human diet as it contains essential elements such as the protein, the vitamins, and the minerals. However, these foods are also vulnerable to microbial pathogens and spoilage, posing significant risks to the human health. The Ionizing radiation is used in the food irradiation to maintain the safety and quality of the food items, specifically the meat [1,2,3,4,5,6,7 and 8].

For decades, the food irradiation has been used to reduce microbial contamination and extend the storage period. The procedure entails subjecting the food item to a regulated amount of the ionizing radiation, usually accomplished by applying gamma rays, electron beams, or X-rays. The radiation disrupts the DNA and other cellular components of microbes, making them unable to reproduce and causing their death.The procedure also the breaks down some of the molecules in the food product, which can affect its nutritional quality and sensory properties [46,47,48,49,50,51,52,53 and 54].

Despite its potential benefits, the food irradiation remains controversial, with concerns about its safety, efficacy, and impact on the nutritional quality and sensory properties of food products [55,56,57,58,59,60,61,62 and 63]. Some critics argued that the food irradiation could create the harmful compounds or destroy the essential nutrients. In contrast, others questioned the need for the irradiation, considering other food safety measures, such as the good manufacturing practices and the foodtesting. The Consumer acceptance of the irradiated food products also needs to be addressed, with some people expressing concerns about their safety and the acceptability [73,74,75,76,77,78,79,80 and 81].

This comprehensive research aims to critically evaluate the existing literature on the food irradiation and its repercussions on the quality and safety of the meat. The proof of the irradiation effectiveness at lowering the microbial contamination and prolonging the shelf life of the meats is explored along with its potential impact on the physical and the chemical characteristics, nutrient content, and sensory properties (92, 93, 94, 95, 96, 97, 98, 99 and 100). This paper will also address the regulatory framework for the food irradiation, including labeling requirements and government oversight, as

well as identify areas for further research and policy development (101,102,103,104,105,106,107 and 108).

The Sources and the Principles of the Food Irradiation

The Ionizing radiation, such as the gamma rays, X-rays, or the high-energy electrons, is used to irradiate the food. The Food irradiation is generally determined by the absorbed dose expressed in Gray (Gy) or kilo Gray (kGy), with 1 Gray being equivalent to 1 J/kg of product. The technique is considered a safe and effective way to decrease or eliminate hazardous microbes, prolong shelf life, as well as enhance the quality and safety of the food products. The principles of the food irradiation are determined by the ability to disrupt the genetic material of microorganisms, preventing them from reproducing or causing the illness. The irradiation affects the microorganisms' genetic material (the DNA or the RNA) directly and indirectly. The Direct irradiation can break the bonds between the base pairs in the genetic material, killing the cell's reproduction ability. Then, on the other hand, the damage to the water molecules creates the free radicals and the reactive oxygen species, which damage the genetic material indirectly [134,135,136,137,138,139 and 140]. The Irradiation also helps to break down certain enzymes and the proteins in the food that can contribute to the spoilage, thereby increasing the shelf life [141,142,143,144,145 and 146]. USA, Canada, as well as several European and Asian nations, allow the food irradiation by using the Cobalt-60, the cesium-137, and the electron-beam accelerators. The Cobalt-60, the most prevalent source of the ionizing radiation for the food irradiation, is a radioactive isotope that emits gamma rays capable of penetrating deep into the food products to destroy harmful microorganisms. Cesium-137 is another source of the ionizing radiation, although it is less commonly used than cobalt-60. In addition, the electron-beam accelerators are used for the food irradiation. These devices generate high-energy electrons that can penetrate the food products to eliminate the harmful microorganisms and extend the shelf life [154,155,156,157,158,159 and 160]. Irradiating the foods has several benefits, including multifunctional applications as well as guaranteed safety and security. The spectrum produced is effective against bacterial spores across a broad range of concentrations. The processing does not involve heat, it is safe for the food, does not significantly reduce nutrient levels, leaves no chemical residues, and is simple to control during the use [37,38,39,40,41,42,43,44 and 45]. To effectively lengthen the lifespan of irradiated food products, the following principles must be observed as the Radurization uses low doses of 0.1–1 kGy. This amount inhibits respiration, delays ripening, disinfects pests, and inactivates the Trichinella parasite. The Radicidation is referred to as a moderate dose. This radiation uses a quantity of approximately 1–10 kGy, which has the effect of reducing the spoilage and the microbial pathogens including Salmonella sp. And Listeria monocytogenes. This dosage is typically found in the frozen foods and its application is identical to that of pasteurization, except irradiation does not rely on the thermal energy. The Radapertization uses extremely high doses which are above or equal to 10 kGy, ranging between 30 and 50 kGy. This dose is typically used in the sterilization process because its effect can kill all microorganisms in the foodstuffs up to the level of spores [161,162,163,164 and 165]. The food irradiation sources and the principles are based on the ability of the ionizing radiation to disrupt the genetic material of the microorganisms, enzymes, and proteins in food products, culminating in improved the safety and the quality. The use of the irradiation is regulated by the national and the international authorities to ensure its safety and effectiveness [166,167,168,169,170 and 171].

3. The Effects of the Irradiation on the Meat

3.1. The Microbial Safety

The Microbial safety is a critical aspect of the meat production and the consumption, as these products can be a source of various harmful microorganisms that can cause the foodborne illness. The Meat products are potentially contaminated with various pathogens, such as the Salmonella, the Escherichia coli, the Campylobacter, and the Listeria monocytogenes, leading to severe illness or the death in vulnerable populations [9,10,11,12,13,14,15 and 16].

Contamination might occur at the production, the processing, or the distribution stage, including on the farm, during transport, in the slaughterhouses or the processing facilities, and in the retail outlets or at the home. The Improper handling and the storage of the meat products can also increase the risk of contamination. The Foodborne illness outbreaks related to the meat have been reported globally, with the various types of products being implicated, including the ground beef, the chicken, the pork, and the processed meats. These outbreaks have led to significant public health and economic consequences, highlighting the importance of effective interventions to reduce the risk of the contamination [109,110,111,112,113,114,115,116 and 117].

The Irradiation has been studied extensively for its efficacy in reducing the microbial contamination of the meat. By exposing the food to the ionizing radiation, the latter reduces or eliminates the harmful microorganisms that can cause the foodborne illness. Previous research showed that the irradiation could effectively reduce levels of the pathogens such as the Salmonella and the Escherichia coli as well as the levels of the spoilage organisms, leading to improve the microbial safety and a reduced the risk of the foodborne illness. The effectiveness of various types of the ionizing radiation on the meat, including the gamma rays and the e-beams, has been studied [82, 83, 84, 85, 86,87, 88, 89,90 and 91]. The gamma ray irradiation is more effective than e-beam irradiation is at inhibiting the microbial growth in the meat. The UV light effectively eliminates the Salmonella spp., the Pseudomonas, the Micrococcus, and the Staphylococcus on the meat. The shelf life of the meat products is extended by eliminating these contaminant ting bacteria. The Gamma irradiation at low doses can improve the microbiological safety, ensure safety, and extend the chicken meat's shelf life without affecting the quality. Three kGy gamma-irradiated bovine meat reduced the growth of the mesophilic bacteria, the coliforms, and the Staphylococcus aureus. The Food and Drug Administration (FDA) determined that a 3.5 kGy gamma ray irradiation dose effectively eliminates the pathogenic microbes from the fresh meat. The Irradiation had the effect of slowing the growth of the bacterial cells and deactivating their metabolism. The Bacteria are inherently resistant to the effects of the irradiation and, in the lag phase or inactive state will be more resistant. In contrast, those in the growth phase will be more vulnerable [64,65,66,67,68,69,70,71 and 72].

The Chemical Properties

The chemical properties of the irradiated meat refer to the changes that occur to the chemical constituents and compositions of the food due to exposure to the ionizing radiation. The Irradiation can cause both desirable and undesirable effects on the chemical characteristics of the meat, depending on the dose and the specific compounds in the food. One of the most significant changes often observed in the irradiated meat products is the formation of the free radicals. They become reactive molecules that damage cellular components and cause the oxidative stress. This leads to the lipid oxidation, which causes off-flavors and odors, as well as a decline in the nutritional quality due to the loss of the essential fatty acids and other nutrients.

However, the irradiation at the lower doses also aids the lipid oxidation by reducing the levels of peroxides and other reactive species. This procedure also affects the protein content of the meat, leading to alterations in the composition of the amino acids, protein structure, and the digestibility [126,127, 128, 129, 130,131,132 and 133]. These changes have potentially positive and negative effects, mostly on the nutritional value of the food, that are contingent upon the particular proteins involved and the dose of the radiation used. The positive effects of the irradiation include the fact that the irradiation can cause the formation of the reactive species, such as the free radicals, which can cause the formation of the covalent bonds between the amino acids in the protein molecules. This cross-linking can change the structure of a protein molecule and make it resistant to the enzymatic digestion, which causes a decrease in the protein digestibility [27,28,29,30,31,32,33,34 35 and 36]. The Irradiation can also cause the denaturation of the protein molecules. The Denaturation involves opening the protein structure, which can facilitate the interactions between the amino acids and increase the accessibility of the digestive enzymes to the protein molecules, and it can also improve the protein digestibility. However, the irradiation can also cause adverse effects; namely, the excessive irradiation can cause a breakdown of or the change in the amino acid compounds in the protein molecules, which causes a decrease in the overall amino acid content and, consequently, decreases the protein digestibility. The electron-beam irradiation at less than 3 kGy did not affect changes in the quality of the smoked duck flesh (the amino acids, the fatty acids, and the volatiles) during the storage [118,119,120,121,122,123,124 and 125].

Aside from these chemical changes, the irradiation also affects the vitamin content of the meat products, with some vitamins being more sensitive than others. For example, the irradiation leads to a loss of the vitamin C, while other vitamins, such as the vitamin A and E, are relatively stable. The Irradiation has been shown to alter the meat's oxidation–reduction ability, accelerating the lipid oxidation, the protein breakdown, and the flavor and the odor changes [147,148,149,150,151,152 and 153].

When combined with certain antioxidants, such as the flavonoids, the irradiation can help prolong the induction period of the lipid oxidation. The storage of the irradiated meat at 5–10 C for one week almost did not change the pH, the texture, the total volatile base nitrogen (TVBN), or the microbe number. The higher dose of the UV irradiation increased 2-thiobarbituric acid (TBA) content, decreased water-holding capacity (WHC), and decreased the beef color intensity and tenderness. Two point five and 5 kGy gamma irradiation reduced nitrite content in the chicken sausages and prevented the oxidation when combined with antioxidants. The titratable acidity and the acid value in the meat samples can be reduced by the irradiation [17,18,19,20,21,22,23,24,25 and 26].

Conclusion

One promising technique that might enhance the safety and the quality of the meat is the food irradiation. According to recent study, the irradiation can preserve the nutritional value of the meat products, decrease microbial contamination, and increase shelf life.
To overcome this issue, more study is necessary as the sensory characteristics can be adversely affected. It is also significant to remember that labelling regulations for irradiated meat products exist, and that the irradiation in the food processing is governed by both the national and the international bodies. The Government organisations play a crucial role in guaranteeing the security and the quality of the customers.

Conflicts of Interest

The author declares no conflicts of interest

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