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Review article
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A REVIEW OF THE IRRADIATION EFFECT ON THE QUALITY AND SAFETY OF DIFFERENT TYPES OF MEAT

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Abstract
This review explores the benefits of irradiation in improving the quality and safety of different meat types. The process involves exposing meat in a shielded room using one source of radiation that can be gamma radiation, electron beam or X-radiation for a specified period of time. Through the use of this technology, parasites, viruses, insects and bacteria can be effectively reduced, which in turn increases the lifespan and quality of meat products. According to products to be irradiated and the bacteria to be eradicated, the radiation dose could be high, low or medium. Irradiating meat at an appropriate dose does not affect its sensory qualities such as taste, texture and color. The impact of irradiation on nutritional and chemical aspects of different types of meat is complex, since free radicals can cause lipid oxidation and alter vitamins, fatty acids, and amino acids. Furthermore, irradiation can also affect physical properties of meat, such as texture and tenderness. This review also summarizes the available information on the impact of irradiation on the extension of meat shelf life.

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Introduction

Nowadays, meat plays an important role in the human diet due to its protein, vitamins, and minerals [1]. However, meat is susceptible to microbial contamination, which can adversely affect its quality and safety [2]. Historically, Hippocrates (460 BC) recognized a direct connection between human illness and food consumption, based on his observation of how illness is directly linked to food consumption [3]. According to the World Health Organization (WHO), approximately 600 million people around the world are estimated to be ill due to consumption of contaminated food and 420000 people die every year [4,5]. Over 60 types of food have been approved by health and safety authorities for food irradiation, including meat, spices, grains, vegetables and fruits [6].

Ionizing radiation is used for treatment of meat as a physical process to ensure the safety and quality of food products. In addition to improving the safety of fresh meats by reducing food-borne pathogens, irradiation can also extend the shelf life of meat when stored at refrigeration temperatures or create shelf stable products without deterioration of the nutritive quality [7]. In the food industry, gamma radiations, electron beams and X-radiations are the main sources of radiation used to process food. Additionally, UV–C is widely used in the sterilization and microbial reduction of food, and was approved to delay the ripening and senescence of different fruits and vegetables. Microbes on surfaces of food can be quickly inactivated by pulsed ultraviolet (PUV) light. PUV light contains UV–C light, and its wavelength ranges between 180 and 1100 nm [8]. During food irradiation, radiation is not permitted to escape from a shielded room. When radiation is used at the prescribed energy level, food is not contaminated with radioactivity. The radiation dose absorbed by food treated by irradiation does not make it radioactive. Radiation damages deoxyribonucleic acid (DNA) or other critical molecules in bacteria, killing or preventing them from reproducing, and therefore, helps achieve the desired food safety and security objectives [9].

There are still concerns about the efficacy, safety, and impact of food irradiation on nutritional and sensory properties despite its obvious benefits. Some critics claim that food irradiation destroys vitamins and proteins or creates harmful compounds depending on a level of irradiation, which effects differ from food to food [10]. Irradiation can significantly extend the shelf life of various foods such as meat and fruits. Several studies have reported that irradiating fruits and meat before ripening extends their shelf life [11]. Singh and Singh [12] concluded that there is no significant effect of irradiation on the chemical composition of food. This process does reduce some vitamins; however, this is also common in other traditional food preservation methods, such as drying, canning and smoking. Temperature, oxygen, moisture, and pH are also important environmental factors that influence the consequences of food irradiation. For example, in the presence of oxygen, ionizing radiations have a greater lethal effect, while in the absence of oxygen and in wet environments, radiation resistance increases by 2–4 times [13].

Meat irradiation has been studied by many researchers regarding the chemical composition, microbiological safety, shelf life, physical and chemical properties, sensory properties and nutritive values of foods. They have demonstrated that irradiation can inactivate microorganisms in any food product, such as fruits, vegetables or meat [14–16]. Gamma radiation was also shown to be a successful alternative remedy for inactivating microorganisms and extending shelf life [17]. Acceptance and use of irradiated food can be influenced by consumers' perception. Additionally, the flavor, nutritional content and presence or absence of additives determine the acceptance rate of products. The main purpose of this review is to investigate the principles, applications, technological and safety aspects of irradiated meat.

Objects and methods

A review of scientific literature published in English is included in this paper. Google Scholar, PubMed, Web of Science, Research Gate, Springer Link, ScienceDirect, Taylor & Francis, and Scopus, as well as the Google search engine, were elaborately reviewed to retrieve relevant keywords like food safety, meat irradiation, meat quality, pathogenic bacteria, chemical and physical properties, microbiological safety, and shelf life extension. As for the publications, they were as follows: published between 1975 and 2024 (72 references were selected for this review).

In this paper, we review the principles and applications of irradiation in food preservation. There is a schematic representation of the entire process of food irradiation using gamma rays, electron beams, and X-rays. Moreover, authors also discuss the benefits and limitations of food irradiation as a way to ensure that food is healthy and safe.

In addition, the Google search engine was used to capture more documents, reports, and theses from other reputable sources. Computers were used to store the information gathered. A title and abstract assessment was carried out on all papers collected for screening and analysis.

Some methods used for investigation of the effects of meat irradiation

Several authors have used several methods to analyze the effect of meat irradiation in some different ways. Asmarani et al. [18] employed a meta-analysis to investigate the effects of gamma irradiation on the quality of chicken meat and its products in Indonesia. The objective was to evaluate several parameters including oxidation, microbial activity, physicochemical characteristics, sensory properties, and nutrient quality. The study was carried out from August 2, 2023, to October 31, 2023. The study employed a mixed-model methodology where gamma irradiation treatment was treated as a fixed effect and the differences between experiments as random effects. A number of oxidation parameters were measured, including thiobarbituric acid-reactive substances (TBARS), total volatile base nitrogen (TVBN), and peroxide value. The microbial load parameters consisted of total aerobic bacteria, coliforms, lactic acid bacteria, enterobacteria, *Salmonella*, *Pseudomonas*, staphylococci, yeast, and mold. Physicochemical characteristics included pH, lightness (L*), redness (a*), and yellowness (b*). Moreover, parameters of sensory perception, such as acceptability, flavor and texture, were assessed.

In the study carried out in China, chicken breast samples were obtained from a local supermarket [19]. The samples were aseptically cut into uniform cubes (5 cm × 5 cm × 1.5 cm), weighing approximately 50 grams each. Three samples were packaged in a sterile polyethylene bag designed to prevent re-contamination. The samples were transported to the irradiation facility under chilled conditions (0–4 °C) immediately after preparation. The chicken breast samples were irradiated using an X-Rad 320 Biological Irradiator with a tungsten anode. The irradiation was performed at 160 kV and 25 mA, with doses of 0.0 (control), 0.75, 1.00, 1.25, 1.50, 1.75, and 2.00 kGy administered at a rate of 39.5 Gy/min. The X-ray source was capable of generating a high flux of up to 4 kW with a tunable broadband energy spectrum from 5 to 320 Ke V. The study evaluated various quality indicators of the irradiated chicken meat, including microbial counts, thiobarbituric acid reactive substances (TBARS), total volatile basic nitrogen contents (TVB-N), pH, color, texture, and sensory properties.

The study by Alahakoon et al. [20] investigated the effects of electron beam irradiation and high-pressure processing on the quality characteristics of marinated chicken breast meat, both with and without the addition of citrus peel extract (CPE). Fresh skinless chicken breast meat was purchased from a local market in Daejeon, Korea. The meat was transported in a polystyrene box with ice and stored at –18 °C until use. CPE was prepared by treating citrus peels with 70% ethyl alcohol (1:3, w/v) for 72 hours at room temperature (approximately 20 °C), followed by solvent evaporation and lyophilization. The marinade was created using water, salt, sugar, sodium pyrophosphate, and monosodium glutamate, with or without 2% CPE. Chicken meat (approximately 25 g) was mixed with the marinade by hand for 5 minutes to ensure maximum absorption. Each meat sample was vacuum packed before treatment. Samples were irradiated using a linear electron beam accelerator with doses of 1 kGy and 2 kGy. The beam power was set to 40 kW with a conveyor velocity of 10 m/min and a dose rate between 1.1 and 2.2 kGy/s. Samples were subjected to pressures of 300 MPa and 400 MPa. These methods provide a comprehensive approach to evaluating and enhancing the safety and quality of poultry products through innovative food processing techniques.

Sources of meat irradiation

An electromagnetic or particulate wave is a form of radiation that travels through matter or space. The term radiation refers to ionizing radiation, which can be divided into two types. First, directly ionizing radiations can ionize atoms of their target material through columbic interactions with the electrons of the material, and the amount of this columbic force depends on the kinetic energy of the particles, such as alpha radiation, beta radiation (high energy electron beams), and many other charged particles.

Secondly, indirectly ionizing radiations are neutral particles such as neutrons, gamma rays, X-rays that ionize atoms indirectly by ejecting energetic electrons called secondary electrons through their interactions [21]. Ionizing radiation sources can only be used in three main types of meat processing.

1) Gamma radiations are a type of the electromagnetic wave that have very short wavelengths and high energy photons emitted from Cobalt-60 (^{60}Co) or Cesium-137 (^{137}Cs) radioactive sources, which give off ionizing gamma radiations of 1.17 MeV, 1.33 MeV and 662 keV [22]. Both of them eject highly penetrating gamma radiations that can be normally applied for irradiation of meat and agriculture products. ^{60}Co is more commonly used than ^{137}Cs because it penetrates deeply into meat products and destroys harmful microorganisms [23]. Moreover, ^{60}Co is water insoluble and poses less or no environmental hazard. Using gamma rays at doses below 10 kGy can enhance meat safety by inactivating pathogenic microorganisms, such as *Salmonella* and *Campylobacter*, as well as extend the shelf-life of foods by removing microorganisms that cause food spoilage. Electron beams and X-rays are becoming more accepted due to the extensive shielding to prevent radiation and the potential health risks associated with gamma rays.
2) Electron beams are high energy electrons that are generated from an electron accelerator with the maximum energy level (8–10 MeV) [24]. The main disadvantages of electron beams are low dose uniformity and low penetration depth (approximately 2.5 cm). However, they have a lower cost compared to gamma rays and X-rays [25]. Additionally, a radioactive source is not required, and the device can also be turned off when not in use [26]. Applications for low energy electron beam of 0.1–1 MeV include packaging modifications, surface sterilization and aseptic packaging. Electron beams with medium energies of 1–5 MeV can be used to sterilize surfaces, pasteurize food in customized packaging, and modify packaging material. In contrast, applications for electron beams with high energies of 5–10 MeV can include food sterilization, waste treatment and phytosanitary treatment in the food industry and pasteurization [9]. All types of food can be irradiated with electron beams, including meat, fruits, seafood, vegetables, cereals and dairy products [27].
3) X-radiations are high-energy photons, which are emitted from orbital electrons when they interact with target material. Like electron beams, the device does not use a radioactive substance and can be easily shut off when not needed. The penetration depth of X-rays is high but they are expensive because only 8% of incident energy is converted to X-rays [28]. Recently, they have been applied to seafood, vegetables, and dairy products for the reduction of microbial contamination [29,30].

Applications of various doses in meat preservation

Irradiation of meat is determined by radiation absorbed dose represented as units of Grays (1 Gy = 100 rad) or kiloGray (kGy), with 1 kGy equal to 1000 joule of absorbed energy per kilogram. International health and safety authorities have endorsed the safety of irradiating food up to 10,000 Gy (10 kGy) [31]. There are three different principles involved in using radiation doses to preserve food.

1) Radurization involves decreasing the number of bacteria to the barest minimum on meat or seafood in order to enhance the keeping quality by using low doses of ionizing radiation (0.1–1 kGy) [32].
2) Radicidation uses middle doses of 1–10 kGy. Meat must be exposed to radiation doses necessary to reduce spoilage and microbial pathogens. The application of this dosage is similar to pasteurization, but since it does not use thermal energy, it is commonly used for frozen meat and other frozen foods [33].
3) Radappertization uses high doses (10–50 kGy) and is applied in the sterilization process since it can destroy microorganisms down to the level of spores in foodstuffs. In general, food irradiation sources and principles focus on using radiation to disrupt bacteria, enzymes, proteins, and microorganisms' genetic material, resulting in increased food safety and quality. For the safety and effectiveness of irradiation, national and international authorities regulate its use [34].

Principles of meat irradiation processing

Microorganisms and pests are controlled with a process, and the products are packaged before they are irradiated in order to avoid recontamination or re-infestation. Due to the exposure to radiation, packaging materials must be radiation resistant, and they should not transmit toxic substances into food, nor should they alter the texture or flavor of the food. Packaging materials are chosen based on radiation dose levels [33].

After meat has been prepared beforehand by packaging, it is exposed to a measured dose of ionizing radiation during the process as shown in Figure 1. The process is carried out in an irradiation room using a conveyor belt for a specified period of time. In the shielded room, meat passes through a defined amount of ionizing radiation for a certain

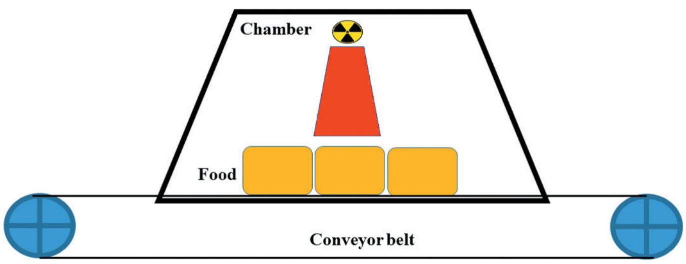

Figure 1. Meat irradiation process. First, meat is transported in a package to the irradiation chamber by the conveyor system, then meat is irradiated for a specified period of time, and finally it is unloaded and shipped to markets

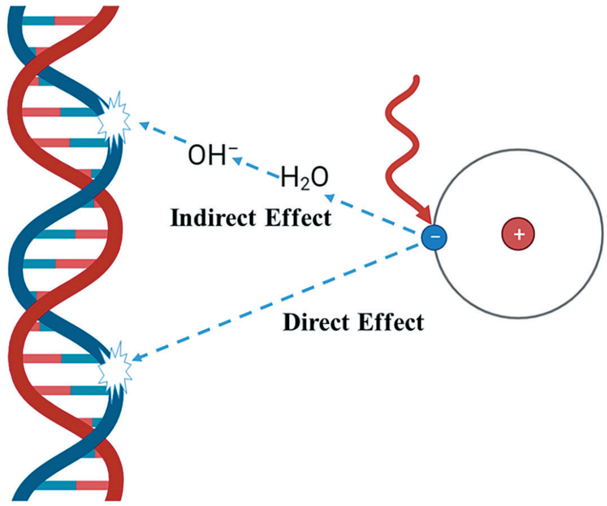

Figure 2. Radiation effects on microorganisms' genetic material DNA. Microorganisms can be killed or rendered inactive by radiation by damaging their DNA directly or by causing water molecules to undergo radiolysis to produce free radicals. As a result of these free radicals attacking DNA and other organic molecules in a microbe, a microbe may die, if it is not able to recover from the radiation-induced damage

amount of time before being redirected to the unloading area. The amount of time of exposure depends on meat type and sources of radiation being used. When radiation passes throughout meat, it breaks the chemical bonds, damaging food-borne pathogens or spoilage organisms by inactivating DNA in living cells, either directly or indirectly through the production of radicals and ions that damage DNA as shown in Figure 2. Gamma irradiation is mostly utilized for meat irradiation in commercial scale facilities such as the ^{60}Co source with high energy of 1.33 MeV [33]. The source is stored in a shielded container or under water to absorb all radiation, when the source is not used [35]. The second most used source are electron beams produced by an electron accelerator with high energy of 10 Me V. They are widely used to inactivate foodborne pathogens. X-rays, which are produced by striking a target material such as tungsten with high velocity electrons, are less commonly used for meat irradiation [33].

Effect of irradiation on the quality of different meat types

Sensory quality

The sensory qualities of meat can be affected both positively and negatively by irradiation. The sensory characteristics of meat including color, texture and taste, are not significantly affected by irradiation when an appropriate dose is used. However, high doses of irradiation can negatively impact sensory attributes, such as taste, odor and texture. Meat products may be perceived differently by consumers as a result of these changes. To minimize sensory changes that occur when meat is irradiated and improve sensory acceptability, storage conditions, packaging and flavor enhancers or additives can be used. Irradiation up to a dose of 10 kGy has no effect on the nutritional properties of meat or food safety [36]. According to Du et al., [37] radiation accelerates the oxidation and discoloration of lipids, and it decreases the levels of sensory properties in meat and meat products that cause off-flavors. It was found that the flavor score decreased with each doubling of the dosage by the same amount. It has been shown by Merritt et al. [38] that sensory acceptance can decrease as irradiation treatment dose and temperature increase. Shah et al. [7] showed that higher than 10 kGy may cause biochemical modifications and negatively affect the sensory qualities of food. In the study by Huang et al. [39] irradiation using gamma radiation at 2 kGy had no discernible effect on sensory attributes of smoked chicken breast. However, irradiation using gamma radiation at 3, 4 and 6 kGy led to a decrease in sensory qualities.

It is important for irradiated meat to have a good sensory quality, so strategies for improving meat sensory quality should be considered in the development and marketing of these products. Table 1 shows research findings on gamma irradiation regarding the sensory qualities of meat.

Microbiological safety

Irradiation has a significant effect on reducing the growth of microorganisms such as viruses, bacteria, as well as parasites, and therefore, reduces the risk of foodborne illness. Consequently, it enhances the quality and safety of meat

Table 1. Effect of gamma irradiation on the sensory qualities of meat

Meat	Radiation source	Dose rate (kGy)	Sample storage conditions	Sensory quality	References
Chicken meat	Gamma irradiation	1 and 2 kGy	Vacuum-packed; refrigeration storage at 4 °C; 14 days	Irradiation at 2 kGy did not affect sensory properties with turmeric powder	[40]
Camel meat	Gamma irradiation	0, 3, 5 and 7 kGy	Refrigeration storage at 1–4 °C; 42 days	Irradiated and non-irradiated camel meat had similar sensory properties	[41]
Ostrich meat	Gamma irradiation	0, 1 and 3 kGy	Air-packaged, under refrigerated storage at 4 °C; 9 days	Ostrich meat packaged in air quickly lost its qualities such as odor and texture	[14]
Rabbit meat	Gamma irradiation	0, 1.5 and 3 kGy	Packed in polyethylene pouches; refrigeration storage at 3–5 °C; 21 days	The sensory qualities of rabbit meat were not significantly affected by gamma irradiation	[42]
Turkey meat	Gamma irradiation	0, 0.5, 2 and 4 kGy	Refrigeration storage at 18 °C; 60 days	Sensory properties of irradiated and non-irradiated samples were similar and were equally accepted in terms of odor	[43]
Beef	Gamma irradiation	10, 25, 50 kGy	Refrigeration storage at 5 °C; 17 days	High doses of irradiation resulted in a brownish color of meat surface	[44]
Camel meat	Gamma irradiation	1.5, 3 and 4.5 kGy	12-month storage	Gamma rays had little sensory effects on odor and taste	[45]

products. At very low doses, irradiation is not effective in killing microbial toxins or viruses on meat. Therefore, a specific dose that is suitable for killing germs should be used according to a type of meat [46]. There are several food-borne bacterial pathogens that can cause severe illness or death in vulnerable populations, including *Salmonella*, *E. coli*, *Campylobacter* and *Listeria* [47].

Most current research has shown that ionizing radiation is used to irradiate meat, reducing microbial contamination and preserving nutritional value [48,49]. Arshad et al. investigated an effect of radiation doses on frozen duck meat using the electron beam. They concluded that at the dose of 3 kGy, the total bacterial and coliform counts were reduced by 1 log and 2 log cycles, respectively [50]. A study conducted by Sedeh et al. discovered that using 3 kGy gamma irradiation reduced mesophilic aerobic bacteria, coliforms, and *Staphylococcus aureus* in meat [51]. According to the research by Park et al., electron beams have less effect on meat products than gamma irradiation. Therefore, gamma irradiation is more effective in inhibiting the growth of microorganisms on meat [52].

Shelf life

It is very important to extend the shelf life of meat products using irradiation without losing safety and quality. Meat can have its shelf life doubled by applying relatively adequate doses of radiation without changes in color, flavor and texture. Certain factors affect shelf life extension such as a type of source, processing method, packaging and storage temperature [53]. Quality of meat products is determined by four parameters, such as nutritional quality, technological quality, sensory quality and safety quality. All those parameters affect the shelf life of meat types [54]. When ionizing radiation is applied to meat, it can cause reduction or elimination of microorganisms, which is one of the important factors that increase the shelf life of products [55].

Previous research has shown that irradiation is an appropriate process for meat types as shown in Table 2. In the recent study, the shelf life of boneless chicken was increased by 8 days using gamma irradiation. The results also showed that *Allium sativum* essential oil and gamma irradiation can extend shelf life of boneless chicken for 14 days [56]. Otoo et al. [57] reported that gamma irradiation at a dose rate of 0.74 kGy/hr can increase the shelf life of smoked guinea chicken under refrigeration. Generally, irradiation can extend the shelf life of meat types, but it is only one element of the comprehensive preservation strategy that also involves handling, storage, and other food safety measures. Previous studies show that irradiation has an effect of extending the shelf life of meat (Table 2).

Nutritional properties

Important components of meat are lipids, which are compounds crucial to cellular metabolism and several physiological functions [62]. Lipid oxidation can cause changes in the color, flavor and nutritional quality of meat. These changes depend on appropriate dose, meat type and packing conditions [63]. Earlier, some investigations showed that irradiation can lead to some changes in the nutritional composition of meat types.

Jai et al. demonstrated that lipidomics technology can be used to determine the composition of lipids of goat meat and their nutritional value [64]. As a result of two hours of gamma irradiation treatment, modified polyunsaturated fatty acids were found in goat meat after exposure to different radiation doses. Jia et al. applied five doses of gamma irradiation (0 kGy, 1 kGy, 2 kGy, 4 kGy and 6 kGy) to vacuum-packed goat meat for up to 2 hours. The results showed that irradiation increases the content of lipids that are rich in polyunsaturated fatty acids [64]. Another study examined an irradiation effect on the nutritional properties and lipid composition of marbled beef by using electron beam irradiation of 0, 2.5 and 4.5 kGy. The findings showed that irradiation of marbled beef had an effect on lipids, but with increasing the radiation dose from 2.5 kGy to 4.5 kGy little difference was observed [65].

In conclusion, it is important to note that irradiating meat may potentially affect its nutrient composition and quality, but it is a safe and effective way for protecting against foodborne illness.

Chemical properties

In irradiated meat, chemical properties refer to changes in the composition and constituents that occur due to exposure to ionizing radiation. These changes of chemical properties depend on a radiation dose and ambient oxygen when it reacts with

Table 2. Effect of irradiation on the shelf life of meat

Meat	Radiation source	Dose rate	Sample storage conditions	Shelf life	References
Turkey Bologna	Gamma irradiation	10 kGy	Vacuum-packed; 8 weeks at 4 °C	Irradiation at 10 kGy increased the storage life	[58]
Chicken wings	Gamma irradiation	0, 3, 5 and 7 kGy	Vacuum-packaged and cooked samples were stored at 2 and 7 °C; 7 weeks	Chicken wings had a shelf life of more than 7 weeks at 2 °C	[59]
Broiler meat	Gamma irradiation	0, 1, 2 and 3.5 kGy	Stored for 0, 30 and 60 days at –20 °C	Gamma irradiation at 2.0 kGy resulted in shelf life extension of broiler meat compared to non-irradiated meat	[60]
Mutton	Gamma irradiation	0, 1.5, 2 and 4 kGy	Stored for 0, 30 and 60 days at –20 °C	The shelf life of mutton was increased by 4 kGy irradiation	[16]
Chicken, salmon and beef fillets	UV–C irradiation	360 J/m^2	Vacuum-packaged storage; 5 days	The shelf life of chicken, beef and salmon fillets can be prolonged by 66.6% by irradiating with UV–C and vacuum sealing	[61]

meat [66]. Therefore, meat should be packaged after irradiation. When irradiated meat is exposed to free radicals, chemical changes occur, and a reaction between meat compounds and free radicals generates sulfur-containing volatiles. As a result of chemical reactions, fat oxidation, volatile production and gas production, meat loses sensory properties and is changed in quality [67].

Meat is rich in protein and vitamins (B1, B2, B6 and E), but irradiation can lower protein and vitamin content in meat. Using low radiation doses in combination with other mild treatments minimizes the effects of irradiation on organoleptic changes and vitamin loss in meat [68].

Physical Properties

Physical properties can also change, including water holding capacity (WHC), color and tenderness of meat. WHC refers to fresh meat ability to retain its own water during grinding, cutting and heating and also during transport, storage and cooking [69]. Changes in physical qualities of meat regarding tenderness will cause more tenderness or hardness in meat by the appropriate dose of radiation. However, sometimes meat loses its color. Poultry and beef are more prone to changes in color. The study by Bliznyuk et al. investigated the impact of electron beam irradiation at 0, 1.5, 3, 4.5 kGy on raw beef [70]. They found that electron beam irradiation decreased the color value (L*, a* and b*).

Meat irradiated with more than 10 kGy has lower myofibrillar protein content. As a result of changes in the secondary structure of the myofibrillar protein, the functional properties of the protein change, which affect the texture of meat. Several factors play a role in these changes, including radiation dose, pH, temperature, packaging conditions, muscle type and storage time. In addition, different protein types are sensitive to different effects of irradiation on meat texture [32,71]. Rane et al. analyzed changes in pH, TBA (thiobarbituric acid) values, and tyrosine levels in irradiated chicken nuggets over time with electron beam doses of 3, 3.5 and 4.5 kGy. They found that pH values of chicken nuggets increased gradually during storage, indicating possible spoilage or quality changes. TBA values, which measure lipid oxidation, also increased, suggesting oxidative changes in both control and irradiated samples over time [72]. Moreover, color changes were monitored using a color difference meter, noting variations in L*, a*, and b* values throughout the storage period.

Advantages of meat irradiation technique

1) Taste, color and texture of meat are not significantly changed by irradiation when an appropriate dose is used.
2) The shelf life of meat is extended by the use of irradiation, which can slow down the spoilage of meat.
3) Irradiation can replace chemical fumigants for disinfestation and microbial control as it causes no radioactivity in meat and leaves no harmful radioactive residues on meat.
4) Irradiation can reduce or kill viruses, bacteria, and parasites on meat depending on the radiation doses used.
5) When meat is irradiated, it helps companies and businesses to easily import meat to other countries as they ensure the safety and quality of meat.
6) Meat that has been irradiated does not have significant changes in its nutritional content. Physical and chemical properties of meat are preserved after irradiation. Furthermore, this technique can be used on packed meat to prevent recontamination.
7) A greater safety and quality of products can be achieved through irradiation in conjunction with other methods of meat preservation.

Conclusions

Irradiation technique is a beneficial technology in improving the safety and quality of meat types. The process can extend the shelf life of meat and prevent spoilage. In addition, a certain amount of radiation dose can reduce or completely destroy bacteria, viruses and parasites on meat. Taste, odor and color, which are the most important characteristics of meat according to most researchers, are not significantly affected when the right dose is used. When high radiation dose is used, it affects the chemical and physical qualities of meat and can reduce the vitamin content in meat or destroy its tender texture. Finally, it is important to perform further research in the future for products that have not been tested for worldwide acceptance.

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