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REVIEW ARTICLE

The Relationship between the Food Nutritional Value and the Absence of Microbial Hazards

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ABSTRACT

Meat is a valuable element of the human diet as it contains essential elements such as protein, vitamins, and minerals. However, these foods are also vulnerable to microbial pathogens and spoilage, posing significant risks to human health. Ionizing radiation is used in food irradiation to maintain the safety and quality of the food items, specifically beef. For decades, 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 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 breaks down some of the molecules in the food product, which can affect its nutritional quality and sensory properties.

Key words: Beef, DNA gamma rays, food irradiation, human health

INTRODUCTION

Despite its potential benefits, food irradiation remains controversial, with concerns about its safety, efficacy, and impact on the nutritional quality and sensory properties of food products. Some critics argued that food irradiation could create harmful compounds or destroy essential nutrients. In contrast, others questioned the need for irradiation, considering other food safety measures, such as good manufacturing practices and food testing. Consumer acceptance of irradiated food products also needs to be addressed, with some people expressing concerns about their safety and acceptability.[1-6] This comprehensive research aims to critically evaluate the existing literature on food irradiation and its repercussions on the quality and safety of beef. The proof of irradiation effectiveness at lowering microbial contamination and prolonging the shelf life of the beef is explored along with its potential impact on the physical and chemical characteristics, nutrient content, and sensory properties. This paper will also address the regulatory framework for food irradiation, including labeling requirements and government oversight, as well as identify areas for further research and policy development.[7-12]

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SOURCES AND PRINCIPLES OF THE FOOD IRRADIATION

The ionizing radiation, such as the gamma rays, the 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 the shelf life, as well as enhance the quality and safety of food products.[13-18] The principles of the food irradiation

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are determined by the ability to disrupt the genetic material of microorganisms, preventing them from reproducing or causing illness. The irradiation affects the microorganisms' genetic material (DNA or RNA) directly and indirectly. Direct irradiation can break the bonds between base pairs in the genetic material, killing the cell's reproduction ability. Then, on the other hand, damage to water molecules creates free radicals and reactive oxygen species, which damage genetic material indirectly. Irradiation also helps to break down certain enzymes and proteins in the food that can contribute to spoilage, thereby increasing the shelf life.[9,19-23] The US, Canada, as well as several European and Asian nations, allow the food irradiation using Cobalt-60, cesium-137, and electron-beam accelerators. Cobalt-60, the most prevalent source of ionizing radiation for the food irradiation, is a radioactive isotope that emits gamma rays capable of penetrating deep into the food products to destroy the 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 beef shelf life.[24-29] 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. Given that 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 use. To effectively lengthen the lifespan of the irradiated food products, the following principles must be observed, and radurization uses low doses of 0.1–1 kGy.[30-35] This amount inhibits respiration, delays ripening, disinfects pests, and inactivates the *Trichinella* parasite. Radicidation is referred to as a moderate dose. This radiation uses a quantity of approximately 1–10 kGy, which has the effect of reducing spoilage and microbial pathogens including *Salmonella* spp. 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 thermal energy.[36-41] 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. Generally, the food irradiation sources and principles are based on the ability of ionizing radiation to disrupt the genetic material of microorganisms, enzymes, and proteins in the food products, culminating in improved safety and quality. The use of irradiation is regulated by national and international authorities to ensure its safety and effectiveness.[27,42-46]

THE EFFECTS OF IRRADIATION ON THE BEEF

The Microbial Safety

Microbial safety is a critical aspect of beef production and consumption, as these products can be a source of various harmful microorganisms that can cause foodborne illnesses. The beef products are potentially contaminated with various pathogens, such as *Salmonella*, *Escherichia coli*, *Campylobacter*, and *Listeria monocytogenes*, leading to severe illness or death in vulnerable populations.[47-52] Contamination might occur at the production, processing, or distribution stage, including on the farm, during transport, in slaughterhouses or processing facilities, and in retail outlets or at home. Improper handling and storage of the beef products can also increase the risk of contamination.[13,53-67] Foodborne illness outbreaks related to the beef have been reported globally, with various types of products being implicated, including the ground beef, the chicken, the pork, and the processed beef. These outbreaks have led to the significant public health and the economic consequences, the highlighting the importance of the effective interventions to reduce the risk of contamination.[58-63] Irradiation has been studied extensively for its efficacy in reducing microbial contamination of beef. By exposing the food to the ionizing radiation, the latter reduces or eliminates the harmful microorganisms that can cause foodborne illness. Previous research showed that irradiation could effectively reduce the levels of the pathogens such as Salmonella and Escherichia coli as well as levels of spoilage organisms, leading to improved microbial safety and a reduced risk of the foodborne illness.[64-69] The effectiveness of various types of the ionizing radiation on the beef, including the gamma rays and the e-beams, has been studied gamma ray irradiation is more effective than e-beam irradiation at inhibiting microbial growth in the beef. The UV light effectively eliminates *Salmonella* spp., *Pseudomonas*, *Micrococcus*, and *Staphylococcus* on the beef. The shelf life of beef products is extended by eliminating these contaminant bacteria.[70-75] Gamma irradiation at low doses can improve microbiological safety, ensure safety, and extend the chicken meat's shelf life without affecting the quality. The 3 kGy gamma-irradiated beef reduced the growth of the mesophilic bacteria, coliforms, and *Staphylococcus aureus*.[60,76-80] The Food and Drug Administration determined that a 3.5 kGy gamma ray irradiation dose effectively eliminates the pathogenic microbes from fresh beef. Irradiation had the effect of slowing the growth of the bacterial cells and deactivating their metabolism.[58,81-85] 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.[67,86-90]

Chemical Properties

The chemical properties of the irradiated beef refer to the changes that occur to the chemical constituents and the compositions of the food due to exposure to the ionizing radiation. Irradiation can cause both desirable and undesirable effects on the chemical characteristics of beef, depending on the dose and the specific compounds in the food.[91-96] One of the most significant changes often observed in irradiated beef products is the formation of free radicals. They become reactive molecules that damage cellular components and cause oxidative stress. This leads to the lipid oxidation, which causes off-flavors and odors, as well as a decline in nutritional quality due to the loss of essential fatty acids and other nutrients.[97-102] However, the irradiation at lower doses also aids lipid oxidation by reducing the levels of peroxides and other reactive species. This procedure also affects the protein content of the beef, leading to alterations in the composition of the amino acids, protein structure, and digestibility. These changes have potentially positive and negative effects, mostly on the nutritional value of the food, that is contingent upon the particular proteins involved and the dose of radiation used.[103-114] The positive effects of irradiation include the fact that irradiation can cause the formation of reactive species, such as free radicals, which can cause the formation of covalent bonds between the amino acids in protein molecules.[109-116] This cross-linking can change the structure of a protein molecule and make it resistant to enzymatic digestion, which causes a decrease in the protein digestibility.[117-122] The irradiation can also cause the denaturation of the protein molecules. Denaturation involves opening the protein structure, which can facilitate the interactions between the amino acids and increase the accessibility of the digestive enzymes to protein molecules, and it can also improve the protein digestibility.[89,123-127] However, irradiation can also cause adverse effects; namely, the excessive irradiation can cause a breakdown of or changes 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 <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.[37,40,128-130] Aside from these chemical changes, the irradiation also affects the vitamin content of the beef 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. Irradiation has been shown to alter the beef oxidation–reduction ability, accelerating the lipid oxidation, the protein breakdown, and the flavor and the odor changes.[38,105,132-135] When combined with certain antioxidants, such as the flavonoids, the irradiation can help prolong the induction period of the lipid oxidation, storing the irradiated beef at 5–10°C for 1 week almost did not change the pH, the texture, the total volatile base nitrogen, or the microbe number.[136-141] Meanwhile, a higher dose of the UV irradiation increased 2-thiobarbituric acid content, decreased the water-holding capacity, and the decreased beef color intensity and tenderness.[142-147] The 2.5 and 5 kGy gamma irradiation reduced the nitrite content in the chicken sausages and prevented the oxidation when combined with the antioxidants.

The titratable acidity and the acid value in the beef samples can be reduced by the irradiation.[148-153] Beef contamination may occur at the production, the processing, or the distribution stage, including on the farm, during the transport, in the slaughterhouses or the processing facilities, and in the retail outlets or at the home.[13,154-158]

CONCLUSION

The Improper handling and the storage of the beef products can also increase the risk of the beef contamination. Foodborne diseases outbreaks related to the beef have been reported globally, with the various types of the meat products being implicated, including the ground beef, the chicken meat, the pork, and the processed beef.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

REFERENCES

1. Shaltout A, Riad M, Abou Elhassan A. Prevalence of *Mycobacterium tuberculosis* in imported cattle offals and its lymph nodes. Vet Med J Giza 2017;63:115-22.
2. Saucier L. Microbial spoilage, quality and safety within the context of meat sustainability. Meat Sci 2016;120:78-84.
3. Shaltout FA, Riad EM, Abou-Elhassan A. Prevalence of *Mycobacterium* Spp. In cattle meat and offal's slaughtered in and out Abattoir. Egypt Vet Med Assoc 2017;77:407-20.
4. Abd Elaziz O, Hassanin F, Shaltout F, Mohamed O. Prevalence of some foodborne parasitic affection in slaughtered animals in local Egyptian Abottoir. J Nutr Food Sci Technol 2021;2:1-5.
5. Pereira PM, Vicente AF. Meat nutritional composition and nutritive role in the human diet. Meat Sci 2013;93:586-92.
6. Abd Elaziz OM, Hassanin FS, Shaltout FA, Mohamed OA. Prevalence of some zoonotic parasitic affections in sheep carcasses in a local abattoir in Cairo, Egypt. Adv Nutr Food Sci 2021;6:25-31.
7. Al Shorman AA, Shaltout FA, Hilat N. Detection of Certain Hormone Residues in Meat Marketed in Jordan. In: Jordan University of Science and Technology, 1st International Conference on Sheep and Goat Diseases and Productivity; 1999.
8. Saleh E, Shaltout F, Abd Elaal E. Effect of some organic acids on microbial quality of dressed cattle carcasses in Damietta Abattoirs, Egypt. Damanhour J Vet Sci 2021;5:17-20.
9. Edris AA, Hassanin FS, Shaltout FA, Elbaba AH, Adel NM. Microbiological evaluation of some heat treated fish products in Egyptian markets. EC Nutr 2017;12:134-42.
10. Edri A, Hassan MA, Shaltout FA, Elhosseiny S. Chemical evaluation of cattle and camel meat. Benha Vet Med J 2013;24:191-7.
11. Edris AM, Hassan MA, Shaltout FA, Elhosseiny S. Detection of *E.coli* and *Salmonella* organisms in cattle and camel meat. Benha Vet Med J 2012;24:198-204.
12. Edris AM, Hemmat MI, Shaltout FA, Elshater MA, Eman FM. Study on incipient spoilage of chilled chicken cuts-up. Benha Vet Med J 2012;23:81-6.
13. Shaltout FA, Zakaria IM, Nabil ME. Incidence of some anaerobic bacteria isolated from chicken meat products with special reference to *Clostridium perfringens*. Nutr Food Toxicol 2018;2:429-38.
14. Arvanitoyannis IS, editor. Consumer behavior toward irradiated food. In: Irradiation of Food Commodities: Techniques, Applications, Detection, Legislation, Safety and Consumer Opinion. Boston, MA: Academic Press; 2010. p. 673-98.
15. Shaltout FA, Maarouf AA, Elkhouly ME. Bacteriological evaluation of frozen sausage. Nutr Food Toxicol 2017;1:174-85.
16. Fajardo-Guerrero M, Rojas-Quintero C, Chamorro-Tobar I, Zambrano C, Sampedro F, Carrascal-Camacho AK. Exposure assessment of *Salmonella* spp. In fresh pork meat from two Abattoirs in Colombia. Food Sci Technol Int 2020;26:21-7.
17. Shaltout FA, El-Toukhy EI, Abd El-Hai MM. Molecular diagnosis of Salmonellae in frozen meat and some meat products. Nutr Food Technol Open Access 2019;5:1-6.
18. Shaltout FA, Ali AM, Rashad SM. Bacterial contamination of fast foods. Benha J Appl Sci 2016;1:45-51.
19. EdrisAM, HemmatMI, ShaltoutFA, ElshaterMA, EmanFM. Chemical analysis of chicken meat with relation to its quality. Benha Vet Med J 2012;23:87-92.
20. Borrego-Soto G, Ortiz-López R, Rojas-Martínez A. Ionizing radiation-induced DNA injury and damage detection in patients with breast cancer. Genet Mol Biol 2015;38:420-32.
21. Edris AM, Shaltout FA, Abd Allah AM. Incidence of *Bacillus cereus* in some meat products and the effect of cooking on its survival. Zag Vet J 2005;33:118-24.
22. Edris AM, Shaltout FA, Arab WS. Bacterial evaluation of quail meat. Benha Vet Med J 2005;16:1-14.
23. Edris AM, Shaltout FA, Salem GH, El-Toukhy EI. Incidence and Isolation of Salmonellae from Some Meat Products. In: Benha University, Faculty of Veterinary Medicine, Fourth Scientific Conference 25-27th May 2011 Veterinary Medicine and Food Safety) Benha, Egypt; 2011. p. 172-9.
24. Edris AM, Shaltout FA, Salem GH, El-Toukhy EI. Plasmid Profile Analysis of Salmonellae Isolated from Some Meat Products. In: Benha University, Faculty of Veterinary Medicine, Fourth Scientific Conference 25-27th May 2011 Veterinary Medicine and Food Safety),

Benha, Egypt; 2011. p. 194-201.
25. Ragab A, Edris AM, Shaltout FA, Salem AM. Effect of titanium dioxide nanoparticles and thyme essential oil on the quality of the chicken fillet. Benha Vet Med J 2022;41:38-40.
26. Hassan MA, Shaltout FA, Arafa MM, Mansour AH, Saudi KR. Biochemical studies on rabbit meat related to some diseases. Benha Vet Med J 2013;25:88-93.
27. Hassan MA, Shaltout FA. Occurrence of some food poisoning microorganisms in rabbit carcasses. Alex J Vet Sci 1997;13:55-61.
28. Hassan M, Shaltout FA, Saqur N. Histamine in some fish products. Arch Anim Husband Dairy Sci 2020;2:1-3.
29. Mkhungo MC, Oyedeji AB, Ijabadeniyi OA. Food safety knowledge and microbiological hygiene of households in selected areas of Kwa-Zulu Natal, South Africa. Ital J Food Saf 2018;7:126-30.
30. Singh R, Singh A. Food irradiation: An established food processing technology for food safety and security. Def Life Sci J 2019;4:206-13.
31. Shaltout FA, Zakaria IM, Eltanani J, Elmelegy AS. Microbiological status of meat and chicken received to University student hostel. Benha Vet Med J 2015;29:187-92.
32. Yeh Y, de Moura FH, Van Den Broek K, de Mello AS. Effect of ultraviolet light, organic acids, and bacteriophage on *Salmonella* populations in ground beef. Meat Sci 2018;139:44-8.
33. Saad SM, Edris AM, Shaltout FA, Shimaa E. Isolation and identification of Salmonellae and *E.coli* from meat and poultry cuts by using A multiplex PCR. Benha Vet Med J 2012;Special issue:16-26.
34. Saad SM, Shaltout FA. Mycological evaluation of camel carcasses at Kalyobia Abattoirs. Vet Med J Giza 1998;46:223-9.
35. Rastogi RP, Richa, Kumar A, Tyagi MB, Sinha RP. Molecular mechanisms of ultraviolet radiation-induced DNA damage and repair. J Nucleic Acids 2010;2010:592980.
36. Saad SM, Shaltout FA, Abou Elroos NA, El-Nahas SB. Antimicrobial effect of some essential oils on some pathogenic bacteria in minced meat. J Food Sci Nutr Res 2019;2:12-20.
37. Saad SM, Hassanin FS, Shaltout FA, Nassif MZ, Seif MZ. Prevalence of methicillin-resistant *Staphylococcus aureus* in some ready-to-eat meat products. Am J Biomed Sci Res 2019;4:460-4.
38. Gómez I, Janardhanan R, Ibañez FC, Beriain MJ. The effects of processing and preservation technologies on meat quality: Sensory and nutritional aspects. Foods 2020;9:1416.
39. Saad SM, Shaltout FA, Abou Elroos NA, El-Nahas SB. Incidence of Staphylococci and *E. coli* in meat and some meat products. EC Nutr 2019;14:6.
40. Shaltout FA, Riad EM, Ahmed TE, Abou Elhassan A. Studying the effect of gamma irradiation on bovine offal's infected with *Mycobacterium tuberculosis* bovine type. J Food Biotechnol Res 2017;1:1-5.
41. Shahi S, Khorvash R, Goli M, Ranjbaran SM, Najarian A, Mohammadi Nafchi A. Review of proposed different irradiation methods to inactivate food-processing viruses and microorganisms. Food Sci Nutr 2021;9:5883-96.
42. Hassan MA, Shaltout FA. Comparative study on storage stability of beef, chicken meat, and fish at chilling temperature. Alex J Vet Sci 2004;20:21-30.
43. Erkmen O, Bozoglu TF. Food preservation by irradiation. In: Food Microbiology: Principles into Practice. Hoboken, NJ: John Wiley and Sons Ltd.; 2016. p. 106-26.
44. Klurfeld DM. What is the role of meat in a healthy diet? Anim Front 2018;8:5-10.
45. Hassan MA, Shaltout FA, Maarouf AA, El-Shafey WS. Psychrotrophic bacteria in frozen fish with special reference to *Pseudomonas* species. Benha Vet Med J 2014;27:78-83.
46. Hassan MA, Shaltout FA, Arafa MM, Mansour AH, Saudi KR. Bacteriological studies on rabbit meat related to some diseases. Benha Vet Med J 2013;25:94-9.
47. Hassanin FS, Hassan MA, Shaltout FA, Shawqy NA, Abd-Elhameed GA. Chemical criteria of chicken meat. Benha Vet Med J 2017;33:457-64.
48. Hassanin FS, Hassan MA, Shaltout FA, Elrais-Amina M. *Clostridium perfringens* in vacuum packaged meat products. Benha Vet Med J 2014;26:49-53.
49. Hassanien FS, Shaltout FA, Fahmey MZ, Elsukkary HF. Bacteriological quality guides in local and imported beef and their relation to public health. Benha Vet Med J 2020;39:125-9.
50. Bantawa K, Rai K, Subba Limbu D, Khanal H. Food-borne bacterial pathogens in marketed raw meat of Dharan, Eastern Nepal. BMC Res Notes 2018;11:618.
51. Hassanin FS, Shaltout FA, Mostafa EM. Parasitic affections in edible offal. Benha Vet Med J 2013;25:34-9.
52. Hassanin FS, Shaltout FA, Lamada HM, Abd Allah EM. The effect of preservative (Nisin) on the survival of listeria monocytogenes. Benha Vet Med J 2011;Special issue 1:141-5.
53. Shaltout FA, Hassan MA, Hassanin FS. Thermal Inactivation of Enterohaemorrhagic *Escherichia coli* o157: H7 and Its Senstivity to Nisin and Lactic Acid Cultures. In: 1st Annual Conference FVM Moshtohor; 2004.
54. Food and Drug Administration, HHS. Irradiation in the production, processing and handling of food. Final rule. Fed Regist 2012;77:71316-20.
55. Shaltout FA, El-Diasty EM, Elmesalamy M, Elshaer M. Study on fungal contamination of some chicken meat products with special reference to 2 the use of PCR for its identification. Vet Med J Giza 2014;60:1-10.
56. Bintsis T. Foodborne pathogens. AIMS Microbiol 2017;3:529-63.
57. Shaltout FA. Microbiological aspects of semi-cooked chicken meat products. Benha Vet Med J 2002;13:15-26.
58. Khattab E, Shaltout F, Sabik I. Hepatitis A virus related to foods. Benha Vet Med J 2021;40:174-9.

59. Saad SM, Shaltout FA, Farag AA, Mohammed HF. Organophosphorus residues in fish in rural areas. J Prog Eng Phys Sci 2022;1:27-31.
60. Saif M, Saad SM, Hassanin FS, Shaltout FA, Zaghloul M. Molecular detection of enterotoxigenic *Staphylococcus aureus* in ready-to-eat beef products. Benha Vet Med J 2019;37:7-11.
61. Saif M, Saad SM, Hassanin FS, Shaltout FA, Zaghlou M. Prevalence of methicillin-resistant *Staphylococcus aureus* in some ready-to-eat meat products. Benha Vet Med J 2019;37:12-5.
62. Farag AA, Saad SM, Shaltout FA, Mohammed HF. Studies on pesticides residues in fish in Menofia Governorate. Benha J Appl Sci 2023a;8:323-30.
63. Farag AA, Saad SM, Shaltout FA, Mohammed HF. Organochlorine residues in fish in rural areas. Benha J Appl Sci 2023b;8:331-6.
64. Shaltout FA, Thabet MG, Koura HA. Impact of some essential oils on the quality aspect and shelf life of meat. Benha Vet Med J 2017;33:351-64.
65. Park JG, Yoon Y, Park JN, Han IJ, Song BS, Kim JH, *et al*. Effects of gamma irradiation and electron beam irradiation on quality, sensory, and bacterial populations in beef sausage patties. Meat Sci 2010;85:368-72.
66. Shaltout FA, Farouk M, Ibrahim HA, Afifi ME. Incidence of coliform and *Staphylococcus aureus* in ready to eat fast foods. Benha Vet Med J 2017;32:13-7.
67. Shaltout FA, Zakaria IM, Nabil ME. Detection and typing of *Clostridium perfringens* in some retail chicken meat products. Benha Vet Med J 2017;33:283-91.
68. Maherani B, Hossain F, Criado P, Ben-Fadhel Y, Salmieri S, Lacroix M. World market development and consumer acceptance of irradiation technology. Foods 2016;5:79.
69. Shaltout FA. Studies on Mycotoxins in Meat and Meat by Products. M.V.Sc Thesis Faculty of Veterinary Medicine, Moshtohor, Zagazig University Benha Branch; 1992.
70. Shaltout FA. Mycological and Mycotoxicological profile of Some Meat products. Ph.D.Thesis, Faculty of Veterinary Medicine, Moshtohor, Zagazig University Benha Branch; 1996.
71. Amiri A, Zandi H, Khosravi HM. Effect of electron beam irradiation on survival of *Escherichia coli* O157:H7 and *Salmonella enterica* serovar Thyphimurium in minced camel meat during refrigerated storage. J Food Qual Hazards Control 2019;6:174-8.
72. Shaltout FA. Proteolytic psychrotrophes in some meat products. Alex Vet Med J 1998;14:97-107.
73. Da Vinha AC, Sousa e Silva CA. Overview of irradiation: Advantages to foods of plant origin. South Florida J Health 2022;3:248-62.
74. Shaltout FA. Anaerobic bacteria in vacuum packed meat products. Benha Vet Med J 1999;10:1-10.
75. Song BS, Lee Y, Park JH, Kim JK, Park HY, Kim DH, *et al*. Toxicological and radiological safety of chicken meat irradiated with 7.5 MeV X-rays. Radiat Phys Chem 2018;144:211-7.
76. Shaltout FA. Protozoal foodborne pathogens in some meat products. Assiut Vet Med J 2000;42:54-9.
77. Shaltout FA. Quality evaluation of sheep carcasses slaughtered at Kalyobia abattoirs. Assiut Vet Med J 2001;46:150-9.
78. D'Souza C, Apaolaza V, Hartmann P, Brouwer AR, Nguyen N. Consumer acceptance of irradiated food and information disclosure-a retail imperative. J Retail Consum Serv 2021;63:102699.
79. Lianou A, Panagou EZ, Nychas GJ. Meat safety-I foodborne pathogens and other biological issues. In: Toldra F, editor. Lawrie's Meat Science. 8th ed. Cambridge, UK: Woodhead Publishing; 2017. p. 521-52.
80. Shaltout FA. *Yersinia enterocolitica* in Some Meat Products and Fish Marketed at Benha City. In: The Third International Conference Mansoura; 2003.
81. Putri MS, Susanna D. Food safety knowledge, attitudes, and practices of food handlers at kitchen premises in the Port 'X' area, North Jakarta, Indonesia 2018. Ital J Food Saf 2021;10:9215.
82. Shaltout FA, El-Diasty EM, Salem RM, Hassan AM. Mycological quality of chicken carcasses and extending shelf-life by using preservatives at refrigerated storage. Vet Med J Giza 2016;62:1-10.
83. Shaltout FA, Salem RM, El-Diasty EM, Hassan WI. Effect of lemon fruits and turmeric extracts on fungal pathogens in refrigerated chicken fillet meat. Glob Vet 2019;21:156-60.
84. Shaltout FA, Salem RM, El-Diasty E, Diab FA. Mycological evaluation of some ready to eat meat products with special reference to molecular characterization. Vet Med J Giza 2016;62:9-14.
85. Otoo EA, Ocloo FC, Appiah V. Effect of gamma irradiation on shelf life of smoked guinea fowl (*Numida meleagris*) meat stored at refrigeration temperature. Radiat Phys Chem 2022;194:110041.
86. Shaltout FA, Hussein MN, Elsayed NK. Histological detection of unauthorized herbal and animal contents in some meat products. J Adv Vet Res 2023;13:157-60.
87. Shaltout FA, Heikal GI, Ghanem AM. Mycological quality of some chicken meat cuts in Gharbiya governorate with special reference to *Aspergillus flavus* virulent factors. Benha Vet Med J 2022;42:12-6.
88. Shaltout FA, Salem RM, Eldiasty EM, Diab FA. Seasonal impact on the prevalence of yeast contamination of chicken meat products and edible giblets. J Adv Vet Res 2022;12:641-4.
89. Shaltout FA, Helmy Barr AA, Abdelaziz ME. Pathogenic microorganisms in meat products. Biomed J Sci Tech Res 2022;41:32836-43.
90. Farkas J. Irradiation for better foods. Trends Food Sci Technol 2006;17:148-52.
91. Shaltout FA, Mohammed IZ, Afify EA. Bacteriological profile of some raw chicken meat cuts in Ismailia city, Egypt. Benha Vet Med J 2020;39:11-5.
92. Schevey CT, Toshkov S, Brewer MS. Effect of natural antioxidants, irradiation, and cooking on lipid oxidation

in refrigerated, salted ground beef patties. J Food Sci 2013;78:S1793-9.
93. Shaltout FA, Mohammed IZ, Afify EA. Detection of *E. coli* O157 and *Salmonella* species in some raw chicken meat cuts in Ismailia province, Egypt. Benha Vet Med J 2020;39:101-4.
94. Shaltout FA, El-Diasty EM, Asmaa- Hassan MA. Hygienic quality of ready to eat cooked meat in restaurants at Cairo. J Glob Biosci 2020;8:6627-41.
95. Shaltout FA, Nasief MZ, Lotfy LM, Gamil BT. Microbiological status of chicken cuts and its products. Benha Vet Med J 2019;37:57-63.
96. Shaltout FA. Poultry meat. Sch J Food Nutr 2019;22:1-2.
97. Shaltout FA. Microbiological Quality of Chicken Carcasses at Modern Poultry Plant. In: The 3rd Scientific Conference, Faculty of Veterinary Medicine Benha University; 2009.
98. Morrison RM. Economics of food irradiation: Comparison between electron accelerators and cobalt-60. Int J Radiat Appl Instrum Part 1990;35:673-9.
99. Shaltout FA, Abdel-Aziz AM. *Salmonella enterica* serovar Enteritidis in poultry meat and their epidemiology. Vet Med J Giza 2004;52:429-36.
100. Lima F, Vieira K, Santos M, de Souza PM. Effects of Radiation Technologies on Food Nutritional Quality. London, UK: IntechOpen; 2018. p. 137-46.
101. Shaltout FA, Abdel Aziz AM. *Escherichia coli* strains in slaughtered animals and their public health importence. J Egypt Vet Med Assoc 2004;64:7-21.
102. Shaltout FA, Amin AR, Nassif MZ, Abdel-Wahab SA. Detection of aflatoxins in some meat products. Benha Vet Med J 2014;27:368-74.
103. Marin C, Cerdà-Cuéllar M, González-Bodi S, Lorenzo-Rebenaque L, Vega S. Research note: Persistent *Salmonella* problem in Slaughterhouses related to clones linked to poultry companies. Poult Sci 2022;101:101968.
104. Shaltout FA, Afify JR, Riad EM, Abo Elhasan A. Improvement of microbiological status of oriental sausage. J Egypt Vet Med Assoc 2012;72:157-67.
105. Castell-Perez ME, Moreira RG. Irradiation and consumers acceptance. Innov Food Process Technol A Compr Rev 2021;2:122-35.
106. Shaltout FA, Daoud JR. Chemical analytical studies on rabbit meat and liver. Benha Vet Med J 1996;8:17-27.
107. Chun HH, Kim JY, Lee BD, Yu DJ, Song KB. Effect of UV-C irradiation on the inactivation of inoculated pathogens and quality of chicken breasts during storage. Food Control 2010;21:276-80.
108. Shaltout FA, Edris AM. Contamination of Shawerma with pathogenic yeasts. Assiut Vet Med J 1999;40:34-9.
109. Shaltout FA, Maarouf AA, Ahmed EM. Heavy metal residues in chicken cuts up and processed chicken meat products. Benha Vet Med J 2018;34:473-83.
110. Shaltout FA, Lamada HM, Edris EA. Bacteriological examination of some ready to eat meat and chicken meals. Biomed J Sci Tech Res 2020;27:20461-5.
111. Sobhy A, Shaltout F. Prevalence of some food poisoning bacteria in semi cooked chicken meat products at Qaliubiya governorate by recent Vitek 2 compact and PCR techniques. Benha Vet Med J 2020;38:88-92.
112. European Food Safety Authority. Scientific opinion on the efficacy and microbiological safety of irradiation of food. EFSA J 2011;9:2103.
113. Sobhy A, Shaltout F. Detection of food poisoning bacteria in some semi-cooked chicken meat products marketed at Qaliubiya governorate. Benha Vet Med J 2020;38:93-6.
114. Shaltout FA. Abattoir and Bovine tuberculosis as a reemerging foodborne disease. Clin Med Rev Report 2024;6:1-7.
115. Shaltout FA. Viruses in beef, mutton, chevon, venison, fish and poultry meat products. Food Sci Nutr Technol 2023;8:1-10.
116. Yemmireddy V, Adhikari A, Moreira J. Effect of ultraviolet light treatment on microbiological safety and quality of fresh produce: An overview. Front Nutr 2022;9:871243.
117. Munir MT, Federighi M. Control of foodborne biological hazards by ionizing radiations. Foods 2020;9:878.
118. Shaltout FA. Food hygiene and control. Food Sci Nutr Technol 2019;4:1-2.
119. Hassanin FS, Shaltout FA, Homouda SN, Arakeeb SM. Natural preservatives in raw chicken meat. Benha Vet Med J 2019;37:41-5.
120. Hazaa W, Shaltout FA, El-Shate M. Prevalence of some chemical hazards in some meat products. Benha Vet Med J 2019;37:32-6.
121. Ahn DU, Kim IS, Lee EJ. Irradiation and additive combinations on the pathogen reduction and quality of poultry meat. Poult Sci 2013;92:534-45.
122. Hazaa W, Shaltout FA, El-Shater M. Identification of some biological hazards in some meat products. Benha Vet Med J 2019;37:27-31.
123. Shaltout FA, Eldiasty E, Mohamed MS. Incidence of Lipolytic and Proteolytic Fungi in Some Chicken Meat Products and Their Public Health Significance. In: First International Conference on Food Safety and Technology. Cairo, Egypt: Animal Health Research Institute; 2014. p. 79-89.
124. Ehlermann DA. Particular applications of food irradiation: Meat, fish and others. Radiat Phys Chem 2016;129:53-7.
125. Shaltout FA, Eldiasty E, Salem R, Hassan A. Mycological quality of chicken carcasses and extending shelf-life by using preservatives at refrigerated storage. Vet Med J Giza 2016;62:1-7.
126. Sedeh FM, Arbabi K, Fatolahi H, Abhari M. Using gamma irradiation and low temperature on microbial decontamination of red meat in Iran. Indian J Microbiol 2007;47:72-6.
127. Shaltout FA, Elshater M, Wafaa A. Bacteriological assessment of street vended meat products sandwiches in Kalyobia Governorate. Benha Vet Med J 2015;28:58-66.
128. Gaafar R, Hassanin FS, Shaltout FA, Zaghloul M. Molecular detection of enterotoxigenic *Staphylococcus aureus* in some ready to eat meat-based sandwiches. Benha Vet Med J 2019;37:22-6.

129. Gaafar R, Hassanin FS, Shaltout FA, Zaghloul M. Hygienic profile of some ready to eat meat product sandwiches sold in Benha city, Qalubiya Governorate, Egypt. Benha Vet Med J 2019;37:16-21.
130. Ehlermann DA. Safety of food and beverages: Safety of irradiated foods. In: Motarjemi YB, editor. Encyclopedia of Food Safety. Vol. 3. Waltham, MA: Academic Press; 2014. p. 447-52.
131. Nam KC, Jo C, Ahn DU. Irradiation of meat and meat products. In: Emerging Technologies in Meat Processing: Production, Processing and Technology. Hoboken, NJ: John Wiley and Sons Ltd.; 2016. p. 7-36.
132. Shaltout F. Pollution of chicken meat and its products by heavy metals. Research and reviews on healthcare. Open Access J 2019;4:381-2.
133. Oh H, Yoon Y, Yoon JW, Oh SW, Lee S, Lee H. *Salmonella* risk assessment in poultry meat from farm to consumer in Korea. Foods 2023;12:649.
134. Shaltout FA, EL-Diasty EM, Mohamed MS. Effects of chitosan on quality attributes fresh meat slices stored at 4°C. Benha Vet Med J 2018;35:157-68.
135. Ham YK, Kim HW, Hwang KE, Song DH, Kim YJ, Choi YS, *et al*. Effects of irradiation source and dose level on quality characteristics of processed meat products. Radiat Phys Chem 2017;130:259-64.
136. Shaltout FA, Hashim MF, Elnahas S. Levels of some heavy metals in fish (*Tilapia nilotica* and *Claris lazera*) at Menufia Governorate. Benha Vet Med J 2015;29:56-64.
137. Shaltout FA, Ibrahim HM. Quality evaluation of luncheon and Alexandrian sausage. Benha Vet Med J 1997;10:1-10.
138. Farkas J, Mohácsi-Farkas C. History and future of food irradiation. Trends Food Sci Technol 2011;22:121-6.
139. Shaltout FA, Nassif M, Shakran A. Quality of battered and breaded chicken meat products. Glob J Agric Food Saf Sci 2014;1:283-99.
140. Shaltout FA, Amani M, Salem AH, Mahmoud KA. Bacterial aspect of cooked meat and offal at street vendors level. Benha Vet Med J 2013;24:320-8.
141. Reygaert WC. An overview of the antimicrobial resistance mechanisms of bacteria. AIMS Microbiol 2018;4:482-501.
142. Madoroba E, Magwedere K, Chaora NS, Matle I, Muchadeyi F, Mathole MA, *et al*. Microbial communities of meat and meat products: An exploratory analysis of the product quality and safety at selected enterprises in South Africa. Microorganisms 2021;9:507.
143. Shaltout FA, Gerges MT, Shewail AA. Impact of organic acids and their salts on microbial quality and shelf life of beef. Assiut Vet Med J 2018;64:164-77.
144. Shaltout FA, Ghoneim AM, Essmail ME, Yousseif A. Studies on aflatoxin B1 residues in rabbits and their pathological effects. J Egypt Vet Med Assoc 2001;61:85-103.
145. Shaltout FA, Hanan MT, El-Lawendy. Heavy metal residues in shawerma. Beni Suef Vet Med J 2003;13:213-24.
146. Monteiro ML, Mársico ET, Mano SB, Teixeira CE, Canto AC, Carvalho Vital H, *et al*. Influence of good manufacturing practices on the shelf life of refrigerated fillets of tilapia (*Oreochromis niloticus*) packed in modified atmosphere and gamma-irradiated. Food Sci Nutr 2013;1:298-306.
147. Shaltout FA, Hashim MF. Histamine in salted, smoked and canned fish products. Benha Vet Med J 2002;13:1-11.
148. Hassanzadeh P, Tajik H, Rohani SM, Moradi M, Hashemi M, Aliakbarlu J. Effect of functional chitosan coating and gamma irradiation on the shelf-life of chicken meat during refrigerated storage. Radiat Phys Chem 2017;141:103-9.
149. Shaltout FA, El-Shorah HF, El Zahaby DI, Lotfy LM. Bacteriological profile of chicken meat products. Sci Fed Food Dairy Technol J 2018;1:83-90.
150. Shaltout FA, El-Shater MA, Abd El-Aziz WM. Bacteriological assessment of street vended meat products sandwiches in Kalyobia Governorate. Benha Vet Med J 2015;28:58-66.
151. Indiarto R, Pratama AW, Sari TI, Theodora HC. Food irradiation technology: A review of the uses and their capabilities. SSRG Int J Eng Trends Technol 2020;68:91-8.
152. Shaltout FA, El Shatter MA, Fahim HM. Studies on antibiotic residues in beef and effect of cooking and freezing on antibiotic residues beef samples. Sch J Food Nutr 2019;2:1-4.
153. Indiarto R, Qonit MA. A review of irradiation technologies on food and agricultural products. Int J Sci Technol Res 2020;9:4411-4.
154. Shaltout FA, Salem RM. Moulds, aflatoxin B1 and ochratoxin A in frozen livers and meat products. Vet Med J Giza 2000;48:341-6.
155. Al-Tarazi YH, Al-Zamil A, Shaltout FA, Abdel-Samei H. Microbiological status of raw cow milk marketed in northern Jordan. AVMJ 2002;49:180-94.
156. Bonomo L. A Critical Analysis Risk Assessment: Food Irradiation: Pro or Con? Vol. 4. ESSAI; 2006. p. 8. Available from: https://dc.cod.edu/essai/vol4/iss1/8 [Last accessed on 2023 Mar 30].
157. Gunes G, Deniz Tekin M. Consumer awareness and acceptance of irradiated foods: Results of a survey conducted on Turkish consumers. LWT 2006;39:444-8.
158. Shaltout FA, El-Diasty EM, Mohamed MS. Incidence of Lipolytic and Proteolytic Fungi in Some Chicken Meat Products and Their Public Health Significance. In: 1st Scientific Conference of Food Safety and Technology; 2014. p. 79-89.