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An American National Standard

~~Standard Practice for~~ Irradiation of Fresh and Frozen Red Meat and Poultry to Control Pathogens and Other Microorganisms[1]

This standard is issued under the fixed designation F 1356; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

INTRODUCTION

The purpose of this ~~guide~~practice is to present information on the use of ionizing ~~energy (radiation)~~ radiation in treating fresh or frozen red meat and poultry products to eliminate or reduce the numbers of vegetative, pathogenic microorganisms and parasites, and to extend the refrigerated shelf-life of those products by reducing the numbers of vegetative spoilage microorganisms.

This ~~guide~~practice is intended to serve as a set of recommendations to be followed when using irradiation technology where approved by an appropriate regulatory control authority. It is not to be construed as ~~a~~setting forth rigid requirements for the use of ~~irradiation, nor as a rigid code of practice.~~ irradiation. While the use of irradiation involves certain essential requirements to attain the objective of the treatment, some parameters can be varied in optimizing the process.

This ~~guide~~practice has been prepared from a Code of Good Irradiation Practice published by the International Consultative Group on Food Irradiation (ICGFI) under the auspices of the Food and Agriculture Organization (FAO), the World Health Organization (WHO), and the International Atomic Energy Agency ~~(IAEA).~~(IAEA) ~~(1)~~ .[2]

1. Scope

~~1.1This guide outlines procedures for the irradiation of fresh or frozen meat and poultry as defined by the Codex Alimentarius Commission (CAC), (CAC/RCP 11-1976 and CAC/RCP 14-1976). Codex defines meat as "the edible part of any mammal slaughtered in an abattoir," and poultry as" the edible part of slaughtered domesticated birds, including chicken, turkeys, ducks, geese, guinea-fowls, or pigeons."~~

1.1 This practice outlines procedures for the irradiation of fresh or frozen meat and poultry.

~~NOTE1—Current U.S. regulations limit the definition of livestock species to cattle, sheep, swine, goat, horse, mule, or other equine and poultry species to chicken, turkey, duck, goose, and guinea~~ **1—The Codex Alimentarius Commission defines meat as "the edible part of any mammal" and poultry as "any domesticated bird, including chicken, turkeys, ducks, geese, guinea-fowls, or pigeons" (CAC/MISC 5).**

NOTE 2—Current U.S. regulations limit the definition of livestock species to cattle, sheep, swine, goat, horse, mule, or other equine and poultry species to chicken, turkey, duck, goose, and guinea **(2, 3)**.

~~1.2This guide covers absorbed doses used for inactivation of parasites and reduction of bacterial load. Such doses are typically less than 10 kiloGray (kGy).~~

~~1.3This guide addresses irradiation of pre-packaged product for retail sale or for use as an ingredient in other products. It also addresses the in-line irradiation of unpackaged product.~~

1.2 This practice covers absorbed doses used for inactivation of parasites and reduction of bacterial load in fresh and frozen red meat and poultry. Such doses are typically less than 10 kGy.

1.3 This practice addresses irradiation of pre-packaged product for retail sale or for use as an ingredient in other products. It also addresses the in-line irradiation of unpackaged product.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

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[1] This ~~guide~~practice is under the jurisdiction of ASTM Committee E10 on Nuclear Technology and Applications and is the direct responsibility of Subcommittee E10.01 on Radiation Processing: Dosimetry and Applications.

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[2] The boldface numbers in parentheses refer to ~~a~~the list of references at the end of this standard.

2. Referenced Documents

2.1 *ASTM Standards:* [3]

E 170 Terminology Relating to Radiation Measurements and Dosimetry ~~E1204Practice for Dosimetry in Gamma Irradiation Facilities for Food Processing~~[3]

~~E1261Guide for the Selection and Calibration of Dosimetry Systems for Radiation Processing~~[3]

~~E1431Practice for Dosimetry in Electron and Bremsstrahlung Irradiation Facilities for Food Processing~~[3]

~~E1539Guide for the Use of Radiation Sensitive Indicators~~[3]

2303 Guide for Absorbed-Dose Mapping in Radiation Processing Facilities

F 1416 Guide for ~~the~~ Selection of Time-Temperature Indicators

F 1640~~Guide for Packaging Materials for Foods to Be Irradiated~~[4]

~~2.2 *Codex Alimentarius Commission Recommended International Codes and Standards:*~~ *Guide for Selection and Use of Packaging Materials for Foods to Be Irradiated*

2.2 *ISO/ASTM Standards:*[3]

51204 Practice for Dosimetry in Gamma Irradiation Facilities for Food Processing

51261 Guide for the Selection and Calibration of Dosimetry Systems for Radiation Processing

51431 Practice for Dosimetry in Electron and X-ray (Bremsstrahlung) Irradiation Facilities for Food Processing

51539 Guide for the Use of Radiation-Sensitive Indicators

2.3 *Codex Alimentarius Commission Recommended International Codes and Standards:*[4]

~~CAC/RCP 1-1969, Rev. 3, (Annex)Hazard Analysis and Critical Control Point (HACCP) System and Guidelines for Its Application~~ CAC/RCP 1-1969, Rev. 4-2003, A Recommended International Code of Practice—General Principles of Food Hygiene (Including Annex): Hazard Analysis and Critical Control Point (HACCP) System and Guidelines for Application

~~CAC/RCP 11-1976Recommended International Code of Hygienic Practice for Fresh Meat~~ CAC/RCP 19-1979, Rev-2003, Recommended International Code of Practice for the Radiation Processing of Food

~~CAC/RCP 14-1976Recommended Code of Hygienic Practice for Poultry Processing~~

CX STAN 1-1985, Rev. 1991, Amd. 2001, General Standard for the Labeling of Prepackaged Foods

~~CAC/Vol ARecommended International Code of Practice, General Principles of Food Hygiene, Edition 2~~

~~STAN 1-1985General Standard for the Labelling of Prepackaged Foods~~ CX STAN 106, Rev. 2003, General Standard for Irradiated Food

~~STAN 106-1983General Standard for Irradiated Food~~ CAC/MISC 5-1993, Amd. 2003, Glossary of Terms and Definitions (Veterinary Drug Residues in Food)

3. Terminology

3.1 *Definitions*—Other terms used in this ~~guide~~practice may be defined in Terminology E 170.

3.1.1 ~~*absorbed dose*, *n*—the quantity of energy from ionizing radiation imparted to a unit mass of a specified material (food). The special name for the unit of absorbed dose is the Gray (Gy). One Gy is equal to one joule of absorbed energy per kilogram. Formerly, the unit of absorbed dose was the rad (1 rad = 0.01 Gy).~~ absorbed dose—quantity of ionizing radiation energy imparted per unit mass of a specified material. The SI unit of absorbed dose is the gray (Gy), where 1 gray is equivalent to the absorption of 1 joule per kilogram of the specified material (1 Gy = 1 J/kg).

3.1.1.1 *Discussion*—A standard definition of absorbed dose appears in Terminology E 170.

3.1.2 ~~*D_{10}-value*, *n*~~D_{10}-*value*—absorbed dose required to reduce the microbial population in a given food by 90 % (1 $\log_{10}$).

3.1.3 *dose distribution*~~, *n*—the variation~~—variation in absorbed dose within a process load exposed to ionizing radiation.

3.1.4 *process load*~~, *n*—a volume~~—volume of material with a specified loading configuration irradiated as a single entity.

3.1.5 *transport system*~~, *n*—the conveyor~~—conveyor or other mechanical system used to move the process load through the irradiator.

4. Significance and Use

4.1 The principal purpose of irradiation is to control (reduce the number of) pathogenic bacteria in fresh or frozen red ~~meats~~meat and poultry to ~~make~~ ensure the safety of these foods ~~safer~~ for human consumption. Irradiation significantly reduces the numbers of ~~viable,~~ vegetative pathogenic bacteria such as *Campylobacter*, *Escherichia coli*, *Listeria*, *Salmonella* , *Staphylococcus aureus*, or ~~Salmonella~~ *Yersinia enterocolitica*.

4.2 The process also inactivates parasites such as *Trichinella spiralis* and *Toxoplasma ~~gondii.~~*gondii.

4.3 The process may extend the shelf- life of fresh red ~~meats~~meat and poultry by reducing the numbers of viable, vegetative spoilage bacteria, such as *Pseudomonas* species.

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[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* ~~, Vol 12.02.~~volume information, refer to the standard's Document Summary page on the ASTM website.

~~[4] Annual Book of ASTM Standards, Vol 15.09.~~

[4] Available from the Joint FAO/WHO Food Standards Programme, Joint Office, FAO, Via delle Terme di Caracalla, 00100 Rome, Italy.

4.4 Radiation processing of fresh and frozen red meat and poultry is a critical control point (CCP) of a Hazard Analysis of Critical Control Points (HACCP) program. It serves as an important measure to control any residual risk from pathogenic microorganisms before the product reaches the consumer.

5. Pre-Irradiation Product Handling

5.1Product should be handled in an environment that does not increase the risk of contamination from physical, chemical, or biological hazards. Take measures at all times to minimize microbial contamination and growth by following relevant standards of Good Manufacturing Practice (GMP); see for example U.S. Food and Drug Administration (FDA) GMP **Criteria for Assessing Irradiation Efficacy**

5.1 *Irradiation for Control of Pathogenic Bacteria* —The numbers of pathogenic bacteria that can result in an infectious product vary with the specific bacterium and the susceptibility of the consumers involved. The adoption of criteria, such as those used in the U.S. for the pasteurization of milk or in scheduled processes for low-acid canned food, is the most reasonable in the absence of microbiological end product criteria for expected pathogenic bacteria **(4)**, U.S. Food Safety and Inspection Service (FSIS) Standard Sanitary Operating Procedures (SSOP) **(, 5)** , and CAC Recommended International Codes of Practice, (CAC/RCP 11-1976, CAC/RCP 14-1976, and CAC/Vol A)(see 2.2).).

5.2 *Irradiation for Inactivation of Parasites*—The criterion should be that the parasites in uncooked, irradiated product are noninfectious or noninvasive, as appropriate. (This does not necessarily require the parasite to be killed by the irradiation process.)

5.3 *Irradiation for Shelf-Life Extension*—The criterion should be the bacterial plate count using appropriate time, temperature, and media parameters. Reduction in bacterial counts as final criteria cannot be specified unless local regulations, customer specifications, or both, are known. Therefore, the final product specification regarding bacterial plate count should be established by the customer.

5.4 Failure to meet these criteria should direct attention to the scheduled process (see 8.1) and the reestablishment, if necessary, of Good Manufacturing Practice (GMPs). The hazard analysis and critical control point (HACCP) system or another similar process control system should be applied to the entire processing and distribution chain. With this system, any point in the chain where a hazardous or critical situation could result is monitored and controlled to prevent unsafe and unwholesome product from reaching the consumer. See CAC/RCP 1 and **(6, 7)**.

5.4.1 Implementation of a process control system to assess radiation-processing efficacy should include bacteriological examination of the product before and immediately after irradiation, use of time/temperature indicators throughout the processing chain (see Guide F 1416), and testing of package integrity. Bacteriological testing should reveal a significant reduction in relevant bacterial counts compared to those of the non-irradiated product. Temperature monitoring should alert observers of any product abuse that could result in increases in bacterial counts after irradiation.

6. Pre-Irradiation Product Handling

6.1 Product should be handled in an environment that does not increase the risk of contamination from physical, chemical, or biological hazards. Minimize microbial contamination and growth by following relevant standards of GMPs; see for example U.S. Food and Drug Administration (FDA) GMPs **(8)**, U.S. Food Safety and Inspection Service (FSIS) Standard Sanitary Operating Procedures (SSOPs) **(9)**, CAC Recommended International Codes of Practice, (CAC/RCP1 (see 2.3) and HACCP) **(10)**.

6.2 *Unpackaged Product*—In facilities handling unpackaged product, the irradiation environment and equipment should be designed and constructed to be cleanable and durable to maintain a sanitary condition and, thereby, not increase the risk of contamination.

NOTE2—An 3—An operating environment with high moisture or airflow may contribute to the risk of bacterial contamination. Moisture provides a growth medium for bacteria and airflow provides a means of transport for bacteria. Food contact surfaces may contribute chemical or physical contaminants to products unless such surfaces are fabricated from appropriate materials and properly maintained and cleaned. Also, employee hygiene and pest control should be closely monitored.

5.36.3 *Pre-Packaged Product*—For pre-packaged product, the package itself provides a barrier that helps to reduce the risk of recontamination. Thus, many of the requirements for the irradiation environment and equipment necessary for handling unpackaged product may not be applicable for facilities handling only pre-packaged product. Obtain information Information on applicable requirements should be obtained from the appropriate regulatory authorities before starting operations.

5.46.4 *Pre-Irradiation Inspection*—Inspect packages —Packages and containers of fresh and frozen red meat and poultry should be inspected upon receipt at the irradiation facility to ensure that the product is suitable for irradiation. (see 5.4.1, 5.4.2, and 5.4.3). Written acceptance criteria for inspection frequency, product temperatureproduct temperature, package integrity and package integrity,inspection frequency, as applicable, should be established by the product owner and agreed to by management of the irradiation facility prior to accepting product from anthe owner. Also, disposition criteria for handling of product unsuitable for irradiation should be among the criteria established.

5.4.16.4.1 *Product Temperature*—Using a calibrated temperature-sensing device, measure the temperature of the product upon receipt. Temperature should be between −2 and +4°C for fresh red meat or poultry or −18°C or lower for frozen red meat or poultry. For unpackaged product, insert the device directly into the product and sanitize the device between each measurement. For prepackaged product, use a device that can be placed between individual packages without puncturing packaging materials in direct contact with the product.

5.4.2—*Upon receipt of product, its temperature should be measured using a calibrated sanitized temperature-sensing device, at a predetermined location and frequency as specified by HACCP and GMPs. Temperature should be between –2 and +4°C for refrigerated fresh red meat and poultry or –18°C or lower for frozen red meat and poultry. For unpackaged product, insert the device directly into the product and sanitize the device between each measurement. For prepackaged product, use a device that can be placed between individual packages without puncturing them.*

6.4.2 *Package Integrity*—Perform a sensory inspection of the product. No leakage of fluids or odor indicative of product spoilage should be evident upon inspection.

5.4.3Count the number of containers to be irradiated and compare that count with documentation from the product owner. A comparison of this pre-irradiation count with a count performed after irradiation provides a check that all product received has been irradiated.

5.5—*A visual inspection of the product packaging should be performed to ensure there is no evidence of compromised or damaged product. Also, a sensory inspection should be performed. No leakage of fluids or odor indicative of product spoilage should be evident upon inspection.*

6.4.3 *Product Inventory*—The number of containers should be counted and the description/identification of the product to be irradiated should be verified and compared with the documentation from the product owner. A comparison of this pre-irradiation count with a count performed after irradiation provides a check that all products received have been irradiated.

6.4.4 *Product Identification*—A unique identification number for tracking the product throughout the irradiation process should be issued and documented for the incoming product.

6.5 *Pre-Irradiation Storage*:

5.5.1For

6.5.1 For fresh meats red meat and poultry, the principal requirement for pre-irradiation storage is maintenance of the product temperature between −2–2 and +4°C without freezing.

NOTE3—U.S. poultry regulations presently require a maximum temperature of 40°F (4.4°C) for fresh poultry.**(6)**

5.5.2A second requirement is that the pre-irradiation storage period at the irradiation facility be minimized, approximately one day or less, whenever possible.

5.5.3For frozen meats and poultry, maintain the product temperature at or below −18°C at all times. The relatively short duration of frozen storage prior to irradiation is not particularly critical under normal commercial conditions. However, freezing does not provide an unlimited product life without loss of quality, and the pre-irradiation storage period should therefore be minimized.

5.6Handling of red meats and poultry differently from the procedures described in 5.5 violates the principles of GMP, which constitute the total of all measures taken to produce meat and poultry products containing as low a level of contaminants as possible. Holding product under refrigeration for an unduly long time would violate these principles because such treatment may result in excessive bacterial growth and undesirable changes in products. Radiation processing can neither reverse these undesirable changes nor replace GMP.

5.7*Product Separation*—It may not be possible to distinguish irradiated from unirradiated product by inspection. It is therefore important that appropriate means integral to the facility design, such as physical barriers or clearly defined staging areas, be used to maintain unirradiated product separate from irradiated product.

6.Packaging

6.1Packaging meat or poultry products prior to irradiation reduces the risk of contaminating the product and the irradiation facility. Prepackaging may not be necessary in the case of irradiation for inactivation of parasites or if other control procedures (for example, aseptic processing) are in place to maintain the intended effect of the treatment.

6.2If products are packaged, use materials suitable to the product considering any planned processing (including irradiation) and consistent with any regulatory requirements (see Guide F1640).

6.2.1Packaging materials should provide appropriate gas and moisture permeability to maintain product quality. (see 7.6)

6.2.2For frozen red meats and poultry, the package should be as free as possible of voids or open spaces. Such spaces can cause a form of desiccation known as "freezer burn."

6.3To achieve a more uniform dose distribution within a process load, the product packages or containers should be geometrically well defined and uniform in shape and size. With certain irradiation facilities, it may be necessary to limit use to particular package shapes and sizes based on the density of the product and validation testing at known product densities in the irradiation facility. See Practices E1204 and E1431 4—U.S. poultry regulations presently require that the temperature of fresh poultry be maintained at or below 4.4°C **(10)** .

NOTE 5—Holding product under refrigeration for an unduly long time would violate principles of GMPs because such treatment may result in excessive growth of psychrotrophic bacteria and undesirable changes in products.

6.5.2 A second requirement is that the pre-irradiation storage period at the irradiation facility be minimized, approximately one day or less, whenever possible.

6.5.3 For frozen red meat and poultry, the product temperature should be maintained at or below –18°C at all times. The relatively short duration of frozen storage prior to irradiation is not particularly critical under normal commercial conditions.

However, freezing does not provide an unlimited product life without loss of quality, and the pre-irradiation storage period should therefore be minimized.

6.6 *Product Segregation*—Distinguishing irradiated from non-irradiated product by inspection might not be possible. Therefore, the use of appropriate means integral to the facility design, such as physical barriers or special segregation in clearly defined staging areas, to maintain non-irradiated product separate from irradiated product is important.

NOTE 6—Radiation-sensitive indicators undergo a color change when exposed to radiation in the pertinent dose range. These indicators may be useful within the irradiation facility as a visual check for determining whether or not a product has been exposed to the radiation source. They are not dosimeters intended for measuring absorbed dose and must not be used as a substitute for proper dosimetry. Information about dosimetry systems and the proper use of radiation-sensitive indicators is provided in ISO/ASTM Guides 51261 and 51539, respectively.

7. Packaging and Product Loading Configuration

7.1 *Packaging Materials*:

7.1.1 Use packaging materials suitable to the product, taking into account planned processing (including irradiation) and consistent with regulatory requirements (see Guide F 1640).

7.1.2 Packaging materials should provide appropriate gas and moisture permeability to maintain product quality.

7.2 *Product Loading Configuration* :

7.2.1 The size, shape, density and loading configuration of a process load to be irradiated should be determined primarily by considering design parameters of the irradiation facility. Critical design parameters include the characteristics of product transport systems and of the radiation source as they relate to the dose distribution obtained within the process load.

7.2.2 The dose distribution within the process load can often be optimized by using product packages that are geometrically well defined and uniformly loaded. With certain irradiation facilities, it may be necessary to limit the use of particular package shapes and sizes depending on the density of the product and facility Operational Qualification (OQ) data (see ISO/ASTM 51204 and 51431).

7.2.3 Prescribed product dose specifications should be taken into account when determining the appropriate product-loading configuration (see 8.4).

8. Irradiation

~~7.1*Scheduled Process*—Irradiation of food should conform to a scheduled process. A scheduled process for food irradiation is a written procedure that is used to ensure that the absorbed dose range and irradiation conditions (for example, product temperature) are adequate under commercial processing conditions to achieve the intended effect on a specific product in a specific facility. The procedure should also address disposition of improperly irradiated product and corrective actions to be taken if the irradiation process is not adequately controlled. The scheduled process should be established and validated by qualified persons having expert knowledge in irradiation requirements specific for the food and the processor's irradiation facility. See, for example, FDA regulations (7~~

8.1 *Standard Operating Procedures (SOPs)*—A standard operating procedure, or scheduled process, for food irradiation is a written procedure that is used to ensure that the technologically advisable dose range and irradiation conditions selected by the radiation processor are adequate under commercial processing conditions to achieve the intended effect on a specific product in a specific facility. The procedures shall be established by qualified persons having knowledge in irradiation requirements specific to the food and the irradiation facility **(11)**. The procedures shall meet the requirements of CX STAN 106 and should follow the recommendations of CAC/RCP 19.

~~7.2~~

8.2 *Radiation Sources*—The sources of ionizing radiation that may be employed in irradiating fresh and frozen red meat and poultry products are limited to the following (see ~~CAC~~CX STAN ~~106-1983~~106):

~~7.2.1Gamma rays from the radionuclides~~

8.2.1 *Isotopic Sources*—Gamma rays from the radionuclides ^{60}~~Co or~~ Co (1.17 and 1.33 MeV) or ^{137}~~Cs,~~

~~7.2.2X-rays generated from machine sources operated at or below an energy level of 5 MeV, and~~

~~7.2.3Electrons generated from machine sources operated at or below an energy level of 10 MeV.~~ Cs (0.66 MeV);

8.2.2 *Machine Sources*—X-rays and accelerated electrons.

~~NOTE4—The depth of penetration of electrons in a material is dependent on the energy of the electrons and the density of the material.~~

~~7.3*Radiation Process Parameters* :~~

~~7.3.1*Absorbed Dose*— Food irradiation specifications from the owner of the product should include minimum and maximum absorbed dose limits (see 7.4): a minimum necessary to ensure the intended effect; and a maximum to prevent product degradation. One or both of these limits may be prescribed by regulation for a given application. See, for example, FDA regulations **(8)**. It is necessary to configure irradiation parameters to ensure that processing is carried out within these limits. Once this capability is established, it is necessary to monitor and record absorbed dose values during routine processing (see 11.2.2).~~

~~7.3.1.1Routine dosimetry is part of a verification process for establishing that the irradiation process is under control.~~

~~7.3.1.2Select and calibrate a dosimetry system appropriate to the radiation source being used, the environmental conditions, and the range of absorbed doses required (see Guide E1261).~~

7.3.1.3Verify that the product receives the required absorbed dose by using proper dosimetric measurement procedures, along with appropriate statistical controls and documentation. Place dosimeters in or on the process load at locations of maximum and minimum absorbed dose. If those locations are not accessible, place dosimeters at reference locations that have a known and quantifiable relationship to the maximum and minimum absorbed dose locations (see Practices E1204 and E1431) 7—For electron beam processes, the depth of penetration of electrons in a material is dependent on the energy of the electrons and the density of the material.

NOTE5—Radiation sensitive indicators (RSIs), such as labels, papers, or inks, that undergo a color change or become colored when exposed to irradiation in the pertinent dose range are commercially available. The purpose of RSIs is to determine visually whether or not a product has been irradiated, rather than to measure the absorbed dose received by the product. RSIs are not dosimeters and must not be used as a substitute for proper dosimetry (see Guide E1539 8—The Codex Alimentarius Commission as well as regulations in some countries currently limit the maximum electron energy and nominal X-ray energy for the purpose of food irradiation (CX STAN 106).

7.3.2*Process Load Design*—The size and shape of the process load are determined partly by certain design parameters of the irradiation facility. Critical design parameters include the characteristics of the transport system and of the radiation source as they relate to the dose distribution obtained within the process load. The size and shape of the product and minimum and maximum dose limits may also affect the loading configuration of the process load.

7.4

8.3 *Absorbed Dose*:

8.3.1 *Absorbed Doses Required to Accomplish Specific Effects*—The minimum absorbed dose that has been shown to achieve the intended objective of the process should be used. Too high an absorbed dose can cause the formation of an off-flavor in the product. The sensitivity to this off-flavor formation varies with the type and cut of meat, the packaging atmosphere, the product temperature during irradiation, and other factors. In addition, excessive absorbed doses may cause discoloration in some meats **(9,10—The owner of the fresh and/or frozen meat or poultry product shall provide required minimum and maximum absorbed dose limits: the lowest dose necessary to ensure the intended effect (for example, microbial load reduction, pathogen inactivation), and the highest dose that does not negatively affect the product quality through the formation of off-flavors, aromas and color changes (12). Care should therefore be taken to control the absorbed dose and other irradiation conditions that may affect the intended process objective and product quality. Experience indicates that a higher minimum dose may be required for frozen product than that for product irradiated in the fresh state to achieve the same intended objective. The owner of the product is responsible for specifying for each lot the required absorbed dose range to achieve the intended objective. Historical information on previously processed lots may be useful for determining the appropriate range. The irradiation facility is responsible for delivering the specified dose range (see Practices E1204 and E1431).**

7.4.1*Absorbed Dose for the Control of Pathogenic Bacteria*—A number of pathogenic bacteria may be present in red meats and poultry, including *Salmonella* species, *Campylobacter jejuni, Escherichia coli* O157:H7, *Staphylococcus aureus*, and *Listeria monocytogenes*. The absorbed dose required to reduce the numbers of these bacteria to levels commensurate with product that is safe for consumption depends on a number of criteria. The required absorbed dose range should be established on the basis of the microbial load in the unirradiated product, the radiation sensitivity of the bacteria present, the temperature of the product during irradiation, the atmosphere surrounding the product during irradiation, and the regulatory or customer requirement for acceptable residual numbers of bacteria. Appendix X1 provides some information, taken from the scientific literature, about the radiation sensitivity (D_{10} values) of the principal vegetative pathogenic bacteria found in meat and poultry products.

7.4.2. *One or both of these limits may be prescribed by government authorities for a given application. The sensitivity of red meat and poultry to irradiation varies with the type of product, the packaging atmosphere, the product temperature during irradiation, and other factors. A higher minimum dose may be required for frozen product than for product irradiated in a refrigerated state to achieve the same intended objective because bacterial resistance to radiation damage is higher at sub-freezing temperatures* **(13, 14)**.

8.3.2 *Absorbed Dose for the Control of Pathogenic Bacteria* —Pathogenic bacteria that may be present in or on fresh or frozen red meat and poultry products include *Salmonella* species, *Campylobacter jejuni*, *Escherichia coli* O157:H7, *Staphylococcus aureus*, *Listeria monocytogenes*, and *Yersinia enterocolitica*. The absorbed dose required to reduce the numbers of these bacteria to levels commensurate with product that is safe for consumption depends on a number of criteria. The required absorbed dose range should be established on the basis of the microbial load in the un-irradiated product, the radiation sensitivity of the bacteria present, the temperature of the product during irradiation, the controlled atmosphere surrounding the packaged product during irradiation, and the regulatory or customer requirement for acceptable residual numbers of bacteria. Appendix X1 provides some information, taken from the scientific literature, about the radiation sensitivity (D_{10} values) of the principal vegetative pathogenic bacteria found in red meat and poultry products.

8.3.3 *Absorbed Dose for Inactivation of Parasites*—Most parasites will be rendered noninfectious by absorbed doses of less than 1 kGy. The minimum effective absorbed dose will depend on the specific parasite to be inactivated **(11-15(15-19)**.

7.4.3

8.3.4 *Absorbed Dose for Shelf-Life Extension*—The absorbed dose that produces shelf-life extension of fresh meats and poultry