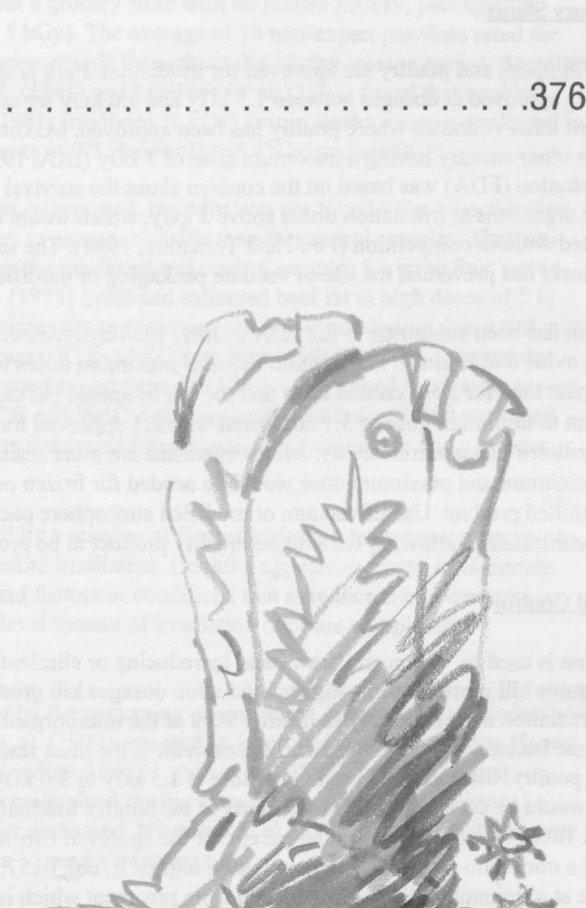
# SECTION C

## Meat Preparation, Preservation & Packaging



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# IRRADIATION PRESERVATION OF FRESH MEAT

**DENNIS G. OLSON**
**Iowa State University**
**194 Meat Laboratory**
**Ames, IA 50011 USA**

Societal pressure to enhance the safety of fresh meat has driven a technology development rush to find new ways to prevent, reduce or eliminate pathogenic bacteria on meat. High media exposure of food borne disease outbreaks has sensitized consumers to the dangers of bacterial pathogens. Regulatory agencies are focusing on bacterial contamination. The Food Safety Inspection Service (FSIS) of the U.S. Department of Agriculture in September, 1994 declared *Escherichia coli 0157:H7,* which had previously been considered to be a natural contaminant, an adulterant in fresh meat. In January, 1995, FSIS issued proposed regulations that, for the first time, mandated microbial testing of fresh meat which would be used to establish microbial standards. Many states are mandating medical doctors to test and report for *E. Coli 0157:H7* of individuals exhibiting bloody stools which will certainly increase the number of cases detected. The Center for Disease Control is developing new methods to better estimate the number of cases of food borne diseases. The awareness of food borne diseases by consumers will increase and therefore, pressure to improve the safety of the food supply will also increase.

Response to the pressure to enhance the safety of fresh meat has been the following: to determine contamination sources, to build programs to prevent contamination and to develop technologies to reduce or eliminate contamination. Some of the new technologies being pursued are rapid bacterial detection methods for on-the-farm testing, animal washing stations before slaughter, carcass washes with organic acids, high pressure, hot water, chlorine, phosphates, and etc., rapid carcass cooling, and many others that treat the meat before packaging. These technologies have the potential to reduce the amount of pathogenic bacteria in the fresh meat supply.

While not a new technology, irradiation has the potential to eliminate pathogenic bacteria in fresh meat. Before widespread adaptation of irradiation occurs, issues regarding quality changes and consumer acceptance must be more thoroughly addressed.

## Regulatory Status

In the U.S., pork and poultry are approved for irradiation. Pork is approved at dosages between 0.3 and 1.0 kGy for trichina control. Poultry is approved at dosages between 1.5 kGy and 3.0 kGy for control of pathogenic bacteria. These dose ranges are more restrictive than most other countries where poultry has been approved. Maximum irradiation doses for poultry are 7 kGy in seven countries with only one other country having a maximum dose of 3 kGy (IAA, 1991). The low maximum dose approved by the U.S. Food and Drug Administration (FDA) was based on the concern about the survival of *Clostridium botulinum* spores and the loss of competitive spoilage organisms at irradiation doses above 3 kGy, which would allow the *C. botulinum* spores to germinate and produce toxin undetected without competition (Pauli and Tarantino, 1994). The same concern about *C. botulinum* toxin production in an anoxic environment has prevented the use of vacuum packaging or modified atmosphere packaging on irradiated poultry.

A petition has been submitted to the FDA in July, 1994 by Isomedix, Inc. for the approval of irradiation of all red meats (bovine, porcine, ovine and equine). The petition requests maximum doses to be slightly higher than approved for poultry, higher doses fbr frozen meat than for fresh chilled meat and the use of anoxic packaging. The higher maximum doses would move the ratio of maximum to minimum dose to 3:1 compared with 2:1 approved for poultry. The higher ratio would enable full pallet loads of product to be irradiated in a gamma facility. Microorganisms are more resistant to irradiation in frozen product than fresh chilled, hence a higher minimum and maximum dose would be needed for frozen product to achieve an equivalent microbial kill at the lower doses for a fresh/chilled product. Use of vacuum or modified atmosphere packaging was requested so that oxidative changes in the product would be minimized allowing for a higher quality product to be produced.

## Bacterial Control

Irradiation is used to "pasteurize" raw meat by reducing or eliminating pathogenic bacteria. As with cooking, where higher temperatures kill more bacteria, higher irradiation dosages kill greater bacterial numbers. D-value is the death rate of an organism at a given irradiation dose necessary to destroy 90% of the microorganisms present. Table 1 shows D-values of several of the important pathogenic bacteria found in raw meat. *Salmonella* is the most resistant pathogenic bacteria having a D-value in the range of about 0.6 kGy. In poultry, the approved irradiation dose is 1.5 kGy to 3.0 kGy. Hence, about 99.9% (3 logs) to 99.999% (5 logs) of *Salmonella* present would be destroyed within the limits of the poultry irradiation regulations. In addition, all of the other pathogenic bacteria listed in Table 1 would be controlled except for the spores of *Clostridium botulinum.* E. coli 0157:H7 has a D-value of about 0.24 kGy. At a minimum dose of 1.5 kGy at least 6 logs of E. coli 0157:117 would be destroyed. Obviously, irradiation would be extremely effective at eliminating this microorganism from raw meat which is critical since it is listed as an adulterant in raw meat.

While the primary objective of irradiation is to destroy pathogenic bacteria, substantial reduction of spoilage organisms also occurs. Niemand et. al. 1983) reported over a four log reduction in total anaerobe counts and almost a five log reduction in anaerobe counts in chilled ground beef irradiated to 2.5 kGy. They found an extension in shelf-life of nine days before counts reached seven logs when stored at 4°C. With vacuum-packaged beef sirloin cuts irradiated to 2 kGy, refrigerated shelf-life more than doubled from about four weeks for non- irradiated product stored at 0°C to 10 weeks for inrradiated product stored at 4°C (Niemand et. al., 1981). Lefebvre et. al. 1992) found a three log reduction in psychrotrophic aerobic bacteria in ground beef irradiated at 2.5 kGy. The irradiated ground beef had a shelflife of 10 days before counts reached seven logs compared to the unirradiated control which lasted only one day

Lambert et. al. (1992) found pork loin slices packaged under nitrogen and irradiated to 1 kGy had a 26-day shelf life (21 days more than the control) stored at 5°C. Thayer et. al. (1993) found uninoculated ground pork, irradiated at 1.9 kGy, had no surviving bacteria when stored at 2°C for up to 35 days.

The predominant spoilage organisms are gram-negative psychrotrophic microorganisms which are very susceptible to irradiation (Monk Ct. al., 1995). Several researchers have shown that irradiation at dosages of 1 kGy and higher virtually eliminates gram-negative microorganisms with a much smaller affect on gram-positive lactic acid-producing microorganisms Dempster et. al., 1985; Ehioba et. al., 1988; Lambert et. al., 1992; Mattison et. al., 1986; Niemand et. al., 1983; Thayer et. al., 1993). Psuedomonads and Enterobacteriaceae which are common spoilage bacteria are easily eliminated even with low dosages of irradiation. However, in all of these studies at dosages in the range of 1 to 5 kGy, gram-positive microorganisms survived to cause spoilage conditions after prolonged refrigerated storage.

## Quality Effects

The quality of raw meat can be greatly affected by the microbial numbers present, especially in ground meat. Science Irradiation can significantly reduce microbial numbers, irradiating meat may affect quality by other than microbial concerns. Meat exposed to ionizing radiation results in the formation of radiolytic products from free-radicals that are formed during irradiation. These radiolytic products can cause oxidation of myoglobin and fat, leading to discoloration and rancidity or other off-odor or off-flavor compounds (Lagunas-Solar, 1995).

Odor of raw meat after irradiation has been shown to be different than non- irradiated control (Lefebvre et. al., 1994; Lynch et. al., 1991). Lynch et. al. (1991) packaged fresh turkey breast pieces in polythene bags or vacuum barrier bags (composition unknown), irradiated to 2.5 kGy and stored for 21 days at 1°C. They found a higher percent of 10 professional panelists accepted the raw meat odor of polythene packaged turkey than barrier packaged turkey for both irradiated (2.5 kGy) and non-irradiated product at 1 and 21 days of storage. Lefebvre et. al. (1994) irradiated ground beef purchased from a grocery store with no known history, packaged in polyethylene bags and irradiated at three different dosage levels (1, 2.5 and 5 kGy). The average of 10 non-expert panelists rated the irradiated samples in the "less appreciated" range compared to a fresh reference sample throughout the 14-day storage period. Samples receiving the higher irradiation dosages had lower ratings. Both Lynch et. al. (1991) and Lefebvre et. al. (1994) found that cooking greatly reduced the effect of irradiation on odor detection. Niemand et. al. (1981) irradiated (2 kGy) sirloin steaks vacuum-packaged in medium density polyethylene and polyester bags and stored for up to ten weeks at 0°C (control) and 4°C (irradiated).

Six trained panelists detected an irradiation odor on the day of irradiation but, as reported, the odor was not found to be objectionable. From 2 to 10 weeks, the panelists scored raw meat odor of irradiated samples as more acceptable than the control samples. They also reported no significant difference ($P<.05$) in cooked aroma and taste between the irradiated and control samples for up to four weeks of storage which was the shelf-life limit of the control steaks. Kosaric et. al. (1973) irradiated extracted beef fat at high doses of 5 to 100 kGy and at temperatures from 30°C to 196 °C. They found rancid odor intensity to increase with higher irradiation doses and with higher temperatures. The rate of odor intensity increase was much greater from 0°C to 30 °C than from - 196°C to 0°C, suggesting that temperatures just above 0° can be critical for odor development. In a second experiment, beef fat was packaged in air and vacuum bags (composition was unreported) and irradiated at 10, 30 and 60 kGy at 0°C and 30°C. Odor intensity was lower for fat packaged under vacuum and fat irradiated at 0°C at all irradiation doses. However, they determined that irradiation temperature had a greater effect on reducing odor intensity than oxygen removal.

In summary, development of an irradiation odor on new meat can be affected by a number of factors including temperature, packaging environment and material, irradiation dose, and condition of the raw meat before irradiation. Cooking appears to lessen or eliminate the irradiation odor. More research is needed to fully characterize the odor and factors or conditions that may increase or decrease its presence. It is important that all factors that could potentially influence the development of irradiation odor are completely documented.

Irradiation can cause some color changes in meat which is greatly influenced by the packaging environment. Meat packaged under vacuum and irradiated can develop a brighter red or pinkish color. Lebepe et. al. (1994) reported an improved red color (higher Hunter "a" values) in pork chops from irradiated, vacuum packaged loins than non-irradiated loins Lynch et. al. (1992) found irradiated vacuum-packaged turkey breasts developed an intense pink color which was maintained during storage and subsequent cooking. However, if the breasts were exposed to oxygen during storage, the pink color decreased. Niemand et. al. (1983) showed that vacuum-packaged beef steaks had a more acceptable appearance when irradiated over 10 weeks of storage.

In the presence of oxygen, irradiated meat can become very discolored. Grant and Peterson (1991) show pork to become discolored when irradiated in the presence of oxygen while a pink color developed when pork was irradiated under vacuum or modified atmospheres excluding oxygen. During irradiation, ozone is produced from oxygen which is a strong oxidizer. It is likely that ozone interaction with myoglobin oxidizes the pigment causing discoloration.

## Packaging

To obtain the full benefit of eliminating pathogenic bacteria and reducing the total microbial load, meat should be packaged to prevent post-irradiation contamination. Consequently, the packaging material is irradiated while in contact with the meat and therefore, must not be adversely affected by irradiation. Packaging materials must be approved by the U.S. Food and Drug Administration. There is a list of approved materials in 21CFR--Part 179.45. This list of approved materials cannot be extended for co-extruded or laminate films which are in common use in the industry and therefore, film manufacturers must seek approval for each multicomponent film.

Irradiation has the potential for chemically changing packaging films. Cross- linking could affect tensile and flexural strength. Degradation of polymers to smaller units could affect strength and porosity. Interactions with plasticizers and stabilizers could affect adhesion. Irradiation of film could result in gas evolution such as hydrogen and production of low-molecular weight hyrdrocarbons and halogenated polymers (Kilcast, 1990). At dosages approved for food, only the low-molecular weight polymers and gas evolution has the potential for migrating into the product (Kilcast, 1990), which may have some potential for influencing the quality of the product.

Polyvinylchloride (PVC) has been shown to have some taint-transfer problems when irradiated at 3.9 kGy using an alcohol simulant and water simulant (Kilcast, 1990). PVC does not appear on the FDA approved list, however it is commonly used as an overwrap which, when conducting irradiation studies, should be avoided. Some other important polymers such as polystyrene and polyethylene, have had noticeable odors developed at the lowest doses applied of 10 kGy (Buchalla et. al., 1993). It is not known whether the volatiles produced have any significant affect on product quality. Antioxidants used in packaging films can also be significantly degraded, although there is no indication of any migration of the antioxidants into the product (Buchalla et. al., 1993). It is obvious that more research is needed to determine the effect on packaging films on product quality during irradiation.

## Consumer Acceptance

In the U.S., irradiated food has been sold continuously in four retail stores for over three years (Pszczola, 1993). These stores, located in Illinois (one store) and Florida (three stores), have offered a variety of irradiated foods including chicken. The success of these stores clearly show that consumers will accept irradiated food. However, there are large segments of the population which are not close enough to these retail outlets to have an opportunity to experience irradiated foods. Hence, there still are questions about the acceptance of the larger population of irradiated foods.

Resurreccion et. al. (1995) conducted a survey and found that 72% of responders are aware of irradiation but, among those, 87.5% indicated that they really do not know that much about it. They also found that consumers are less concerned about irradiation than they are about food additives, pesticide residues, animal drug residues, growth hormones and bacteria. Risks to workers and environmental issues are among the concerns regarding irradiation. They found that 45% of the consumers would buy irradiated food, 19% would not buy it, and the others were undecided. Bruhn (1995a) reported that the number of consumers, concerned about the safety of irradiated food, has decreased in the last 10 years, and is less than the number concerned about pesticide residues, microbiological contamination, and other food-related issues. Consumer acceptance of irradiated food increases when consumers are provided with information about specific advantages of the irradiation process.

Irradiated foods marketed in numerous countries were judged superior by consumers and have sold well (Bruhn, 1995a). Communication with consumers is critical for expansion of irradiated food markets. Communication strategies involve identifying the audience, selecting the communication medium, presenting the benefits of the process, and addressing the myths (Bruhn, 1995b). Irradiation should be described in lay terms and presented as an additional step to enhance microbiological safety. Nutritional safety and environmental myths must be addressed. Nutritional presentations utilizing the popular press are most effective. Since health authorities are the most credible spokespersons, opportunities for information exchange between health officials and community leaders need to be developed for greater acceptance of irradiated food (Bruhn, 1995b).

There seems to be a common belief that the technology of irradiating food would be utilized by the food industry if there was a clear signal that consumers would accept irradiated products. Because food companies respond to consumer preferences, they would provide irradiated food if consumers demanded irradiated foods. The difference between accepting irradiating food and demanding irradiated food appears to be the main obstacle to expanding consumption of irradiated foods.

## Summary

Currently, only poultry has been approved to be irradiated in the U.S. However, a petition has been submitted in July, 1994, to the U.S. FDA, to expand irradiation approval to all red meats. Irradiation dosages in the 1.5 to 4.5 kGy range are very effective at destroying pathogenic bacteria. At the same time a substantial reduction of spoilage organisms (especially gram-negative organisms) occurs to more than double the shelf-life of raw meat in refrigerated storage. Quality deterioration due to irradiation has been found, especially in raw meat odor. However, this problem is lessened or eliminated during cooking. The raw meat odor problem may be prevented by modification of irradiation conditions (i.e. temperature, modified atmosphere) or by alternative packaging materials. More research in this area is needed. Finally, consumers accept irradiated foods when informed of the benefits of the process especially by credible spokespersons. With enhanced communication to consumers it is expected that the market for irradiated food will increase.

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Table 1.D values of some important foodborne pathogens and spoilage organisms.

| Organism | D values (kGy) | Suspending medium | Irradiation temperature (0°C) | References |
|---|---|---|---|---|
| *A. Hydrophila* | 0.14 - 0.19 | Beef | 2 | Palumbo *et al.,* 1986 |
| *C. Jejuni* | 0.18 | Beef | 2 - 4 | Clavero *et al.,* *1994* |
| *E. coli* 0157:H7 | 0.24 | Beef | 2 - 4 | Clavero *et al.,* *1994* |
| *L.monocytogenes* | 0.45 | Chicken | 2 - 4 | *Huhtanen et al,* 1989 |
| *Salmonella spp.* | 0.38 - 0.77 | Chicken | 2 | Thayer *et al*, 1990 |
| *S. aureus* | 0.36 | Chicken | 0 | Thayer *et al.*, 1992 |
| *Y. Enterocolitica* | 0.11 | Beef | 25 | El-Zawahry *et al.,* 1979 |
| *C. botulinum* (spores) | *3.56* | Chicken | -30 | Anellis *et al.*, 1977 |