Chapter 1

INTRODUCTION: FOOD IRRADIATION MOVING ON

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Abstract: This chapter discusses the applications of irradiation technology for a wide variety of food products. Irradiation has been widely used for spices and other food ingredients for many years; but for perishables (meat and produce), it is just now emerging into a significant commercial reality. Two major separate driving forces are moving adoption of food irradiation forward. One is the need to effect microbial reduction, primarily for purposes of food safety enhancement. The second major driver is the need for an effective and environmentally friendly technology to disinfest fruits and vegetables for quarantine security purposes associated with interregional trade. These two main driving forces translate into two distinct business opportunities on which the current implementation activities are centered. Irradiation with ionizing energy is very effective in killing many of the common microbial pathogens such as *Escherichia coli* O157:H7, *Listeria monocytogenes*, *Salmonella* spp., and *Vibrio* spp. that are significant contributors to foodborne illness. A major advantage of irradiation for this purpose is that the food can be processed after it has been sealed in its final packaging, thereby reducing or entirely eliminating the possibility of recontamination following this treatment. Irradiation is increasingly being recognized as an excellent agent for disinfestation purposes. There is considerable interest around the world in bringing this potential into reality. USDA-APHIS is playing a leading role in the effort to put in place the regulatory infrastructure needed to allow its use for products imported into the United States, as well as for export of American horticultural products.

Keywords: microbial food safety; disinfestations; phytosanitation; fruits and vegetables; USDA-APHIS

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Introduction

There is an old Chinese proverb that says, "May you live in interesting times." With respect to food irradiation (Borsa 2000), today's proponents and other observers of this technology have good reason to feel that indeed these are interesting times in this unfolding story. Studied intensively for more than half a century, and approved in some 50 countries around the globe for a wide variety of food products (ICGFI 2005), irradiation has been widely used for spices and other food ingredients for many years, but for perishables (meat and produce) it is just now emerging into a significant commercial reality. This chapter focuses primarily on these emerging applications, in which just in the past half dozen years or so the changes in what we might call the food irradiation landscape have been dramatic, and at times go well beyond that. These changes have been most pronounced in the United States but the effects are beginning to be felt in other countries around the globe as well. In the United States from basically a standing start at the beginning of this recent period, but powered by a high level of entrepreneurial energy and zeal, commercialization of irradiation technology in the food industry accelerated rapidly to reach heights far beyond anything previously achieved. Almost overnight, irradiated products appeared in literally thousands of retail and foodservice outlets (SureBeam 2001). Investors took notice (Titan Corp 2001) and millions of dollars were raised for ventures targeting the opportunity presented by the very real needs recognized in food safety (Osterholm and Norgan 2004) and quarantine security (IAEA 2004). The fact that those needs are evident all over the world added to the investment appeal. In these positive circumstances, interest in food irradiation rapidly escalated, giving rise to an exciting play in the investment world.

Unfortunately, in 2004 a major business miscalculation intervened and this nascent industry suffered a significant setback just as it appeared to be getting over the hurdles associated with its launch. Not surprisingly, and to the great satisfaction of the skeptics and antitechnology activists, unreasonable expectations had exceeded the actual pace of adoption, especially by the major food processors, and the simple but inexorable math of the business world led SureBeam™, the most prominent player in the field, to declare bankruptcy (Egerstrom 2004). This failure caused considerable consternation and uncertainty in the fledgling industry, raising concerns as to whether it would survive the setback. Now, more than a year later and with the dust largely settled, it appears that emerging from this uncertainty is a restructured food irradiation industry that is gradually regaining momentum. The fundamental benefits offered by the technology remain the same (Olson 2004) and the new path forward, although lacking the brash boldness and dash of the SureBeam approach, offers prospects for a more sustainable long-term future.

Two Tracks Going Forward

Two major separate driving forces are moving adoption of food irradiation forward. One is the need to effect microbial reduction, primarily for purposes of food safety enhancement. This need is associated especially with those foods that are derived from animals, although similar food safety needs are increasingly being recognized for fresh fruits and vegetables (Sewall and Farber 2001). Shelf-life extension constitutes a significant additional incentive for adoption of this technology, and in some specific applications it may serve as the primary benefit being sought.

The second major driver is the need for an effective and environmentally friendly technology to disinfest fruits and vegetables for quarantine security purposes associated with interregional trade (NAPPO 2003). These two main driving forces translate into two distinct business opportunities on which the current implementation activities are centered.

The Food Safety Track

Irradiation with ionizing energy is very effective in killing many of the common microbial pathogens such as *Escherichia coli* O157:H7, *Listeria monocytogenes, Salmonella* spp. and *Vibrio* spp., among others, that are significant contributors to foodborne illness. A major advantage of irradiation for this purpose is that the food can be processed after it has been sealed in its final packaging, thereby reducing or eliminating entirely the possibility of recontamination following this treatment. This unique operational capability makes irradiation particularly suitable for (cold) pasteurization of ready-to-eat foods, such as hot dogs and other deli items, that are at risk of contamination with *L. monocytogenes* during postprocess slicing and packaging operations.

How does irradiation fit into the overall food safety strategy, based on Hazard Analysis Critical Control Point (HACCP), which is now the dominant food safety paradigm in the food industry? Although the incidence of positive samples for both *E. coli* O157:H7 (USDA 2005) and *L. monocytogenes* (USDA 2003) has declined significantly since HACCP was made mandatory in the late 1990s, the need for further improvement remains. A simple calculation puts this into useful perspective. The latest sampling statistics from USDA-FSIS indicate that the incidence of ground beef samples testing positive for contamination with *E. coli* O157:H7 stands at 0.17% (USDA 2004). This translates into roughly 17 million pounds of such contaminated ground meat presumably randomly interspersed through the approximately 10 billion pounds of this product consumed annually in the United States. Expressed in terms of commonly consumed units of ground beef, this amount represents some 68 million average-size hamburger patties that are contaminated by this pathogen and which therefore have the potential to cause illness in consumers. Of course, this scenario is for only one pathogen; there are others, including some newly emerging ones, which multiply the risk.

In the present situation eating such product with the documented levels of contamination becomes a statistical game of chance as to whether one gets exposed to this pathogen or not. Although the probability of falling ill due to consumption of a randomly selected hamburger borders on the infinitesimally small, this is one of those situations in which a very small probability multiplied by the very large number of people at risk amounts to a significant number of seriously sick people, as attested to by CDC statistics (Mead et al. 1999). Of course, for those unlucky enough to actually become sick, or whose child gets hemolytic uremic syndrome (HUS), the talk of probabilities becomes irrelevant (STOP 2003). Thus the need for further improvement is still very real. The "zero tolerance" regulatory policy in effect for this pathogen (USDA 1999) reflects the seriousness of the hazard.

In the context of HACCP irradiation is an excellent CCP (Molins et al. 2001) for *E. coli* O157:H7 and other bacterial pathogens in ground beef and similar products. Its use would reduce the probability of contamination in the finished product by several orders of magnitude, depending on the specifics of any particular application. No other technology exists that can offer the convenience of processing in the final shipping cases, and even on pallets, while still treating every last gram of product to a standard that essentially guarantees absence of the target pathogen. Irradiation can offer to solid and semisolid foods such as meat, poultry, and fish the same benefits that thermal pasteurization has brought to milk and other liquid products.

In the past two years, since SureBeam's failure, two new irradiation plants for processing food for the purpose of microbial reduction have been commissioned in the United States. Of course, the ultimate success of these ventures will be decided in the market place, subject to all the realities, scrutiny, and judgments of the business world. On this basis it seems safe to predict that the days ahead will continue to provide "interesting times."

The Disinfestation Track

Growth in international trade of agricultural products, especially tropical fruits and vegetables, is seen as a foundation component of the economic development strategy of many underdeveloped countries (World Trade Organization 2001). Disinfestation technology for quarantine security purposes is a critical enabler for such trade in agricultural products (Henson and Loader 2001). Currently, fumigation with methyl bromide is the predominant technology used for this purpose. However, the continuing availability of methyl bromide for this purpose is an open question, due to its ozone depleting potential. An international agreement (Montreal Protocol) is in effect to phase out the use of this chemical because of this negative effect on the environment (UNDP 2002). In addition, methyl bromide is phytotoxic to some commonly traded fruits and vegetables (Hallman 1998), bringing further pressure to bear to find a suitable alternative. Irradiation is increasingly being recognized as an excellent agent for disinfestation purposes, and there is considerable interest around the world in bringing this potential into reality. USDA-APHIS is playing a leading role in the effort to put in place the regulatory infrastructure needed to allow its use for products imported into the United States, as well as for export of American horticultural products. Success has already been achieved for irradiated products routinely being shipped from Hawaii to mainland United States (Hawaii Pride 2005). Efforts currently under way should lead, in the relatively short term, to expansion of the list of US trading partner countries for which irradiation will be accepted as a suitable disinfestation measure for products shipped between them. It can be anticipated that successful establishment of irradiation as a quarantine security technology for trade involving the United States will rapidly lead to its use for this purpose in trade involving other trading partners. The recent commencement of shipment of irradiated Australian fruit to New Zealand (TVNZ 2004) represents a first step along this path.

Currently, besides the Hawaiian and Australian/New Zealand examples, there is interest in and movement toward implementation of irradiation disinfestation as part of a trade-enabling infrastructure in several countries in different regions around the world, including the Asia Pacific group and Latin America. The future for irradiation in this application looks bright indeed.

Bumps Still Remain on the Road Ahead

Although implementation of food irradiation has taken great strides forward and is building momentum, it has not yet reached a condition of clear sailing. Several troublesome hindrances remain, which need to be addressed.

On the regulatory front, much remains to be done, even in the United States, where most of the implementation progress to date has taken place. Specifically, petitions for clearance of irradiation for several categories of food that could benefit from this treatment continue to languish somewhere in the evaluation process. These include petitions for ready-to-eat foods and for seafood. Elsewhere, an encouraging sign is that in some parts of the world, as in Brazil (ICGFI 2005), the authorities have granted blanket approval for irradiation of all foods, consistent with Codex Alimentarius recommendations (Codex 2003). Perhaps this will encourage other member states of Codex Alimentarius to base their national regulations for food irradiation on the international standard to which they are party. It seems likely that as food irradiation registers more and more successes, countries currently on the sidelines will join the growing movement toward greater acceptance and utilization of this powerful technology.

Regulatory requirements for the labeling of foods that have been irradiated remain a deterrent to some processors who would otherwise use it on their products. This issue has been under review for several years now, but to date no suitable alternative has been put forth that would satisfy both the needs of industry to inform but not alarm consumers, and the consumers' right to know. Also very important is the need to extend the list of clearances for irradiation of food packaging materials, to include more of the common modern polymers and films (ICGFI 2005).

At present there is a major logistical impediment, stemming from the scarcity of processing capacity within reach of many food manufacturers that are interested in using irradiation. This difficulty can be alleviated only by building new capacity in strategic locations to provide easy access for those wishing to use it. Installation of contract service irradiators in distribution centers and cold storage warehouses that serve many clients would be a logical and cost-effective approach to meeting this logistical need. Such locations have the advantage of easy and convenient access for their clients without incurring any additional transportation costs. New irradiation systems currently available (Stichelbaut and Herer 2004) that can process fully loaded pallets of food allow seamless interfacing between the irradiation facility and the existing warehouse, distribution, and transportation networks that use pallets as the basic unit of product handling.

Another challenge is that with some products the maximum dose that can be tolerated without sensory degradation is low enough that it can be difficult to effect the wanted benefit to the extent desired. Excellent research progress in improving the effectiveness of irradiation in such difficult cases is being made. Different approaches involve one or more of increasing the product tolerance to radiation (Kalsec 2005), increasing the sensitivity of pathogens to radiation so that lower doses can effect the needed kill (Chiasson et al. 2004), and improvements to irradiator design permitting the delivery of more uniform dose distributions in product stacks (Stichelbaut and Herer 2004), thereby reducing the regions of overdose wherein the sensory degradation is most likely to occur. These and other technical issues will undoubtedly serve as the focus of research at universities and other institutions for some time to come.

Summary

Implementation of food irradiation continues to move forward. The biggest gains are happening in the United States, but progress is being made in other parts of the world as well. Both the food safety and the disinfestation applications are growing, with the disinfestation application being especially active. It seems likely that this expansion will continue for an extended period of time, perhaps decades.

References

Borsa, J. (2000) Irradiation of foods. In: *Wiley Encyclopedia of Food Science and Technology*, Vol. 3 (ed. JF Francis) 2nd edn. pp. 1428–1436. John Wiley & Sons, New York.

Chiasson, F., Borsa, J., Ouattara, B. & Lacroix, M. (2004) Radiosensitization of Escherichia coli and Salmonella Typhi in Ground Beef. *Journal of Food Protection*, **67** (6), 1157–1162.

Codex (2003) Revised Codex General Standard for irradiated foods. Codex Stan 106-1983, Rev.1-2003. Available at: ftp://ftp.fao.org/codex/standard/en/CXS_106e_1.pdf.

Egerstrom, L. (2004) Midwestern meat processors scramble as irradiation firm liquidates. Knight Ridder Business News, 15 January 2004.

Hallman, G.J. (1998) Efficacy of methyl bromide and cold storage as disinfestation treatments for guavas infested with Caribbean fruit fly. *Tropical Science,* **38** (4), 229–232.

Hawaii Pride (2005) Available at: www.hawaiipride.com.

Henson, S. & Loader, R. (2001) Barriers to agricultural exports from developing countries: the role of sanitary and phytosanitary requirements. *World Development (Oxford)*, **29** (1), 85–102.

IAEA. (2004) Irradiation as a phytosanitary treatment of food and agricultural commodities. IAEA-TECDOC-1427. p. 181. IAEA, Vienna, Austria.

ICGFI. (2005) Clearance database. Available at: www.iaea.org/icgfi/data.htm.

Kalsec. (2005) Managing oxidation in irradiated meats. Available at: http://wwwkalsec.com/products/oxid_irrad_over.cfm.

Mead, P.S., Slutsker, L., Dietz, L. et al. (1999) *Emerging Infectious Diseases*, **5** (5), 607–625.

Molins, R.A., Motarjemi, Y. & Kaferstein, F.K. (2001) Irradiation: a critical control point in ensuring the microbiological safety of raw foods. *Food Control*, **12** (6), 347–356.

NAPPO (2003) NAPPO Regional Standards Phytosanitary Measures (RSPM). RSPM No.19. Guidelines for Bilateral Workplans. Available at: www.nappo.org/Standards/NEW/RSPM19-e.pdf.

Olson, D. (2004) Food irradiation future still bright. *Food Technology,* **58** (7), 112.

Osterholm, M.T. & Norgan, A.P. (2004) The role of irradiation in food safety. *New England Journal of Medicine*, **350** (18), 1898–1901.

Sewall, A.M. & Farber, J.M. (2001) Foodborne outbreaks in Canada linked to produce. *Journal of Food Protection*, **64** (11), 1863–1877.

Stichelbaut, F. & Herer, A. (2004) The Palletron: an X-ray pallet irradiator designed for food products. Paper 49H-32. IFT Annual Meeting, 12–16 July 2004, Las Vegas, NV. Available at: http://ift.confex.com/ift/2004/techprogram/paper_24302.htm.

STOP (2003) Why are people still dying from contaminated food? Available at: www.safetables.org/pdf/STOP_Report.pdf.

SureBeam (2001) Fact vs. fiction: SureBeam turns the tide on irradiated foods (Brief Article). *Progressive Grocer,* **80** (8), 30.

Titan Corp (2001) SureBeam IPO priced at $10.00 per share. Press release. 16 March. Available at: www.titan.com/investor/archives/pressreleases/2001/010316_surebeam.html.

TVNZ (2004) Nuked mangoes to hit NZ shops. TVNZ One News. 20 December. http://tvnz.co.nz/view/news_national_story_skin/465318%3fformat=html.

UNDP (2002) The Vienna Convention and the Montreal Protocol. Available at: http://www.undp.org/seed/eap/montreal/montreal.htm.

USDA (1999) Policy on beef products contaminated with *E. coli* O157:H7. *Federal Register*, **64** (11), 2803–2805. Available at: http://www.fsis.usda.gov/OPPDE/rdad/FRPubs/97-068N.htm.

USDA (2003) Listeria in FSIS ready-to-eat products shows significant decline. Available at: http://www.fsis.usda.gov/OA/news/2003/rtedata.htm.

USDA (2004) Microbiological results of raw ground beef products analyzed for Escherichia coli O157:H7. Available at: http://www.fsis.usda.gov/Science/2004_EColi_Positive_Results/index.asp.

USDA (2005) FSIS ground beef sampling shows substantial *E. coli* O157:H7 decline in 2004. Available at: http://www.fsis.usda.gov/News_&_Events/NR_022805_01/index.asp.

World Trade Organization (2001) Trade and Development. Available at: http://www.wto.org/english/tratop_e/devel_e/devel_e.htm.