Irradiation for Quality Improvement and Microbial Safety of Fresh Produce

Chapter · December 2017

DOI: 10.1016/B978-0-12-811025-6.00001-X

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CHAPTER

1 Irradiation for Quality Improvement and Microbial Safety of Fresh Produce

OVERVIEW

With the development of pathogen resistance to some of the common chemical synthetic compounds and with the increased wish to receive fresh products free of chemical residues leading to public risk, research for alternative substances or treatments has been increased. These included the use of natural chemical compounds, the introduction of "generally recognized as safe" compounds, the use of biocontrol agents, the development of genetically engineered crops, the modulation of the natural host defense substances (Terry and Joyce, 2004; Charles et al., 2008) and the increased interest in physical control methods, such as cold storage, heating, modified or controlled atmosphere storage, hypobaric pressure, and ionizing radiation. The nonresidual feature of ionizing radiation as a physical means for postharvest disease control has been regarded as an important advantage in treating fresh fruits and vegetables.

Studies aimed at evaluating the possibilities of using ionizing radiation for extending the useful life of fresh fruits and vegetables via suppressing postharvest diseases and retarding physiological deterioration have been conducted since the 1950s. These studies were accompanied by investigations on the possible use of ionizing radiation as a means for extending the storage life of tuber, bulb, and root crops by sprout inhibition.

With the increased interest in minimally processed or fresh-cut fruits and vegetables, enhanced efforts were dedicated to evaluating the ability of ionizing radiation to enhance microbial safety by eliminating human pathogenic microorganisms that frequently contaminate the fresh-cut produce.

Studies on irradiation effects on fresh fruits and vegetables and later on minimally processed fruits and vegetables for improving their keeping quality aspects have been discussed along the years in a great number of reviews such as those by Sommer and Fortlage (1966), Dennison and Ahmed (1975), Brodrick and Thomas (1978), Thomas (1983, 1984, 1985, 1986a,b, 1988), Thayer (1990), Barkai-Golan (1992, 2001), Molins (2001), Groth (2007), Arvanitoyannis et al. (2009), Arvanitoyannis (2010), Niemira and Fan (2009), Cia et al. (2010), Fan (2010, 2012a,b, 2013b), Niemira (2013) and Fan and Sommers (2013a,b). A great number of other reviews have been focused on special aspects of fresh fruits and vegetables irradiation.

Irradiation for Quality Improvement, Microbial Safety and Phytosanitation of Fresh Produce.
http://dx.doi.org/10.1016/B978-0-12-811025-6.00001-X

Early studies have already shown that the possible application of ionizing radiation for decay control may be limited by the susceptibility of the host plant tissue to irradiation, as expressed by radiation-induced damage and adverse changes in nutritional contents, color, texture, flavor, or aroma. Thus, the use of ionizing irradiation as a means for decay control will depend on the balance between pathogen sensitivity to irradiation and host resistance to its application.

To reduce the radiation dose effective for decay control and postharvest life extension, the possibility of using combined treatments of radiation with other physical treatments, mild chemical applications, or other accepted postharvest treatments has been developed.

The first part of the book brings together the variety of approaches aimed at using ionizing radiation as an alternative physical means for improving the shelf life of harvested products, including studies in various countries over the last six decades. The studies involved are aimed mainly at four directions: (1) the extension of postharvest life or shelf life directly by inactivating postharvest pathogens alone or combined with other known postharvest control means; (2) the extension of postharvest life by delaying the ripening and senescence processes, which may indirectly lead also to decay suppression in harvested fruits and vegetables; (3) the improvement or enhancement of microbial safety associated with human pathogens in minimally processed or fresh-cut fruits, vegetables, and mushrooms, a subject that gained increased interest during the last decades; (4) postharvest life extension of subterranean vegetables via sprout inhibition of tubers, bulbs, and roots.

An important advantage of ionizing radiation over chemical application is its ability to penetrate deeply into the host tissues without leaving residues. Thus, in contrast to chemicals, gamma radiation enables the control of not only surface- or wound-infecting microorganisms but also pathogens implanted within the host either as latent or as active infections. Therefore, ionizing radiation may also be considered as a therapeutic means for postharvest diseases.

The data given in part 1 of the book include, along with up-to-date information on irradiation effects on the fresh produce, also early studies because some basic or pioneer studies associated with the ability of irradiation to extend the useful shelf life of fresh fruits and vegetables by inhibition of pathological and physiological changes and enhancement of their safety and wholesomeness have been carried out in earlier investigations.

RADIATION PURPOSES—SAFETY AND WHOLESOMENESS OF FRESH PRODUCE

The aim of food irradiation, similar to that of other food technologies, such as freezing and high-temperature or chemical treatments, is to maintain its quality, enhance its safety, and prolong its shelf life by eliminating microbial development and food-borne illness caused by contaminating human pathogenic microorganisms. Regarding fruits and vegetables, irradiation may act as postharvest fungicidal or fungistatic means against spoilage microorganisms and will replace chemical treatments without leaving residues in the vegetal tissues intended for consumption. Irradiation is capable of inhibiting the accumulation of human pathogenic bacteria that frequently contaminate the surface of fresh and fresh-cut fruits and vegetables and are responsible for serious outbreaks. Irradiation may also extend postharvest life by retarding the physiological activity of fresh fruits and vegetables, mainly those associated with the ripening and senescence processes, and by inhibiting sprout inhibition of potato tubers or onion and garlic bulbs during postharvest stages.

Safety and wholesomeness are basic factors for applying irradiation. Extensive research on food exposed to ionizing irradiation from different sources provided evidence that ingestion of irradiated food is safe (WHO, 1988; CAST, 1996; IAEA, 2006; EFSA, 2011). The process of irradiation includes the passage of the food items through the radiation field without having contact with radioactive substances (O'Beirne, 1989; Crawford and Ruff, 1996; Grolichova et al., 2004). Wholesomeness implies satisfactory nutritional quality and microbiological safety for consumers. Regarding wholesomeness of irradiated food, early studies have already indicated that the nutrient breakdown is considerably reduced after irradiation than after other established processes, such as heating and canning (Brodrick et al., 1985). To assess the biological safety of irradiation and provide relevant data on the wholesomeness of irradiated food, investigation of biochemical changes occurring in food exposed to irradiation has been included in many laboratories in various countries.

The new terminology of wholesomeness means "safety for consumption" in the widest possible sense. It includes the radiological, toxicological, and microbiological safety and the nutritional adequacy and the sensory quality of the irradiated product (Ehlermann, 2005).

RADIATION SOURCES AND DOSE TERMINOLOGY

Sources of ionizing radiation aimed at suppressing or inactivating pathogenic microorganisms of fruits and vegetables and those contaminating the surface of the fresh produce include gamma rays emitted by the radio-isotopes cobalt-60 (with levels of 1.17 and 1.33 MeV) or cesium-137 (with 0.662 MeV) and by high-energy electrons (e-beams) with a maximum energy level of 10 MeV. Another type of ionizing radiation that may be applied to foods is X-rays with maximum energy of 7.5 MeV (FDA, 2008). Doses of irradiation are quantified in terms of energy absorbed by the irradiated product. None of these kinds of radiation, when used for food irradiation purposes established by Codex Standard, have energy levels suitable to induce radioactivity in the irradiated food (European Food Safety Authority – EFSA Journal, 2011).

Compared to gamma rays, e-beams are characterized by a lower penetrative capacity. They can only penetrate food up to a depth of a few centimeters, which can limit the type of food that can be processed and are particularly useful for surface-contaminated products (WHO, 1988).

Regarding radiation application to foods, several terms are associated with absorbed doses (Juneja and Thayer, 2001). These include

1. Rad (used in the past)—a unit equivalent to the absorption of 100 ergs energy/g of irradiated material
2. Gray (Gy), the currently used unit of absorbed dose: 1 Gy is an energy absorption of 1 J/kg (1 J = 10^7 ergs; 1 krad = 10 Gy; 1 Gy = 100 rad = 0.1 krad; 1 kGy = 1000 Gy = 100 krad).

CLEARANCES OF IRRADIATION

The use of irradiation for preservation of food must be approved by the US Food and Drug Administration (FDA) before being commercially applied. The FDA has already approved the use of irradiation for sprout inhibition of white potatoes in 1964 and for ripening inhibition and insect control in 1986. Since the last three decades, the amount of commercially irradiated food products has been markedly increased. As was summed up by Ehlermann (2005), the Joint Expert Committee of Food Irradiation concluded in 1980 that food irradiation is safe and acceptable for any kind of food, at least at up to an overall average dose of 10 kGy (WHO, 1988). This conclusion was adopted by Codex Alimentarius, revising its provisional standard of 1979 into the general standard of 1983, which was further modified in 2003.

A major international conference was held in Geneva, Switzerland, on December 1988 by the Food and Agriculture Organization, International Atomic Energy Agency, World Health Organization, and ITC-UNCTAD/GATT. The purpose of the conference was to establish an international document for the acceptance, control of, and trade in irradiated food. Based on a critical evaluation of available scientific data concerning the safety and wholesomeness of irradiated food, the conclusions reached were that foods irradiated up to an overall average dose of 10 kGy were nutritionally sound and safe for human consumption (WHO, 1988).

Permissions to irradiate food items may vary considerably in different countries. Lists of countries that have cleared along the years different irradiated fruits and vegetables for human consumption and the levels of clearance are given in Appendix I (Tables A.1–A.5).

Regarding clearances, important changes took place for strawberries and for lettuce and spinach.

CLEARANCE FOR STRAWBERRIES IRRADIATION

Following the fact that strawberries are characterized by a very short postharvest life because of both physiological and pathological processes, a clearance for strawberry irradiation was given by 19 countries with a dose of 3 kGy (International Consultative

Group on Food Irradiation, ICGFI, 2002). This dose was found to extend shelf life of strawberries by a factor greater than 2. Higher doses resulted in changes in fruit texture, cell wall composition, and decrease in color intensity (d'Amour et al., 1993; Yu et al., 1995).

CLEARANCE FOR LETTUCE AND SPINACH IRRADIATION

In 2008 an approval was given by the US FDA for the use of ionizing irradiation on fresh Iceberg lettuce and spinach at doses not exceeding 4 kGy to enhance microbial safety and extend their shelf life (FDA, 2008). The European Food Safety Authority (EFSA, 2011) came to the conclusion that in general the radiation dose needed to inactivate food-borne pathogens depended on the target pathogens, the reduction required, and the physical state of the food item rather than the food classes. Studies by Fan et al. (2012a) indicated that overall irradiation at doses of 1 and 2 kGy is feasible to enhance microbial safety of fresh-cut lettuce and of spinach with minimal effect on their quality.