Potentiality of use of Irradiation for Dairy Products

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Food Irradiation is a process in which food products are exposed to ionizing radiation in form of gamma radiation, X-rays and electron beams in controlled amount to destroy pathogenic microorganisms in order to increase its safety and shelf life (WHO, 1991). Irradiation as a food preservation technology has been studied in various parts of the world for more than five decades. Acceptance and commercialization have been slow, somewhat similar to the controversial and slow development of pasteurization of liquid milk at the turn of the 20th century (Moy, 2004). In 1981, the United Nation's Food and Agricultural Organization (WHO) endorsed irradiation doses up to 10 k Gray, as a major technology for the prevention of food borne illness and for the reduction in food losses due to spoilage by microorganisms and vermin. Ionizing radiation is now approved for use in more than 41 countries for over 35 specified foods, and the list is growing (CAST, 1989). Approximately 26 countries currently employ radiation on a commercial scale for food application (Stevenson, 1994). The Radura logo is required for irradiated foods and Irradiated ingredients are excluded and Only "First Generation" foods must be labeled (FAO, 1992). Many consumers are not adequately educated about the safety of irradiated foods. Investment for a commercial irradiator facility is high. As a result, it is very challenging for a food preserved with an unconventional technology to enter and compete in the market place (Fox, 2002).

Food irradiation methods

By and large, two methods are used to irradiate food products (Anon, 1997): Gamma ray irradiation and linear accelerator irradiation. Gamma Ray Irradiation method uses sources of gamma rays such as the isotopes Cesium 137 or cobalt 60. Gamma rays can penetrate the food products to a great depth exposing the pathogens in deep layers of irradiated products. Gamma irradiation machines can irradiate whole palates of food products. Such a machine has a large capacity but operates at low speed. The process is better than any means of pasteurization currently available ,even though it is not 100 percent effective. The radiation source is normally Cobalt 60 pencils installed on either side of an 8 by 16 foot stainless steel rack. The pencils are stainless steel tubes containing two zirconium alloy tubes that encapsulate nickel-coated pellets of Cobalt 60 (ICGFI, 1991). Linear Accelerator Irradiation consists of a linear particle accelerator which is used to create an electron beam. The electron machine is high speed, but low in capacity as compared to gamma ray machine. This device generates a beam of electrons that directly contact the product, or convert the accelerated electrons into x-rays which can penetrate the irradiated product deeper, but are less effective than the electronic beam (ICGFI, 1991).

A third source of ionizing radiation for food application is converted x-rays. When electrons from a linear accelerator collide with a dense, heat-resistant plate, such as tungsten or a titanium alloy, x-rays are produced on the other side of the plate called bremsstrahlung. The energy level is limited to 5 MeV. The conversion efficiency from electrons to x-rays is in the range of 5–12%, limited by the law of physics (Kunstadt, 2001).

The irradiation resistance or sensitivity of a microorganism is commonly given as the D10 dose. This is the dose that is required to kill 90% of a population. The radiation dose unit, previously referred to as the rad, is currently known as the Gray (Gy). The Gray is the absorption of 1 joule of energy/kg irradiated material and is equivalent to 100 rads; 1 krad equals 10 Gy and 1 Mrad equals

10 kGy (Ma and Maxcy, 1981). Dosimeters are devices to measure radiation doses (Farrar, 1999). When a certain dose is measured in a set time frame, it can be expressed as dose rate (kGy/min or kGy/hr). There are a number of dosimeters. A basic reference standard is the Fricke dosimeter. It is based on the oxidation of ferrous ions (Fe2+) to ferric ions (Fe3+) in a standardized aqueous solution measured by UV spectrophotometry (ASTM, 1997). The approximate doses of radiation needed to kill various organisms is presented in Table 1 and typical irradiation D-values of pathogens is presented in Table 2.

polymerization, decarboxylation, and dehydration reactions even at low doses (Giroux, 1998). In particular, polyunsaturated fatty acids are prone to oxidation by free radicals produced during treatment. In addition, oxidation of casein and the production of methyl radicals has been shown to result in the generation of "wet dog" off-flavors (Hsu *et al*., 1972). These chemical reactions, to some extent, can be reduced if the products are initially frozen and/or treated in an environment with limited water, light, and oxygen. Yet, despite these shortcomings, low-dose radiation for the specific purpose of extending dairy product shelf life does hold promise. In such applications, the treatment should be considered as supplemental or complementary with use of other preservation techniques including refrigeration and/or preservatives such as sorbic acid. Bongirwar and Kumta reported that Cheddar cheese developed off-flavors when irradiated at 0.5 kGy; however, none was detected when the dose was reduced to 0.2 kGy. A dose greater than 1.5 kGy, when applied to Turkish Kashar cheese, not only resulted in off-flavor development but also contributed

Table 1 - Approximate doses of radiation needed to kill various organisms

Organisms	Dose (kGy)
Higher organisms	0.005 to 0.1
Insects	0.01 to 1
Non spore forming bacteria	0.5 to 10
Bacterial spore	10 to 50
Viruses	10 to 200

(Source: Yadav and Tyagi, 2005)

Table 2 - Typical irradiation D-values of pathogens

Organism	Fresh (refrigerated)	Frozen
	kGy	
Campylobacter jejuni	0.08	0.21
E.Coli 0157:H7	0.24	0.31
Staphylococcus aureus	0.26	0.30
Salmonella spp.	0.30	0.40
Listeria monocytogenes	0.27	0.52

(Source: Yadav and Tyagi, 2005)

Irradiation of Dairy Products

Shelf life extension and/or sterilization of dairy products for making it shelf stable using radiation treatment is not a widely accepted practice. The reason for its limited use is that ionizing energy, through the formation of radiolytic products especially in high lipid-based foods, generates unacceptable off-odors and flavors via oxidation, to color deterioration (Jones and Jelen, 1988). By decreasing the dose to 1.2 kGy the sensory problems were eliminated and the mold-free shelf life was extended 12 to 15 days when stored at room temperature. In contrast, non-irradiated cheese became moldy within 3 to 5 days. When combined with refrigeration storage, radiation increased the shelf-life period of the cheese fivefold. With Gouda cheese, however, no taste difference was reported between irradiated (3.3 kGy) and non-irradiated samples. (Rosenthal *et al.*, 1983). In this study, a Gouda-based process cheese was initially frozen to –78°C and then gamma irradiated at 40 kGy. Although mozzarella cheese was similarly treated, the result of sensory evaluation was far less favorable. Interestingly, both cheeses maintained their characteristic mouth-feel properties despite being frozen. In addition, the relatively high treatment dose resulted in only slight color changes. It should be pointed out that while higher doses are required for sterilization purposes, the product once treated has an indefinite shelf life from a microbiological standpoint, provided of course that sterility is maintained. For Camembert cheese, flavor changes described as burnt or musty first became noticeable when treated with 0.30 kGy. (Hashisaka *et al.*, 1990). In order to stabilize the cheese by preventing additional growth of *Penicillium roqueforti*, a minimal dose of 2.0 kGy was recommended. Results from a subsequent study, however, reported that full fat Camembert cheese suffered no off-flavor development up to a dose of 3 kGy (Chincholle, 1991) and that treatment at 2.5 kGy was sufficient to eliminate initial populations of 103 to 104 colony forming units (cfu)/g of the pathogen *Listeria monocytogenes* (Bougle and Stahl, 1994). In contrast, flavor changes were quite noticeable when radiation treatment was applied to cottage cheese, the minimal threshold dose being 0.75 kGy. At this dosage the cheese was described as having a slight bitter, cooked, or foreign taste. However, in order to reduce spoilage by psychrotrophic bacteria by at least three logs, the applied dose would have to be nearly doubled. (Jones and Jelen, 1988). This resulted in cheese with a definite burnt off-flavor. Using electron beam irradiation and doses of 0.21 and 0.52 kGy, the shelf life of vacuum packaged cheddar cheese at 10°C containing 101 cfu/cm^2 *Aspergillus ochraceus* spores was extended by approximately 42 and 52 days, respectively (Blank *et al.*, 1992). Under similar conditions, inoculation of cheese with *Penicillium cyclopium* spores resulted in shelf-life extensions of only 3 and 5.5 days, respectively. Overall, the efficacy of the treatments was shown to be heavily reliant on the irradiation resistance of the target microorganisms and the temperature of storage. Increasing the post-irradiation storage temperature from 10 to 15°C, for example, decreased the extension in shelf life. Although these results are to be expected, based on the mesophilic nature of the target fungi, the increase in temperature may also have contributed to more efficient repair of injury by the survivors.

Sterilization of yogurt bars, ice cream, and nonfat dry milk by gamma irradiation using a dose of 40 kGy at –78°C resulted in an overall decrease in acceptance. (Jones and Jelen, 1988). Although the use of MAP or the inclusion of antioxidants appeared to reduce the level of off-flavors, the effects were product specific. Irradiation of fluid milk also resulted in unacceptable flavor scores. Off-flavors and browning originating from chemical reactions involving lactose were identified. Irradiation preservation of yogurt was similarly investigated. Left at room temperature, plain yogurt reached a population of 109 cfu/g by 6 days and was judged unacceptable; however, when treated with gamma irradiation using a dose of 1 kGy this population level was not reached until 18 days of incubation. Irradiation combined with refrigeration further extended the shelf life of yogurt to 29 to 30 days. In comparison, the shelf life of the refrigerated controls was only 15 days (Kunstadt, 2001).

Conclusion

Irradiation processing has been extensively researched and is now being used for many food commodities. It has been successfully used to reduce pathogenic bacteria, eliminate parasites, decrease postharvest sprouting, and extend shelf life of fresh perishable food. It has a potential for use in preservation and extending the shelf life of certain milk and milk products.

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