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Food Irradiation for Mushrooms: A Review

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Food irradiation may be considered as a second big breakthrough after pasteurization. It is the process of exposing food to ionizing radiation in order to destroy microorganisms or insects that could be present in the food and some time to improve the functional properties of food or to eliminate toxins, with the least compromise on sensory and nutritive quality. Mushrooms are fleshy fungi, being used as food and medicine. However, their short shelf-life and high initial microbial load are the major problems regarding their easy distribution and safe consumption. The irradiation of mushrooms can be a safe and cost effective method to enhance shelf-life as well as to ensure hygienic and sensory quality. For quarantine requirements and consumer awareness, different detection methods for irradiated mushrooms, such as electron spin resonance, photostimulated luminescence, and thermoluminescence are available, which are effective and validated. Safety of irradiated mushrooms is well documented providing evidences that this technology is safe with some added advantages.

Key words: irradiation, mushrooms, preservation, quality, safety

Mushrooms, belong to the fungi kingdom, are being used for food and medicinal purposes by humans since time immemorial. Some species of mushroom are very poisonous. Over time mankind learnt to differentiate between edible and poisonous mushrooms and now mushrooms with nutraceutical properties are part of the daily food in many countries. In regards to the Romans, mushrooms were considered as “Food for Gods”. The number of recognized mushroom species has been reported to be 14,000, which is about 10% of the total estimated mushroom species on the earth [Cheung, 2008]. They are known as filamentous fungi and must obtain their nutrients from waste products or living things, as all fungi lack the chlorophyll required for obtaining energy directly from the sun [Yoon and Kwon, 1990]. With the increase in the demand and consumption of mushrooms, the production and supply chain for mushrooms also require the use of highly developed technology. These days a large volume of mushrooms are being produced by means of cultivation with advanced agricultural practices. Then different preservation techniques are utilized in order to preserve their nutritional value as well as to increase their shelf life, while giving prime importance to consumer safety. The two most cultivated and popular mushrooms in the world are the button (*Agaricus bisporus*) and shiitake mushrooms (*Lentinus edodes*). In general, the moisture content of mushrooms ranges from 85 to 95% of their fresh weight. Mushrooms are quite high in protein, ranging from 19 to 35% (dry weight), including all nine essential amino acids. They are low in fat, but are still a source of unsaturated fatty acids, especially oleic and linoleic acids. They also contain relatively large amounts of carbohydrates and fiber, ranging from 51 to 88% and from 4 to 20% (dry weight), respectively, regarding all cultivated species. In addition, mushrooms contain significant amounts of minerals and vitamins mainly thiamin, riboflavin, ascorbic acid, and vitamin D_2. The mushroom is the only vegetative source of vitamin D, which is very important for normal bodily functions, especially regarding the deposition of calcium in bones [Mattila *et al.,* 2000].

Food irradiation may be defined as the intentional exposure of food to ionizing radiation (such as gamma and electron beam) in order to enhance its shelf life as well as the safety of food. The softening and browning process associated with the ripening of certain fruits and vegetables, such as in mushrooms, can be delayed by utilizing irradiation. Therefore, to preserve nutrition as well as to enhance shelf life of mushrooms in conjunction with advanced food processing methods, irradiation can serve the purpose [Robertson and Hoy, 2000]. Many

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researchers studied different aspects of irradiation, using mushrooms to determine the safety and efficacy of the process, and attempted to establish the threshold limit for safe and wholesome food processing with irradiation. Consumer acceptability with respect to irradiated food products is basically related to the consumer's awareness of the irradiation process, in that this process is as safe as other conventional food preservation techniques, with added advantages [Brown, 2002]. Different market studies regarding consumer acceptability of irradiated food products in various countries have determined that consumers usually accept this processing technique. From 1994 to 1996, several irradiated products including dried mushrooms and dried vegetables were market tested in the Republic of Korea and were found acceptable to consumers due of their added advantages [ICGGI, 1999]. Irradiated fruit and vegetables (mango, citrus, potato, seeds for sprouts etc.) are now available in some U.S. stores. Long term animal feedings with irradiated food, for several generations, have proven that irradiated foods are safe and nutritious. The irradiation of many food products has been approved by many reliable regulatory bodies, including the Food and Drug Administration (FDA), WHO, the CODEX Alimentarius Commission, the American Medical Association and the Institute of Food Technologies: These regulatory agencies assure that food irradiation is a safe process with respect to food processing for humans [Thayer *et al.,* 1996]. The recommended dose for extending the shelf life of fresh mushroom in different countries is 1-3 kGy, while the recommended dose regarding the decontamination of dried mushrooms (come under food additives with spices), used as seasonings, is 10-50 kGy [ICGGI, 1999]. List of clearances of irradiated mushroom in different countries with permitted dose and targeted objective is illustrated in Table 1.

The general ways in which irradiation can be useful in treating foods may be listed as follows [Chichester, 1978]:

- Control of spoilage microorganisms
- Complete sterilization for unlimited product life
- Reduction of numbers to delay microbial spoilage
- Control of food-borne pathogenic microorganisms
- Control of helminths and other food-borne parasites
- Control of insects
- Delay of senescence
- Product improvement

This review will outline the various applications regarding mushroom irradiation in reference to the published scientific work, in order that a general understanding of irradiation techniques can be developed with respect to mushroom processing.

Effects of Irradiation on Hygienic Quality of Mushroom

The biggest challenge in any food system is the elimination of spoilage and pathogenic microorganisms.

Table 1. List of clearances of irradiated mushroom in different countries

Country	Objective	Date	Permitted dose (kGy)
Argentina	Delay in ripening/physiological growth of fresh mushrooms	02/08/1994	3
China	Delay in ripening/physiological growth of fresh mushrooms	3011 1/1984	1
Croatia	Disinfestations of dried mushrooms	21/06/1994	1
Croatia	Microbial control in dried mushrooms	21/06/1994	10
Hungary	Delay in ripening/physiological growth of fresh mushrooms	15/04/1982	3
Hungary	Delay in ripening/physiological growth of fresh mushrooms of *Agaricus spp.*	15/04/1982	2.5
Israel	Shelf life extension of fresh mushrooms	17/02/1987	3
Korea, Rep. of	Disinfestations of fresh mushrooms	16/10/1987	1
Korea, Rep. of	Disinfestations of dried mushrooms	16/10/1987	1
Mexico	Delay in ripening/physiological growth of fresh mushrooms, Quarantine treatment	07/04/1995	1
Mexico	Shelf life extension of fresh mushrooms	07/04/1995	2.5
Poland	Shelf life extension of fresh mushrooms	04/07/2003	1-2.5
Poland	Reduction in microbial load in dried mushrooms	04/07/2003	3-10
United Kingdom	Disinfestations of fresh mushrooms	01/01/1991	2
Former Yugoslavia	Disinfestations of dried mushrooms	17/12/1984	10

[Food Irradiation Clearances Database, accessed date 11/11/2009, http://www-naweb.iaea.org/nafa/databases-nafa.html; Wilkinson and Gould, 1998]

Different studies exhibited great effect of irradiation at all dose levels on reducing microbial counts. The inactivation of microorganisms is achieved by hitting the genetic material of microorganisms by ionizing radiation, making it unable to multiply and terminating different cell functions [Meeroff, 2001]. The survival of a microorganism, after having sufficient ionizing radiation as gamma or electron beam, depends upon its enzymatic DNA repair system, the number of copies of a given gene within the DNA, and the given radiation dose [Molins, 2001]. The qualitative and quantitative changes in the microflora of mushrooms by irradiation contribute to overall increase in the shelf life of fresh mushrooms. Irradiation treatment was used by many scientists to lower total plate counts, coliform count, psychrotrophic counts, yeast and mold count and valuable results were found to ensure hygienic quality of fresh mushrooms [Byun *et al.,* 1990; Beaulieu et al. 1992; Gautam *et al.,* 1998; Koorapati *et al.,* 2004]. Effects of irradiation on the microbiological quality of mushrooms are illustrated in Table 2.

In regards to preservation methodology, usually a combination of different techniques is used to achieve the most optimum results regarding desired quality with minimum possible processing loss. The applications of irradiation in conjunction with other food preservation techniques were studied and were found to be more effective than an individual preserving method [Minnaar *et al.,* 1995). The combined heat and irradiation processes satisfactorily preserved mushrooms in cream and brine, in regards to the inactivation of *Clostridium sporogenes* spores [Minnaar *et al*., 1995; Wilkinson and Gould, 1998], which are considered as target organisms to eliminate, in canning process, in order to prevent food spoilage [McLandsborough, 2004]. Gamma irradiation of *C. sporogenes* spores with sub lethal doses increased their sensitivity to subsequent heat treatment. The degree of heat-sensitivity of this organism increased with the increase in radiation dose [Shamsuzzaman *et al.,* 1990].

Dried mushrooms are being used as popular seasonings but, in conjunction with the microorganism's threat, this commodity may also be damaged by several insect species, of which the moth, known as *Nemapogon granellus,* is the most important [Kovacs, 1991]. In order to make the dried mushroom insect free, a low dose of 0.5 kGy can retard the growth of moth's adults within 5 days after treatment [Boshra, 2007]. The dividing cells of insects are most sensitive to the irradiation while adult cells are comparatively resistant to irradiation [Hasan *et al.,* 2008]. Low dose of radiation causes DNA damage, resulting in the retardation of cell growth and multiplication, while higher doses may be required in order to produce immediate sterilization by causing insect death [Molins, 2001]. In order to avoid the spoilage of mushrooms during storage, and to ensure consumer safety regarding their consumption, irradiation of mushrooms may be a best possible option [Malec-Czechowska *et al.,* 2003].

Effects of Irradiation on Shelf Life of Mushrooms

Extended shelf life is a key factor for making any food commodity more profitable and commercially available for long periods of time at the best possible quality. The producer will benefit from the longer shelf-life to develop the market over greater distances. Mushrooms have a short shelf-life (1-2 days) due to post-harvest changes, such as browning, stalk elongation and cap opening

Table 2. Effect of irradiation on microflora of mushrooms

Type/dose of irradiation	Parameter	Results	Ref.
Gamma irradiation/ 2-3 kGy	Microbial counts	Decrease in microbial count initially and during storage period was strongly associated with doses & remained significantly lower than unirradiated control mushrooms for a period of up to 2 to 3 week.	Byun *et al.,* 1990
Gamma irradiation/ 2 kGy	Aerobic count and psychrotrophic count	Reduced aerobic counts by 5 to 9 logs and psychrotrophic counts by 6 logs immediately after treatment, and lower counts were maintained during the storage period of 10 to 11 d at 10 to 15°C.	Beaulieu *et al.,* 1992; Gautam *et al.,* 1998
Electron-beam irradiation/0.5, 1, 3.1, and 5.2-kGy	Total plate counts, yeast and mold, and psychrotrophic counts	Irradiation levels above 0.5 kGy reduced total plate counts, yeast and mold, and psychrotrophic counts to below detectable levels and prevented microbial induced browning.	Koorapati *et al.,* 2004
Gamma irradiation/ 1 kGy	Coliforms, total plate counts	Decreased microbial contamination, coliforms by ≤99.8% and total plate counts by ≤80.8%.	Czapski, 2007

[Patterson, 1990]. The shelf life extension regarding various vegetables, including mushrooms appears to be promising at dose levels of a few kGy or less within ambient storage conditions after irradiation [ICGGI, 1999; Miller, 2005]. A radiation dose of even 0.5 kGy can improve the sensory quality of fresh mushrooms, and provide an increase in the shelf life of 2 days at ambient temperature, while with respect to inhibition of stem growth and cap opening, leading to increased shelf-life, the dose of approximately 1 kGy was found most effective [Koorapati *et al.,* 2004].

The results of various experimental studies indicate that gamma irradiation could prevent the enzymatic browning of mushrooms and extend their shelf life by means of the inactivation of mushroom polyphenol oxidase (PPO), which is reported to cause enzymatic browning in mushrooms [Gautam *et al.,* 1998]. Mushroom PPO (tyrosinase) solutions, when irradiated by up to 10 kGy, PPO activities were significantly affected by gamma irradiation, while treatment of 5 kGy decreased the activity of this enzyme by 93%. This investigation has clearly demonstrated that the gamma irradiation dose rate has a significant effect on the PPO (polyphenol oxidase) activity, on the browning process and therefore, regarding the shelf-life of mushrooms. Low dose rate at 4.5 kGy/h provided more valuable effect in extending the shelf life in comparison to dose rate as high as 32 kGy/h. High dose rate causes the loss of the cellular membrane integrity, which would favor both the enzymatic and nonenzymatic oxidation of phenols and thus would be responsible for the more important browning processes at very high dose rates [Beaulieu *et al.,* 1999; 2002]. Recently Xiong *et al.* [2009] studied and concluded that peak levels of polyphenoloxidase activity were significantly lower ($p<0.05$) in regards to fruit bodies exposed to 1.2 kGy in comparison to non-irradiated controls. Another very important enzyme in regards to the mushrooms shelf life study is phenylalanine ammonia-lyase (PAL). Its activity in mushrooms is directly linked to the synthesis of phenols. Gamma-irradiation can cause a significant increase regarding PAL activity of mushrooms at early stages of storage, and as a result it also produces a significant increase in total phenolic content [Benoit *et al.,* 2000].

The use of the combination treatment of heat and irradiation was found to offer a feasible alternative to solely thermally processed or irradiated mushrooms, as their sensory and nutritional quality could be affected adversely by severe processing conditions [Minnaar *et al.,* 1995]. Food irradiation may be used quite effectively, in conjunction with other food preservation techniques, like the use of low or high temperatures to acquire maximum synergetic effect with minimum process losses [Minnaar *et al.,* 1996]. At lower storage temperature near 0°C, the slowing down of microbial growth and deterioration was observed in regards to mushrooms, but effective treatment as irradiation is required for mushrooms stored in excess of 5°C. An increase in the shelf-life of 5 days may be achieved, using a dose of 1 kGy, whereas a dose of 2 kGy extended the shelf-life of *Agaricus bisporus* mushrooms by 3-4 days, even at a relatively high storage temperature of 15°C. A low radiation dose of 0.5 kGy following ambient storage temperature of 22-25 °C can improve the sensory quality of fresh mushrooms as well as increase the shelf-life to 2 days [Wilkinson and Gould, 1998]. It is proposed that, in regards to low acid and freeze sensitive food commodities, minimum heat conditions required to cook the food should be combined with the maximum allowable limit of irradiation, while giving special consideration to nutrition and sensory qualities in order to achieve wholesome food products with longer shelf lives [Minnaar *et al.,* 1996]. There will be particular additional advantages regarding less nutrition loss, a longer shelf life as well as high consumer acceptability if this irradiation technique is used in conjunction with other preservation treatments such as low or high temperature in order to achieve higher quality products [Farkas, 1990; Patterson, 1990].

Effects of Irradiation on Sensory Quality of Mushrooms

Various scientists attempted to evaluate the effects of irradiation on sensory parameters of mushrooms [Beaulieu *et al.,* 1999; Koorapati *et al.,* 2004]. Kwon *et al.* [1990b] comprehensively studied the effects of gamma irradiation on fresh mushrooms (*Agaricus bisporus*), where volatile flavor components, identified by means of GC and GC-MS, were primarily composed of 1-octen-3-ol (68%), benzaldehyde (13%), 3-octanone (8%), benzyl alcohol (5%), 3-octanol (2%), and 1-octen-3-one (1%). Treatment with 2 kGy gamma-irradiation, and subsequent storage for 17 days at 9±1°C and 80±7% RH, resulted in appreciable changes in their contents, even though negligible changes were observed in regards to GC patterns between the nonirradiated and 2 kGy-irradiated samples. Sensory data, comparing irradiated mushrooms with nonirradiated controls showed that irradiated mushrooms had equal or superior flavor and texture to those of both raw and cooked samples [Sapers *et al.,* 2005]. It is also interesting to note that total volatile compounds in regards to dried shiitake mushrooms had been reduced by more than 50% after irradiation at doses of 5 or 10 kGy, whereas a sensory panel evaluation did not detect any significant differences in flavor between irradiated and non irradiated samples [Lai *et al.,* 1994]. Mushrooms have long been used as a food or food-flavoring material due to their unique and subtle flavors. Mau and Hwang [1997] tried to prove the reality of quality changes at different doses, and found that a dose of 0.25 kGy was ineffective in controlling senescence, while a dose of 2 kGy showed no significant improvement over 1 kGy in terms of keeping quality of mushroom (*Agaricus bisporus*). They found that characteristic volatile compounds present in mushrooms comprised of eight-carbon compounds, including 1-octanol, 3-octanol, 3-octanone, 1-octen-3-ol, 2-octen-1-ol, and 1-octen-3-one. Among them, 1-octen-3-ol is the most important compound associated with fresh mushroom flavor. Gamma irradiation of 1 kGy retained 48% of eight-carbon compounds and 47% of their 1-octen-3-ol contents. After the irradiation of mushrooms (*Agaricus bisporus*), this flavor loss was not easily perceived by consumers, due to the extremely low threshold of 1-octen-3-ol (0.01-0.43 ppm) in mushrooms. In addition, the 1-octen-3-ol contents of mushrooms usually decrease during postharvest storage [Mau *et al.,* 2006]. Moreover, postharvest treatments, such as refrigeration (4°C), can be combined with low dose gamma irradiation to increase shelf life of fresh mushrooms with minimum quality losses [Minnaar *et al*., 1996].

Discoloration of fresh mushrooms was observed after radiation treatment, but there was less color change during storage with the increasing radiation dose up to 3 kGy. Overall less color change was found in irradiated samples as compare to control ones [Kwon *et al.,* 1990a; Yoon and Kwon, 1990]. Irradiation prevented cap opening and lengthening of the stem, where as softening of tissue was observed but not significant upto 5.2 kGy [Brown, 2002; Kwon *et al.,* 1990c; Koorapati *et al.,* 2004]. The effects of irradiation on the color and texture of mushrooms are summarized in Table 3.

Low dose of 1.2 kGy can delay (by 6-9 days) significantly the onset of fruit body softening, splitting and browning in comparison to non-irradiated controls [Xiong *et al.,* 2009]. However, the different results could be attributed to the physiological age of the mushrooms at harvest, time elapsed between harvest and irradiation, different strains, storage conditions, and the type of radiation sources [Thomas, 1988].

In order to get best possible sensory quality, Minnaar *et al.* [1995] explored the effects of heat-irradiation combination on mushrooms. The use of heat-irradiation combination treatments, favoring low dose levels, were found to offer a feasible alternative to thermally processed or irradiated mushrooms in brine in terms of quality. Recently Wani *et al.* [2009] tested gamma irradiation, alone and in conjunction with sulphitation.

Table 3. Effect of irradiation on color and texture of mushrooms

Parameter	Type/dose of irradiation	Results	Ref.
Color	Gamma irradiation/ 2-3 kGy	Discoloration immediately after treatment, but linear preventive influence for discoloration during storage with increasing doses up to 3 kGy.	Kwon *et al.,* 1990a
	Gamma irradiation/ 4.5 & 32 kGy	4.5 kGy dose was more promising with respect to color change whereas very high dose could rupture cell membrane structure.	Beaulieu *et al.,* 1999
	Gamma irradiation/ 1 kGy	Respiration accelerated up to about 3 days after treatment and then slowed markedly, which was associated with low color change after 3 days and in overall shelf life of mushroom.	Campbell *et al.,* 1968
	Gamma irradiation/ 1- 3 kGy	Reduced respiratory activities of stored mushrooms linearly, and prolonged the peak development, overall less browning	Yoon and Kwon, 1990
Texture	Gamma irradiation/ 2-3 kGy	Effective for controlling natural maturation, senescence & weight loss for superior texture.	Byun *et al.,* 1989
	Gamma irradiation/ 1-3 kGy	Softening of tissue but not immediate effect on appearance with increase in shelf life	Kwon *et al.,* 1990c
	Gamma irradiation/ 1 kGy	Applied soon after picking at the closed button stage, gave the best results for retardation of cap opening and stem elongation.	Barkai-Golan, 1992
	Electron beam irradiation/ 0.5, 1, 3.1, & 5.2 kGy	Firmness of all samples was similar during storage except for the 5.2 kGy sample which was too soft.	Koorapati *et al.,* 2004
	Gamma irradiation/ 2-3 kGy	Inhibited cap opening and lengthening of the stem.	Brown, 2002
	Gamma irradiation/ 3 kGy	Caps of non irradiated samples became soft more readily during storage.	Narvaiz, 1994

They observed no synergistic effect of sulphitation and irradiation for preventing the enzymatic browning as well as maintaining other quality attributes of white button mushrooms during storage.

Detection Methods for Irradiated Mushrooms

Simple and reliable methods are required to identify irradiated foodstuffs as different countries have different legislative requirements for irradiated foods. Detection of irradiated food is considered to be necessary to facilitate the international food trade [Delincee, 1991]. In 1993, the European Commission mandated that the European Committee for Standardization (CEN) to standardize its methods regarding the detection of irradiated foods. These European Standards have been adopted by the Codex Alimentarius Commission as general methods [Code of Federal Regulation, 2004].

The detection of irradiation treatment in regards to dried mushrooms can be achieved by means of thermoluminescence (TL) measurement, photostimulated luminescence (PSL), and Electron spin resonance (ESR) spectroscopy methods [Delincee, 1991]. The thermoluminescence (TL) of contaminating silicate minerals of irradiated foods can provide very important information for detection of irradiated foodstuffs [EN 1788, 2001]. In a comprehensive study, about 300 lots of herbs, spices, berries, mushrooms and seafood were detected, with respect to possible irradiation treatment, by the TL method. Irradiated herbs and spices were easily differentiated from their nonirradiated counterparts, even after two years, with irradiation of a 10 kGy dose [Pinnioja, 1993]. The TL method has been validated by means of inter-laboratory trials regarding herbs, spices, their mixtures, fresh fruits, and vegetables (strawberries, avocados, mushrooms, papayas, mangoes, potatoes). As a result of the success of these trials, the TL method was adopted as the European Standard EN 1788 [Molins, 2001; EN 1788, 2001]. However, in some cases problems may arise, due to a limited amount of silicate minerals present in the samples. In regards to one inter-laboratory test, participating laboratories were only able to obtain valid results with respect to 97% of strawberries, 82% of avocados, 48% of mushrooms, 83% of papayas and 95% of mangoes, due to a restricted amount of sample or less amount of concerned inorganic material on sample [Sanderson *et al.,* 1997]. In practice, larger sample volumes will generally overcome these problems [Wilkinson and Gould, 1998], because the thermoluminescence signals regarding irradiated dried herbs and spices are recognized to be due to inorganic dust particles adherent to the surface. The discrimination between irradiated and unirradiated food samples can be enhanced by the preparation of TL samples enriched in extraneous inorganic material and further by the determination of the optimal integration interval giving the highest signal to background ratios. This method yields a more reliable discrimination than whole sample TL techniques [Dangl *et al.,* 1993].

ESR and PSL can both be considered as useful screening methods. Dried mushrooms, when irradiated with a dose of 7 kGy, provided specific, multicomponent ESR signals, whereas PSL may also be applied to discriminate some varieties of mushrooms. In case of positive results, the samples are most likely irradiated, while, if negative results are obtained, an additional detection method, such as TL measurement is needed to confirm the results. Thus, the most reliable method regarding the detection of an irradiation treatment of mushrooms is the thermoluminescence method [Malec-Czechowska *et al.,* 2003]. Frozen mushrooms exhibit significantly greater super cooling, monitored with a differential scanning calorimeter, than do unirradiated control samples. Although there is high variability, it is suggested that this method could have applications with respect to the detection of irradiated foods. The method has the advantage in that it can be applied to water-containing foods, and does not depend on the presence of dry materials, bones or minerals, as do electron spin resonance and the luminescence techniques [Wilkinson and Gould, 1998; Malec-Czechowska *et al*., 2003].

The DNA comet assay offers considerable promise as a simple, low-cost and rapid screening test regarding the qualitative detection with respect to the irradiation treatment of a wide variety of foods of both animal and plant origins. With respect to the mushroom spores of the *Agaricus bisporus* species, lysis of the cell wall was not achieved and, therefore, the comet assay could not be applied [Cerda *et al.,* 1997].

Safety of Irradiated Mushrooms

Consumer safety with respect to irradiated food commodities is a major concern related to the commercialization of this technology. Some people claim, based on the false or poor understanding of this technique, that it can make the food radioactive or can produce some very dangerous substances. However, research over many decades have proven that food irradiation is as safe as other common food preservation techniques. Various authentic studies has concluded that food irradiation can be considered to be a radiologically, microbiologically, and toxicologically safe type of technology [Ehlermann, 2005]. On the basis of research conducted in the United States and elsewhere, the safety and wholesomeness of foods irradiated under Good Manufacturing Practices has been confirmed by major health authorities, such as the FDA and the Codex. Due to the fact that, there is still consumer resistance to food irradiation because of improper awareness, product labeling is mandatory regarding irradiated food products [Xing *et al.,* 2007].

In a study, it was found that the inclusion of 20% of irradiated mushrooms in mouse diets, fed at late pregnancy and lactation stages, had no significant side effects on the average weight of the offspring at 40 days old, nor on their daily food intake and weight gain throughout the subsequent 6-week feeding period [Campbell *et al.,* 1968].

In order to determine the effects of food irradiation on humans, the human research volunteer model was utilized: eight experiments involving 439 volunteers consuming irradiated (0.2-8.0 kGy) foods, (rice, potatoes, peanuts, mushrooms, Chinese sausages, meats, vegetables and staple grain) accounting for 60-66% of the entire diet for periods of 7-15 weeks, were conducted in the people's Republic of China. No significant differences in regards to clinical signs of toxicity or chromosomal aberrations of peripheral blood lymphocytes were observed between the experimental and the control groups [ICGGI, 1999].

Consumers could experience the quality and longer shelf life of irradiated mushrooms and other produce items, if accompanied by educational material and presented by a retailer the consumer trusts. Then irradiated food would be acceptable to the majority of consumers [Taub and Singh, 1998].

Summary

Food irradiation is one of the best and safest food preservation techniques designed to ensure the provision of better quality mushrooms with an extended shelf life. It can also contribute significantly to community health, as the risk of food borne diseases can be minimized with the proper use of this advanced technology. Food irradiation is now being commonly used in many countries, as people are becoming more aware of the role of food irradiation in regards to food safety and product shelf-life extension. Labeling is necessary, so that people can freely choose whether to use this safe and wholesome processed food. Reliable methods for the detection of food irradiation are now available, and are effective in confirming compliance with regulations regarding food irradiation.

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