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The Effects of Food Irradiation on Nutrition and Health

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Abstract: Food irradiation is the process of exposing food to ionizing radiation at different doses in order to disinfest, sterilize, or preserve food. Administered hygienically at low doses, it extends shelf life and delays the ripening or sprouting of fruits and vegetables. At higher doses, it eliminates insects, moulds, bacteria and other potentially harmful micro-organisms that cause spoilage in foods. In today's increasingly densely populated world, where half of the global population lives in near-starvation conditions, the provision of sufficient and safe food is a high priority concern. Irradiation is a safe and effective method of food preservation used in many countries around the world. The present study examines the effects of the fast-growing irradiation technology on nutrition and health.

Key words: Food irradiation, nutrition, health, effect of food, conizing radiation

INTRODUCTION

Foodborne illness is a problem recognized by many as one of the leading health concerns facing consumers worldwide. World Health Organization (WHO) has estimated that 70% of all cases of diarrhoea in infants and young are attributable to consumption of contaminated food. Bacteria, such as *Salmonella* and *Campylobacter* and others, are primarily responsible for a rise in the number cases of foodborne illness in industrialized countries from 1965-1990, with an estimated 7000 annual deaths from salmonellosis in the USA alone (Kaferstein, 1997).

Disease Control and Prevention Center reports show that food-borne bacteria were responsible for 76 million cases of disease, 325,000 hospital cases and 5,000 fatalities observed in the US in 1998. The food-related *E. coli 0157:H7 (E Coli),* particularly, was found to cause 62,458 cases of disease, 1,843 hospital cases and 1,526 fatalities every year. The four types of bacteria known as *Campylobacter sp, Listeria monocytogenes, Salmonella nontyphoidal* and *Toxoplasma gondi* were found to cause 3,420,000 cases of disease and 1,526 fatalities annually (Anonymous, 2000).

Climatic changes, technological deficiencies, seasonal foods and vegetables and natural spoilage make it difficult for many countries to maintain stocks of high quality foods at all times. Therefore importance is attached to developing food preservation methods that will enable the long-term storage of foods without spoilage (WHO, 1994). The scientific and technological improvements of the last few centuries have provided us with technologies such as pasteurization, canning and freezing. The last link in this chain is irradiation technology, which was initiated in early 20th century and developed over the last 40 years (Siyakuş, 2004). The present study examines the effects of the irradiation technology on nutrition and health.

FOOD IRRADIATION METHOD

Food irradiation has been accepted as a viable alternative to traditional methods of food preservation in many developed and developing countries. The most important of these is the effectiveness of irradiation in reducing, if not totally eliminating, microbial pathogens in food. This is especially significant when applied to minimally processed foods, or to foods intended to be consumed raw. Elimination or reduction of foodborne pathogens in such foods is especially important to people with compromised immune systems, such as elderly, cancer patients and AIDS patients (ICGFI, 1999). The American Dietitians Association (ADA) has reported that the food irradiation method helps protect consumers from food-related diseases and increase the quality and safety of food. For these reasons over 50 types of food are currently preserved with irradiation in 47 countries (Anonymous, 2000).

Similar to other food preservation methods, irradiation can not increase the quality of non-fresh food, prevent possible future contamination, or make stale food healthy again. Additionally, it cannot be used effectively with all types of food. It can be used in combination with other preservation methods such as canning, cooling or freezing and with all packaging material. Irradiated materials do not turn into radioactive materials or leave residue (Anonymous, 2000; Çetinkaya, 2002).

FOOD IRRADIATION IN TURKEY

The "Food Irradiation Regulation" has been effective in Turkey since 6 November 1999 when it was issued with the cooperation of the Ministry of Health, Ministry of Agriculture and Rural Affairs and Turkish Atomic Energy Agency (Siyakuş, 2004). Projects pertaining to food preservation and decontamination with irradiation technology have been undertaken in Turkey since the early 1960s by various universities and research institutes supported by the Turkish Atomic Energy Agency (TAEK), State Planning Organization (DPT), the Scientific and Technological Research Council of Turkey (TUBITAK) and national and international organizations (FAO and UAEA). The country owns two gamma irradiation centers known as the Nuclear Agriculture and Stockbreeding Research Center in Ankara (ANTHAM) and Gamma-Pak AŞ in Tekirdağ-Çerkezköy. Gamma-Pak AŞ obtained their food irradiation permit from the Ministry of Agriculture and Rural Affairs in March 2002 and is currently undertaking commercial food irradiation (Çetinkaya, 2002). The foods permitted to be irradiated under this arrangement are apple, peach, avocado, pork, beef, meat products, poultry and poultry products, banana, cereals, cherry, corn, blackcurrant, fish, fig, dried fruits, garlic, grape, ginger, lemon, mango, melon, onion, orange, plum, date, pineapple, potato, rice, tomato, shrimp, flour, wheat and vegetables (Anonymous, 1999).

FOOD IRRADIATION TREATMENTS

Food irradiation treatments are performed in hygienic environments and at the correct dosage, with the aim of eliminating or reducing the activity of microorganisms and biochemical events causing food spoilage, to prolong shelf life, to delay ripening and sprouting, or to ensure another target change (Anonymous, 1999). Food irradiation treatments use 3 main techniques (Aydın, 2002):

- Radurization (0.5-10 kGy): A low-dosage treatment, used mainly to prolong the shelf-life of food.
- Radicidation (3.0-10 kGy): A treatment performed with the aim of eliminating certain pathogen microorganisms.
- Radappertization (25 kGy and higher): A high level dosage to achieve a sterilization-like effect (Anonymous, 1999).

How is food irradiated?: Irradiation basically means exposing food to radiant energy. In this process, food passes through a closed room where it is exposed to ionizing radiation. This ionized energy source may be cobalt 60 gamma rays (^{60}Co), cesium 137 (^{137}Cs) x rays or machine based electrons (Anonymous, 2000). All three of these sources can inactivate disease and spoilage-causing microorganisms without causing harmful changes in the food. In all three treatments, the food remains uncooked and is clear of residue (Anonymous, 2002). The most commonly used source is ^{60}Co. This infuses into food and eliminates unwanted bacteria. Only a small amount of energy is required and the treatment does not lead to any changes in the structure of the food or an increase in its temperature. Lower doses over 1 kGy are used in the elimination of the parasite *trichina* in fresh pork, in delaying sprouting in fruit and vegetables and in controlling insecticides and pesticides. Moderate doses over 10 kGy are used in controlling bacteria in meat, poultry and other foods while higher doses are used in controlling microorganisms in flavorings, spices and dried vegetables (Anonymous, 2000).

THE ADVANTAGES OF FOOD IRRADIATION

The treatment of foods with ionized energy benefits consumers, food producers and sellers. The greatest advantages are increasing the microbiological quality of the food, inactivating microorganisms that cause spoilage in food and prolonging shelf life. Meat products, water products, grains, legumes, fruits and vegetables can all be preserved using this method (Anonymous, 2000; Kozat 2002). When bacteria, moulds, fungi and insects are inactivated with irradiation, the hygiene quality of a food is enhanced and it is safer to consume (ICGFI, 1999; Kozat, 2002). Irradiation of ground beef, turkey and other products at 2 kGy has been shown to be very effective against *Campylobacter jejuni* (Lambert and Maxcy, 1984). *Listeria monocytogenes* and *E. Coli* serotype 0157:H7, pathogens can be easily eliminated by irradiation at medium doses in a variety of products (Radomyski *et al.*, 1994).

Irradiation treatments also minimizing the possibility of cross-contamination between food items in homes and public eateries such as schools, hospitals or restaurants. In addition, irradiation does not cause any color change to fruit and vegetables, while tropical and semi-tropical fruits have a longer life. Less product loss and prolonged shelf life leads to reduced costs (Anonymous, 2000).

Studies about the nutritional value of irradiated foods have found no changes in macromolecules but identified loss in micro molecules (vitamins). Certain precautions, such as ensuring lower temperatures and eliminating oxygen, can be taken to reduce vitamin loss (Kozat, 2002). The changes in the nutritional value of irradiated foods are at the same level as those in foods preserved through other methods (Anonymous, 2004). Irradiation does not leave toxic residue in foods, necessitates a lot less energy than other food preservation methods and can be used in combination with them (Kozat, 2002). Irradiation can replace the use of additives in certain foods or require less of them. For instance, when used with products such as salami or sausages, less nitrite is required for their preservation. This additive is used in meat products not only to add color and flavor but at the same time to eliminate the *C. Botilinum* toxin. With irradiation, this toxin is easily eliminated and less nitrite is therefore required to add color and flavor (Anonymous, 2000; Kozat, 2002).

Foods preserved with irradiation do not require additional temperature treatment. Therefore changes to the flavor, odor, color and texture of foods are minimal. Irradiation can also be used on packaged and frozen foods. With fresh foods, it can be used exclusively with no need for other chemical preservatives (Anonymous, 2004).

LIMITING FACTORS IN FOOD IRRADIATION

Food irradiation has its limits, just like other technologies (ICGFI, 1999). Various unwanted flavor, texture or color changes seen in foods are known as "limiting factors in food irradiation". To illustrate, high doses of radiation lead to color and flavor changes in meat, while in milk or other dairy products it leads to organoleptic changes. Similarly, certain fruits such as some citruses, avocado, pears, plums and melons are not suitable for irradiation as they become soft when free calcium is released as a result of the disintegration of polysaccharides such as pectin when radiation is used. However, in some other cases, the changes caused by irradiation may cause products to gain new characteristics. For example, irradiated dried fruits and vegetables need less cooking time; irradiated fresh fruits have more juice; and bread made from the flour of irradiated wheat yields bigger loaves of bread (Kozat, 2002). It has not been shown to be effective for inactivating toxins or other chemicals that may pose a threat to our food supply. Similarly, it has not been found effective in destroying viruses at the doses that are in use for decontamination of foods from bacterial pathogens. Irradiation, although very effective in eliminating bacterial contaminants, cannot guard the food against contamination after processing through contact with unsanitized surfaces or hands

THE EFFECTS OF IONIZING RADIATION ON FOOD CONSTITUENTS

Irradiation has arisen as a versatile preservation method which can potentially be used in many areas of food production and agriculture. Irradiation is used to preserve the initial positive qualities of the food and can be successful through the use of appropriate doses. Due to the low energy it involves, ionizing radiation is not presumed to have a serious effect on the nutritional values of macro constituents of food (Halkman, 2004). Loss of nutritional value is minimal as the treatment does not increase the temperature of the food. Indeed, less nutritional value loss is seen in irradiation than in canning, drying, pasteurization or sterilization. While no significant change has been observed in proteins, fats or carbohydrates, heat-sensitive elements such as vitamin B and ascorbic acid are sensitive to irradiation (Anonymous, 2000).

NUTRITIONAL VALUE LOSS IN VARIOUS IRRADIATED FOODS

Fruit and vegetables

Mangoes: Irradiating mangoes at 0.1-0.6 kGy prolongs their shelf life by 4-7 days while irradiating them at higher doses than this up to 2 kGy causes changes in their organoleptic quality. When compared to the losses observed in frozen and heat-treated mangoes, the loss caused by irradiation was seen to be less (Mutluer, 1989).

Strawberries: Irradiation does not cause any changes in the evaporation profile or chemical constituents of strawberries (Mutluer, 1989).

Oranges: Irradiating orange juice at 2 and 7.5 kGy leads to a loss of 23.2 and 47.7%, respectively, in its vitamin C content. Doses between 1-2 kGy lead to brown stains on the skin of oranges (Mutluer, 1989).

Tomatoes: While irradiating tomatoes at 1.5-3 kGy causes very few, if at all, changes in their vitamin C content, pH or sugar concentration, it leads to an increase in their pores and spoilage (Mutluer, 1989).

Carrots: Irradiating carrots at 0.75 kGy prolongs their storage and leads to no changes in their sugar, nitrogen and free amino acid and pectin fractions. Their vitamin C and β-carotene content is affected only marginally at 0.8 kGy (Mutluer, 1989).

Potatoes: FAO/IAEA/WHO committee of experts unconditionally accepted the irradiation of potatoes against sprouting in 1976. No nutrient loss was recorded for potatoes as a result of irradiation. Their vitamin C and niacin levels were found to be the same as others treated chemically. Irradiation at 0.1 kGy was observed to increase the normal vitamin C loss of storing by 28% and irradiation at 0.15 kGy by 56%.

Onions: Irradiating onions at 0.05 kGy does not lead to significant changes. However doses of 0.02-0.6 kGy increased the ascorbic acid loss of onions irradiated in aired environments without causing significant changes in their nutritional value (Mutluer, 1989).

Cereals

Rice: Irradiation causes up to 22% loss in thiamine, riboflavin, niacin and pyridoxine. Irradiation performed for the purpose of insect control does not lead to positive or negative changes in aroma, flavor, color or texture (Mutluer, 1989).

Poultry and meat: Irradiated and sterilized poultry and beef do not contain anti-thiamine characteristics and irradiating meat at -40°C leads to very few and acceptable changes in meat proteins (Mutluer, 1989). Fidancı (1998) irradiated pieces of poultry at 3 kGy gamma radiation and stored them for different amounts of time On the 7th day of storage, a slight flavor and odor change was identified. In another study, Fox *et al.* (1995) compared the vitamin B levels in beef, lamb, pork and turkey after irradiation and found that the loss was minimal below 3 kGy. The loss of thiamine, on the other hand, was between 8 and 16%.

Mackerel: Irradiated at 1-45 kGy and kept in plastic bags at-22°C, these fish do not display any changes in amino acids, digestibility, biological values and protein use. Although niacin remains stable at higher doses, 3 kGy causes a loss of 15 and 26% in thiamine and pyridoxine, respectively (Mutluer, 1989).

Shrimps: Irradiated at 2-45 kGy and stored in different temperatures and levels of humidity, shrimps have been shown to lose a small amount of tryptophan.

Paprika and spices: Irradiating paprika at 5-50 kGy at 0-22°C and storing it for 6 months does not cause a significant change in its karotenoid content. Sterilizing various spices at doses up to 10 kGy does not cause any changes in its evaporating oil, aroma or flavor (Mutluer, 1989).

FOOD SAFETY AND IRRADIATION

Food safety denotes not only how safe a certain type of food is to consume, but at the same time its nutritional, sensory and technological characteristics supporting consumer well-being. At the end of a number of internationally coordinated studies, JECFI resolved in 1980 that any food treated with up to 10 kGy ionized radiation is safe to consume and does not lead to nutritional or microbiological problems, therefore eliminating the need for more toxicological studies (Anonymous, 1981; Iç, 2002). The WHO consultation of experts confirmed this in 1992 and added that no safety deficiencies were reported to date. No study has yet concluded that processing food with ionized radiation presents a risk for consumption (Ehlerman, 1999).

CONCLUSION

As a result of the research studies, developments and debates of the last decade, food irradiation has arisen as a viable alternative to overcome obstacles in food trade and meet the nutrition needs of the ever-increasing world population. The most significant benefit of this innovative technology is the protection it affords to solid foods, particularly animal products, from insects. It is also a very effective weapon against food-borne diseases. Irradiation requires less energy than other conventional food preservation methods in ensuring food quality and safety and can also be used in combination with them (Loaharanu, 1999). Organizations such as the WHO, the Institute of Food Technologists and the American Medical Association, among many, have endorsed this technology for the enhancement of food safety that it offers. People have a right to consume nutritious and safe food and thus they need to be informed about this new technology (ICGFI, 1999).

The American Dietitians Association, nutrition and diet experts, health personnel and all food-related organizations are responsible for informing consumers, food producers and sellers about the safe application of this technology (Anonymous, 2000). They must understand the problem before they can be expected to accept a solution. Education regarding foodborne illnesses and the effectiveness of irradiation should, therefore, go hand-in-hand. Products that have government approval must be made available to consumers. Academia, government, industry and activists should work together to bring irradiated foods to the marketplace. These groups are also consumers: they should have the right to choose whether to purchase products made safer by this technology. In previous studies, consumers have stated that they find safety and flavor of irradiated foods more important than their costs and elimination of unwanted bacteria more important than prolonged shelf life. Supermarket surveys have shown that consumers who understand the benefits of irradiated foods are more willing to buy them. Still, greater consumer education and awareness is required in this area (ICGFI, 1999).

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