Food irradiation: a disconcerting technology.

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Abstract

Traditionally, food products are mainly preserved by heating and cooling. With advancements, newer technologies of preservation have been discovered and used, which include pasteurisation, blanching, and sterilisation as modes of heating. Freezing and chilling are modes of cooling; apart from that, chemicals are extensively used. As these processing techniques may reduce the nutritional value of food, minimal food processing techniques have been developed. Irradiating food is one of the tools for minimal processing. It holds higher captivity and is controversial as it uses ionising radiation to sterilise the commodities. It is often perceived as bilateral, meaning that a greater and higher degree of sterilisation can be obtained than with any other method. Later, nutritional destruction, adding junk calories, and the formation of radiotoxins raise major concerns. "Good Food Doesn't Need Irradiation".

Keywords: Food Irradiation, Food Preservation, Nutritional Loss, Health Hazards.

Introduction

Food is consumed for survival and nutritional purposes. Foods are of divergent origin, whether from plant or animal sources. Food in its constitute contains moisture, protein, lipids, carbohydrates, vitamins, minerals, and other organic substances. Various physical, chemical, and biological parameters in and out of the food induce spoilage. Spoilage in terms of affecting its nutritional profile and sensory properties and making it unfit for human consumption [1]. Several approaches have been made and numerous techniques developed to stop food spoilage, maintain nutritional value and safety, and ultimately meet the demands of consumers. Preservation methods tend to extend the shelf life of food products while maintaining their integral properties and safety. Throughout the centuries, food preservation techniques have been continuously evolving to keep up with the tremendous rate of population expansion [2]. Irradiation of food is one of those methods of preservation. Researches on irradiating food dates back to the turn of the century. Initial patents for the application of ionizing radiation to destroy bacteria in food were issued by the U.S and British in 1905. The U.S. Food and Drug Administration (FDA) approved the sale of irradiated wheat and wheat flour in 1963, which marked the beginning of the technology's widespread application in the food processing industry [3]. Food that has been subjected to ionising radiation is referred to as irradiated food [4]. The possibility of irradiation to maintain food hygiene, minimize the losses from post harvest, enhance exports, adhere to quarantine requirements has been considerably noticed by several countries [5]. Like other food processing methods, irradiation can cause alterations to organoleptic properties and nutritional profile of the food commodities [6]. Research also states they induce generation of radiotoxins [7]. Physical, chemical, biological, and functional alterations noted in irradiated food are mainly due to the uncontrollable energy released during the process [8]. Presently, irradiation techniques have been recognised for use in nearly 55 countries. However, this technique is still disputable due to its potentiality to promote alteration of food qualities, the synthesis of toxic compounds, the fall out of risky processes, and its involvement with the nuclear establishment [9]. The purpose of this research is to highlight the impact of ionising radiation on the nutritional qualities of food.

Food irradiation

Food irradiation is a technique in which food products, packed, whole, or pre packaged are exposed to controlled doses of ionizing radiation such as gamma rays, X-rays or electron beams. Irradiation of foods has direct and indirect effect on the microbes, insects and parasites, which may impose a preservative effect [10].

The principle action of inactivation or destruction of microbes is primarily due to destruction of nucleic acids, cellular membrane and oxidative radicals originated from radiolysis of water [11]. (1) Gamma radiation from cobalt-60 (60Co) with maximum energy of 1.17 and 1.33 MeV, and cesium-137 (137Cs) with energy of 0.662 MeV; (2) accelerated electrons with a maximum energy of 10 MeV and (3) X rays with a maximum energy of 5 MeV are the common sources of ionizing radiations approved for food products [12]. Irradiation doses is the amount of dose absorbed by food when it is exposed and the dose employed depends on various factors such as source of ray, time of exposure, absorption capacity and secondary reactions [13]. To irradiate commodities, three dosage ranges were employed.

Table1. Various dosage of irradiation [2] [14] [15] [16].

Dose level	Purpose	Commodities
1. **Radurization** Low Dose (up to 1 kGy)	Prevent sprouting of garlic, onions and potatoes. Post harvest destruction of insects and larvae in cereals flour, fruits and vegetable. To slow down ripening. To kill parasites.	Ginger, bananas, mangoes and other non-citrus fruits, cereals Potatoes, onions, garlic, pulses, dehydrated vegetables, dried fish and meat, fresh pork.
2. **Radicidation** Medium Dose (1-10 kGy)	Rapid destruction or inactivation of pathogenic microbes associated with food spoilages.	Dehydrated vegetables, fresh/frozen seafood, fish, raw/frozen poultry and meat, strawberries, grape.
3. **Radapertization** High Dose (10-50 kGy)	Sterilization of food for special purpose, food for immunocompromised patients.	Sterilized food.

Effects of irradiation on food components

The ionizing radiations employed primarily destroy microbes but also have an impact on the components in the food and carries out various reactions. Research studies find that low dosages up to 1 KGy had no such significant changes in the nutritional profile, whereas moderate and higher dose levels may cause reductions in nutritional components [17]. These effects widely depend on the molecular compositions of food, packaging materials used, and pre- and post-processing factors [18].

Macronutrients

Carbohydrate

Carbohydrates are the least sensitive macronutrients to irradiation. Oxidative degradation and hydrolysis are the major effects on carbohydrate; depolymerisation of polysaccharides and cellulose is more prone to enzymatic hydrolysis [19]. When subjected to irradiation, some of the glycosidic linkages that connect the monosaccharide break, lowering the degree of polymerization and increasing the viscosity of polysaccharide solutions [20]. With higher dosage the solubility of the solution increases [21] and amylose content decline rapidly [22]. Irradiation has a tendency to break down high molecular weight carbohydrates into smaller components. Through the breakdown of cell wall components, this process is responsible for the softening of fruits and vegetables [23]. In solid state carbohydrate shows modifications in both sensory and organoleptic properties; it is interesting to note that all the irradiated samples fluoresced; it is due to excitation of molecules and probable formation of free radicals [24]. There are many reports on the formation of malonaldehyde from radicals derived from carbohydrate [25]. Irradiation increases the content of malonaldehyde in a variety of food products [26]. Further increasing concentration of malonaldehyde initiate skin carcinogenesis [27].

Protein

Physiochemical properties of proteins are modified by irradiation. The formation of free radicals, breakage of covalent bonds, amino acid oxidation, rupture of peptide bonds, structural and chemical changes occur when proteins are exposed to irradiation [28]. Ionising radiation prompts cleavage and aggregation of protein molecules, as reported by physicochemical research [29][30]. Peptide bonds linking amino acids breakdown at increasing dose levels, resulting in protein coagulation [31], however the recommended level of dosage does not results in such damages [32]. Methionine, leucine, histidine, arginine, threonine, and phenylalanine were more sensitive to irradiation and cystine, tyrosine, tryptophan and aspartic acid are more radio resistant [33]. The source of hydrogen sulphide and other volatile sulfur-containing substance which produce off-flavor are produced due to oxidation of sulphur-containing amino acids. [34].

Lipids

Lipid peroxides are produced when fats are exposed to irradiation. The generation of peroxides is largely dependent on various parameters, such as lipid content, dosage used, oxygen levels, temperature during the process, and antioxidants [35]. Lipids from animal origin undergo rapid peroxidation, and unsaturated fatty acids are faster oxidised than saturated ones [36]. OH radicals induce peroxidation and subsequently followed by production of hydroperoxides [37]. A research revealed that lipid hydroperoxides are associated with cell cytotoxicity [38]. Free radicals are also produced from irradiated lipids, which on reaction with oxygen, form carbonyl compounds that mark undesirable modification in the nutritional and sensory profile of food [39]. Peroxide and TBA values steadily increase with dosage and upon storage [40]. Due to structural changes, the splitting down of double bonds leads to an increase in trans fatty acid and free radical content [41]. Examining the composition of fatty acids prior to and following irradiation shows a reduction of polyunsaturated fats, which are vital fatty acids [42].

Micronutrients

Vitamin losses are the most critical challenges confronting the processing sectors, which are a major concern. Fat soluble vitamins A, D, E and K are more stable than water soluble vitamins B, and C [43]. Vitamins are destroyed during irradiation and later on during storage.

Vitamin B and C are readily oxidised during irradiation [44]. The impact on B complex vitamins, were extensively reviewed [45] [46] [47]. It has been well documented the thiamine is more radiolabile and lost in irradiated foods [48]. Even at the lowest radiation dosage (0.5 kGy), substantial reduction of thiamine was observed in corn and chickpea. [49]. The amount of thiamine level in meat products was lowered by 47% upon 6 kGy dosage, 10% during cooking, and 54% following heating-irradiation combined. Thiamin has been demonstrated to be the most radio sensitive water soluble vitamin. Oxidative stress is considered to be the major causes for its destruction. When thiamin is exposed to irradiation a drop in spectrophotometric absorbance suggests that its pyrimidine ring has been disrupted, depletion of the amino group generates ammonia. Further researches states that 6 amino group of pyrimidine component of thiamine is the source of ammonia [50]. Destruction of thiamine is lower when frozen or chilled meat is irradiated [51]. Wheat retains 90% of thiamine, niacin, and riboflavin after being irradiated with a higher dosage up to 200 KGy [52]. Riboflavin and niacin were more resistant to irradiation [53]. Chicken breasts and Pork chops exposed to irradiation at dosages of as high as 6 kGy at temperatures around -20 °C and +20 °C displayed no depletion of riboflavin, Surprisingly the concentration of riboflavin even increases up to 25% [54]. Further, it was noted that fruits exposed to radiation of up to 2 KGy also had a rise in niacin content [55]. When cod fillets or ground mackerel were exposed to radiation at 0°C at dosages of as great as 10 kGy, there was either no change or small increases in the amount of niacin in the fish muscle [56]. Various studies demonstrate that niacin is more resistant than riboflavin, and the destruction of those vitamins occurs when the dosage exceeds 10 KGy [57]. Irradiation losses of pyridoxine are less than those of thiamine, but the destruction of pyridoxine is much more similar to that of riboflavin at higher dosages exceeding 10 KGy [58]. But more intensive studies suggest that even at lower dose levels, there were losses [59]. On contrast to it another study [60] found that it was not significantly affected at dose less than 10KGy. Folic acid degradation was observed at all dosage ranges [61]. In liquid state cobalamin is found to be radiosensitive [62]. Among all the vitamins ascorbic acid is the most sensitive in all food processing and also in food irradiation process [18]. Ascorbic acid content declines rapidly with increasing dosage levels [63]. One research implies the reduction of ascorbic acid is due to metabolic breakdown of the tissues rather than irradiation [64], another study states, irradiation initiates metabolic oxidation pathway which degrades ascorbic acid to dehydroascorbic acid [65]. No losses of vitamin C at sprout inhibition doses observed in onion, garlic and potato [66]. Studies concludes that the sensitivity of ascorbic acid depends on various elements, which includes the alteration in pH level, temperature changes during processing, and oxygen reactivity [67].

The fat-soluble vitamin E was the one that was most vulnerable to radiation. Carotenoids which are the precursors of vitamin A, found in papayas, potatoes, and mangoes. After irradiation with a lower dosage, there were no observed effects on carotenoids levels, but up on frozen storage post irradiation, there is a reduction in carotenoids levels of around 30% and 90% on canned papayas [68] and in case of potatoes 50% losses occurred on storage [69]. Studies claimed a decline of 70% of rectinol, 41% of carotenoids, and 60% of vitamin E after irradiating whole milk with 400 KGy [70]. Even at a lower dosage of 0.25 KGy, γ-tocopherol content of garlic has a significant reduction [71]. Among fat soluble vitamins, vitamin D has the highest stability to irradiation. It have been reported that form of vitamin D vitamin D2 (Ergocalciferol) increases post-irradiation in mushrooms [72], but the mechanism behind it is not still known. Decades of research studies shows there was considerable destruction of crucial vitamins in irradiated foods, major loss of ascorbic acid and thiamine were observed.

Conclusion

Food irradiation studies have demonstrated its higher efficiency in the preservation of food through the destruction of microbes. There might be a loss of essential nutrient components like vitamins that affects the nutritional profile of food products. If consumption of irradiated foods continues, there will be increasing cases of malnutrition complications will heighten. It can be stated that the nutrient losses during processing can be substituted by methods of fortification or nutritional enrichment, but that does not hold any significant value for the consumption of those foods. The microbial toxins that are already present in foods are not destroyed by irradiation, which raises a major issue about food intoxication. Long-term consumption holds insignificant value, with loads of radiotoxins and a higher risk of carcinogenicity. The prescribed dose of irradiation by the regulatory agencies does not destroy the microbes to a greater extent. Furthermore, the radiation doses used by the manufacturer are not stated in the package label; only the radura symbol is displayed, which raises the question of reliability. Considering the potential health hazards and effects on food components, it is not a wise choice to opt for irradiation. Other conventional methods can be used. All research studies state that lower doses have no effect on food or health and clearly state that more intensive research studies are required, which is inconclusive, and no long-term intensive studies have been conducted to date. These insufficient research gaps and reports should not be used as a tool to hide the cross-contamination, intentional adulteration, and poor sanitary hygiene of the food processing industry. "Good Food Doesn't Need Irradiation".

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