4. EFFECTS OF IRRADIATION ON FOOD NUTRITIONAL COMPOSITION

The radiation techniques have been widely studied and, like most food processing techniques, can induce some changes that are able to modify the chemical and nutritional characteristics on foods. These changes are dependent on some factors such as the radiation dose, the constitution of the irradiated food, the type of packaging, and how it was processed, besides the variables of the process as temperature and oxygen saturation on the atmospheric. Activists and consumers have been questioned about the nutritional value of foods submitted to these processing techniques. The main questions and hypotheses about the use of irradiation are related to the excessive denaturation of nutrients, the conception that there is generation of toxic substances in irradiated foods, and they became radioactive. However, research conducted since the 1950s does not confirm these hypotheses of radioactivity in food, demonstrating there is no induction. Thus, the radiation methods used in food are considered safe and effective, according to several agencies such as the Food and Drug Administration (FDA) and the United Nations (UN).

Among the advantages cited by studies related to food irradiation are the minimal changes caused in food constituents. According to research, macronutrients—carbohydrates, proteins, and lipids—are relatively stable when they come in contact with doses of ionizing radiation up to 10 kGy. Regarding to micronutrients, in particular vitamins are perceived since they are sensitive to any processing technique. Thus, vitamins are unstable in food and dependent on specific arameters such as the cooking time or time of exposure to the method, pH, temperature, and among others. The water-soluble vitamins are labile to any process technique, and the fat-soluble vitamins are destroyed by the radiation methods.

4.1. Macronutrients

When food is irradiated, its components may be subject to significant changes. Among the existing macronutrients, the carbohydrates are less sensitive to radiation. Some of the glycosidic bonds linking the monosaccharides break when exposed to radiation, reducing the degree of polymerization and subsequently increasing the viscosity of polysaccharide solutions. Regarding proteins, the amino acid chains can be altered in the presence of water, due to electron transfer, and might accelerate the denaturation protein process by altering the secondary and tertiary structures before destroying the amino acid chains. Nevertheless, the denaturation is less intense than in a thermal processing. In the case of lipids, in the presence of oxygen, radiation processes can accelerate oxidation, and other reactions such as the production of free radicals, the formation of hydrogen peroxides, and the destruction of compounds as carboxylic acids and antioxidants. Thus, radiation processes are not recommended for products with a high fat content [49, 50]. The effects of UV-C on the composition of macronutrients in eggs were evaluated, demonstrating that cholesterol is oxidized to cholesterol oxides in contact with UV-C light, presenting reduction in doses higher than 5.910 J cm−2. In addition, UV-C light seems to be able to generate vitamin D3 (cholecalciferol), from the precursor 7-dehydrocholesterol. However, further testing may be required to identify oxidation products and to evaluate the production of vitamin D3 [51]. Unlike the results found for UV-C light applied in eggs, in pasteurization, cholesterol levels remained almost unchanged in the temperature range of 110–120°C, and less than 10% was oxidized after 80 hours of heating, corroborating with the fact that cholesterol is quite resistant to heat up to that temperature. However, cholesterol levels are extensively oxidized by exceeding the temperature range [52]. In relation to the protein content, it was observed that in the presence of oxygen, the total amount of protein decreased, occurring an aggregation of the proteins, and after the UV-C treatment, this situation indicates that some sulfhydryl groups were oxidized to the formation of new disulfide bonds [51]. Analyzing the effects of UV-C light on cow's milk and comparing the results with the pasteurization treatments, it is possible to visualize there was no change in fat concentration. On the protein content, there were no significant changes when compared to the samples treated with ultraviolet against the raw milk. Therefore, it is suggested that ultraviolet radiation is an alternative to traditional heat treatments, for better preserving the nutrients, unlike pasteurization that causes nutrient loss. The effects of gamma radiation on milk proteins demonstrate that solubility decreases, probably due to the denaturation and agglomeration of proteins. A study was conducted on the effects of agricultural production systems (organic and conventional), UV-C radiation and different types of drying (greenhouse and lyophilization) in grape waste and flour formulated from the wastes. The results showed, regardless of the method, there was no interference in the fiber contents, but it was observed that the samples that were produced by the method of organic cultivation with application of UV-C light showed a higher protein content. The effects of different thermal treatment methods were conducted in beef and chicken burgers cooked in microwave, conventional oven, and fry in oil. Samples of the two types of burgers submitted to microwave process obtained the highest loss of moisture, weight, and greater degree of retraction. In the chicken burger, the loss of moisture resulted in higher percentages of fat, protein, and ashes. In the beef hamburger, the highest percentage of proteins and ashes were observed in the microwave treatment, while the highest percentage of lipids was found in the oil frying treatment. Studies on the application of UV-C light to tilapia fillets demonstrated that this type of treatment was not able to increase lipid oxidation due to the low fat content in this type of food. Regarding the protein content, UV-C light provided an increase in the carbonyl content with changes directly related to the doses of applied radiation, presenting a pro-oxidant action. Action that can be explained by the capacity of stimulus of generation and reactivity of oxygen species, causing the protein oxidation, raises carbonyl formation. In the literature, the oxidative effect of proteins and lipids has a direct connection and might vary according to the protein and lipid composition and pro-oxidant and antioxidant compounds of a food. Therefore, these chemical modifications promoted by UV-C light depend on the nutritional composition and the dose to be used.

4.2. Micronutrients

At commercial doses, gamma irradiation causes no higher nutrient loss than the other methods used in food processing. The destruction of vitamins from the use of ionizing radiation applying doses of up to 60 kGy does not differ from the degradation generated from the cooking process. The degradation of vitamins presents varied sensitivity to gamma radiation, since this level depends on the doses used and the state of matter from the food analyzed. The fat-soluble vitamins in descending order of sensitivity to gamma radiation are Vitamin E > Vitamin A > Vitamin D > Vitamin K. While the order of sensitivity of water-soluble vitamins is thiamine > ascorbic acid > pyridoxine > riboflavin > cobalamin > nicotinic acid. However, studies related to the effects of radiation on the content of vitamins are still inconclusive. In order to minimize nutrition losses and negative effects on sensory quality, some factors are applied, such as the use of low doses (less than 10 kGy) of gamma radiation and controlled conditions of process such as temperature and presence of oxygen.

Among the nonthermal technologies used in food, UV-light treatment presents great commercial potential as an alternative for thermal treatments in liquid foods, such as pasteurization. However, as well the other methods used in food preservation, UV-light causes changes in the vitamin content. UV-light treatment has been shown to be able to significantly alter vitamin content in milk samples when compared to the traditional pasteurizing process. The vitamins present in the cow's milk in descending order of sensitivity are C > E > A > B2. However, the number of samples passes through the UV-C system and the initial vitamin concentration in a sample are important factors to affect the level of loss in vitamin content.

The minerals present in foods (i.e., iron, phosphorus, and calcium) are not affected by technologies that employ radiation. No more data were reported in the literature relating the effects of irradiation on vitamins and minerals, and more studies are needed.

4.3 Antioxidant activity

The relationship between the treatments that use radiation and the antioxidant content of foods is still inconclusive. Several studies discuss that radiation treatments have demonstrated the decrease or increase in antioxidant activity of foods, and these variations are related to the type of treatment, the dose of radiation used, the exposure time, and the composition and state of matter of the raw material. With positive effect, it is proven that the ultraviolet radiation, when applied in appropriate conditions, is able to increase the antioxidant capacity of fruits and vegetables, being a technology with commercial potential to be used in post-harvest stages in order to extend shelf life and increase quality, such as papaya, grape, and pineapples. Supposedly, UV-C radiation is able to increase phenolic content and antioxidant enzymatic activities as a defense mechanism against oxidative stress, thus increasing the antioxidant activity of vegetables. In commercial doses, it is not possible to obtain conclusive answers regarding the effect of gamma radiation on the content of the antioxidant activity in foods. However, most of the studies mention gamma radiation as a conservation method related to the increase or maintenance to the potential of the antioxidant activity of foods such as, soybean, olive, starch, and safflower powder. However, it is possible to find studies that report the reduction of antioxidant activity when the radiation process is mediated with another parameter, as changes in moisture and application of different doses of gamma radiation in mung bean.

4.4. Food allergens

Food processing methods using radiation, ionizing, and nonionizing can be used to reduce the potential of food allergenicity. The UV-light, gamma irradiation, and ultrasound have the capacity to reduce the allergenicity of food proteins from the formation of protein aggregation, protein crosslinking, and/or amino acid sequence alteration. Studies carried out with the application of gamma radiation on cow's milk proteins have demonstrated the reduction of the allergenicity and antigenicity of the proteins when submitted to the irradiation process. However, to date, the processes that involve radiation are not capable of completely inactivating the allergenic compounds.