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Effect of Gamma Irradiation in Food Biopolymers

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Abstract

Gamma irradiation on food thermo physical and thermochemical balance in relation to food bio-functionalities of cereal, tubers, legumes and roots biopolymers were reviewed. Food polymers are macromolecule with varied chemical and biochemical pockets exhibiting varied functionality in food systems. Physicochemical, morphological and pasting properties of irradiated food materials varied significantly. Carboxyl content, water content, amylose leaching, transmittancecapacity in Gray andX-ray diffraction pattern remained varied upon irradiation on starch-protein plant derived flourspast and bio-food systems, but a dose dependent decrease in relative crystalline were usuallyobserved. The use of gamma irradiation ray in biomedical and biotechnological cellular or tissues sphere were cross examined.Gamma irradiation is a sterilization tool, another safer tool to encourage utilization of grains especially in Africa and to obtain maximal safety in nutrition and across food macromolecules.

Keywords: Gamma irradiation; Food; Polymers; Application; Modification

Introduction

Irradiation is an ionic, no-heat process used as a preservation and functional modification agent in polymer research and application [1]. It was considered as one of the physical modification of natural polysaccharide [2,3]. In comparison with microwave, UV, ultrahigh hydrostatic pressure and hydrothermal treatments, irradiation treatment is rapid, convenient and more extensive because ionizing energy penetrates through the polysaccharide granule rapidly [4].

Gamma irradiation uses material as lead, steel, or concrete to halt its travel, a characteristics commonly associated with radiation. It differs fundamentally from both alpha and beta, in that gamma radiation does come in from pure energy and not rays. So it is from the same family as radio waves, visible light, ultraviolet light, an electromagnetic spectrum. Typical gamma emitters include iodine-131, barium-137m, cobalt-60, and radium-226 [2]. These materials have tremendous penetrating power and could travels at the speed of light, and in some cases can cover hundreds or even thousands of meters through the air.

This process is useful in solving various agricultural problems: reduction of post-harvest losses through suppressing sprouting and contamination, eradication or control of insect pests, reduction of food-borne diseases, extension of shelf life, and breeding of high performance well adapted and disease resistant agricultural crop varieties [2,5].Medical input of gamma irradiation have been noted in hydrogel making, biopolymeric materials. Potential biomedical and biotechnological applications including implants, topical wound dressings, treatment devices and drug delivery systems.

Principle of Gamma Irradiation

The broad Principle here is based on validation strategy, quality audits and dosiometry of the irradiation process.The standards functions are to determine how much radiation is permitted in order to achieve the desired level of sterilization when measured in terms of sterility assurance. The sterility assurance level is normally 106Gy,that is a theoretical concept in which, no more than one item sterilized out of one million would contain one or more microorganisms after the completion of the sterilization process [6,7].

Dosage Measures of Radiation

The radiation dose for food irradiation and sterilization generally is measured using the conventional unit rad or the SI unit gray (Gy). The rad, which stands for radiation absorbed dose, was the conventional unit of measurement, but it has recently been replaced by the Gy; 1 Gy is equal to 100 rad. The prefix kilo (k), for 1000, is commonly used with the gray unit, kGy. Mega (M) for 1,000,000 is often used with the rad unit Mrad.

Packaging and dose determination

Although gamma radiation is commonly used to sterilize plastics, not all types of plastics can be treated at a sufficient dose to achieve sterilization without degrading the plastic [6-8]. The application of ionizing radiation causes the excitation of polymer molecules, over time, the adsorbed dose can result in changes to the physical or chemical properties of the polymers.

Given the range of different types of single-use sterilized disposable products being developed, and the range of different packaging configurations, the required gamma radiation dose to achieve sterilization or to protect the product from degradation will vary considerably. Considering these factors, a common radiation dose used for plastics is in the range 15 KGy-25 KGy [9].

For the process of sterilization, the wrapped product is normally packed into a special container, typically manufactured from aluminum, called a tote. A tote has fixed internal dimensions and is designed to transport product through the radiation process. The weight and dimensions of the tote must be accounted for when establishing the radiation dose. The dose determination is the key validation step when using gamma radiation.

Preparation and Irradiation in the Laboratory

Flour and paste samples of about (200 g) were sealed in polyethylene bags (ca. 80 lm thick) and kept chilled in ice-cooler boxes prior to and during irradiation [1]. Samples were irradiated at Isotron S.A. using a 60Co source. Target doses were 2KGy, 10KGyand 50 KGy[1].

Preparation and Irradiation in the Industry

The two common irradiator types are continuous and batch. Continuous units function with an automated conveyance system moving product through a “maze” (which prevents photons from exiting the shield), past a gamma source, and back out on a continuous basis. A batch unit works by loading a set number of totes or carriers and positioning the totes in the irradiation chamber. The cobalt is then raised from its shielded storage position (normally underwater) to an exposure position, and the product is irradiated for a specified period of time. The source is then returned to its shielded position and the product totes are moved out of the chamber as a “batch”.

Gamma Irradiation Application in Food Polymers and Biopolymers

Application in Legume flour and past Processing. Gamma irradiation, usually applied to cowpeas for reasons such as insect and pest disinfestations [10,11]. Cowpea flour protein digestibility and cowpea protein functionality [12].Gamma irradiation has been employed to cross-link biodegradable films from). Whey, casein and soy proteins [13]. Ionizing radiation, through the production with free radicals, can affect proteins by promoting reactions such as protein-protein association, deamination, and cleavage of peptide and disulphide bonds and by association of aromatic and heterocyclic residues [13-16]. These changes depend on factors such as dose, pH, hydration state and temperature during irradiation as well as the presence or absence of oxygen [17]. Gamma irradiation is capable of modifying functional properties of some legumes, Emulsion, foam, water and oil absorption capacities evidenced in peanut flour and protein solubility and red kidney bean [17-20]. In some of these studies, irradiation was applied to isolated proteins.

The effects of irradiation on proteins in multi-component food systems such as cowpea flours and pastes may be expected to be less drastic given that large molecules such as starch may confer some protection against irradiation effects on smaller molecules such as proteins [21]. However, earlier findings showed significant changes in most protein-related functional properties of multicomponent cowpea flours and pastes following their exposure to medium and high dose irradiation, despite such potential protective effects.

On the elucidation of irradiation on cowpeas flour,according to Abu et al. [1] most functional properties of cowpea proteins isolated from gamma-irradiated cowpea flours are affected by gamma irradiation at 2 KGy, whereas proteins from pastes are affected mainly at 10 KGyand 50 KGy.Its deduced that Irradiation-induced decrease in NSI is accompanied by increase in OAC due to a probable increase in hydrophobicity, emanating from denaturation and cross-linking of cowpea proteins. Differential Scanning Calorimetry (DSC) and Size Exclusion High Performance Liquid Chromatography (SEHPLC) show that cowpea protein denaturation and cross-linking, respectively, may occur with irradiation [1].

Legumes(Lotus Seed) Processing

The paucity of protein-rich food and protein food supplements poses problems of malnutrition in children and lactating women in developing countries, and it has become a prime concern to food scientists, nutritionists, and local governments [1]. γ-radiation resulted in a dose dependent increase of the crude proteins and carbohydrates with an elevation in the overall functional properties of the seed flour [22]. Also, a drastic reduction in the anti-nutritional factors was recorded in the seed flour post γ-radiation treatments. Lotus seed flour has a great potential for exploitation for food and pharmaceutical purposes [22]. As these seeds are an economically valued commodity in national and international markets, the application of a specific dose of ionizing radiation along with other appropriate food processing methods might facilitate the exploitation of the nutritional potential [22].

Gamma Irradiation Application in Preservation of Food (Cowpea Seeds)

The application of gamma irradiation in cowpea preservation and processing is not new. Low and medium irradiation doses have been employed to prevent insect and pest infestation [23] and to improve cowpea seeds protein digestibility. Gamma irradiation between 2.5KGyand 10 KGywas found to reduce the cooking time of soya beans by as much as 30%-60% of the non irradiated (control) samples [2]. Earlier, also recorded a decrease in cooking time and consequently, a higher retention in B-vitamins in 10KGyirradiated and cooked red gram bean when compared with the non irradiated (control) cooked samples. According to Abu, et al. [1] asserts that it is possible that the reduction in cooking times of these legumes were achieved partly through the effects of irradiation on various structural and molecular aspects of the seeds. In previous reports, it was shown that the functional properties of cowpea flours and pastes were modified to varying extents because of various irradiation-induced physicochemical changes such as decreased protein denaturation temperatures, increases in high molecular weight proteins as well as starch degradation [1]. The physicochemical properties of legumes could also be expected to influence their cooking times.The work on gamma irradiation of cowpea seeds at 2 KGyand 10 KGy led to significant reduction in the cooking time of cowpea seeds possibly because of irradiation-induced structural changes such as degradation of starch and pectic substances leading to increased heat and mass transfer across the seed cotyledon and cell wall.Using dose of 50KGy, observed that the cooking time of cowpea seeds is prolonged owing probably to complex structural and chemical changes such as extensive starch, pectic substances and protein crosslinking occurring at such a high dose. Significant leaching of nutrients from the cooked seeds into the cook water occurs with gamma irradiation in a dose dependent manner. In addition, a highly significant reduction in the splitting of cowpea seeds occurs during cooking when seeds are irradiated at a high dose (50 KGy), but not at low and medium doses (2 KGyand 10 KGy) [1].

Gamma Irradiation Application as Fumigants

Consequently, γ-irradiation has been suggested as an alternative to the use of fumigants [15]. Groundnuts are high moisture seeds that permit mold growth even when roasted [8]. It is expected that γ-irradiation of groundnuts would help to prevent mould growth, reduce microbial contamination and eliminate pest and insects, the seeds will be able to bestored for long periods. Various studies have reported that irradiated food item such as sunflower, almond oil, pine nuts, cowpea, sweet potato and millet showed better chemical and physicochemical properties than non-irradiated counterparts [23].

Effects of Electron Beam Irradiation on Zearalenone and Ochratoxinshow that the degradation rates of ZEN and OTA solutions increased with the irradiation dose [24]. The results also indicated that the initial amount of mycotoxins negatively influenced degradation. The decrease in ZEN and OTA was mainly ascribed to the direct degradation of ZEN and OTA molecules because the splitting of ZEN and OTA molecules caused by EBI was roughly similar under the same irradiation dose. Therefore, ZEN and OTA solutions with low concentration presented a high rate of declinefound that increasing the dose of gamma radiation can destroy the increase in aflatoxin B_1 (AFB_1), but the effect of gamma rays is substantially reduced when the concentration of AFB_1 is increased 50-fold. Liu et al. proved EBI-induced ZEN and OTA detoxification in contaminated corn kernel or corn flour show that the degradation rates increased with the irradiation dose [24]. At the irradiation dose of 50 KGy, the degradation rates of ZEN and OTA in corn kernel were 71.1% and 67.9%, respectively. Itsfound that (MC) moisture content shows positive significant effects ($p<0.05$) on mycotoxin reduction; in spite of the gamma irradiation dose and type of mycotoxin. Maximum reduction values of 45.87% and 55.27% were found for MC of 12% and 18%, respectively. These reports were consistent with findings, that high MC was favorable for the effect of irradiation on mycotoxins. High Moisture Content (MC) was favorable for the degradation effect, and the quality parameters of corn were affected by irradiation.

Gamma Irradiation Application in Starch Modification

Starches have been modified extensively using gamma irradiation to induce physicochemical transformations in starch granules, for example in wheat, rice, maize potato bean and cowpea. Desired functional and processing traits like reduction of viscosity, high water solubility, reduction of gelatinization enthalpy and others can be attained through gamma irradiation of starchwas able to produce modified corn starch with low viscosity and sufficient viscosity stability using gamma irradiation and addition of Ammonium Persulfate (APS). Past research also showed that gamma irradiation could significantly increase the resistant starch content in corn starches depending on the irradiation dose applied and the total amount of amylose in the starch [5-10].

Extensive studies on various starches reported different alterations by irradiation on the physicochemical properties. Gelatinisation enthalpy of rice, corn and potato starch were found to decrease for gamma irradiationup to 40 KGy [24-27], but not grain amaranth starchwhich could be irradiated up to 10 KGy andcorn starch,irradiated up to 50KGy[28].

It has also been found that the amylose-to-amylopectin ratio affects the sensitivity of starch toward gamma irradiation [12-15]. Various studies have been carried out on single type of starch with different amylose content to investigate the aforementioned relationship. For instance, studied the effects of gamma irradiation (3 KGy) on physicochemical properties of various types of rice cultivars [29,30].

Gamma Irradiation Application instarch Rheology and Plasticity

As one of the most plentifully used ingredients, starch imparts structure, texture, consistency, and appeal to many food systems [23,24]. However, the properties of native starch such as low shear resistance, low thermal resistance, thermal decomposition, and high retrogradation tendency, are not optimal in some industrial food applications [25]. Starch has therefore been chemically, physically, or enzymatically modified to suit relevant end products. Gamma irradiation, which has been used to extend the shelf life or to increase safety of food by reducing spoilage and pathogenic microorganisms, produces free radicals that can alter the size and structure of starch molecules[26] Food products subjected to gamma irradiation are confirmed to be nutritionally adequate and safe for human consumption [27,29]. Degradation of starch polymers by gamma irradiation results in progressive reduction in molecular weight of amylose and amylopectin, decreased viscosity, increased solubility, and increased acidity with increasing radiation dose [1].However, some physicochemical properties have been altered differently, depending on botanical origin and irradiation conditions. The corn starch granule structure remains visually unchanged up to 40 KGy [5], but an increase in roughness of the starch granule surface was reported for a corn starch treated with a dose of 10 KGy[7]. Crystallinity of irradiated wheat and rice starches increased with radiation dose [3], but decreased in potato starch [30,31].

The gelatinization enthalpy increased in bean starch, but decreased in rice, corn, wheat, and potato starches with gamma irradiation [2,5]. Retrogradation extent was reported to increase in corn starch irradiated up to 30 KGy and decrease in wheat starch with 2 KGyirradiation [30,31].

A decrease or no difference in starch digestibility was observed at low doses, but at high doses. According toRupnow JH [2] gamma irradiation reduced starch digestibility.

Gamma irradiation of starch caused an increase in carboxyl content, the proportion of short amylopectin branch chains and retrogradation temperature, and a decrease inapparent amylose content, the proportion of longer amylopectin branch chains, relative crystallinity, pasting viscosity, gelatinization enthalpy and temperature, and retrogradation enthalpy, suggesting degradation of amylose and amylopectin. Resistance Starch content of starch irradiated at a higher dose (10 KGyor 50 KGy) increased compared to non-irradiated starch. Slow irradiation dose rate reduced the carboxyl content, and pasting viscosity, and increased the crystallinity, gelatinization enthalpy, and retrogradation enthalpy, indicating that both degradation and cross-linking of starch chains were occurring simultaneously during irradiation [2].

Effect of Irradiation on Pasting Properties of Cowpea Seeds

As expected, irradiation results in significant decreases in pasting properties such as peak and final viscosities of milled cowpea seeds in a dose-dependent manner. This is consistent with literature [22,30] and is mainly a consequence of irradiation-induced starch degradation. However, the extent of decrease in most pasting properties observed in this study in relation to the pasting properties of the control samples was generally lower than those previously reported for cowpea flours subjected to identical irradiation conditions and doses [1] implying that particle size may be an important factor to consider when carrying out irradiation of foodmaterials.

Gamma Irradiation Application in Polymer Biomaterials

Common applications for gamma processing (treatment) include the sterilizing (killing of bacteria) of medical devices, microbial reduction of foods, cosmetics and their packaging, and the de-infestation of agricultural products. Sterilility means the total absence of living organisms, in this context specifically of microbial life. Sterilization is defined as any process that effectively kills or eliminates all microorganisms like fungi, bacteria, viruses, spore forms. There are many different sterilization methods depending on the purpose of the sterilization and the material that will be sterilized. The choice of the sterilization method alters depending on materials and devices for giving no harm. These sterilization methods are mainly heat sterilization (dry heat, pressured vapor), chemical sterilization (ethylene oxide, paraceticacid, hydrogen peroxide and glutaraldehyde), radiationsterilization (e-beam and gamma rays).None of sterilization method adequates for all applications. All sterilization methods have their limitations, but all sterilizing methods have one thing in common; they must remove or destroy all microorganisms [18].

Gamma Irradiation Application on Living Organisms

Inactivation of bacteria and fungi by gamma irradiation is brought about partly by directCollision action in sensitive part of the cell and partly by indirect action via highlyreactive radicals produced in the cell liquid by radiation. The direct action of radiation involves the interaction between the ionizing radiation and critical biological molecules (DNA) resulting in excitation and scission of the polymeric structure. High energy radiation pass through a cell, interact with atom or molecules along the path, and break the DNA strand. The indirect effect involves the formation of water molecules or radiolysis of water. The presence substantial quantities of water in microorganisms lead to the formation of reactive radical such as OH, H. and e-aq. These radicals will further interact with DNA resulting in the damage of DNA. Consequently, the indirect action of radiation normally occurs as important part of the total action of radiation [20,21]

Radiation damage is mainly associated with the impairment of metabolic reactions. Much evidence shows that the damage occurs more in DNA molecules compared to the other critical sites including membranes and ribosomes of microorganism [6].A single-strand break and double strand break and a lesion in the nitrogenous bases of DNA cell of microbes are the main cause of cell death. The amount of absorbed radiation energy required to inactivate the microorganism in a product (medical, pharmaceutical) depends on its resistance to radiation.

Bioburden and Sterility Assurance

Level Bioburden is defined as the quantitative estimation of the number of viable microorganisms in or on a medical products, device or raw material before sterilization. The kinetic of microbial inactivation is of an exponential nature, which means that there is always probability that some microorganisms may survive regardless the extent of treatment applied. Although inactivation of microorganisms by ionizing radiation usually follows an exponential curve or rate. Some organisms display a sigmoid inactivation curve with a brief shoulder before the exponential inactivation commences. This shoulder may be due to the repair mechanism of the organism with a proportion of the organisms requiring multiple hits to be inactivated. The exponential decline is usually converted to a linear relationship by taking log10 initial contamination level (bioburden). From log10 bioburden the D10-value can be calculated. The D10-value is the dose of sterilization procedure required to reduce bioburden by one log10, this is to inactivate 90% of the microorganism [16].

The D10 value is calculated as the gradient of the linear part of the curve as follows:

D10 ¼ D=½logNo/logN

where D¼ the radiation dose (KGy),

No¼ the initial viable count

N¼viable count at dose D.

The D10 value is influenced by the type and species of microorganism, cell cycle stage, oxygen, temperature during irradiation, water content, chemicals and nutrients, and to a certain extent, by the dose rate. The equation can be used to determine the radiation sterilization dose (D) when No (obtained from bioburden test) and N (sterility assurance level.

Gamma Irradiation Application in Potential Biomedical and Biotechnology Applications

These new materials include implants, typical dressings, treatment devices and drug delivery systems, injectable formulations, drug delivery devices, diagnostic assays, immobilized enzyme and cell culture surfaces [8].

Gamma Irradiation Application in Hydrogels Biofilms

Hydrogels are cross linked polymeric networks, which have the ability to hold water within the spaces available among the polymeric chains.The water holding capacity of the hydrogels arise mainly due to the presence of hydrophilic groups, viz. amino, carboxyl and hydroxyl groups, in the polymer chains. The hydrogels have been used extensively in various biomedical applications such as wound dressing, drug delivery, and tissue engineering.

Limitation of Gamma Irradiation

Gamma radiation is not widely used for aqueous drug products and pharmaceuticals with a proteinaceous component because it can degrade such products. Also, food with a high fat content may not be good candidates.

Conclusion

Gamma irradiation a non-thermal approach in food processing is one of the best tool for safer and convenience ways of process-modification of food micro and macro structures.

Application of gamma irradiation has shown promising results in extending the shelf life of cereals and pulses by disinfestation and preventing microbial growth. Irradiation has also resulted in increased antioxidant properties besides decreasing the anti-nutritional content of the grains.

Recommendation

The technology should be made available by Africa regional Governments for comprehensive food safety and security process practices.

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