iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 3 **Issue:** XI **Month of publication:** November 2015

DOI:

International Journal for Research in Applied Science & Engineering Technology (IJRASET)

Irradiation as a Food Preservation Method in Nigeria: Prospects and Problems

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Abstract-Food irradiation is a food preservation method which involves the process of exposing foodstuffs to a source of energy capable of stripping electrons from individual atoms in the targeted material (ionizing radiation). This method of food preservation can be referred to as a more advanced form of food preservation. Some school of thought criticize the use of irradiation for food preservation because of the negative impressions of the nuclear industry, and this has made irradiation one the most investigated forms of food preservation. Food irradiation has being endorsed by the World Health Organization (WHO), and is currently being used in over 40 countries and approximately 500,000 tons of food items are irradiated yearly all over the world. This work has highlighted some problems associated with the use of food irradiation technology in Nigeria, and has also proffered solutions that can help tackle the said problems. This work has also discussed the process of food irradiation, the recommended sources and the dose range required for effective irradiation of food products.

Key words: Irradiation, Prospects, Problems, Food preservation, Nigeria.

I. INTRODUCTION

Food is very essential to the survival of man and as such, food preservation is one of the oldest technologies used by human beings. Food preservation has undergone so much investigation and also some significant improvements and discoveries have being made, allowing for life to be healthier, more efficient and safer. Among the forces driving scientists into these many improvements is the strong desire to preserve the one fuel that keeps life going, i.e. food.

As early as the beginning of the 19th century, major breakthroughs in food preservation had begun. Soldiers and seamen, fighting in Napoleons army were living off salt-preserved meats. These poorly cured foods provided minimal nutritional value, and frequent outbreaks of scurvy were developing. It was Napoleon who began the search for a better mechanism of food preservation by offering 12,000-franc pieces to the person who devised a safe and a dependable food-preservation process. The winner was a French chemist named Nicolas Appert, who observed that food heated in sealed containers was preserved as long as the container remained unopened or the seal did not leak *(Jean-Paul,* 1994*)*. This breakthrough followed by Louis Pasteur's discovery on the relationship between micro-organisms and food spoilage increased the dependability of the food canning process *(Nummer,* 2002*)*. Other forms of food preservation methods that followed include freezing, drying and dehydration, freeze drying, irradiation etcetera.

II. FOOD PRESERVATION

Food preservation usually involves preventing the growth of bacteria, fungi (such as yeasts), or other micro-organisms (although some methods work by introducing benign bacteria or fungi to the food), as well as retarding the oxidation of fats that cause rancidity. Food preservation may also include processes that inhibit visual deterioration, such as the enzymatic browning reaction in apples after they are cut during food preparation.

Maintaining or creating nutritional value, texture and flavor is an important aspect of food preservation, although, historically, some methods drastically altered the character of the food being preserved. In many cases these changes have come to be seen as desirable qualities with cheese, yogurt and pickled onions being common examples. The following section discusses irradiation as a food preservation method.

III. IRRADIATION

Irradiation is the process by which an object is exposed to radiation. The exposure can originate from various sources including natural sources. The term most times refers to ionizing radiation, and depends on the level that fits a specific purpose, rather than radiation exposure to normal levels of background radiation.

Food irradiation is a food preservation method which involves the process of exposing foodstuffs to a source of energy capable of stripping electrons from individual atoms in the targeted material (ionizing radiation) *(Anon,* 1991*)*. The radiation can be generated electrically using beta particles (high-energy electrons) or the use of gamma rays (emitted from radioactive sources as cobalt-60 or caesium-137). This treatment is used to preserve food, reduce the risk of food borne illness, prevent the spread of invasive pests, delay or eliminate sprouting (as in tubers) or ripening (as in fruits), increase juice yield and improve re-hydration and at higher doses induces sterility.

Food irradiation is criticized because irradiation can initiate chemical changes that are different than those that occur when heating food (unique radiolytic products). Some people worry that there is the potential of danger from these substances. Research has discovered that one family of chemicals is uniquely formed by irradiation, and this product is nontoxic. When heating food, all other chemicals occur in a lower or comparable frequency *(Anon,* 1994*)*. Others criticize irradiation because of confusion with radioactive contamination or because of negative impressions of the nuclear industry.

The regulations that dictate how food is to be irradiated, as well as the food allowed to be irradiated, vary greatly from country to country. In Austria, Germany, and many other countries of the European Union only dried herbs, spices, and seasonings can be processed with irradiation and only at a specific dose, while in Brazil all foods are allowed at any dose *(Kume et al.,* 2009*)*.

Irradiation is also used for non-food applications, such as medical devices, plastics, tubes for gas pipelines, hoses for floor heating, shrink-foils for food packaging, automobile parts, wires and cables (isolation), tires, and even gemstones.

It is permitted by over 50 countries including Nigeria (*Liberty et al., 2013)* with around 500,000 metric tons of foodstuffs processed annually worldwide *(Adu-Gyamfi, 2002)*.

A. The Process of Food Irradiation

In the process of food irradiation, most of the radiation passes through the food without being absorbed (Roberts et al., 1995). The small amount that is absorbed is capable of destroying any insects on grains, food produce or spices; extend shelf life and prevent fruits and vegetables from ripening too fast. The absorbed dose is primarily a function of the duration of exposure and the distance from the source. The food is exposed to effective amounts of ionizing radiation so that pathogens, pests, and spoilage organisms can be destroyed. The organisms are destroyed by the electrons breaking the bonds that hold the pathogen's DNA together. Damage to the DNA disables the organism's ability to grow or multiply. The radiation dose to which food is exposed is based on extensive research to ensure the destruction of pests and pathogens while at the same time preserving the wholesomeness of the food.

The food irradiation method is a cold treatment that achieves its effects without raising the food's temperature significantly, leaving the food closer to its original state. Even spices which are treated for 2-4 hours remain essentially at room temperature. By not using high temperatures, food irradiation minimizes nutrient losses and changes in food texture, color, and flavor.

Low doses are required for control of growth processes in some food products such as yams, potatoes and onions, and for the delay of ripening and senescence in fruits and vegetables such as tomatoes, mangoes and bananas. Slightly higher doses are required for insect and parasite disinfestations and can kill Salmonella and other harmful bacteria that can contaminate meats and poultry and cause food borne diseases. Irradiation is carried out in specially designed and shielded facilities in a continuous or batch process. The choice of the mode of irradiation operation depends on the type of products, quantity of products, shape, size, bulk density and the required dose *(Refai et al.,* 1996*)*. For example, electron beam irradiation in a continuous process is sufficient to treat most pre-packaged food items whereas treatment of large bulk quantities of food would require a batch system either with x-rays or gamma rays from a radioactive source *(FSAI,* 2002*)*.

B. Irradiation with Gamma Rays Produced From Radioisotopes

The common sources of gamma rays applied for food irradiation purposes are those, which are produced from radioactive substances (called radioisotopes). The common sources are cobalt-60 (60Co; the most common) and cesium-137 (137Cs). They contain energy levels of 1.17 and 1.33 MeV (60Co) and 0.662 MeV (137Cs) *(Kyriakos,* 2010*)*.

Both cobalt-60 and cesium-137 emit highly penetrating gamma rays that can be used to treat food in bulk or in its final packaging *(Steward,* 2001*)*. To irradiate food products, the cobalt-60 source is pulled out of the water into a chamber with massive concrete walls that keep any rays from escaping. Food products to be irradiated are brought into the chamber and are exposed to the rays for a defined period of time. After it has been used, the source is returned to the water tank *(Kyriakos,* 2010*)*.

However, cesium-137 is seldom used. Large cesium-137 sources are not readily available due to practical difficulties in handling this isotope. Cesium chloride is highly soluble in water and the use of cesium-137 in this form is not recommended. The use of cesium-137 has been limited to small self-contained, dry storage irradiators, used primarily for the irradiation of blood and for insect sterilization. Currently, all industrial radiation processing facilities employ cobalt-60 as the gamma radiation source *(Kyriakos*, 2010*)*. Food products that can be treated with this method of irradiation include tubers such as yam, potatoes etc., cereal grains such as rice, sesame seeds etc. *(Fapohunda et al.*, 2012*)*, spices *(Farkas et al.*, 1982*)*, poultry products such as eggs, chicken and turkey frozen meat, dairy products such as milk, cheese etc., fresh fruits, beef, pork etcetera *(Liberty et al.*, 2013*)*. Table 1 gives a list of the food products that can be treated with gamma irradiation and their achievable dose range.

The following are some of the advantages cobalt-60 has over cesium-137 *(Kyriakos*, 2010*)*.

Up to 95% of its emitted energy is available for use.

It penetrates deeply.

It yields substantial uniformity of the dose in the food product.

It is considered to pose a low risk to the environment.

The food products move along the conveyer belt and enter an inner room where they are exposed to the rack containing source pencils (see Figure 1). Energy in the form of gamma rays (or photons) passes through the encapsulated rods and treats the food. After food is irradiated, it is stored and may be transported back to the processing plant for further handling and packaging. Once the food has been irradiated, it must be handled appropriately to prevent recontamination *(Roberts et al.*, 1995*)*.

C. Irradiation with Machine Sources

The common sources of ionizing radiation based on machine sources, and used for irradiation of food products are the electron beam and x-rays. The electron beam or e-beam is a stream of high-energy electrons, propelled out of an electron gun (see Figure 2). The e-beam generator can be switched on or off simply by pushing a button. The electrons can penetrate food only to a depth of 3 cm, or slightly more than 1 inch, so the food to be treated must be no thicker than this for it to be treated all the way through. This is a disadvantage of electron radiation compared with gamma rays produced by radionuclide. Two opposing beams can treat food that is twice as thick.

To be useful for food irradiation, electrons should be accelerated to energies of at least 5 MeV. The maximum energy approved for use in food is 10 MeV. Higher energy electrons have greater penetration into the product. However, at 5 MeV and irradiating the product from both sides, the maximum thickness that can be penetrated is approximately 3.8 cm (1.5 inch). At 10 MeV and with two-sided irradiation, the maximum thickness that can be penetrated is approximately 8.9 cm (3.5 In) (*Woods and Pikaev*, 1994*)* and as such are suitable only for foods of relatively shallow depth *(Steward*, 2001*)*. A treatment of food with ionizing electrons is often more easily accepted because there are no radioactive substances in the process.

Table 1: Dose level and uses of gamma irradiation for food preservation

Dose level	Purpose	Product examples
Low dose: Disinfestations/ delay in ripening (up to 1 kGy).	Inhibits the growth of sprouts on potatoes and other foods. Kills insects and larvae that can be found in wheat, flour, fruits and vegetables after harvesting. Slows the ripening process.	Potatoes, onions, garlic, root ginger, bananas, mangoes and certain other non-citrus fruit, cereals and pulses, dehydrated vegetables, dried fish and meat, fresh pork
Medium dose pasteurization (1-10 kGy).	Dramatically reduces the number of or eliminates certain microbes and parasites that cause food to spoil. Reduces or eliminates a number of pathogenic microorganisms	Fresh fish, strawberries, grapes, dehydrated vegetables, fresh or frozen seafood, raw or frozen poultry and meat.

Volume 3 Issue XI, November 2015
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

High dose sterilization (10-50 kGy)	Sterilizes food for a variety of uses, such as meals for hospital patients who suffer from immune disorders and can eat only bacteria-free foods. Eliminates some disease-causing viruses. Decontaminates certain food additives and ingredients.	Meat, poultry, seafood and other food prepared for sterilized hospital diets, spices, enzyme preparations, natural gum.

(Lester and Eric, 1996*)*

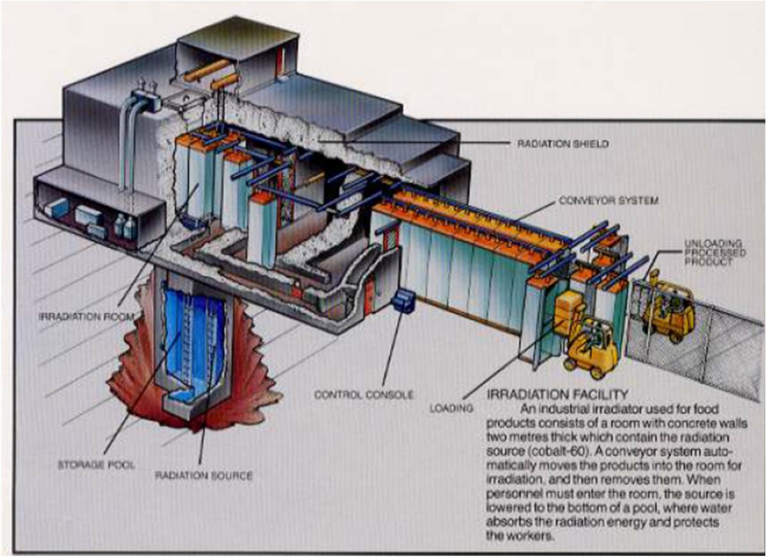

Figure 1: Atypical gamma irradiation facility *(ccr.ucdavis.edu*, 2006*)*

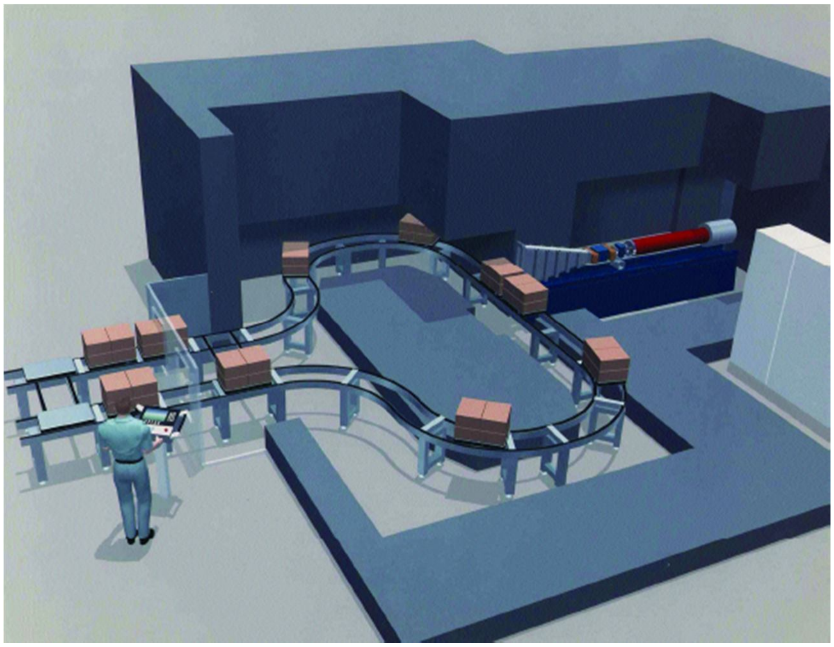

Figure 2: An electron beam irradiation facility (Don et al., 2002)

For food treatment, x-ray machines must be operated at an energy level of 5 MeV or lower. This restriction is based on the need to prevent induced radioactivity. X-ray production is relatively inefficient, but it can be competitive with gamma radiation for high-capacity plants. The possibility of using electron beams and x-rays in the same irradiation facility is also attractive (*Farkas,* 1988*; Wilkinson and Gould,* 1996*).*

IV. AN OVERVIEW OF THE PRINCIPLES AND EFFECTS OF IRRADIATION ON FOOD PROCESSING AND PRESERVATION

According to the Codex General Standard for irradiated Foods, ionising radiations recommended for use in food processing are: (i) Gamma rays produced from the radioisotopes cobalt-60 (60Co) and cesium-137 (137Cs), and (ii) Machine sources generating electron beams (maximum level of 10 MeV) and x-rays (maximum level of 5 MeV).

Both cobalt-60 and cesium-137 emit highly penetrating gamma rays that can be used to treat food in bulk or in its final packaging. Cobalt-60 is, at present, the radioisotope most extensively employed for gamma irradiation of food *(Steward,* 2001*).*

Machine-sourced ionising radiations have the advantage that no radioactive substance is involved in the whole processing system. Electron-beam machines use linear accelerators to produce accelerating electron beams to near the speed of light. The high-energy electron beams have limited penetration power and as such can only be used on foods of relatively shallow depth *(Steward,* 2001*),* or on foods less than 10 centimeters (cm) thick because of the limited penetrating capacity of the electron beams.

Electron beams can be converted into various energies of x-rays by the bombardment with a metallic target. Although x-rays have been shown to be more penetrating than gamma rays from cobalt-60 and cesium-137, the efficiency of conversion from electrons to x-rays is generally less than 10% and this has hindered the use of machine sourced radiation so far *(ICGFI,* 1999*).*

Regardless of the source of ionizing energy, the process involves exposing the food to the energy source for a precise time period. In the case of e-beam, food is irradiated in just a few seconds, while it takes gamma and x-rays considerably longer. The food is never in contact with the energy source; the ionizing energy merely penetrates into the food but does not stay in the food. It takes very little energy to destroy harmful bacteria. At these levels there is no significant increase in temperature or change in composition. Irradiation does not make food radioactive nor does it leave any residues.

After food is irradiated, it is stored and may be transported back to the processing plant for further handling and packaging. Once the food has been irradiated, it must be handled appropriately to prevent recontamination *(Roberts et al.,* 1995*).*

The basic unit for measuring irradiation is the gray (Gy), which is the amount of irradiation energy that 1 kilogram of food receives. The amount of irradiation applied to a food product is carefully controlled and monitored by appropriate regulatory authorities. The irradiation dose applied to a food product will depend upon the composition of the food, the degree of perishability, and the potential to harbor harmful microorganisms. A low-to-medium dose of below 1-10 kGy is usually sufficient to render a product safe from harmful bacteria or insects such as fruit flies, while causing little or no effects on product quality or nutrition. The amount of radiation that a food product absorbs is measured by a dosimeter *(Roberts et al.,* 1995*).*

V. SOME EFFECTS OF FOOD IRRADIATION

A. Effect of Irradiation On Lipids

In response to the continuously growing role of irradiation in food preservation, several reviews and research studies have been published on the irradiation of foods of both animal and plant origin over the past years *(Arvanitoyannis et al.,* 2009; 2010*).* The application of ionizing radiation results in the radiolysis of water, which is present in most foods such as meat and fish products. This triggers the development of species such as OH−, hydrated electron and H+, which can then induce several chemical reactions with food constituents. Studies show that the quantity of radiolysis products varies as a function of fat content and fat composition, as well as with the temperature during the irradiation process and the actual dose of radiation used *(Merrit et al.,* 1979*).* When fatty acids are exposed to high-energy radiation they undergo preferential cleavage in the ester-carbonyl region giving rise to certain radiolytic compounds that are specific for each fatty acid *(Nawar et al.,* 1996*).* The strong oxidizer ozone is produced from oxygen during food irradiation and can promote the oxidization of lipids and myoglobin *(Venugopal et al.,* 1999*).*

Experiments carried out on chicken revealed no significant difference in total saturated and unsaturated fatty acids between irradiated (1, 3, 6 kGy) and non-irradiated frozen (−20°C) chicken muscle *(Rady et al.,* 1987*).* Other studies showed that e-beam irradiation (2.5 kGy) seemed to increase the levels of thiobarbituric acid-reactive substances (TBARS) in ground beef, but the difference between irradiated and non-irradiated samples was not statistically significant *(Nam et al.,*2003*).* The results of Yilmaz and Gecgel (2007) showed that irradiation in ground beef induced the formation of trans fatty acids. However, the ratio of total unsaturated fatty acids to total saturated fatty acids was 0.85, 0.86, 0.87, and 0.89 in irradiated ground beef samples at 1, 3, 5, and 7 kGy, respectively whereas for the control samples it was 0.85. An examination of the effect of irradiation at 10 kGy on the linoleic and linolenic acid contents of grass prawns found that irradiation resulted in 16% decrease in linoleic acid content, whereas linolenic acid was not affected significantly *(Hau et al.,* 1993*)*. In the case of Spanish mackerel, C16:0 and C16:1 fatty acids decreased when irradiated at 1.5 to 10 kGy *(Al-Kahtani et al., 1996)*. No changes were reported in the fatty acid composition of two species of Australian marine fish irradiated at doses up to 6.0 kGy and the levels of fatty acids in oil remained stable in the irradiated fish samples whereas they decreased in non-irradiated fish *(Armstrong et al.,* 1994*)*. The extent of lipid oxidation was dependent on the irradiation dose. An analysis of the literature concluded that when lipids are irradiated under conditions which are met in commercial food processing (≤7 kGy), there is no significant loss of nutritional value *(Thomas,* 1988*)*.

B. Effect of Irradiation On Proteins And Amino Acids

Damage caused to protein by ionizing radiation includes deamination, decarboxylation *(Diehl,* 1990*)*, reduction of disulfide linkages, oxidation of sulfydryl groups, cleavage of peptide bonds and changes of valency states of the coordinated metal ions in enzymes *(Delincee,* 1983*)*. Other studies indicated that there was no significant destruction of cystine, methionine and tryptophan up to a dose of 71 kGy *(Josephson et al.,* 1978*)*. The majority of amino acids in minced lean beef or pork and chicken breast muscle are stable up to a dose of 5 kGy *(Partmann et al.,* 1979*)*. Irradiation does not generally affect the stability of amino acids and proteins in situ. The stability to irradiation at 2 to 45 kGy of tryptophan of shrimp muscle was measured after storage under different temperature and moisture conditions. The results revealed that the loss of tryptophan was small under all the conditions applied *(Antunes et al.,* 1977*)*. Essential amino acids were not affected in electron- beam processed (53 kGy) haddock fillets *(Lagunas,* 1995*)*. Reports from literature indicate that irradiation of meat at commercial doses (2–7 kGy) has no significant effect on the nutritional value of proteins or amino acids *(Thayer,* 1987*)*.

C. Effect of Irradiation On Vitamins

Many authors have studied the effect of irradiation on the stability of vitamins in foods *(Liu et al.,* 1991; *Kilcasti,* 1994; *Muller and Diehl,* 1996; *Song et al.,* 2007; *Hussain and Maxie,* 1974*)*. No loss of riboflavin was found in pork chops and chicken breasts irradiated at temperatures between −200°C and 200°C at doses up to 6.6 kGy. Some irradiated samples even exhibited an increase in riboflavin concentration of up to 25% *(Kilcast,* 1994*)*. Pork chops irradiated at different temperatures with doses up to 5 kGy displayed no loss in niacin. A loss of 15% was observed with a dose of 7 kGy when irradiation was applied at 0°C *(Fox et al.,* 1989*)*. Furthermore, in the case of pantothenic acid, it has been shown that there was no loss in many foods irradiated at doses of ≥10 kGy *(Thayer et al.,* 1991*)*. The application of gamma irradiation (1, 2, and 6 kGy) on fillets of Black bream (Acanthopagrusaustralis) and Redfish (Centroberyxaffinis) resulted in vitamin E loss but this could not be correlated with the treatment dosage. All irradiated fillets were found to have vitamin E muscle contents above the levels considered to be desirable for human consumption *(Armstrong et al.,* 1994*)*. No loss of vitamin B12 was observed in haddock fillets irradiated up to 25 kGy. Similarly, there was no loss of niacin in cod irradiated at 1 kGy *(Murray,* 1981*)*. Irradiation of shrimps at 2.5 kGy induced a 15% loss of riboflavin in air, 8% in vacuum, and 20% in nitrogen *(Diehl,* 1995*)*.

There are several methods that can be employed in order to decrease such detrimental effects of irradiation. These include oxygen exclusion, the replacement of oxygen with inert gases, addition of protective agents such as antioxidants, and post-irradiation storage to allow the flavor to return to near-normal levels *(Brewer,* 2009*)*.

D. Effect of Irradiation On Microorganisms

A large amount of data is available on the sensitivity of microorganisms to irradiation processing; this varies greatly from microorganism to microorganism and is also dependent on other extrinsic factors. Vegetative cells are less resistant to irradiation than spores, whereas moulds have a susceptibility to irradiation similar to that of vegetative cells. However some fungi can be as resistant as bacterial spores *(Farkas,* 2006*)*. Compared to bacteria, viruses generally require higher radiation doses for inactivation *(Crawford et al.,* 1996*)*. Studies have shown that irradiation doses of 2 and 3 kGy destroyed Yersinia spp. and Listeria spp., respectively, with the microorganisms being undetectable during storage of irradiated fish *(Montgomery et al.,* 2003*)*. Irradiation at 1, 2, and 3 kGy significantly improved the microbiological quality of the chicken by reducing the total bacterial count (TBC), with the decrease in TBC being dose-dependent. In all the irradiated samples, no fecal coliforms were detected *(Kanatt et al.,* 2005*)*.

VI. CONCERNS ABOUT FOOD IRRADIATION

According to the World Health Organisation (WHO), the renowned global authority on public health. "Food irradiation is a thoroughly tested process and when established guidelines and procedures are followed, it can help ensure a safer and more plentiful food supply" *(Lester and Eric,* 1996*)*.While irradiation in theory has a significant potential to enhance food safety, its use for this purpose has been of concern. Irradiation can undeniably kill food-borne bacteria, but radiation at doses useful for that purpose can adversely affect the sensory quality of foods. Early studies of irradiated fruits and vegetables indicated that these fresh, plant-derived foods are more sensitive to radiation damage than meats, spices, or grains. In fact, the doses of radiation required to reduce pathogen levels to effectively safe levels generally caused unacceptable sensory damage in fresh produce. For many years it was therefore assumed that fresh fruits and vegetables, and related products like non-pasteurized fruit juices and pre-cut salads were not suitable candidates for food irradiation. With growing awareness of the magnitude of pathogen contamination of produce, that conclusion is being reassessed *(Groth,* 2007).

Research in the past decade or so has explored the use of lower doses of irradiation on fresh produce, to find out whether acceptable reductions in pathogen loading can be achieved while preserving the taste, aroma, color and texture of the foods. This still relatively small field of research has produced some promising evidence that it may be possible, in many cases, to strike the right balance between pathogen reduction and preserving produce quality. When irradiation is combined with other anti-microbial treatments and food preservation steps, recent studies suggest that irradiation may eventually be usefully applied to some current produce pathogen problems. However, this same research indicates that applying food irradiation to a particular food-pathogen combination requires knowledge about a large number of parameters that affect the results of irradiation. The problems are complex, and research to date has identified many needs for additional and better data *(Groth,* 2007).

A number of compounds are formed when food is irradiated, just as there are when food is cooked or exposed to other processing methods. However, based on hundreds of scientific tests, there is broad agreement among scientists and health agencies that these compounds are not a human health issue. In fact, more chemical changes occur when toasting bread or barbecuing steak than when irradiating food *(Anon,* 1994).

Food irradiation provides an added layer of protection to food without significant changes to taste, nutritional value, color or texture. Since irradiation does not substantially raise the temperature of food or cook it, taste and nutrient losses are small and considerably less than other methods of preservation, such as canning, drying or heat pasteurization *(ICGFI,* 2002*)*. Carbohydrates, fats and proteins are the main components of food, and a wide body of research has shown that these nutrients do not change significantly during irradiation (*Thayer,* 1987*; Randy et al.,* 1987). Some vitamins, most notably the B vitamins, have some sensitivity to irradiation, but processors can minimize nutrient losses by irradiating food in an oxygen-free environment or a cold or frozen state *(Brewer*, 2009*)*. But in as much as food irradiation can be an effective food preservation method, it has been noted that it should never replace proper and hygienic food handling methods.

VII. THE STATE OF FOOD IRRADIATION TECHNOLOGY IN NIGERIA

Food irradiation technology in Nigeria is still at its early stages, and has not gone beyond the experimental stages. Lots of research has been carried out on some common Nigerian crops, and results have favoured its use as a preferred form of food preservation *(Fapohunda et al.,* 2012*; James et al.*, 2012*)*. The involvement of the Nigerian government in advocating for the use of irradiation technology as a food preservation method to reduce post harvest losses is a positive indicator that this technology will soon reach its commercial stage in Nigeria. Government agencies such as the Small and Medium Enterprise Development Agency of Nigeria (SMEDAN) and Nigeria Atomic Energy Commission (NAEC) have concluded agreements that would pave way for the private sector to participate fully in the food irradiation industry *(Emeka,* 2009*)*.

Nigeria for now possesses one Gamma Irradiation Facility (GIF), located at the Nuclear Technology Centre (NTC), Nigeria Atomic Energy Commission (NAEC), Sheda Abuja, Nigeria. The GIF is a category IV (wet storage source) multipurpose industrial irradiation facility with six different modes of operation. It consists mainly of an irradiation room with a steel reinforced concrete walls thickness of about 1.8m to house the Co-60 radioactive source of current activity of about 5.5 x 10^{15}Bq (170 kCi) *(Fapohunda et al.,* 2012). It has a continuous overhead conveyor transport system for large products. The choice of the mode of operation depends on type of product, quantity of product, shape, size, bulk density and the required dose. Uniform irradiation and accurate computer controlled irradiation dosage are ensured in all the modes of operations and as much as 18 metric tons of products could be irradiated in a single batch irradiation using the four-path irradiation mode of operation *(James et al.,* 2012*)*.

The GIF is a multipurpose industrial plant with a comprehensive research and development facility built by government for the preservation of food and agricultural products, sterilization of medical devices, pharmaceuticals, cosmetic products and packages, improvement of mechanical, electrical and thermal properties of plastics *(Emeka,* 2009*).*

VIII. THE PROSPECTS AND PROBLEMS OF FOOD IRRADIATION TECHNOLOGY IN NIGERIA

A. The Prospects

One of the most effective strategies that could be used in solving the problem of population-food imbalance especially in the developing countries where a quarter of the harvested food is said to be lost due to wastage and spoilage *(NAS,* 1978*)*; is to drastically reduce the amount of food lost in the post-harvest system. Several forms of research has already been carried out by some Nigerians from various fields of discipline to ascertain the efficacy of the food irradiation technology in reducing or curbing sprouting or spoilage of some basic Nigerian foodstuffs such as yam, water yam *(James et al.,* 2012*)*, onions *(Agbaji et al.,* 1981*)*, sesame seeds *(Fapohunda et al.,* 2012*)* etcetera. The results and conclusions drawn from these investigations has shown time and time again that food irradiation technology will find good use in the country if it is properly and adequately utilized. Being aware of that, Nigeria has developed a research and development programme in various fields of nuclear science including food irradiation. This section tries to describe the research and development activities carried out on food irradiation in Nigeria.

In this vain, the Nigerian Atomic Energy Commission (NAEC) was formulated as early as 1976. The Commission was established as a multi-disciplinary body in order to identify problems of national and regional importance and to contribute to their solution through irradiation techniques. It is in this light that the NAEC created six nuclear research centers among which is the Nuclear Technology Centre (NTC), Sheda Science and Technology Complex, for research and development *(Agedah,* 2014*)*, which houses a 340 kCi Co-60 Gamma Irradiation Facility (GIF) so as to enable meaningful research work on the usefulness of this technology on Nigerian food products and to facilitate the smooth introduction of this technology in Nigeria. This facility is currently being utilized by various researchers in the country. With the availability of the GIF and the interest of several researchers in the food irradiation technology, it is hoped that the process of food irradiation may in the nearest future be more readily accessible for widespread use.

B. The Problems

The use of food irradiation technology as an alternative food preservation method is yet to reach the stage of commercialization in Nigeria, and as such very little can be said concerning the problems faced during the use of this technology in Nigeria. The following are some factors that have nevertheless limited the use of this technology commercially in Nigeria. Food irradiation technology is yet to find widespread use in Nigeria, because of lack of adequate equipment in view of the only irradiation facility presently in place and which is located at the nuclear technology centre (NTC), Nigeria atomic energy commission (NAEC), Sheda Abuja, Nigeria. The fact that there is just one irradiation facility will make it difficult for intending and potential users to access it. The fact that Nigeria has just one functional irradiation facility is a setback. If Nigeria has to measure up with other developed countries as regards the use of irradiation technology for the preservation of food and other materials commercially, then she will need to begin setting up more irradiation facilities at strategic locations, so as to enhance easy accessibility from all parts of the country. The cost of procurement of the facility is also considered as a serious problem.

There is also the issue of the cost arising from the actual service. Though not much can be said concerning this topic because the use of food irradiation technology is yet to reach the stage of commercialization in Nigeria, and as such very little can be said concerning the pricing. But taking a cue from some more developed countries like the USA that have commercialized the use of this technology, a slight increase in price for the irradiated products is expected *(Kevin,* 2013*).*

There is also a lack of adequate sensitization as regards the use of this technology in Nigeria. There is no proper rapport between the relevant government agencies or extension workers and food producers especially in the rural areas on the use of irradiation as an alternative food preservation method. The results of a study conducted by Okoedo-Okojie and Onemolease (2009), reveals that ignorance of existence of improved storage methods such as irradiation is a major factor for its non-adoption.

Transporting is the marketing function for moving goods. The efficient flow of agricultural produce requires a good quality system for shipping and moving goods. A country's infrastructures and transport system are often seen as key aspects of its development. In Nigeria, road and rail systems are the means for transporting agricultural produce down south and up north. Despite their obvious importance, transport systems do not function as they should. The roads and rail are in a dilapidated condition and a significant proportion of investments made in road networks in 1960s and 1970s have disappeared because of lack of maintenance. The poor state of roads slows down the development of supply systems and food distribution. It is common to see trucks conveying perishable produce breaking down and remaining in that state for from three days to a week without removing the produce. In cities like Jos, Kano and Lagos, piles of spoiled fruits tell the tale of the ineffectiveness of the transport system *(Oyewole and Oloko,* 2006*)*. The highlighted problems in addition to others particularly the location of the only gamma irradiation facility in Sheda, Abuja will constitute problems that limit the adoption of this method of food preservation in Nigeria.

IX. POSSIBLE SOLUTIONS TO THE PROBLEMS ASSOCIATED WITH FOOD IRRADIATION TECHNOLOGY

If food irradiation technology is to gain widespread usage in Nigeria, then the problems highlighted in the previous chapter needs to be addressed. This section will attempt to proffer possible solutions to the problems highlighted in the previous chapter.

A. Lack of Adequate Equipments

The fact that Nigeria has just one functional irradiation facility is a setback. If Nigeria has to measure up with other developed countries as regards the use of irradiation technology for the preservation of food and other materials commercially, then she will need to begin setting up more irradiation facilities at strategic locations, so as to enhance easy accessibility from all parts of the country. To address the above issues properly, a system must be put in place that brings public and private sectors together for active interaction. A cue could be taken from the Food Corporation of India, which has played a significant role in transforming the Indian food economy. It operates through a countrywide network of institutions and infrastructures at zonal, regional and district level *(Oyewole and Oloko,* 2006*)*. Active co-operation between the relevant government agencies and the private sector will in more ways than one hasten the creation or construction of more irradiation facilities at strategic geo-political zones and locations in the country, in order to make this technology accessible to potential users.

Once these structures are put in place, it will also go a long way to address the issue of transportation. Once GIFs are available at strategic geo-political zones and locations in the country, places where production is high, then the constraint of moving food produce over long distances will be considerably minimized.

B. Cost Arising From the Actual Service

There is also need for production incentives in terms of favorable pricing linked with efficient marketing facilities, if losses are to be reduced. In Nigeria, however, incentives are generally minimal or non-existent. There is no provision for cushioning farmers against periods of sharp price fluctuations. The issue of price assurance must be addressed so that the farmer can increase production to levels that will ensure stability of supplies to meet both normal and emergency requirements.

Also, the slight increase in price for irradiated food is insignificant considering the benefits the consumers get in terms of convenience, improved hygiene of the food, quantity and availability *(Frenzen et al.,* 2000*)*.

C. Lack of Adequate Sensitization

To solve the issue of inadequate sensitizations, there should be a platform for extension agents to actively disseminate information on improved storage techniques to farmers in the rural areas through use of mass media (e.g. radio/television) and farmers groups. Available sources of storage technologies should also be communicated to farmers by the zonal extension service.

Also, the use of some modern storage technologies requires specialized skills and technical know-how which farmers are lacking. Farmers should be trained on the use of these improved storage methods such as storage by irradiation. Institutions, the government and other organizations should arrange regular workshop training for farmers and those who operate agricultural machinery, in a bid to educate and familiarize them with this technology, and to encourage its adoption.

D. Transport System

Also necessary, is the Construction of Feeder Roads**.** These must be built to convey the large amounts of farm produce now wasting away in the fields because of lack of transport facilities. This problem can also be solved setting up more irradiation facilities at strategic locations, so as to enhance easy accessibility from the farms to the facility.

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X. CONCLUSION

This report has attempted to discuss the prospects and problems associated with the use of food irradiation as a food preservation method in Nigeria. Food irradiation is a food preservation method which involves the process of exposing foodstuffs to a source of energy capable of stripping electrons from individual atoms in the targeted material (ionizing radiation) *(Anon,* 1991*).* This method of food preservation can be referred to as a more advanced form of food preservation. Some school of thought criticize the use of irradiation for food preservation because of the negative impressions of the nuclear industry, and this has made irradiation one the most investigated forms of food preservation. Food irradiation has being endorsed by the World Health Organisation (WHO), and is currently being used in over 40 countries and approximately 500,000 tons of food items are irradiated yearly all over the world.

The common sources of ionizing radiation recommended by the codex general standard for use in food irradiation include;

Gamma rays produced from the radioisotopes cobalt-60 (60Co) and celsium-137 (137Cs)

Machine sources generating electron beams and x-rays.

Machine sources have the advantage that no radioactive substance is involved, and it can be switched off and on with the just the push of a button.

Though food irradiation brings about some chemical changes in food, these changes are not different from those that occur when food is exposed to other forms of food processing or probably when food is cooked. However based on hundreds of scientific tests, there is a broad agreement among scientists and health agencies that these changes do not pose a human health issue.

Food can be irradiated either in its prepackaged form or its packaged form depending on the type of food product. The food products are exposed to ionizing radiation over a particular period of time, to achieve the desired and recommended dose rate. This process is carried out in specially designed and shielded facilities so as to avoid incidences of environmental pollution.

In Nigeria, food irradiation has not gone beyond the experimental stages. But with the present efforts of some relevant government agencies such as the Small and Medium Enterprise Development Agency of Nigeria (SMEDAN) and Nigeria Atomic Energy Commission (NAEC), and also some promising research from various scholars in Nigeria, there is a promising indicator that this technology will soon reach its stage of commercialization in Nigeria.

The problem of population-food imbalance, caused by food wastage and spoilage is common to most developing nations of the world including Nigeria. One of the effective strategies that can be used in solving this problem is to reduce the amount of food lost in the post-harvest system. Several investigations by Nigerian scholars have confirmed that food irradiation technology will adequately help reduce spoilage and wastage of some basic food products in Nigeria.

The Nigerian government under the directive of the NAEC also shares the same view and as such have begun to put some structures in place so as to enable meaningful research work on the usefulness of this technology on Nigerian food products and to facilitate the smooth introduction of this technology in Nigeria. It is in this light that the NAEC created six nuclear research centers among which is the Nuclear Technology Centre (NTC), Sheda Science and Technology Complex, for research and development *(Agedah,* 2014*),* which houses a 340 kCi Co-60 Gamma Irradiation Facility (GIF). This facility is currently being utilized by various researchers in the country.

Despite all these efforts, there are still some critical issues that need to be addressed for the smooth introduction of this technology in Nigeria. These problems include; lack of adequate irradiation facilities, cost of procuring this service, cost of setting up more irradiation facilities, lack of adequate sensitization etcetera.

If irradiation is to gain widespread use in, then the highlighted problems would need to be adequately tackled.

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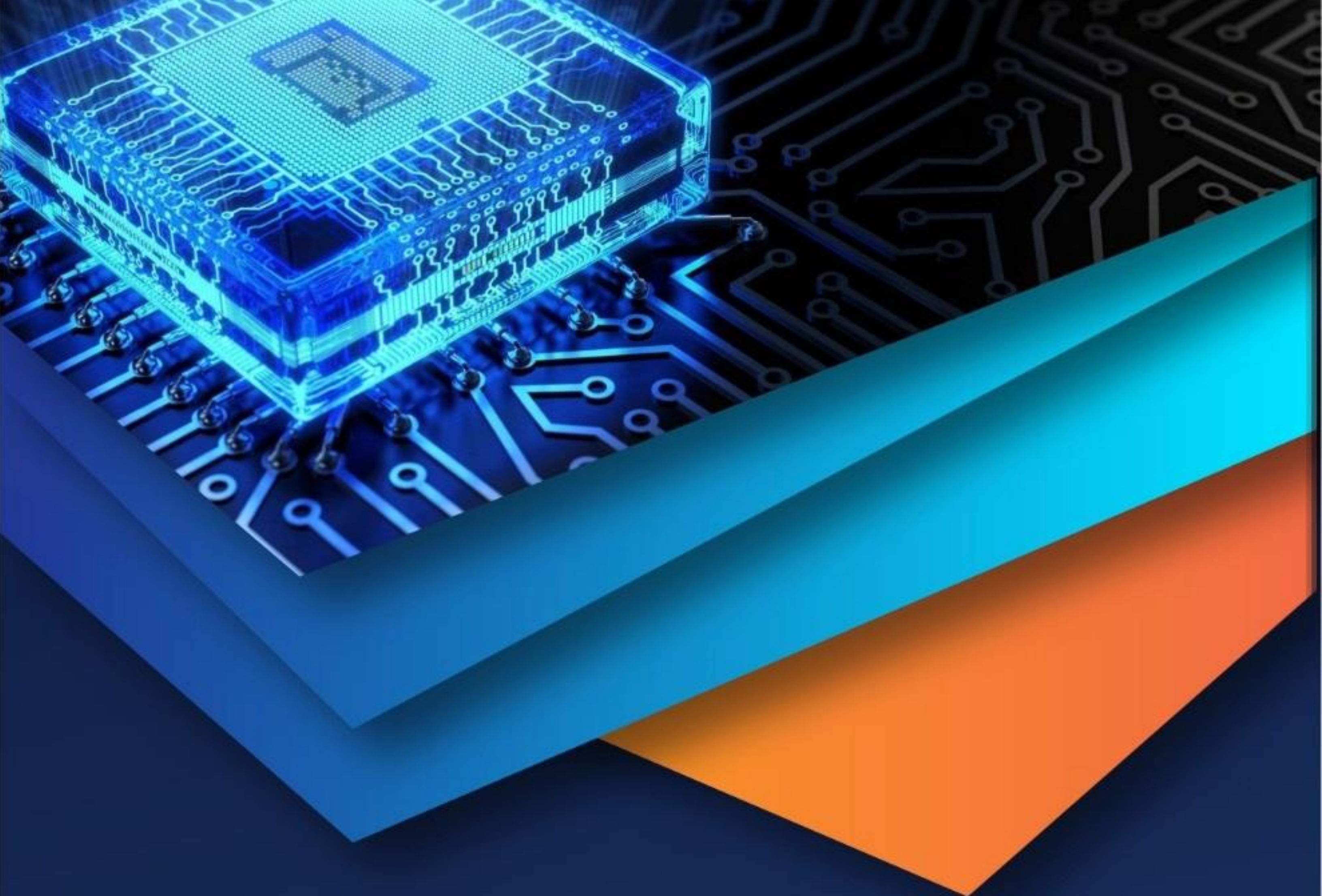

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