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Reducing post harvest losses of foods: The prospect of food irradiation in Nigeria

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Abstract

The prevailing wave of colossal losses of post-harvest foods in Nigeria is a sure menace that needs urgent and decisive action. The present knowledge of food handling after harvest in Nigeria needs to be upgraded as most of our handling methods are riddled with traditional techniques that leave much to be desired. The use of ionizing irradiation as a means of extending the shelf life of foods in European countries had gained prominence due to its veracity and safety but in Nigeria it is not very popular. This paper tends to address the possible ways of handling foods to reduce post-harvest losses of foods and the benefits of Gamma Irradiation as a veritable preservative technique that should be popularized in Nigeria.

Keywords: Gamma irradiation, Food losses, Macronutrients, Post-harvest.

Introduction

The need to strike a balance between the quantities of food produced and the amount readily available for consumption by the teaming populace is very crucial. With a projected global population increase from more than 7 billion in 2012 to 9 billion in 2050, it is estimated that food production must increase by more than 70% to meet future demand. At present, Nigeria is bedeviled by unwarranted loss of food from the farm gate up to the point of consumption (Ogugbuaja, 2017; Ashaye, 2018; Akinyele 2010). These occurrences are observed to be mainly due to the uncoordinated ways in which food crops are handled from the farm gate.(Ojofeitimi *et al;* 1984; Aworh, 2010). A lot of interventions are, however, been enacted over the years in order to avert this dangerous trend. The use of different preservative methods such as smoking freezing, etc has been done with the aim to improve on the availability and food consumption patterns. There have been trickles of successes in some of these preservative methods; although trials of other methods are still at experimental stage. Most of these preservative practices are, however, not sufficient to address this looming problem of food wastages (FAO 2013; Atanda *et al*, 2011). In order to reduce this problem, a novel preservative method was introduced in Nigeria called Gamma Irradiation.

Food irradiation with the use of gamma rays 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) (Ashaye, 2008*).* 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 (Ashaye, 2005; Akinloye *et al,* 2015). The present status of the use of Gamma Irradiation in the preservation and extension of shelf life of foods in Nigeria needs to be revisited in order to allay fears of end users and also to increase its popularity across the Nation.

Post-harvest Handling Techniques

Postharvest begins when the process of collecting or separating food of edible quality from its site of immediate production has been completed. The food must be separated from the medium that produced it by a deliberate human act with the intention of getting it to the table. The post- harvest ends when the food enters the mouth. (Aworh, 2005; Ashaye, 2018).

Primary unit operations

Husking

Husking can be done by dry method or the wet method. Traditionally in African and Asian countries, the dry method involves pounding of the dried grains in mortar with pestles or in hand- operated wooden or stone sheller. Improved power-operated sheller is a good alternative. Wet grinding process for husking involves soaking of the grains before drying. (Agboola, 1980; Ashaye, 2009).

Winnowing

The separated husks are removed from the cotyledons by winnowing. Winnowing can be done manually which is time consuming and laborious or by improved abrasive hulling machines which separate husk form cotyledons (Agboola, 1980; Ashaye, 2009).

Separation

This process is used to remove or separate whole grains from split, broken and powdery ones. It is done manually using sieves or mechanically with machines designed with a sieving device. Sieving manually is laborious and time consuming (Ashaye, 2009).

Secondary cleaning operations

Sorting and cleaning

Crops are sorted and cleaned to remove dirt, stones, chaff, broken and spoilt seeds and other foreign materials. Sorting is done by hand which is laborious and time consuming or through mechanical or electronic sorting device. Cleaning can be done by dry or wet methods. Dry cleaning is suitable for grains meant for storage purpose (Ashaye *et al,* 2015; Ashaye *et al,* 2007; Ashaye *et al,* 2006; Ashaye and Fasoyiro 2009).

Soaking

Different grains are soaked in water for different periods of time. Soaking in water allows the grains to absorb water, to decrease and eliminate anti-nutritional factors especially in legumes. However, soaking for long periods of time has been found to reduce nutritional quality of legumes through leaching of nutrients into the soak water (Ashaye *et al,* 2007; Cardoso *et al,* 2005).

Blanching

Blanching is a mild heat treatment of seeds. Some crops are usually blanched by soaking in hot water or boiled in water for few minutes. This process destroys food enzymes and some anti-nutritional factors e.g. soybean. Blanching can also aid the dehulling process (Aworh, 2005; Ashaye, 2009).

Boiling/cooking

This process improves the appeal and sensory properties of crops. It tenderizes the seeds through water absorption. It can also eliminate heat labile anti-nutritional factors such as trypsin inhibitors (Igene, 1992; Ashaye *et al*, 2007).

Roasting

Crops such as legumes are roasted on the open frying pan in the presence or absence of salts or ash. Roasting improves the taste and edibility of legumes. It is important also in reducing and eliminating anti-nutritional factors. Roasted legumes are characterized by unique flavours which can increase their sensory appeal (Ihekeronye and Ngoddy, 1985;Ashaye *et al,* 2007).

Germination

Germination enhances desired qualities such as improved digestibility, reduced anti-nutrients like trypsin inhibitors. It improves nutritional quality of the proteins by hydrolyzing them into absorbable polypeptides and essential amino acids. Germinated or malted legumes and cereals are eaten in form of sprouts and are better than ungerminated ones. Sprouting improves the availability of vitamins B and C. It also reduces polyphenols content. Chicken pea and broad beans are commonly germinated before eating, cooking or use in salad dressing and germinated cereals such as maize are used in the preparation of malt drinks (Ihekeronye and Ngoddy, 1985; Ashaye *et al,* 2007).

Milling

Milling is a size reduction process of the seeds into smaller particle forms. Wet milling of seeds will produce a paste while dry milling results in flour production. Different types of equipment have been designed for milling for household or industrial purpose. Wet milled legume may be mixed with other ingredients and steamed in leaves to produce pudding (*moinmoin)* or fried in hot oil to obtain bean cake (*akara*). In cereals products such as 'abari', 'kokoro' and 'ogi' from maize are obtained through wet milling processes. (Adeyemi, 1987; Aworh, 2008; Ashaye *et al,* 2007).

Sieving

Sieving removes unwanted materials from whole ground legume seeds (dry or wet). Example of wet sieving is in the filtration of ground soybean paste in the production of soymilk. The sieving process removes the unwanted residue. For the dry-milled legume flour, sieving helps to achieve different ranges of particle sizes. Wet sieving can be done using cheese-cloth or muslin cloth while dry sieving can be done with different kinds of local or standard sieves. Some milling equipment have sieving devices incorporated into the design (Ihekeronye and Ngoddy, 1985).

Frying

Several crops are wet milled, mixed with other ingredients in preparing different local or oriental dishes before being fried. Frying improves their appeal and eating quality. It also improves digestibility and reduces anti-nutritional factors (Ihekeronye and Ngoddy, 1985).

Canning

This is a sophisticated technology of packaging processed foods in cans. The packaged food products are sometimes soaked in brine, sugar or tomato purees.

This technology allows for all year round availability of the product and for food preservation (Ihekeronye and Ngoddy, 1985).

Fermenting

The process increases the digestibility of plant proteins and also reduces the anti-nutritional factors. Fermentation enhances flavour, colour and texture of crops (Aworh, 1993). Changes in these attributes are major stimuli in development of fermented products (Table 1). It reduces heat stable anti-nutritional factors such as phytate. Fermented crops are consumed as condiments e.g fermented locust bean ('*iru'*) and 'gari' from cassava (Odunfa and Oyewole 1997; Ogundiwin and Oke 1983).

Drying

This technique reduces the moisture content of food to the point where molds and other microbes may fail to grow, but it does not prevent the growth of insects and higher forms of life such as rodents or birds. Drying has been one of the major methods of reducing postharvest losses of food especially for grains and other perishables. Drying also reduces weight, making food more portable and easily packaged for onward transport from one place to the other. Hence, postharvest losses can be curtailed through sustainable drying and value addition (Ashaye *et al,* 2000; Ashaye *et al,* 2004). Drying, preserve foods by removing enough moisture from food to prevent decay and spoilage. Water content of properly dried food varies from 5 to 25% depending on the food (Table 2). When drying foods, the key objective is to remove moisture as quickly as possible at a temperature that does not seriously affect the nutritional composition, flavour, texture and colour of the food. Two basic phenomena are involved in the drying process, namely: the evaporation of moisture from the surface of the materials and the migration of moisture from the interior of a material to the surface There are four major modes of moisture transfer namely liquid movement caused by capillary forces; liquid diffusion resulting from concentration gradient; vapour diffusion due to partial pressure gradients; and diffusion in liquid layers absorbed at solid interfaces. (Banigo and Akpapunam, 1987).

Different kinds of drying systems have been and are still widely used by processors in African countries. Some common ones include open air or sun drying, cabinet drying while recently emerging ones are flash dryer, rotary dryer, tunnel dryer, solar cabinet dryers, and a combination of solar and in- direct heating of the drying room, which can be described as a hybrid drying system. The traditional drying systems in Africa are characterized by drudgery and high processing losses. Sun drying still remains the dominant forms of drying in Nigeria. Unfortunately, sun drying has a lot of limitations and drawbacks due to its dependence on nature. This results in products with varied qualities as a result of uneven drying and contamination from molds and bacteria. (Ashaye *et al*, 2004).

Refrigeration and Cooling

Refrigeration and cooling are of particular interest for extending the storage life of perishable foods in developing countries. They retard senescence which includes ripening and associated physiological and biochemical changes. It also minimizes the sensitivity of horticultural commodities to ethylene. Ethylene damages various

Table 1. Some traditional Nigerian fermented foods

Fermented Food	Raw Material (Substrate)	Microorganisms involved	Uses
Gari	Cassava pulp	*Leuconostoc* spp. *Lactobacillus* spp. *Streptococcus* spp. *Geotrichum candidum*	Main meal
Fufu	Whole cassava roots	*Lactobacillus* spp. *Leuconostoc* spp.	Main meal
Lafun	Cassava chips	*Leuconostoc* spp. *Lactobacillus* spp. *Corynebacterium* spp. *Candida tropicalis*	Main meal
Ogi	Maize, sorghum, millet	*Lactobacillus plantarum* *Streptococcus lactis* *Saccharomyces cerevisiae* *Rodotorula* spp. *Candida mycoderma* *Debaryomyces hansenii*	Breakfast cereal, weaning food
Iru (Dawadawa)	African locust bean (*Parkia biglobosa)* Soybean	*Bacillus subtilis* *B. licheniformis*	Condiment
Ogiri (Ogili)	Melon seed (*Citrullus vulgaris*), Fluted pumpkin (*Telfairia occidentalis*), Castor oil seed (*Ricinus communis*)	*Bacillus* spp. *Escherichia* spp. *Pediococcus* spp.	Condiment
Kpaye	*Prosopsis africana* (algarroba or mesquite)	*Bacillus subtilis* *Bacillus licheniformis* *Bacillus pumilus*	Condiment
Ugba (Ukpaka)	African oil bean (*Pentaclethra macrophylla*)	*Bacillus licheniformis* *Micrococcus* spp. *Staphylococcus* spp.	Delicacy usually consumed with stock fish or dried fish
Palm wine	Palm sap	*Saccharomyces* spp. Lactic acid bacteria Acetic acid bacteria	Alcoholic drink
Burukutu/Pito/Otika	Sorghum Millet & maize	*Saccharomyces* spp. Lactic acid bacteria	Alcoholic drink
Shekete	Maize	*Saccharomyces* spp.	Alcoholic drink
Agadagidi	Plantain	*Saccharomyces* spp.	Alcoholic drink
Nono (Fermented milk)	Milk	Lactic acid bacteria	Drink or converted to butter
Fura-da-nono Kunu-da-nono	Milk-cereal mixtures	Lactic acid bacteria	Drink
Warankasi (Soft cheese)	Milk	Milk coagulated by plant rennet. Lactic acid bacteria produce lactic acid from lactose.	Meat substitute

Source: Aworh, 1990

Table 2: Safe moisture content of some legumes

Legumes	Safe moisture content (%)
Broad bean, cowpea, kidney bean, white bean	15.0
Lentil, pea	14.0
Groundnut (shelled)	7.0
Soybean	13.0

Source: Ihekeronye and Ngoddy, 1985

vegetables and fruits by accelerating senescence or ageing. Acceleration of ripening during transit is generally considered undesirable in many commodities including bananas and plantains. Ageing of vegetative tissue by ethylene can reduce undesirable physiological disorders such as spotting in lettuce usually "russet spotting". It also reduces insect infestation of germs and dry fruits. There is a great need for low cost refrigerating systems for the preservation of perishable foods that is within the economic reach of rural communities (Ladipo *et al,* 1986; Babalola *et al,* 2002).

Chemical Preservation

There are also chemical preservatives that can be used to preserve perishable foods. A number of chemical preservatives such as benzoic acid, sulfur dioxide, sorbic acid, parabens, fat anti-oxidants and propionates are used as permitted food preservatives. Salt is an excellent chemical means of preserving fish, some meats, and some vegetables. Stored roots and tubers are prone to sprouting and decay. Chemicals such as maleic hydrazide, and chlorprofam would stop the sprouting of potatoes and onions and thiobendazole, and benomyl inhibit rotting in stored potatoes and fruit (Ashaye, 2005).

Canning

The thermal sterilization of food in cans or bottles is one of the best means of preserving perishable foods and maintaining good quality, but it is an expensive process and there is little chance that the cost of the container or the processing technique will be reduced substantially. The high cost of canning disqualifies it for large scale preservation techniques in most developing countries.

A new development in this area is the use of heat-sealable plastic pouches to replace the cans. At this time this technology is even more expensive than the use of cans and until the cost of the plastic pouches can be reduced very substantially, it, too, would not be recommended for large scale preservation among subsistence populations (Taiwo *et al,* 2002; Sanni, 1993).

Gamma Irradiation

Gamma irradiation is a process which offers an effective alternative quarantine treatment. It is more environmentally friendly and energy saving, a major advantage over conventional method of food preservation in this era of high-energy cost (Aworh, 1986; Aworh *et al,* 2002). The energy expenditure for irradiation is much lower than for canning or freezing as it allows full use of the most economical type of packaging materials and methods. The need for expensive tin plates as in canning or other specialized packaging materials or methods as in vacuum packaging is eliminated (Ashaye, 2005).

Gamma Irradiation of Foods

There are two well-known irradiation facilities in Nigeria. The first one which is a micro pilot one is located at the Centre for Energy Research at Obafemi Awolowo University Ile-Ife in Osun state while the bigger one called SHESTCO is located at Sheda near Abuja/FCT.

The Gamma Irradiation facility at Obafemi Awolowo University is mainly used for research purposes, while that of SHESTCO is being operated to demonstrate the advantages of irradiation technology in Nigeria.

In SHESTCO special emphasis is given to the versatility of the plant to suit the various modes of operation. Another main feature of this facility is the inclusion of different research laboratories to cover the various investigations and experiments related to the applications of the gamma irradiation techniques. (Ashaye, 2008; Ashaye 2005; Akinloye *et al,* 2015).

Design Concept of a Gamma Irradiation facility

The design of the Gamma Irradiation facility takes into account the different needs of the various research applications which require a wide dose range, a variety of techniques and tests of differently-sized products. For food irradiation purposes, the weight may range from a few kilograms to 500 kg and requiring irradiation doses from 40 to 10,000 gray (Gy). On the other hand, biological seed mutation experiment requires irradiation doses from 10 to 5,000 Gy. Higher irradiation doses are applied for the sterilization of objects (up to 25.000Gy) and for the cross linking of plastics with doses up to 100,000 Gy.

The continuous material throughout can be operated as well as the batch operation or a short irradiation of a sample. The transporting systems are designed accordingly to allow these different types of operation. The irradiation source may be adapted as well to the different requirements (Akinloye *et al,* 2015).

Plant Description

Irradiation Process Equipment

The building of the Gamma Irradiation Facilities should at least consist of a hall with overall dimensions of approximately 48 m long, 40 m wide and a height of 12 m, which contains in its center the irradiation room with the Gamma Irradiation source, the Source Storage Pool and rod-type capsules of austenitic steel containing Cobalt- 60 in form of pellets. Cobalt-60 is normally produced by a nuclear reactor of the metal cobalt-59. It has a half-life of 5.3years. (ICGFI, 1991; Ashaye, 2005).

There should be at times 40 source capsules sized approx. 450 mm long and 11mm in diameter, arranged in stainless steel frames, each one holding up to 20 capsules and which in turn are placed in the source rack. During irradiation the source rack are lifted up into the irradiation room by means of the motor driven source lifting device. For shut down the source rack is let down into the storage pool to be covered by water for shielding purposes. If lower doses are required only one section of the source rack will be lifted up independently. After determining the mode and time of irradiation, the products to be irradiated are filled in suitable containers which are stacked up on pallets. A fork lift places the pallets on the pallet conveyor, where registration and identification is performed. By means of the transfer station, two pallets are put in each cage of the overhead conveyor. Depending on irradiation time and mode of operation the overhead conveyor transports the materials within the cage to the irradiation room, where irradiation takes place.

After the irradiation process, the cages leave the irradiation room and are transported by the overhead conveyor to the transfer station from where they will be placed on the pallete conveyor and removed from there with the fork lift for storage in suitable storage containers. For irradiation of smaller quantities of food materials, a specially provided sample lift can be used independently of the overhead conveyor system. Refrigerated or deep frozen products can be irradiated as well, for which refrigerator and deep freezer storage boxes are provided for irradiated as well as for untreated products. The incoming materials are normally stored at one side of the hall whereas the irradiated products are stored at the opposite side to avoid any mix up (Plate 1). The access to the irradiation room is normally restricted with alarms and protection devices to avoid any accident (Akinloye *et al,* 2015; Ashaye, 2008).

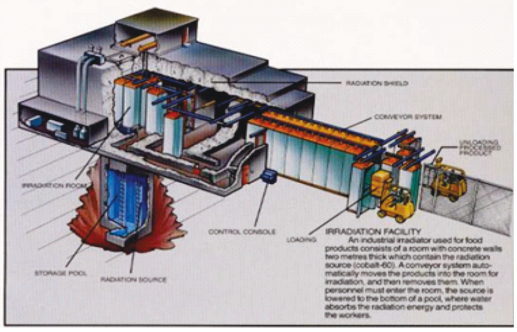

Plate 1: A typical irradiation facility (Ucdavies, 2017)

Other Sources of Irradiation

(a) Radionuclides

Another popular gamma-emitting radionuclide popularly used for industrial processing of materials is Caesium-137. It can be obtained by reprocessing spent, or used, nuclear fuel elements and has a half-life of 30 years (ICGFI, 1991).

(b) Electron machines

Machines capable of accelerating electrons are known to produce high electron beams. Electrons cannot penetrate very far into food, compared with gamma radiation or X-rays; hence it's useful only for very thin packages. Accelerated electrons can be made to strike a metal target and so be converted into X-rays (ICGFI, 1991).

(c) X-rays

X-rays with varying energies are generated by machines and this is usually produced when a beam of accelerated electrons bombards a metallic target. X-rays have a good penetrability into foods (Ashaye, 2005: ICGF, 1991).

Application of Food Irradiation

Extension of shelf life

Irradiation can be used to destroy or inactivate organisms that cause spoilage and decomposition, thereby extending the shelf life of foods (Table 3). A dose of 4.0 kGy was sufficient enough to prevent moulding during storage of cowpea at ambient temperature and humidity of 92% whilst a dose of 5.0 kGy completely suppressed aflatoxin production in soyabean and groundnut when cultures were pre-incubated for 2hrs before irradiation (FAO/WHO, 1984). Irradiation of poultry and poultry products, including mechanically recovered meat, to reduce numbers of Salmonella, Campylobacter and other food poisoning bacteria doses of up to 3 kGy (fresh) and up to 7 kGy (frozen) have been recommended (Webb and Lang, 1990). Irradiation of red meats, including hamburger meat, to reduce numbers of *Escherichia coli* and other food poisoning bacteria with doses of up to 4.5 kGy (fresh) and up to 7 kGy (frozen) has been recommended. Irradiation of dried herbs and spices to reduce levels of contaminating micro-organisms generally and reduce the chances of survival of food poisoning bacteria in particular doses up to 10 kGy have been recommended (Webb and Lang, 1990).

Irradiation of some imported seafood, in particular warm water prawns and other shellfish, to improve their microbiological safety doses up to 3 kGy have been recommended. Irradiation of certain fruit and vegetables in order to reduce the numbers of microorganisms, particularly those which cause spoilage with doses up to 2 kGy have been recommended (FAO/WHO, 1984) as listed in Table 3. It is an energy-efficient food preservation method that has several advantages over traditional canning. The resulting products are closer to the fresh state in texture, flavour, and colour. Using irradiation to preserve foods requires no additional liquid, nor does it cause the loss of natural juices. Both large and small containers can be used and food can be irradiated after being packaged or frozen. (FAO/WHO, 1984).

Control of physiological processes

The development of high-yielding, short duration and disease-resistant varieties of potato in recent years has led to increased production and consequently problems of storage and conservation. Chemical sprout inhibitors are difficult to apply and are not always effective. Sprout inhibiting dose of radiation is also effective in destroying tuber moth, a devastating pest of potato. Irradiation, therefore, offers a satisfactory solution to storage losses because sprouting of the tubers and bulbs and their dehydration can be reduced substantially. Low doses of radiation are effective in delaying the natural processes of ripening in fruits (Table 3). Thus, shelf life of mangoes can be extended by about a week and that of bananas up to two weeks. This could improve the scope for internal trade and augment export of these commercially important fruits (Aina *et al.,* 1990).

Insect disinfestation

Furthermore, gamma radiation can eliminate the seed weevil *Callosobruchus maculatus*. Radiosensitivity of cowpea decreases as *Callosobruchus maculatus* develops from eggs to larvae pupae and adults. A dose of 10 Gy is sufficient to kill the eggs (Table 3) and the latter stages of *C maculatus* development and consequently reducing the number of adults that emerge from irradiated pupae (Ashaye, 2005). Irradiation must be carried out as soon as the bean is stored otherwise higher doses will be required to destroy the adults. In case of reinfestation after irradiation, cowpea with low moisture content can be subjected to re-irradiation and still maintain its wholesomeness (FAO/WHO, 1984). With spices, spice export trade is always faced with stringent quality requirements relating to insect infestation and microbial contamination. Fumigation of spices with chemicals like methyl bromide, ethylene oxide and propylene oxide, has inherent disadvantages, especially retention of chemical residues. Single treatment of gamma radiation can make spices free of insect infection without the loss of flavour components (El-Kady, 1985; Kovacs *et al.*, 1985). The treatment can also be used for pre-packed ground spices and curry powders. In this role, irradiation offers an alternative to chemicals for use with potatoes, tropical and citrus fruits, grains, spices, and seasonings (Anon, 1999).

Table 3: Application of Irradiation

Purpose	Dose KGY	Products
LOW DOSE (up to IKGy)		
Inhibition of sprouting	0.05 – 0.15	Potatoes, onions, ganlic, ginger-root etc.
Insect disinfestation and parasite disinfestation	0.15 – 0.50	
Delay of physiological Processes (e.g. ripening)	0.50 1.00	Cereals and pulses, fresh and dried fruits, dried fish and meat, fresh pork etc.
MEDIUM DOSE (1-10KGy)	1.0– 3.0	
Extension of shelf life		Fresh fruits and vegetables
Elimination of spoilage and pathogenic microorganisms	1.0– 7.0	
	2.0– 7.0	Fresh fish, strawberies
Improving technological properties of food		Fresh and frozen sea food, raw or frozen poultry and meat,
	30 – 50	etc.
HIGH DOSE (10-50KGy)		
Industrial sterilization in combination with wild heat		Meat, poultry, seafood, prepared foods, sterilized
	10 – 50	hospital diets.
Decontamination of certain food additives and ingredients		Spices, enzyme preparations, natural gum, etc.

Source: Webb and Lang, (1990)

Effect of Irradiation on Macronutrients

Lipids

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. 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 (Akinloye *et al,* 2015). The strong oxidizer ozone is produced from oxygen during food irradiation and can promote the oxidization of lipids and myoglobin. 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.

Other studies showed that irradiation (2.5 kGy) increased 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 work of Olotu *et al* (2014) showed that 10 kGy irradiation and cooking made oil extract from African oil bean seed to be more vulnerable to lipid peroxidation (rancidity) because it increased the degree of unsaturation in the fatty acid (more double-bond formation). Ten kilo gray (10 kGy) irradiation, cooking, and combined treatment decreased, prevented, and induced the formation of some of Xthe fatty acids present in the oil, while irradiating African oil bean seeds at 10 kGy led to the loss of 75% of the fatty acid present that were found to be present in the raw African oil bean seed.

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 (Akinloye *et al,* 2015). In the case of Spanish mackerel, C16:0 and C16:1 fatty acids decreased when irradiated at 1.5 to 10 kGy. 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. 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 (Ashaye, 2005; Akinloye *et al,* 2015).

Proteins and Amino Acids

Damage caused to protein by ionizing radiation includes deamination, decarboxylation, reduction of disulfide linkages, oxidation of sulfydryl groups, cleavage of peptide bonds and changes of valency states of the coordinated metal ions in enzymes. Other studies indicated that there was no significant destruction of cystine, methionine and tryptophan up to a dose of 71 kGy. The majority of amino acids in minced lean beef or pork and chicken breast muscle are stable up to a dose of 5 kGy . 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 (Diehl, 1995). 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 (Akinloye et al, 2015).

Vitamins

Many authors have studied the effect of irradiation on the stability of vitamins in foods (Muller and Diehl, 1996). No loss of riboflavin was found in pork chops and chicken breasts irradiated at temperatures between - 200°C and 200°C of doses up to 6.6 kGy. Some irradiated samples even exhibited an increase in riboflavin concentration of up to 25%. 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. 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 (Akinloye et al, 2015: Aworh 1986). The application of gamma irradiation (1, 2, and 6 kGy) on fillets of Black bream (Acanthopagrus australis) and Redfish (Centroberyx affinis) 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 .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 Irradiation of shrimps at 2.5 kGy induced a 15% loss of riboflavin in air, 8% in vacuum, and 20% in nitrogen (Akinloye et al., 2015).

Effect of Irradiation on Food Functionality

In the work carried out by Falade and Kolawole (2012), loose and packed bulk densities, and water (WAC) and oil absorption capacities of the maize flours were not significantly affected by gamma-irradiation. WAC of non-irradiated and gamma-irradiated maize flours ranged from 1.54–1.62 and 1.09–1.70 g /g), respectively. Peak, trough, breakdown, final and setback viscosities decreased significantly ($P < 0.05$) with increased gamma-irradiation dose. Falade et al, (2011) also discovered that the pasting properties of non-irradiated and gamma-irradiated sweet potato showed similar but clearer trend compared with yam flours. Increased irradiation dose (0–8 kGy) resulted in mild to no significant effect on colour (L*, a*, b*) and functional properties (loose and packed bulk densities, WAC and OAC) of millet cultivars (Falade and Kolawole, 2013b).

In bambara nut cultivars there were marginal differences in the pasting properties of non-irradiated and gamma irradiated samples (Falade and Nwajei, 2014). Pasting and some functional properties of cowpea cultivars may be slightly modified by irradiation treatment

(Ashaye, 2008; Ashaye and Aina 2008; Falade and Kolawole 2013a).

In the study carried out by Bamidele and Akanbi, (2013), functional properties of the irradiated pigeon pea flours showed slight increase in water absorption capacity, swelling capacity and bulk density. The peroxide value of crude oil increased significantly with dose increases for the period of storage. Gamma irradiation was found to extend the shelf life of pigeon pea flour.

International Perspective on Food Irradiation

In the UK, the Advisory Committee on Novel and Irradiated Foods approved irradiation in 1986 as a safe and satisfactory method of food processing. This opinion was reaffirmed in 1987 after receiving submissions from industry, consumer groups and interested parties. (Anon, 1999). In 1991, the Food (Control of Irradiation) Regulations in the UK cleared 7 categories of foods for irradiation to specified overall average doses: Fruits (2.0 kGy), Vegetables (1.0 kGy), Cereals (1.0 kGy), Bulbs and tubers (0.2 kGy), Spices and condiments (10 kGy), Fish and shellfish (3.0 kGy) and Poultry (7.0 kGy). The regulations also make provision for labeling to ensure that consumers would be fully informed whether foods or ingredients within them had been irradiated. Under the Food Labeling Regulations (1996), irradiated foods and ingredients have to be identified with the words "irradiated" or "treated with ionising radiation". Irradiation facilities must also meet specified criteria before they can be licensed to process foods. To date, it is now mandatory for all irradiated foods to carry an internationally recognized logo (Anon, 1999).

Major Problems on the Use of Gamma Irradiation in the Preservation of Foods in Nigeria

Irradiation centres at Centre for Energy Research at Obafemi Awolowo University Ile-Ife in Osun state and SHESTCO located at Sheda near Abuja/FCT, may be too small to handle the quantity of harvested food products meant for preservation. The location is not advantageous especially to farmers that stay in the southern part of the country. The issue of travelling so far to the irradiation centre will have a negative effect on their produce such as mechanical injury during transportation and unnecessary heat buildup which may trigger deterioration before it gets to the treatment centre. The cost of transportation is also another issue. With the farmer adding the cost of transportation to irradiation cost may increase the cost price of the produce which may be unaffordable to teaming consumers. The state of our roads is also a major problem. Our roads are very bad and could cause delay in promptness of irradiation and also it could damage the crops during transportation. There is a need for proper enlightenment programme via radio television, internet and extension workers on the safety and benefits of irradiation to health. (Ashaye, 2005; Akinloye *et al,* 2015).

Conclusion and Recommendation

Nigeria needs to come out of her economy doldrums in the area of unnecessary post-harvest losses of foods. In view of this, the following recommendations may serve as a solution to some of the problems facing the country:

Reduction of mechanical injury to perishable fruits and vegetables, roots and tubers during harvest and in subsequent handling and storage.

Use of pallet boxes rather than the traditional jute bags for the irradiation, handling and storage of yams and onions.

Price efficiency inducing policies designed to increase the responsiveness of the marketing system to consumer direction by improving market information and establishing consumer grades and standards.

Structural policies designed to modify the behaviour of the middlemen so as to improve market performance through the establishment of co-operatives.

System analysis of specific marketing procedures in order to determine cost and returns and economies of scale.

Provision of hermetically sealed silos and insect proof bags to prevent post-irradiation re-infestation of irradiated food products and dried fish.

Introduction of consumer packaging if irradiated produce are to be differentiated through labeling at the retail level.

Opportunities should be provided for training of skilled manpower in food irradiation by international and other agencies especially the International Atomic Energy Agency (IAEA).

Irradiation should be introduced at the primary or secondary collection centres of the food distribution system

Government agencies should acquire commercial irradiators to be run essentially as a service facility for local farmers in the areas of product concentration.

Cost of irradiation should be subsidized to start with until the economic and other benefits of irradiation are clearly established.

Optimum conditions to irradiate the produce, best package/produce combination, and best way to present irradiated produce for sale under Nigerian conditions should be established.

Consumer and people involved in the production, marketing and processing of these commodities should be educated on the fact that irradiated food is very safe; even safer than foods preserved by other conventional methods.

Furthermore, it is important that policy makers are educated on the fact that the process was slow in gaining acceptance in the developed countries simply because they already have other viable systems of food preservation before the advent of Food Irradiation Technology. This, in our opinion, will help to narrow down the present suspicion or objection to the introduction of Food Irradiation Technology in food preservation in many developing countries including Nigeria.

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