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EFFECTS OF GAMMA IRRADIATION ON THE SHELF LIFE AND NUTRITIONAL CONTENT OF "OBUBRA" WATER YAM

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ABSTRACT: *The effects of gamma irradiation on the shelf-life and nutritional content of Obubra water yam in Cross River State, Nigeria were investigated. Two hundred tubers of a total of two hundred and fifty water yams were irradiated using gamma irradiation technology at doses of 50Gy, 100Gy, 125Gy 150Gy and 200Gy in order to test for the shelf-life elongation and nutritional content of the tubers after storage. fifty tubers of the water yam were kept as control (un-irradiated). Proximate analysis was done on the tubers after irradiation and also after storage, including those in the control group. Post-irradiation observation in a five month period revealed that the water yam tubers irradiated at dose level of 125Gy and 150Gy gives maximum shelf-life extension. Results further indicated that all the un-irradiated water yams sprouted by the end of the storage period. 80% of the irradiated water yams at 50 gray, 10% of the irradiated water yams at 100 gray sprouted within the storage period. None of the irradiated water yams at 125 and 150 gray sprouted. The results suggest that gamma radiation dose range of 125 – 150 gray effectively inhibit sprouting in water yams for 5 months and the 125 gray is more effective in preventing spoilage. The percentage weight loss (66%) in the un-irradiated was significantly ($p \leq 0.05$) higher than the irradiated tubers There were no significant differences ($p \leq 0.05$) in the average values of the ash, protein and carbohydrate content of the irradiated and un-irradiated water yam tubers. The results suggest that radiation processing preserved the quality of water yam tubers through sprout inhibition, reduction of weight loss, preservation of macro-nutrients such as protein, fibre, and carbohydrate content. The advantages of this technology are efficient energy and materials, easily controlled, no residues and its' environmentally friendly be efficiently deployed to extend the shelf-life of water yam tubers and increase food security.*

KEYWORDS: Irradiation technology, water yam tubers, proximate analysis, shelf-life.

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INTRODUCTION

Water yam is a common specie of Dioscorea cultivated by majority of tuber farmers in Nigeria. There are three major edible Dioscorea species, which include the white guinea yam (Dioscorea rotundata poir), yellow guinea yam (Dioscorea cayenensis lam) and water yam (Dioscorea alata).

Water yam (D. alata) are large plants; the vines can be as long as 10 to 12 m (33 to 39 ft). The tubers most often weigh about 2.5 to 5 kg (6 to 11 lb) each, but can weigh as much as 25 kg (55 lb). After 7 to 12 months' growth, about when they tubers are harvested (Wang,Yang, Gao, Gong, Qu and Feng, 2020). In Africa, most are pounded into a paste to make the traditional dish of "pounded yam", known as Iyan and also grounded into a past-like form for the preparation of 'ekpang' (Christian and Olugbenga, 2016). Although not grown in the same quantities as the African yams, it has the largest distribution worldwide of any cultivated yam, being grown in Asia, the Pacific islands, Africa, and the West Indies. Even in Africa, the popularity of water yam is second only to white yam. The tuber shape is generally cylindrical, but can vary. Tuber flesh is white and watery in texture (Ketenikon, Pertan, Suriya, Rethina, Bashir, Koteswara, Harsha and Haripriya, 2017).

According to Awoyale, Oyedele, & Maziya-Dixon, (2020) Water yams in West Africa are typically harvested by hand, using sticks, spades, or diggers. Wood-based tools are preferred to metallic tools as they are less likely to damage the fragile tubers; however, wood tools need frequent replacement. Water yam harvesting is labor-intensive and physically demanding. Tuber harvesting involves standing, bending, squatting, and sometimes sitting on the ground depending on the size of mound, size of tuber, or depth of tuber penetration. Care must be taken to avoid damage to the tuber, because damaged tubers do not store well and spoil rapidly. Some farmers use staking and mixed cropping, a practice that complicates harvesting in some cases. Roots and tubers such as water yams are living organisms. When stored, they continue to respire, which results in the oxidation of the starch (a polymer of glucose) contained in the cells of the tuber, which converts it into water, carbon_dioxide, and heat energy (Afidin, Hendrawan, and Yulianingsih, 2014). During this transformation of the starch, the dry matter of the tuber is reduced. Storing water yam at low temperature reduces the respiration rates. However, temperatures below 12 °C (54 °F) cause damage through chilling, causing a breakdown of internal tissues, increasing water loss and water yam's susceptibility to decay. The symptoms of chilling injury are not always obvious when the tubers are still in cold storage. The injury becomes noticeable as soon as the tubers are restored to ambient temperatures (Christian & Olugbenga, 2016).

The best temperature to store water yams is between 14 and 16 °C (57 and 61 °F), with high-technology-controlled humidity and climatic conditions, after a process of curing. Most countries that grow water yams as a staple food are too poor to afford high-technology storage systems. Sprouting rapidly increases a tuber's respiration rates, and accelerates the rate at which its food value decreases (Pamphile, and Nassirou, 2020).

Shelf life is the length of time that a commodity may be stored without becoming unfit for use, consumption, or sale. In other words, it might refer to whether a commodity should no longer be on a pantry shelf (unfit for use), or no longer on a supermarket shelf (unfit for sale, but not yet unfit for use).

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It applies to cosmetics, foods and beverages, medicaldevices, medicines, explosives, pharmaceutical drugs, chemicals, tyres, batteries, and many other perishable items. Shelf life is the recommended maximum time for which products or fresh (harvested) produce can be stored, during which the defined quality of a specified proportion of the goods remains acceptable under expected (or specified) conditions of distribution, storage and display (Robertson, 2010)

Food irradiation (sometimes radurization or radurisation) is the process of exposing food (water yam tubers) and food packaging to ionizing radiation, such as from gamma rays, x-rays, or electron beams. Food irradiation improves food safety and extends product shelf life (preservation) by effectively destroying organisms responsible for spoilage and foodborne illness, inhibits sprouting or ripening, and is a means of controlling insects and invasive pests. Irradiation slows the speed at which enzymes change the food (Ezekiel, Singh and Datta. 2008).

MATERIALS AND METHOD

The research was carried out in Ochon clan of Obubra Local Government Area, Cross River State, Nigeria. Ochon clan consist of seven villages with large number of farmers engage in water yam cultivation. The water yam tubers were bought directly from farmers on the same day of harvest, applying pre-informal consultation with the farmers and village elders. The tubers were marked for easy identification with serial numbers and their pre-irradiation weight taken and recorded. The tubers to be irradiated were put in batches and transported in wooden crates so as to avoid physical damage to the tubers, to (Nigeria Technological Centre (NTC) Sheda) the research Centre in Abuja for irradiation.

Pre-irradiation

Based on results from similar studies in the literature, the following gamma rays were applied to the tubers 50 Gy, 100Gy, 125 Gy, 150 Gy and 200 Gy in order to determine weight loss, sprouting and spoilage during storage.

Five batches of 50 tubers each of water yam from five different locations (farmers) were bought, 200 irradiated at these dose levels indicated and 50 serving as control, giving a total of 250 water yam tubers. Out of these water yams to be irradiated, 40 tubers were use for proximate analysis.

Post irradiation

After irradiation the tubers were transported safely back to the farm site of the University of Education and Entrepreneurship, Akamkpa for determination of the following parameters: percentage weight loss, percentage of spoilage and rate of sprouting. These factors were recorded for the treated group and the control group. Statistical significance was established using Analysis of Variance (ANOVA) models to estimate the effect of gamma irradiation on proximate composition of water yam (D.alata) tubers

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Gamma Irradiation Facility

The Gamma Irradiation Facility (GIF) at the Nuclear Technology Centre, Nigeria Atomic Energy Commission (NAEC), Sheda, Abuja, FCT, Nigeria was used for the irradiation. Gamma irradiation is produced from the radioisotopes cobalt-60 and caesium-137, which are produced by neutron irradiation of cobalt-59 (the only stable isotope of cobalt) and as a nuclear fission product, respectively. Cobalt-60 is the most common source of gamma rays for food irradiation in commercial scale facilities as it is water insoluble and hence has little risk of environmental contamination by leakage into the water systems. Cobalt-60 (^{60}Co) is a radioactive isotope of cobalt with a half-life of 5.2713 years. It is produced artificially in nuclear reactors. ^{60}Co undergoes beta decay to the stable isotope nickel-60 (^{60}Ni). The activated nickel nucleus emits two gamma rays with energies of 1.17 and 1.33 MeV of Photon energy for irradiation purposes (NIST, 2011).

Sprouting, Colour change, Rotting and Weight Measurement/Observation

The yam tubers were marked for easy identification and observed in an open store with ambient temperature for five months. The tubers were carefully examined every week for colour change, the appearance of soft spots, wet surface (rotting), fresh shoots to indicate sprouting. Records were made of all these observations including weight masses of the tubers before and immediately after irradiation.

RESULTS AND DISCUSSION

The mean percentage spoilage, data of rotten tubers, weight loss and nutritional content (proximate) analysis of the water yam tubers are presented on tables 1-6.

Results on the effects of irradiation and storage on sprouting is presented in table 1. It was observed that by the end of the fourth month of storage, all the un-irradiated water yam tubers had sprouted. Data also show that irradiated water yam tubers did not start sprouting until about the fifth month. At the end of the storage period (5 months), 80% of the irradiated water yam tubers at 50 Gy had sprouted. 10% of the irradiated yams at 100 Gy had sprouted. The irradiated water yam tubers at 125 Gy and 150 Gy did not sprout. This shows that a dose range of 125 Gy – 150 Gy will completely inhibit sprouting in water yam.

Table 2, as presented shows the cumulative mean percentage spoilage of the tubers. A careful observation of table shows 90% rotten tubers in the control group and that the group of irradiated water yam tubers irradiated at 200 Gy has the highest cumulative mean percentage spoilage at the end of the observation period than in the rest of the irradiated groups, as 70% of the tubers had rotten by the fifth month of observation. The 125 Gy irradiated recorded least percentage of spoilage compare to un-irradiated group with 2.5% rotting within the period of observation (5 months). This could be that the 125 Gy has the ability to kill or to prevent the action of micro-organisms or bacteria that would have cause more spoilage of the water yam tubers within the period of study. 200Gy group of the irradiated performs poor with much spoilage occurring; this

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result is in line with that of (Agba, Afeah and Tyovenda, 2022). The high percentage spoilage of the irradiated water yam tubers observed for 200Gy group could be that the irradiation dose is capable of breaking the chemical bond that exist between the molecules of the water yam tubers, resulting in high spoilage or the radiation damage to the tissue arising from the high concentration of free radicals produced from the irradiation energy. This shows that the 125 Gy dose is best for the storage of Obubra water yam tubers.

Table 3, shows Weight Loss. The initial mean weight (Kg), final mean weight (Kg) after 5 months, the weight loss (Kg) and percentage (%) weight loss of the water yam tubers after 5 months are listed in Table 3. After 5 months the un-irradiated (control) water yam tubers had significant loss in weight with percentage losses of 66%. Also the water yam tubers irradiated with the dose of 50 Gy and 100 Gy had weight loss of 54%. The weight loss in the water yam tubers irradiated at doses of 125 Gy and 150 Gy is significantly reduced to 20%. These indicate that radiation treatment of water yam tubers preserves the freshness of the tubers during storage prior to spoilage to a great extent when compared with the untreated tubers used as control. Weight loss of 49% was recorded for 200 Gy. The high percentage weight losses of 54% and 49% may be as a result of spoilage and sprouting during storage.

Proximate Analysis: The percentage moisture content, ash content, fibre content, protein content and carbohydrate content of water yam tubers before irradiation, immediately after irradiation and after five months of storage are listed in tables 4, 5 and 6 respectively. After five months of storage the moisture contents are significantly higher in the irradiated water yam tubers than the control. Data shows that the moisture and carbohydrate content of fresh water yam tubers constitute the highest percentage of the food content in both groups. 150Gy group retains the highest percentage moisture content. The water yam tubers in the table, has the highest percentage carbohydrate content when irradiated at 125Gy and least at 50 and 200 Gy as sprouting and rotting reduces the carbohydrate content.

When high energy irradiation dose is applied, there is increase in free radical formation from irradiated water molecules this may have acted on carbohydrate molecules thus reducing the percentage carbohydrate content. This can also be observed with irradiation dose of 150Gy which causes the water yam tubers to retain high percentage moisture content but induces lower percentage carbohydrate content.

Proximate analysis further shows that ash content remained almost the same immediately after irradiation with a range of 2.3 to 3.3% and slightly higher after five months of storage with values ranging between 3.1 to 4.2% when compared with 3.3% in the control. Radiation processing does not greatly affect the mineral composition of irradiated water yam tubers. After five months of storage it was observed that the protein contents were slightly higher in the irradiated water yam tubers than the control. The protein content ranged between 3.7 to 4.5% immediately after irradiation and 4.2 to 5.6% after five months of storage while the value of the control was 3.8%. This is an indication that radiation processing preserves the protein content in the irradiated tubers. When yam sprouts in storage, it utilizes stored food to support the sprouting. The result is increase in metabolic activity which leads to increase in respiration and loss of quality.

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The fibre content was slightly higher in the irradiated tubers than the control after five months. It ranged between 0.4 to 0.8% immediately after irradiation and 0.5 to 0.9% after five months of storage while the value of the control was 0.7%.

Table 1. Sprouting Of Water Yam During Storage

Sample	Dose (Gy)	Treatment	Initial No. Of Tubers	Number sprouted per month					Total	Sprouted (%)
				1st	2nd	3rd	4th	5th		
A	50	irradiated	40	-	-	-	12	20	32	80
B	100	irradiated	40	-	-	-	1	3	4	10
C	125	irradiated	40	-	-	-	-	-	-	0
D	150	irradiated	40	-	-	-	-	-	-	0
E	200	irradiated	40	-	-	-	-	-	-	0
F	0	Un-irradiated	50	2	6	12	17	13	50	100

Table 2. Spoilage During Storage

Sample	Dose (Gy)	Treatment	Initial No. Of Tubers	Number Rotten per month					Total	Rotted (%)
				1st	2nd	3rd	4th	5th		
A	50	irradiated	40	-	4	2	7	12	24	60
B	100	irradiated	40	-	-	-	1	2	3	7.5
C	125	irradiated	40	-	-	-	-	-	-	0
D	150	irradiated	40	-	-	-	-	1	1	2.5
E	200	irradiated	40	-	3	8	5	12	28	70
F	0	Un-irradiated	50		6	11	18	10	45	90

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Table 3. Weight Loss of water yam tubers During Storage

Sample	Absorbed Dose (Gy)	Mean Initial Weight (Kg) 1st day of storage	Weight loss after 5 months		
			Mean Final Weight (Kg)	Weight Loss (Kg)	Mean % Weight Loss
A-B	50-100	1.70	0.78	0.92	54
C-D	125-150	1.63	1.30	0.33	20
E	200	1.92	0.98	0.94	49
F	0	1.86	0.63	1.23	66

Table 4. Nutritional Content of the Tubers before Irradiation

Sample	Dose (Gy)	Moisture Content (%)	Ash Content (%)	Fibre Content (%)	Protein Content (%)	Carbohydrate Content (%)
F	0	4.86	3.32	0.76	3.88	86.00

Table 5. Nutritional Content of the Tubers Immediately after Irradiation

Sample	Dose (Gy)	Moisture Content (%)	Ash Content (%)	Fibre Content (%)	Protein Content (%)	Carbohydrate Content (%)
A	50	4.30	3.34	0.59	3.69	86.86
B	100	2.80	3.06	0.52	4.22	88.32
C	125	3.08	3.33	0.40	4.48	89.04
D	150	4.97	2.98	0.80	3.63	88.25
E	200	4.06	3.21	0.65	4.11	86.03

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Table 6. Nutritional Content of the Tubers 5 Months after Irradiation

Sample	Dose (Gy)	Moisture Content (%)	Ash Content (%)	Fibre Content (%)	Protein Content (%)	Carbohydrate Content (%)
A	50	2.72	3.56	0.53	4.20	86.01
B	100	2.89	3.14	0.51	4.53	88.33
C	125	3.02	3.33	0.93	5.60	89.44
D	150	3.64	4.21	0.72	4.31	88.07
E	200	2.94	3.58	0.54	4.80	86.00

CONCLUSION

Findings: This study clearly shows that gamma radiation at the dose of 125-150 Gy will effectively inhibit sprouting and reduce spoilage in water yam tubers

It also to demonstrate that the optimum irradiation dose for preservation of the Obubra water yam is 125Gy. Irradiation dose of 50Gy and 100 Gy does not completely inhibits sprouting of the water yam tubers. The tubers deteriorated fast when irradiated at 200Gy dose levels.

Results of proximate analysis further indicated that irradiation causes the tubers to retain good percentage of their moisture content and other nutrient, thus improving the storability of the water yam tubers and reducing post harvest loss. Irradiation treatment is recommended for large scale storage of water yam tubers and other food produce for sprout inhibition, extension of shelf-life, reduction of microbial load and preservation of nutritional content. Increased radiation food processing will enable farmers to grow more food, which will translate into more money to the rural population and make food available all year.Irradiation technology can be efficiently utilized to extend the shelf-life of locally cultivated water yam tubers in Cross River State.

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