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Full length Research.

Effects of gamma irradiation on the sprouting, nutritional and phytochemical composition of *Meccakusha* yam tubers in Abuja, Nigeria.

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***Meccakusha* yam (*Dioscorea rotundata* L.Poir) tuber samples from Abuja, Nigeria were treated with gamma radiation of doses 40, 80, 120, 150 and 180 Gy respectively and some un-irradiated were used as control. The effects of gamma irradiation on the sprouting, nutritional and phytochemical composition of the *Meccakusha* yam tubers were investigated. All were monitored during storage for eight weeks. After storage, the control and yams irradiated with 40Gy sprouted with average vine lengths of 71.7 and 2.0 cm respectively, while the rest did not sprout. The percentage weight loss (47.2%) in the control was significantly (P≤0.05) higher than the irradiated tubers when the mean values were separated with Duncan Multiple Range (DMRT). At 21 weeks after storage, crude lipids and protein contents were significantly higher in irradiated tubers than the control. Phytochemical analysis showed that flavonoids, tannins and saponins were unaffected by radiation treatment of *Meccakusha* yam tubers. The study confirmed that radiation processing preserved the quality of the yam tubers through sprout inhibition, reduction of weight loss, preservation of lipid and protein while carbohydrate as well as flavonoids remained unchanged.**

Keywords: Food, Gamma irradiation, *Meccakusha*, Nutrition, Phytochemical, Sprout inhibition, Yam tubers.

1.0 Introduction

Yam is the second most important tuber crop in Africa next to cassava. Nigeria is the main producer of yam globally with 71% of world production (FAO, 2002) and according to FAOSTAT data, Nigeria produced 29,092,000 MT in 2009 (FAO 2009). Various cultivars of guinea yam (*Dioscorea rotundata* L. Poir) constitute one of the staple carbohydrate foods for most people in West African countries (Akoroda and Hahn, 1995; Opara, 1999). They also serve as a source of vitamins, iron, calcium and nicotinic acid but are low in saturated fat and sodium (Akissoe *et al*., 2003). *Meccakusha* yam is one of the most preferred indigenous cultivars of white yam produced, marketed and consumed in the southern guinea savannah of Nigeria. It is known for relatively giant cylindrical size tuber that is easily boiled, cooked and pounded; and highly palatable (MTRM, ADP, 2007). *Meccakusha* which locally means "visiting Mecca is made easy" as farmers of the yam can easily become financially buoyant due to high yield, acceptability and high commercial value of the yam.

The production of the yam is seasonal, so storage is necessary before subsequent planting or for use as food. Fresh yam tubers are often difficult to store and are subject to deterioration by sprouting and microbial rot during storage (Passam, 1977). Post-harvest losses usually range from 25 to 60% (Afoakwa and Sefa-Dedeh, 2001). Yams have high contents of moisture, dry matter, starch, potassium, and low vitamin A. The yam *D. rotundata* has more moisture content than other species but with relatively lower carbohydrates, calories, crude fibre and proteins (Akissoe *et al*., 2003).

Loss of yam in storage due to sprouting is very high (Medoua *et al*., 2005). Several inhibitory chemical growth regulators such as maleic hydrazide, Tetrachloronitro benzene, acetic acid, naphthalene have been used to retard sprouting in stored yam tubers. Apart from unavailability of the right type of chemicals and their toxic nature, widespread adulteration of the available chemicals especially in Nigeria is a serious problem (David, 2009). There are several reports on how temperature and age of the tuber affects sprouting of yam (Bansa and Appiah, 1999) Processing of yams into various products including flour is a viable alternative for checking post harvest losses and to promote year round availability.

Radiation technology can complement existing technologies to ensure food security and safety as expressed in IAEA Series: Facts About Food Irradiation (IAEA, 1995, Mbanaso and Nwachukwu, 2009, Mokobia and Anomohanran, 2005, Subramanian, 2003). Radiation processing could be used for anti-infestation of food grains and pulses; inhibition of sprouting in onions, potatoes, garlic, yam and ginger, preventing microbial contamination of spices; extending shelf-life under recommended conditions of storage; and overcoming quarantine barriers in international trade. Ionizing radiations have the potentials of reducing considerable storage losses through inhibition of sprouting, inactivation of food spoilage micro-organism, control of insects and sterilization of food crops (Bansa and Appiah, 1999). Irradiation technology is easy to apply, clean, and environment-friendly (FDA, 1997, Kodia, 1999, Olson, 1998). It is a direct, simple and efficient on-line process. Food irradiation is done in plants approved by the Nigeria Nuclear Regulatory Authority and National Agency for Food and Drug Administration and Control in Nigeria.

The most widely used and best traditional storage method is the yam barn. However, tubers stored in this way are exposed to attack by pests and micro-organisms. Also substantial losses in weight occur due mainly of respiratory processes (Bhandari *et al.,* 2003). One method investigated for use in the small scale storage of yam is the manual removal of the bud as soon as germination or sprouting of the tuber is noticed in the yam barn. This method is found to reduce loss in weight, moisture content and carbohydrate food content but is difficult to apply for large scale storage of yams. Storage at low temperatures, particularly at 15°C, suppresses sprouting in yams. This temperature also reduces weight loss, moisture loss, respiration rate, and maintains good palatability of stored product. However, lack of regular supply of electricity, cost and relatively high temperature tropical weather do not encourage low temperature storage technique.

Unlike most previous studies which have focused on other species or cultivars of root and tuber crops, the aim of this study was to investigate the potential of applying gamma irradiation for improving the quality of the major yam tuber variety in Abuja, Nigeria during storage. It was carried out with the objective to determine the influence of gamma irradiation on sprouting, moisture content, nutritional and phytochemical composition of *Meccakusha* yam tubers in storage in Abuja, Nigeria.

2.0 Materials and Methods

Meccakusha yam (*Dioscorea rotundata*) tuber was investigated in this research work. They were collected from a yam farmer in Gwagwalada, Abuja, Nigeria. The yam tubers were divided into six groups each made of ten tubers. Five groups were treated with gamma radiation doses of 40Gy, 80Gy, 120Gy, 150Gy and 180Gy respectively while the yam tubers in the sixth group were un-irradiated to serve as control.

2.1 Gamma irradiation of yam tubers

The Gamma Irradiation Facility at the Nuclear Technology Centre, Nigeria Atomic Energy Commission, Sheda, Abuja, Nigeria was used for the irradiation. The facility is a multipurpose semi-commercial plant designed as a research and experimentation facility as well as for industrial purposes. It consists mainly of Co-60 radioactive sources of total current activity of about 5.5 x 10^{15} Bq (≈ 170 kCi). Uniform irradiation and accurate computer controlled irradiation dosage are ensured in all the modes of operations. For this study irradiation was carried out in the stationary mode of operation with the possibility of varying dose rates (0.05 – 5 kGy per hr) depending on the location and distance from the source.

2.2 Sprouting and weight loss measurements

The samples were marked for easy of identification and observed in an open store at ambient temperature for 21 weeks. Vine lengths of the sprouting tubers were measured and recorded at 8, 15, 21 weeks after storage (WAS). The weight of each of the yam tuber was also taken and recorded at the start of the work as well as at 8, 15 and 21 WAS to determine weight losses of the tubers.

2.3 Nutritional analysis

The nutritional composition (moisture, ash, fat, crude fibre and carbohydrate) of each yam tuber was determined using the standard methods of the Association of Official Analytical Chemists (AOAC, 2005). The moisture content was determined by oven drying method while crude lipid content was determine by solvent method using Soxhlet apparatus (extractor). Protein was determined using the micro-Kjeldhal method (N x 6.25). This was carried out in the Chemistry Advanced Laboratory, Sheda Science and Technology Complex, Sheda, Abuja, Nigeria.

2.4 Phyto-chemical analysis

Phyto-chemical qualitative analysis was performed at the Chemistry Advanced Laboratory, Sheda Science and Technology Complex, Sheda, Abuja, Nigeria according to standard methods of AOAC, (2005). The yam tubers were carefully cleaned, sliced (1 cm thick) and dried in an air oven at 60°C to constant weight. The dried samples were cooled, pulverized, sieved (0.025mm) and packaged for the analysis.

2.5 Statistical analysis

All analyses were performed in triplicates. Results were expressed as means ± standard deviation. Statistical significance was established using Analysis of Variance

(ANOVA) models to estimate the effect of gamma irradiation on nutritional and biochemical composition of *Meccakusha* yam tubers. Percentage weight losses were separated according to Duncan's multiple range analysis (P ≤0.05), with the help of the software SPSS 16.0.

3.0 Results and Discussion

The results of the effects of gamma irradiation on sprouting, nutritional and phytochemical composition of *Meccakusha* yam tubers are presented and discussed.

3.1 Sprout inhibition

All the un-irradiated yam tubers used as control sprouted a few weeks after storage (WAS). At 8 WAS the mean vine length of the control was 71.7 cm. This mean increased to 181.0 cm and 206.0 cm at 15 WAS and 21 WAS respectively. Also, the yam tubers irradiated with dose of 40 Gy sprouted. However, the vine length for the tubers in this group was only 2.0 cm at 8 WAS. The vine length increased to 6.0 cm at 15 WAS and remained the same at 6.0 cm even at 21 WAS which is an indication that the yam tubers irradiated with dose 40 Gy have stopped sprouting as of 15 WAS. Therefore, a dose of 40 Gy was not enough to completely inhibit sprouting. No sprouting was observed in all the yam tubers irradiated at doses 80 – 180 Gy. These show that any *Meccakusha* yam (*D. rotundata*) tubers treated with gamma radiation dose of 80 Gy and above will not sprout. That is, 80 Gy should inhibit sprouting in *Meccakusha* yam tubers. Similar observation has been recorded by Subramanian (2003) who reported that application of low doses of radiation (0.15 KGy) can arrest the sprouting of potatoes and onions. Storage losses of tubers due to sprouting can be reduced substantially by radiation processing.

3.2 Reduction of weight loss

The initial mean weight (Kg), final mean weight (Kg), the weight loss (Kg) and percentage (%) weight loss at 21 WAS are listed in Table 1. At 21 WAS the un-irradiated control yam tubers had significant loss in weight with percentage losses of 47.16 ± 7.94 %. Also the yam tubers irradiated with the dose of 40 Gy had significant weight loss of 33.37 ± 7.66 %. At this dose level radiation was not effective to significantly reduce the weight loss. The weight losses in the yam tubers irradiated at doses of 80 – 180 Gy were significantly reduced to the range of 5.13 – 12.02%. This point to the fact that radiation treatment of *Meccakusha* yam tubers preserves the composition of the tubers during storage to a great extent when compared with the untreated tubers used as control. Yams stored for a period of time become dehydrated, fibrous and eventually undergo physical and quality losses (Bansa and Appiah, 1999). Respiratory weight loss contributes significantly to total storage loss and yams stored for 5 months may loose up to 10% of dry matter content through respiration (Sahore *et al.*, 2007).

Table 1: Weight Loss of Irradiated and Control *Meccakusha* Yam Tuber Durng Storage

Absorbed Dose (Gy)	Mean initial weight (Kg) 1st Day of Storage	21 Weeks After Storage (WAS)		
		Mean Final Weight (Kg)	Weight Loss (Kg)	% Weight Loss*
0 (control)	5.00±0.10	2.65±0.45	2.35±0.35	47.16±7.94a
40	3.70±0.20	2.45±0.15	1.25±0.35	33.37±7.66b
80	4.45±0.95	4.05±0.65	0.40±0.30	7.91±5.05c
120	4.85±0.85	4.50±0.60	0.35±0.25	6.52±4.02c
150	4.00±0.60	3.50±0.40	0.50±0.20	12.02±3.20c
180	4.85±0.15	4.60±0.10	0.25±0.05	5.13±0.87c

* Means with the same letter(s) are not significantly different at (p>0.05) by DMRT

3.3 Nutritional composition

The percentage weight loss, moisture, ash, crude lipid, crude protein, crude fibre and carbohydrate contents of the irradiated and the un-irradiated control *Meccakusha* yam tubers at 21 WAS are shown in Table 2. Also on Table 2 are range of values of the corresponding nutritional constituents of un-irradiated edible yam species which were recorded by Osagie (1992), cited by Osunde (2008, p. 4) for comparison with the results obtained in this study. At 21 WAS the moisture contents were significantly (P<0.05) higher in the irradiated yam tubers than the control. In yam tubers irradiated with absorbed doses of 80 Gy and above, the moisture contents ranged between 45.27 to 57.67%, which were more than double when compared with the control of 22.38±0.92%. Although it has been observed that tuber moisture content varies considerably among species, harvest date and length of storage (Babajide *et al.*, 2008), it is evident from this work that radiation retained to a large extent the moisture content of the yam tuber during storage. This is an indication that radiation processing of yam tubers could preserve the qualities, such as, freshness from the observed high moisture content of irradiated yam tubers at 21 WAS.

The ash content, which is associated with mineral content in yam tubers remained unaffected by radiation processing. However, at 21 WAS, the ash content was significantly ($P<0.05$) lower in the control of 1,.61±0.79% when compared with values ranging between 2.09 to 2.51% in irradiated tubers. Radiation processing did not affect the ash content of irradiated yam tubers while losses were recorded in the control during storage probably due to sprouting and other activities.

At 21 WAS it was observed that the lipid and protein contents were significantly ($P<0.05$) higher in the irradiated yam tubers than the control. The lipid contents ranged between 2.01 to 2.46% in the yam tubers irradiated with doses of 80 – 180 Gy while the value of the control was 0.65±0.41%. Similarly, the protein contents ranged between 5.35 to 5.92% while the value of the control was 1.47±0.34%. This is an indication that while fat and protein losses occurred in un-irradiated control tubers in storage, radiation processing preserves the fat and protein contents in the irradiated tubers. The general opinion is that when yam sprouts in storage, it utilizes stored food to support the sprouting. This results in increase of metabolic activity which leads to increase in respiration and loss of quality. This may be responsible for the significantly low values of lipid and protein in the control and sprouting yam tubers.

There was little or no observed significant difference in the crude fibre and carbohydrate contents in the irradiated and un-irradiated yam tubers at 21 WAS. In the crude fibre there was no significant ($P<0.05$) difference between the control and the yam tubers irradiated with doses 40 and 150 Gy. Similarly, there was no significant ($P<0.05$) difference between the control and the yam tubers treated with doses 120 and 180 Gy. Radiation processing did not affect the crude fibre and carbohydrate contents in treated yam tubers. The observed values are in good agreement with the values recorded by Osagie (1992) cited by Osunde (2008, p. 4).

Table 2: Nutritional Composition of Gamma Irradiated *Meccakusha* Yam Tuber

Absorbed Dose (Gy)	% Weight * loss	% Moisture at 21 WAS	% Nutritional Composition at 21 Weeks After Storage (WAS) **				
			Ash	Crude Lipid	Crude Protein	Crude fibre	Carbohydrate
0 (control)	47.16±7.94	22.38±0.92	1.61±0.79	0.62±0.41	1.47±0.34[b]	1.71±0.50[c]	25.05±1.54 [d]
40	33.37±7.66	30.42±0.26	2.09±0.22[a]	1.38±0.13	1.96±0.59[b]	1.81±0.94[c]	28.97±1.88
80	7.91±5.05	51.67±0.11	2.51±0.78	2.03±0.25	5.35±0.31	2.26±0.49	28.27±1.83
120	6.52±4.02	57.67±0.26	2.51±0.15	2.22±0.56	5.79±0.35	2.00±0.19	23.29±1.25 [d]
150	12.02±3.20	45.27±0.63	2.41±0.33	2.12±0.45	5.92±0.87	1.70±0.39[c]	30.56±2.04
180	5.13±0.87	56.84±1.73	2.19±0.36[a]	2.46±0.59	6.87±0.90	1.36±0.97	25.15±2.82 [d]
Osagie (1992) cited by Osunde (2008 p.4)		61 - 81	0.6 – 1.7	0.2 – 0.4	1.4 - 3.5	0.4 – 10.0	16.4 – 31.8

* %weight loss was added to the table for all the components to add up to 100% **Means with the same letter(s) are not significantly different at ($p>0.05$) by DMRT

3.4 Phytochemical composition

The results of Phytochemical analysis of *Meccakusha* yam tubers after 21 WAS, showed that there were no changes in the status of flavonoids, saponins and tannins present in the yam tubers as a result of irradiation treatment. Plants that are rich in alkaloids, flavonoids, tannins and saponins have been known to show medicinal activity as well as exhibiting physiological activity (Sofowora, 1993). At dose of 120 Gy and above, there were observed changes in phenols. However, these changes in phenols at doses higher than 120 Gy are being investigated and positively applied for use in another research work on value addition on agricultural products. In a different study, radiation processing is being used for the reduction of enzymatic browning in yam used in production of white "pando" yam flour. The results on sterols and terpenes present in *Meccakusha* yam tubers were inconclusive.

The economic value of yams cannot be overemphasized. It transcends beyond food consumption. Yam tubers contain a steroid sapogenin compound called diosgenin, which can be extracted and used as base for drugs such as cortisone and hormonal drugs. Some yam species contain alkaloids (e.g. dioscorine $C_{13}H_{19}O_2N$) but this was observed to be absent in *Meccakusha* yam tubers. Tannin cells and cells containing bundles of the crystal - raphids are also present, and these crystals are responsible for the itchiness of raw yam tubers and some other crops when placed in contact with the skin (Marie *et. al.*, 2005).

4.0 Conclusion

The study clearly demonstrates that gamma radiation at the dose of 80 Gy and above completely inhibits sprouting in *Meccakusha* yam (D. rotundata) tubers. Radiation processing at doses of 80 Gy above preserved the quality of the yam tubers through sprout inhibition, reduction of weight losses and preservation of food values such as lipid and protein while carbohydrate as well as flavonoids remained unchanged.

Radiation Processing is recommended for large scale storage of yam tubers for sprout inhibition, extension of shelf-life, and preservation of nutritional and phytochemical qualities.

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