

## Effects Of X-Ray Irradiation On The Preservation Of Fresh Orange Fruits

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### **Abstract**

Food irradiation is a preservation technique that uses ionizing radiation like X-rays, gamma-rays, and electron beams for improving the safety and prolonging the shelf life of food and agricultural produce. Orange (*Citrus sinensis*) is one of the outstanding dietary fruits of the world. Its quality and nutritional attributes, the scale of production and ability to grow in the tropical and subtropical regions makes orange fruits a popular fruit item. Population growth in recent years has increased global fruit consumption including oranges. This has increased the demand for quality fruits in large quantity. Most of the oranges in Nigeria are not necessarily grown where they are consumed. It may take from a few days to weeks for the fruits to reach its target market and sometimes before they get sold most of the oranges may have spoiled. This study examined the effects of x-ray irradiation on fresh orange fruits preservation. The study adopted experimental design and was carried out in Uyo, Nigeria using freshly plucked orange fruits obtained from a local orange fruits farm. There were 5 groups of oranges each having 4 orange fruits making a total of 20 orange fruits. One group served as control while 4 groups served as test groups. The control group was stored away from the radiation area, under room temperature of about 25°C. The test groups were equally stored away under the same storage conditions after each exposure. The test groups were exposed to varying energy of x-ray every day at approximately the same time of the day for 7 consecutive days. The energies of the exposures were 60kvp, 70kVp, 80kVp and 90kVp using 40mAs, 50mAs, 60mAs, and 70 mAs respectively. Following each day of irradiation, each group of the test samples as well as the control samples were visually scrutinized for possible physical changes including spoilage and ripening. Each group also had samples taken for laboratory culture to evaluate the growth of spoilage organisms on day 7, day 14 and day 21. The test groups were then physically compared with the control group for any similarities or differences. Results showed that orange fruits irradiated with x-ray had a longer shelf life compared to the non-irradiated fruits, and the increase in shelf life was proportional to the dose of radiation used. Irradiated orange fruits also survived longer before succumbing to microbial or fungal attacks compared to non-irradiated ones. With the high cost of Gamma installations and other expensive types of food irradiation facilities, it might be more cost-effective to consider the use of medical grade x-ray equipment for the purpose of food irradiation since the facilities are readily available and affordable.

**Keywords:** X-irradiation, preservation, orange fruits, shelf life,

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### **I. Introduction**

Food irradiation is a food preservative technique that uses ionizing radiation like X-rays, gamma-rays, and electron beams for improving the safety and shelf life of food and agricultural produce [1]. In addition to serving as a good alternative to thermal treatments, the irradiation technique reduces the need for pesticides, some additives and antioxidants, and some toxic chemical treatments [2]

The world population is estimated at 7.9 billion humans, and this is growing at an unprecedented rate, consuming an ever-increasing amount of global resources and according to United Nations projections, the majority of this growth will occur in the third-world nations of Africa, and, to a lesser extent, Asia, among those peoples least able to afford the increasing burden on available resources [3]. Clearly, what is needed in these African nations in the near future are more efficient, low-cost methods of using those resources they already have.

The most severe among the problems faced by developing nations of Africa is a lack of a reliable, sufficient, and nutritious food supply. Much of the African population survives on malnourished diets irregularly supplied by subsistence agriculture [4]. In addition, crop loss due to both pests and post-harvest spoilage is much higher than in first world nations, with cold-storage technologies and modern pesticides. Equally important are the lives lost each year to food-borne disease. In the United States, food-borne infections cause an estimated 76 million cases of illness and 323,000 hospitalizations annually, for an estimated annual treatment cost of \$6.7 billion and a death toll in their thousands. In developing nations, these losses are much higher but availability of accurate data hinders adequate reporting [4]

In developing countries with warm climates, growing vegetables and fruits, the post-harvest loss is believed to exceed 50%. With commodities such as dried fish, insect infestation is reported to result in a loss of 25% of the product with an additional 10% lost due to spoilage. While not all of these losses can be prevented by food irradiation, the technology does offer unique potential to destroy insect infestation and reduce spoilage [5]

Food irradiation technology in Nigeria is still at its early stages, mostly experimental. 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 [6]. 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 may 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 [7]

In Nigeria one Gamma Irradiation Facility (GIF), is located at the Nuclear Technology Centre (NTC), Nigeria Atomic Energy Commission (NAEC), Sheda Abuja, Nigeria. The GIF is a category IV multipurpose industrial irradiation facility with six different modes of operation and consists mainly of an irradiation room with a steel reinforced concrete wall thickness of about 1.8m to house the Co-60 radioactive source of current activity of about  $5.5 \times 10^{15}$ Bq (170 kCi) [6]. 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 [7].

Most food irradiation facilities are known to be installed with equipment capable of producing high energy photons above most diagnostic x-ray equipment. This has not ruled out the possibility of using diagnostic x-ray equipment for food irradiation especially since these sets of equipment are readily available. Higher diagnostic x-ray quantity above 80kVp has already shown to increase shelf live of mango fruits in a study in Benue State, Nigeria [8].

Orange (*Citrus sinensis*) is a one of the outstanding dietary fruits of the world. Its quality and nutritional attributes, the scale of production and ability to grow in the tropical and subtropical regions makes orange fruits a popular fruit item. Population growth in recent years has increased global fruit consumption including oranges. This has increased the demand for quality fruits in large quantity [9]. Because of this growing demand, there is a pressing need to enhance the quality of these produce to reduce post-harvest losses [10]. Post-harvest losses of fruits like oranges which is a global problem in both developed and developing countries refers to spoilage and degradation of these fruits during transportation from the farm to consumers [11, 12, 13].

Most of the oranges in Nigeria are not necessarily grown where they are consumed. The time it takes for the fresh oranges to move from harvest to the final consumer could range from a few days to weeks and sometimes before they get sold most of the oranges may have spoiled. It remains to be seen the preservative effects of medical-range x-ray on the orange fruits with a view to deloying its easy availability and affordability in fresh orange fruits irradiation for shelf life longevity.

## **II. Materials And Method**

This study adopted experimental design. The experimental research design is a research method used to investigate the interaction between independent and dependent variables, which can be used to determine a cause-and-effect relationship. Experimental research is commonly used within the framework of the scientific method [1]. The study was carried out in Uyo, Akwa Ibom State, Nigeria using freshly plucked orange fruits obtained from a home orchard in the most recent 24 hours period without physical blemish. There were 20 oranges fruits in total, divided into 5 Groups of 4 oranges each. One group served as control while the remaining 4 groups served as test groups.

Four orange fruits were placed in each of 5 different net packs. The packs were made of nets with large holes to allow for natural ventilation. The control group was stored away from the radiation area, under local

temperature which ranged from 25°C to 33°C in Uyo. The test groups were equally stored away under the same conditions after each exposure. The 4 test groups were exposed to varying energy of x-ray every day at approximately the same time of the day for 7 consecutive days. The energies of the exposures were 60kvp, 70kVp, 80kVp and 90kVp using 40mAs, 50mAs, 60mAs, and 70mAs respectively. The relative absorbed doses produced by the exposure were 4.5mGy, 7.5mGy, 11.4mGy and 16.3mGy respectively. Following each day of irradiation each group of the test samples as well as the control samples were visually scrutinized for possible physical changes with respect to spoilage and ripening. Each group also had samples taken for laboratory culture to evaluate the growth of spoilage organisms on day 7, day 14 and day 21 from the beginning irradiation. The test groups were then physically and visually compared with the control group for any similarities or differences.

Data was analyzed using Microsoft Excel 2016 (Microsoft Inc., United States of America). Descriptive statistical methods were used. Caldose\_X version 5.0 ([www.caldose.org](http://www.caldose.org)) was used to convert exposure factors to radiation dose.



Fig 1 Setup of the X-ray exposure of orange fruits

### III. Results

#### Exposure parameters

Exposures were made using variable, increasing Kilovoltage peak (kVp) and Milliampere-Seconds (mAs) with a fixed Source-Image receptor distance (SID). In order to increase the radiation dose to the orange fruits across the experimental groups, both the kVp and mAs were increased by a factor of 10 from one group to the next.

	SID	kVp	MAs	Dose (mGy)
Control	0	0	0	0
Group 1	80cm	60	40	4.5
Group 2	80cm	70	50	7.5
Group 3	80cm	80	60	11.4
Group 4	80cm	90	70	16.3

Table 1: Exposure parameters

**Effect of x-ray irradiation on shelf life of orange fruits**

**Firmness of orange fruits**

On day one all orange fruits were strong and firm to touch. The degree of firmness was rated as follows:

- 1 - Very firm
- 2 - Firm
- 3 - Weak
- 4 - Very weak

	SID	kVp	mAs	Dose (mGy)	Day 1	Day 7	Day 15	Day 30
Control	0	0	0	0	1	2	3	4
Group 1	80cm	60	40	4.5	1	2	3	4
Group 2	80cm	70	50	7.5	1	1	2	4
Group 3	80cm	80	60	11.4	1	1	2	3
Group 4	80cm	90	70	16.3	1	1	1	2

Table 2: Physical firmness of orange fruits

According to the above table, oranges in the control group and group 1 were the first to progress from being very firm on day 1 to being weak in texture by day 15. The oranges in group 4 were the most resistant to weakening hence remained firmer.

**Ripening of orange fruits**

On day one all orange fruits appeared green with interspaced areas of mild ripening. Continuous ripening was observed over the 30 days that followed and differences observed between the different groups. The oranges in group 4 were the most resistant to ripening. The degree of ripening as the experimental days passed by was rated as follows:

- 1 - Ripe with green colouration
- 2 - Very ripe
- 3 - Overripe

	SID	kVp	mAs	Dose (mGy)	Day 1	Day 7	Day 15	Day 30
Control	0	0	0	0	1	1	2	3
Group 1	80cm	60	40	4.5	1	1	2	3
Group 2	80cm	70	50	7.5	1	1	2	3
Group 3	80cm	80	60	11.4	1	1	1	2
Group 4	80cm	90	70	16.3	1	1	1	2

Table 3: Post-harvest ripening of orange fruits

According to table 3, ripening progressed faster in the control group and in the first experimental group compared to the delayed ripening process in 3<sup>rd</sup> and 4<sup>th</sup> experimental groups

**Effect of x-ray irradiation on the growth of spoilage organisms**

Two samples each, including the outer layer and the inner cut from an orange in each group was cultured using Nutrients agar. Observable growths were classified as follows:

- 0 - No growth
- + - Scanty growth
- ++ - Medium growth
- +++ - Heavy growth

Oranges in the control group showed more growths of spoilage micro-organisms by day 15 and day 30 than any other group.

	FFD	kVp	mAs	Day 1	Day 7	Day 15	Day 30
Control	0	0	0	0	+	+++	+++
Group 1	80cm	60	40	0	0	++	+++
Group 2	80cm	70	50	0	0	+	++
Group 3	80cm	80	60	0	0	0	+
Group 4	80cm	90	70	0	0	0	+

Table 4: Fungal growths on orange fruits

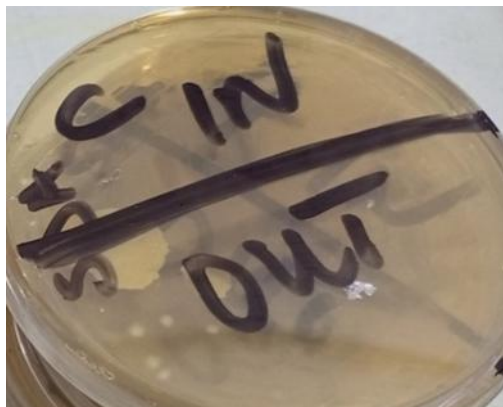


Fig 2: Scanty fungal growth on day 7 in the control group (externally)

According to table 4, the heaviest fungal growth was observed in the control group by day 15 while the 4<sup>th</sup> experimental group managed some scanty growth by day 30. The oranges in the 4<sup>th</sup> group had the most resistance to fungal growth.

#### **IV. Discussion**

This study examined the effects of x-ray irradiation on fresh orange fruits preservation. As shown in Table 2, the shelf life of non-irradiated and irradiated orange fruits were not the same; there were also differences relating to the quantity of radiation used in the different irradiated groups. By day 15 the non-irradiated orange fruits which served as control group for this study had become soft in texture with mixed colouration of the peel. The orange fruits in experimental group 4 remained very firm even after day 15 since the beginning of irradiation and lost just a bit of firmness by day 30. These results support the fact that irradiated fruits are likely to last longer on the shelf than non-irradiated ones. In a study by Tyovenda et al [8], they recorded a longer shelf life of 6 days more in irradiated mango fruits than non-irradiated ones using conventional x-ray equipment. Their study also showed that non-irradiated mango fruits shrunk faster than the irradiated ones while irradiated fruits delayed ripening for up to additional 5 days. Ziman, et al [14] reported the extension of the shelf life of banana by 20 days following Gamma irradiation. Ripening of the bananas was also delayed for up to 20 days.

On the growth of spoilage bacteria or fungi as shown in Table 4, the control group showed scanty fungal growth by day 7 and heavy fungal growth by day 15. The 3<sup>rd</sup> and 4<sup>th</sup> experimental groups showed no growth as at day 15 and only scanty growths at day 30. This indicates the ability of x-radiation to truncate the growth of food spoilage organisms especially at higher doses. In a study by Sultana, et al [15], irradiation of mango fruits yielded similar results. Mahmoud, et al [16] using x-ray treatment on mangoes reported that the microorganisms *E. coli*, *L. monocytogenes*, *Sh. flexneri* and *Salm. enterica* were successfully reduced to non-detectable limits.

#### **V. Conclusion**

This study examined the effects of x-ray irradiation on fresh orange fruits preservation. Results of the study showed that orange fruits irradiated with x-ray had a longer shelf life compared to the non-irradiated fruits, and the increase in shelf life was proportional to the dose of radiation used. Irradiated orange fruits also survived longer before succumbing to microbial or fungal attacks compared to non-irradiated ones. With the high cost of Gamma installations and other types of food irradiation facilities, it might become expedient to consider the use of medical grade x-ray equipment for the purpose of food irradiation since the facilities are readily available and affordable.

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