© JAN 2026 | IRE Journals | Volume 9 Issue 7 | ISSN: 2456-8880
DOI: https://doi.org/10.64388/IREV9I7-1714026

Attenuation Dependent Radio-Sensitivity in Dioscorea Rotundata: Uncovering the Underlying X-Irradiation Induced Response

ALUMUKU LIAMBEE[1], TERVER DANIEL[2], IORTILE JOSEPH TERYIMA[3], IKYUMBUR JONATHAN[4]

[1]*Department of Pure and Applied Physics, Federal University Wukari, Wukari, Nigeria*
[2, 4]*Department of Physics, Rev. Fr. Moses Orshio Adasu University Makurdi Nigeria*
[3]*Department of Physics, National Open University of Nigeria, Abuja*

Abstract- This research investigated the implications of attenuation on Dioscorea rotundata samples that were subjected to X-irradiation. A microbial analysis was conducted prior to and subsequent to the irradiation of Dioscorea rotundata specimens, resulting in an 87% reduction in microbial load. A total of ten Dioscorea rotundata specimens, consisting of five unfertilized varieties and five inorganically fertilized varieties, were subjected to X-ray irradiation utilizing a Philips Medical PXR 321B static X-ray machine. The irradiation procedure was executed at the Radiology Department of Benue State University Teaching Hospital, Makurdi-Nigeria The absorbed dose was quantified through thermoluminescent dosimetry technique, while the attenuation was computed as a function of both thickness and density, emphasizing the interrelations among absorbed dose, thickness, and density. The study encompassed the treatment of various Dioscorea rotundata species, employing both fertilized and unfertilized specimens, followed by their exposure to X-ray irradiation. The outcomes of the study demonstrated a negative correlation between absorbed dose and attenuation, signifying that increased doses resulted in decreased attenuation. Furthermore, a notable inverse relationship was identified between attenuation and thickness, indicating that more substantial Dioscorea rotundata specimens manifested lower attenuation. The research also uncovered a robust positive correlation between density and attenuation, suggesting that materials with greater density exhibited enhanced attenuation properties. These findings possess significant implications for the application of X-ray irradiation in the domains of food preservation and radiation therapy, emphasising the necessity for further inquiry into the mechanisms that govern attenuation within biological materials. The conclusions derived from this investigation can be leveraged to refine X-ray irradiation protocols aimed at augmenting the shelf life and quality of Dioscorea rotundata.

Keywords: X-irradiation, Radio-sensitivity, Dioscorea rotundata, attenuation and stress-induced physiological response.

I. INTRODUCTION

Dioscorea rotundata, widely recognized as "white yam," holds a prominent position within the diverse *Dioscorea genus*, which includes over 600 distinct varieties, each characterized by its unique attributes and applications [1]. This tuber, thriving underground, is native to various regions across Africa, Asia, and the Americas, and it particularly flourishes in tropical climates that offer warmth and ample rainfall. In West Africa, *Dioscorea rotundata* transcends its role as a staple food; it represents a rich tapestry woven from tradition, culture, and daily life. Local communities rely heavily on this crop not only for sustenance but also as a vital means of preserving their cultural heritage and fostering social cohesion [2] [3].

The cultivation and consumption of yams play an integral role in the regional economy, supporting the livelihoods of millions who depend on this essential crop for economic stability. Examining the yam reveals its distinctive rough and scaly skin, which serves as a protective barrier for the nutritious flesh inside. Once sliced, the interior displays a spectrum of colours—white, yellow, or even purple—depending on the variety, and these tubers can grow to impressive sizes, often hidden below the surface, attesting to the remarkable potential of this crop [4][5].

Nutritionally, yams are a powerful source of carbohydrates and dietary fibre, essential for promoting healthy digestion. They are also rich in

© JAN 2026 | IRE Journals | Volume 9 Issue 7 | ISSN: 2456-8880
DOI: https://doi.org/10.64388/IREV9I7-1714026

proteins, fats, and vital vitamins such as vitamin C and vitamin B6, contributing significantly to overall health and wellness. Their culinary versatility is demonstrated in a myriad of dishes, ranging from hearty soups and savoury stews to delightful fried snacks, cementing their role as an indispensable staple across various culinary traditions.

In Nigeria, yam cultivation embodies a cultural practice passed down through generations, reflecting a profound tradition. Local cultivars such *as Amula, Gbangu, Igyeigye, Alakpa, Faketsa, Hembam Kwase, and Anyam Ayua* are integral to this heritage, each name resonating with historical and cultural significance[6][1].

However, farmers face numerous challenges, including climate change, soil degradation, and microbial threats that jeopardize the shelf life of *Dioscorea rotundata* varieties. In response, researchers have turned to advanced preservation techniques such as gamma irradiation, X-irradiation, and dehydration to extend the shelf life of food products [7] [8]. For instance, [9] explored the detrimental effects of fungal infections on the storage efficacy of *Dioscorea rotundata*, revealing that infestations from pathogens like *Aspergillus* and *Fusarium* lead to weight loss, accelerated spoilage, and a significant decline in overall quality. These fungi not only compromise the texture of the yams but also diminish their nutritional value, resulting in products that are both quantitatively and qualitatively inferior.

There was demonstration of [10] that low-energy X-ray irradiation is more effective than traditional preservation techniques, including gamma rays and high-energy X-rays, in eradicating microbial populations. This effectiveness stems from low-energy X-rays imparting energy more efficiently into biological tissues, conferring enhanced lethality against microbial cells. Consequently, low-energy X-ray irradiation represents a superior method for ensuring food safety and freshness without compromising quality [11].

Additionally, research by [12] on gamma irradiation's effects on "obubra" water yam revealed promising results. They found that administering gamma rays at doses between 125 and 150 Gray (Gy) significantly reduced both sprouting and spoilage rates, identifying 125 Gy as the optimal dose for preserving quality and shelf life without harmful effects. In contrast, lower doses, such as 50 Gy or 100 Gy, were ineffective, leading to ongoing sprouting and decreased longevity during storage [13][14].

Despite the considerable advantages of X- irradiation in enhancing the postharvest quality of *Dioscorea rotundata*, there exists a notable lack of understanding regarding the effect of attenuation, on the irradiated *Dioscorea rotundata* in terms of absorbed dose, density and thickness, especially under varying fertilization conditions. This work seeks to fill this knowledge gap by analysing the effect of Attenuation using unfertilized and fertilized varieties of *Dioscorea rotundata*.

II. MATERIALS AND METHODS

This study received ethical approval from the Benue State University Teaching Hospital with reference number: BSUTH/MKD/HREC/2025/142. The laboratory analysis was done at Microbiology and the Radiology Department of the hospital, following established ethical review protocols. Ten yam seeds namely; *Gbangu, Amula, Hembam Kwase, Faketsa, and Anyam Ayua* from five different varieties were chosen for the investigation. These seeds were sourced from a farm in Gbajimba, Benue State, Nigeria, which practices organic farming and avoids synthetic fertilizers. The area is known for its rich, loamy soil with a reddish-brown colour, making it particularly suitable for yam cultivation.

The yam seeds were planted in clean, woven polypropylene sacks (60cm x 45cm), filled with loamy soil to create an ideal growing environment. Each yam variety was planted in five separate sacks, in February 2024. Different fertilization strategies were applied to the soil: inorganic and a control group with no fertilizer. The growing conditions in each sack were carefully monitored throughout the development period, focusing on growth metrics and weed prevention until harvest time in January 2025.

2.1 Microbial Investigation

After harvesting, microbial analyses were conducted before and after irradiation. Ten samples were prepared and inoculated on several culture media,

© JAN 2026 | IRE Journals | Volume 9 Issue 7 | ISSN: 2456-8880
DOI: https://doi.org/10.64388/IREV9I7-1714026

including Sabouraud Dextrose Agar, MacConkey Agar, and Blood Agar, which facilitated the identification and quantification of microbes present in the samples. The plates were incubated for 48 hours, after which the colonies were manually counted using a colony counter to ensure accuracy. An average of 87% of the microbial were reduced after irradiation

2.2 Irradiation of Samples

Ten samples of Dioscorea rotundata five each of unfertilized and inorganic underwent X-irradiation at the Radiology Department of Benue State University Teaching Hospital. The research team maintained strict control over all aspects of the process, including dosage and exposure conditions. Philips Medical PXR 321B static X-ray machine, manufactured in 2018, with a maximum capacity of 125kVp and 630mAs was utilized, providing ample power and precision for the task. Each sample received a carefully measured dose customized to its specific requirements. To ensure uniform exposure, the samples were arranged in a single layer on a tray. The machine's kilovolt peaks and milliampere-seconds were adjusted for each run, assuring that each sample received the appropriate level of irradiation. This approach allowed the team to thoroughly investigate the effects of X-irradiation on microbial load.

Measurements of absorbed dose within *Dioscorea rotundata* specimens was executed by the use of thermoluminescent dosimetry (TLD) technique specifically Harshaw 4500 TLD reader.

The X-ray machine underwent a calibration process, and established safety protocols were adhered to in order to guarantee the precision of the dose measurement, which was articulated in kilograys (kGy).

III. RESULTS AND DISCUSSION

Table: I 1rradiation of Un-Fertilized Dioscorea at FFD of 100cm and SSD of 80cm

Sample	Moisture (%) Before Irradiation	Density (g/cm^3)	Thickness (cm)	Mean kVp (KV)	SD	mAs (mAs)	SD	Initial Dose (kGy)	Mean Dose (kGy)	SD	Attenuation
Gbangu	46.06	0.53	11.00	86.50	±0.71	9.00	±1.41	1.60	0.45	±0.02	0.12
Amula	67.18	0.57	08.00	83..50	±0.71	8.00	±0	1.60	0.38	±0.02	0.18
Faketsa	57.60	0.56	10.00	84.00	±2.83	9.00	±1.41	1.60	0.39	±0.03	0.14
Hembam	63.75	0.48	16.00	111.00	±1.41	12.00	±1.41	1.60	0.86	±0.02	0.04
Kwase Anyam Ayua	53.60	0.52	13.00	92.00	±2.83	11.00	±0	1.6	0.64	±0.02	0.07

Table 2: Irradiation of Inorganically Fertilized Samples at FFD of 100cm and SSD of 80cm

Sample	Moisture (%) before	Density	Thickness (cm)	Mean kVp (KV)	SD	mAs (mAs)	SD	Initial dose	Mean	SD	Attenuation

	Irradiation	(g/ cm^3)						(kGy)	Absorbed Dose (kGy)		
Gbangu	52.86	0.56	10.00	90.00	±1.41	8.00	±1.41	1.60	0.41	±0.01	0.14
Amula	66.32	0.55	11.00	100.00	±1.41	8.50	±0.71	1.60	0.49	±0.02	0.11
Faketsa	52.60	0.54	12.00	112.00	±2.83	9.00	±0.71	1.60	0.67	±0.03	0.07
Hembam Kwase	64.58	0.52	13.00	115.00	±2.83	12.00	±1.41	1.60	0.94	±0.03	0.04
Anyam Ayua	55.57	0.56	9.00	85.00	±1.41	7.50	±0.58	1.6	0.32	±0.03	0.18

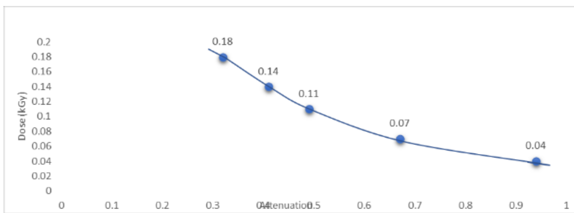

Figure 1: Absorbed Dose verse Attenuation in inorganic fertilization

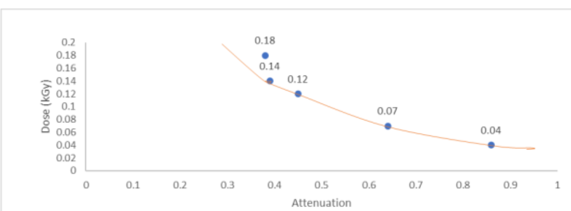

Figure 2: Absorbed Dose verse Attenuation in unfertilised samples

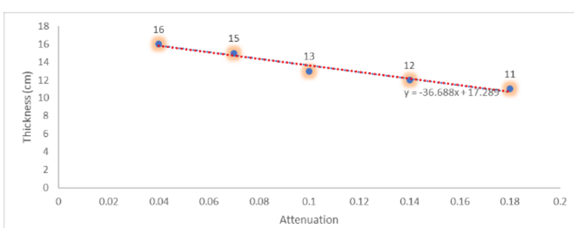

Figure 3: Inorganically fertilized sample thickness verse Attenuation

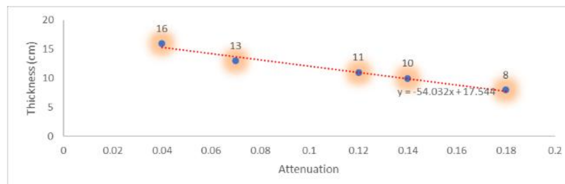

Figure 4: Unfertilized sample thickness verse Attenuation

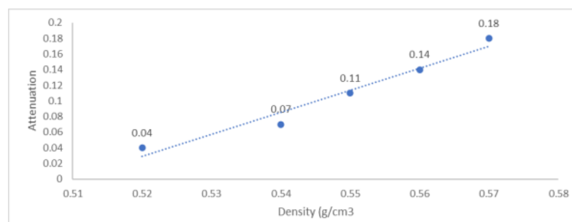

Figure 5: Attenuation verse density for inorganically fertilized sample

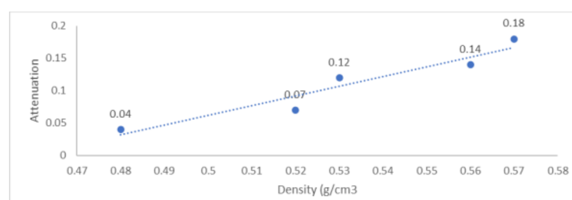

Figure 6: Attenuation verse density for unfertilized sample

IV. DISCUSSION

The work presented here involved an evaluation of the impacts of X-Irradiation on different species of *Dioscorea rotundata*, treated with fertilized and unfertilized samples. This investigation particularly emphasized the application of X-ray irradiation and the effect of attenuation on *Dioscorea rotundata* samples after X-irradiation

4.1 Absorbed Dose and Attenuation

The study showed the relationship between absorbed dose and attenuation as illustrated in Figures 1 and 2, where a negatively sloped curve is seen. This pattern shows the behaviour observed in samples treated with fertilizers. Specifically, it suggests that as the dosage of the substance increases, there is a corresponding decline in attenuation levels. This trend may indicate that higher doses lead to a more pronounced effect, resulting in reduced attenuation, which could be attributed to various underlying mechanisms at play in the interaction between the dosage and the *Dioscorea rotundata* properties

4. 2 Attenuation and Thickness

The analysis of Dioscorea rotundata samples subjected to various fertilization methods reveals significant understanding into the relationship between sample thickness and X-ray attenuation. The samples that received inorganic fertilization demonstrated a thickness range of 8.00-13.00 cm, with a mean thickness of 10.80 cm. The attenuation for these samples was recorded between 0.30 and 0.41, resulting in a mean value of 0.36 as seen in Figure 3. The un-fertilized samples displayed a thickness range from 8.00-16.00 cm, with an average thickness of 11.20 cm as represented in Figure 4. The attenuation values were notably lower, ranging from 0.02 - 0.12, and a mean of 0.08. This suggests that for every 1 cm increase in thickness, attenuation decreases by a mere 0.006.

The consistent inverse relationship observed between attenuation and thickness across all sample indicates that as the thickness of the yam samples increases, the attenuation decreases [15] [16-20] [21-26]. The inverse slope is the slope of the inverse relationship between attenuation and thickness, in this case, the inverse slope is not directly equal to the linear attenuation coefficient (μ). Instead, the inverse slope is related to the reciprocal of the linear attenuation coefficient. This phenomenon can be interpreted through several ways:

1. Reduced Absorption: The inverse relationship implies that thicker yam samples allow the X-ray beam to travel a longer distance, yet the attenuation is lower than anticipated. This could suggest that the density of the yam samples is less than expected, permitting a greater number of X-rays to pass through without significant absorption.

2. Scattering Effects: Another plausible explanation for the decreased attenuation is the scattering of X-rays within the yam sample. As thickness increases, the X-rays may scatter in various directions rather than being absorbed, thereby reducing the overall attenuation measured.

The implications of this inverse relationship in the context of X-ray irradiation of yams are dependent on depth Penetration: The findings suggest that X-rays can penetrate deeper into the yam samples, which could enhance the efficacy of the irradiation process. Dose Distribution: The observed reduction in attenuation with increasing thickness could influence the distribution of the X-ray dose within the sample. This may lead to a more uniform dose distribution, which is crucial for achieving reliable and consistent results in irradiation applications.

4.3 Attenuation and Density

The findings from the research expose a significant relationship between the measured density of Dioscorea samples and attenuation. This relationship is characterized by a strong, positive correlation, as evidenced by the data illustrated in Figures 5 and 6. Such a correlation aligns well with the intuitive understanding of physical principles: denser materials inherently contain a greater number of atoms packed into a specified volume. Consequently, this increased atomic density creates a greater number of potential "targets" for incoming radiation photons to engage with. In essence, the density of a material directly influences the number of atoms within a given volume, which in turn affects how those atoms interact with radiation. Attenuation occurs primarily through interactions between photons and atoms, which can take place through various mechanisms, including the photoelectric effect and Compton scattering. The photoelectric effect involves the complete absorption of a photon by an atom, resulting in the ejection of an electron, while Compton scattering refers to the elastic collision between a photon and a loosely bound electron, leading to a transfer of energy and a change in the direction of the photon. Thus, as the density of the *Dioscorea* rotundata samples increases, so too does the likelihood of these interactions, leading to enhanced attenuation of the radiation.

V. CONCLUSION

The study investigated into how X-irradiation affects *Dioscorea rotundata*, particularly focusing on the role of attenuation. The findings reveal an interesting inverse relationship: as the thickness of yam samples increases, the attenuation decreases. This behaviour is linked to reduced absorption and scattering effects, which are crucial for understanding how X-rays penetrate the samples and distribute doses. Moreover, the research highlights a significant positive correlation between the density of the *Dioscorea rotundata* samples and the level of attenuation. This emphasizes the role that material density plays in how radiation interacts with biological materials. The implications of these findings extend to various applications, such as food irradiation, suggesting that the study could enhance practices in these fields. Overall, this research enriches our comprehension of the complex interactions between X-rays and biological substances. By providing insights that can lead to improved X-ray irradiation techniques, the study aims to help refine irradiation protocols, by enhancing the quality and safety of food products and improving the effectiveness of radiation therapies.

REFERENCES

[1] Adomėnienė, A., and Venskutonis, P. (2022). Dioscorea spp.: Comprehensive Review of Antioxidant Properties and Their Relation to Phytochemicals and Health Benefits. *Molecules*. https://doi.org/10.3390/molecules27082530

[2] Agba, S. A., Ode, I. O., Ugbem, C. E., & Nwafor, S. C. (2019). Impact of Yam Postharvest Activities on Standard of Living of Yam Farming Households in North-East Zone of Benue State, Nigeria. *Journal of Applied Life Sciences International*. https://doi.org/10.9734/JALSI/2019/V21I130095

[3] Agre, P., Darkwa, K., Olasanmi, B., Kolade, O., Mournet, P., Bhattacharjee, R., Lopez-Montes, A., De Koeyer, D., Adebola, P., Kumar, L., Asiedu, R., & Asfaw, A. (2022). Identification of QTLs Controlling Resistance to Anthracnose Disease in Water Yam (*Dioscorea alata*). *Genes*. https://doi.org/10.3390/genes13020347

[4] Aighewi, B. A., Maroya, N., Kumar, P. L., Balogun, M. O., Aihebhoria, D., Mignouna, D., & Asiedu, R. (2021). Seed Yam Production Using High-Quality Minitubers Derived from Plants Established with Vine Cuttings. *Agronomy*. https://doi.org/10.3390/AGRONOMY11050978

[5] Ajibola, O. J. (2020). *An overview of irradiation as a food preservation technique*. https://doi.org/10.21608/NRMJ.2020.95321

[6] Akinbo, O. K., Opara, E. U., & Ikoro, A. I. (2016). Isolation and Characterization of Soft Rot pathogen of Yam (Dioscorea spp) in Nigeria-A Review. *Journal of Agriculture and Sustainability*.

[7] Alexander, C. B. (2022). Climate change: a factor to farmers/herders crisis in Benue State, North Central, Nigeria. *MOJ Ecology & Environmental Sciences*. https://doi.org/10.15406/mojes.2022.07.00261

[8] Alfarobbi, R., & Anggraini, N. (2018). Preservation of Foodstuffs with Gamma Ray Irradiation Technology for Decreasing Pathogen Bacteria on Food and Maintain Sustainable Food Security: A Review. *Social Science Research Network*. https://doi.org/10.2139/SSRN.3201078

[9] Amadi, H. O., Kawuwa, M. B., Abubakar, A. L., Adesina, C. T., & Olateju, E. K. (2022).*A Community integrated concept that minimises death of most vulnerable neonates at poor-resource environments*. https://doi.org/10.15406/jpnc.2022.12.00475

[10] Amaefula, A., Farquharson, R. J., Ramilan, T., & Asumugha, G. N. (2018). Evaluation of Yam-Based Production Enterprises in Nigeria.*Nigeria Agricultural Journal*. https://doi.org/10.4314/NAJ.V49I1

[11] Analysis of hypervelocity impacts: the tungsten case. (2022). *Nuclear Fusion*. https://doi.org/10.1088/1741-4326/ac42f6

[12] Ano, Q. U. (2019). Natural plant extracts and post harvest management of yams in storage: a review. *Nigeria Agricultural Journal*.

[13] Application of certified reference materials of absorbed dose for process validation of irradiation of medical supplies and food products. (2022). *Эталоны. Стандартные Образцы*. https://doi.org/10.20915/2687-0886-2021-17-4-23-32

[14] *Application of irradiation in the food industry*. (2023). https://doi.org/10.1016/b978-0-12-818717-3.00014-7

[15] Arapcheska, M., Spasevska, H., & Ginovska, M. (2020). *Effect of irradiation on food safety and quality*. https://doi.org/10.47068/CTNS.2020.V9I18.014

[16] Ariyo, O. A., Balogun, B. I., Atojoko, M., & Ogundare, M. T. (2022). Nutritional, antinutritional and sensory properties of composite pounded tubers from yam (Dioscorea esculenta), cassava (Manihot esculata) and sweet potato (Ipomoea batatas). *Bayero Journal of Pure and Applied Sciences*. https://doi.org/10.4314/bajopas.v14i2.13

[17] Ashamo, M. O. (2010). Management of the yam moth, Dasyses rugosella Stainton, a pest of stored yam tubers (Dioscorea spp.) using plant products. *Julius-Kühn-Archiv*. https://doi.org/10.5073/JKA.2010.425.071

[18] Awoyale, W., Awoyale, W., Oyedele, H., & Maziya-Dixon, B. (2020). Correlation of the sensory attributes of thick yam paste (amala) and the functional and pasting properties of the flour as affected by storage periods and packaging materials. *Journal of Food Processing and Preservation*. https://doi.org/10.1111/JFPP.14732

[19] Back, M., LeMottee, M., LeMottee, M., Crasta, C., Bailey, D. L., Bailey, D. L., Wheeler, H., Wheeler, H., Guo, L., Eade, T., Eade, T., & Eade, T. (2017). Reducing radiation dose to normal brain through a risk adapted dose reduction protocol for patients with favourable subtype anaplastic glioma. *Radiation Oncology*. https://doi.org/10.1186/S13014-017-0782-3

[20] Badeson, A. N. (2020). An Assessment of New Methods and Techniques in Teaching and Learning in Nigeria Towards Sustainable Development Goals.*Social Science Research Network*. https://doi.org/10.2139/SSRN.3607939

[21] Badewa, O. D., Parkes, E., Tsado, E. K., Gana, A. S., Tolorunse, K. T., Akpotuzor, P. A., Iluebbey, P., & Ayankanmi, T. (2022). Effect of Rainfall on Yield Related Traits and Total Carotenoids Contents of 42 Accessions of Provitamin A Cassava at Two Cropping Seasons in Ibadan.*Open Journal of Agricultural Research*. https://doi.org/10.31586/ojar.2022.314

[22] Basuki, R. S., Khaririyatun, N., Kirana, R., & Thamrin, M. (2022). Farmers' Preferences on the Quality of Indonesian Chili's Varieties for Developing New Varieties.*IOP Conference Series: Earth and Environmental Science*. https://doi.org/10.1088/1755-1315/995/1/012001

[23] Ehounou, A. E., Cornet, D., Desfontaines, L., Marie-Magdeleine, C., Maledon, E., Nudol, E., Beurier, G., Rouan, L., Brat, P., Lechaudel, M., Nous, C., N'guetta, A. S.-P., Kouakou, A. M., & Arnau, G. (2021). Predicting quality, texture and chemical content of yam (Dioscorea alata L.) tubers using near infrared spectroscopy. *Journal of Near Infrared Spectroscopy*. https://doi.org/10.1177/09670335211007575

[24] Ekpenyong, E. M., Agbo, B. E., Essien, E. E., & Ikpoh, I. S. (2024). Mycoflora Of DioscoreaRotundata Tubers In Calabar Metropolis And Their Effect On The Nutrient Composition Of The Tubers. *Global Journal of Pure and Applied Sciences*. https://doi.org/10.4314/gjpas.v30i3.4

[25] Szpunar-Krok, E., Szostek, M., Pawlak, R., Gorzelany, J., & Migut, D. (2022). Effect of Fertilisation with Ash from Biomass Combustion on the Mechanical Properties of Potato Tubers (Solanum tuberosum L.) Grown in Two Types of Soil.*Agronomy*. https://doi.org/10.3390/agronomy12020379

[26] Tan, Y., Duan, Y., Chi, Q., Wang, R., Yin, Y. X., Cui, D., Li, S., Wang, A., Ma, R., Li, B., Jiao, Z., & Sun, H. (2023). The Role of Reactive Oxygen Species in Plant Response to Radiation. *International Journal of Molecular Sciences*. https://doi.org/10.3390/ijms24043346