Published by

British Journal of Contemporary Research

BEXFORD PUBLISHING

Proximate Nutrient Profile of X-irradiated Fertilized Dioscorea rotundata: an Investigative Analysis

Original Research Article | Volume 1 | Issue 4 | 2026 | Article Number: 022

Accepted: 24 August 2026 | Published: 10 September 2026 | ISSN: 2979-8582 (Online)

Crossref : https://doi.org/10.67693/BJCR-FMTPHA9U

Alumuku Liambee[1], Shaapera Ugbidye[2], Magit Godwin Mafuyai[3]

[1]Department of Pure and Applied Physics, Federal University Wukari, Wukari, Nigeria,

[2]Department of Chemical Sciences, Karl Kumm University Vom, Jos, Nigeria,

[3]Department of Chemistry University of Jos, Jos, Nigeria

Correspondence: Alumuku Liambee, liambeealumuku@gmail.com

Abstract

The study examines the impact of X-irradiation and fertilization on the proximate nutrient profile of Dioscorea rotundata, focusing on how fertilization and X-irradiation influences the composition. The samples were analysed for ash content, moisture content, crude fat, crude fibre, crude protein, and carbohydrates before and after irradiation for inorganic as well as for the unfertilized samples which served as a control. The results show that both irradiation at a dose range of 0.32-0.94kGy and fertilization method produce notable effects on the proximate nutrient profile with significant increase in moisture content (p-value < 0.01). A reduction in ash content and crude fat content was observed in the unfertilized samples. For inorganically fertilized samples, the result demonstrated minimal reduction in ash and crude fat following irradiation (p-value < 0.01), with a significant rise in moisture content (p-value < 0.01).

Keywords: X-irradiation, Dioscorea Rotundata, Proximate Nutrition, Fertilized, Unfertilised

INTRODUCTION

Dioscorea rotundata, is recognized as a significant tuber in numerous tropical and subtropical regions across the globe (Obidiegwu *et al.*, 2020). It is not only used for its abundant and diverse nutrient profile, but also for its remarkable culinary versatility, that allows it to be incorporated into various dishes and cuisines (Bakayoko *et al.*, 2026). The nutrients derived from various sources are of paramount importance as it influences human health and shapes dietary uptake (Chen *et al.*, 2018).

Recent advancements in the innovative techniques of food preservation and enhancement shows there has been an increasing interest in investigating the application of X-irradiation as a viable method to prolong the shelf life of tubers (Danyo *et al.,* 2023).

X-ray irradiation, which is classified as a non-thermal food preservation technique, has gained significant prominence in the food industry due to its remarkable ability to substantially reduce microbial populations, thereby extending their overall shelf life and usability for consumers (Raza *et al*., 2026).

The fundamental principle behind this method involves the emission of high-energy X-rays that penetrate the food items, leading to damage of the DNA within various microorganisms; this may include harmful bacteria, viruses, and fungi that can compromise food safety (Mshelia *et al*., 2022). The genetic disruption caused by irradiation results in either the death of these pathogenic microorganisms or the inhibition of their ability to grow and reproduce, which enhances both the safety and the longevity of food items available to consumers (Demirpençe and Beyaz, 2025).

In order to achieve optimal yields, application of fertilizers becomes an essential practice that cannot be underestimated. This encompasses a diverse array of methods, including inorganic, organic, and mixed fertilization techniques, each of which possesses its own unique and distinct effects on the diversity and abundance of microbial life that resides within the soil ecosystem, which influences plant health and productivity (Dibi *et al.,* 2021).

Consequently, it is clear that the combined effects of X-irradiation and fertilization play a significant role in determining the overall yield of the crop (Edu *et al.,* 2023). Research has revealed that the impact of irradiation on the overall nutrient composition of food items tends to be relatively minimal, suggesting that the nutritional quality of irradiated foods is largely maintained throughout the process (Bhatnagar *et al*., 2022).

Furthermore, various studies have demonstrated that the nutritional losses that may occur as a result of the X-irradiation process are often outweighed by the substantial advantages it delivers in terms of enhancing food safety and extending the shelf life of products (Zehi *et al*., 2020), (Indiarto *et al*., 2020). In fact, irradiated foods have undergone rigorous testing and scrutiny, which is recognized as safe for human consumption by numerous food safety authorities across the globe (Bevelacqua and Mortazavi, 2020).

The existing body of literature is inadequate regarding the effects of X-irradiation combined with fertilization on the proximate nutritional profile, therefore the need to investigate the effects of X-irradiation and fertilization by X-irradiated *Dioscorea rotundata* varieties subjected to either inorganic fertilization or non - fertilization.

MATERIALS AND METHODS

Study Area

Sampling

This section provides an overview of the materials and methods employed in the experimental procedures designed for investigating the impact of X-irradiation and fertilization on the proximate nutritional profile of *Dioascorea rotundata*. Five varieties of yams, namely *Hembam Kwase*, *Gbangu, Amula, Anyam Ayua, and Faketsa* were carefully chosen not only for their unique agronomic characteristics but also for their significance within local agricultural practices, which vary widely across different regions.

Sampling and Preparation for analysis

The five varieties of un-fertilised and inorganically fertilized *Diascorea rotundata*, were carefully harvested from the farm specifically cultivated for the purpose of this research from January, 2025-February, 2026 as seen in figure 1, distinguishing the fertilizer species from the unfertilized varieties for the investigation of proximate nutritional profile.

Prior to any analysis, the tubers went through a careful process of washing to remove any dirt and subsequently cutting them into uniform size before subjecting them to a drying process in a dehydrator.

The dry samples were then digested and analysed for proximate nutritional composition, which include moisture, ash, protein, fat, fibre, and carbohydrate content.

Moisture content

Exactly 2.0 g of the yam sample was weighed into a pre-weighed moisture crucible then dried in the oven at 105°C for 3 hours to a constant weight. Cooled in a desiccator and reweighed (Bradely, 2003). The processes were repeated until constant weight was obtained. The moisture content of the sample was calculated using equation:

$$\text{Moisture content (\%)} = \frac{W_2 - W_3}{W_2 - W_1} \quad 1$$

where:

W_1 = weight of empty dish (g)

W_2 = weight of dish + undried sample (g)

W_3 = weight of dish + dried sample (g)

Ash content

Approximately 2.0 g of sample was weighed into a preheated cooled crucible and charred on a Bunsen burner in a fume cupboard until it stops smoking. Transfer to a muffle furnace and incinerate at 550°C for 3 hours until a light gray or white ash was formed then cooled in a desiccator and weighed (AOAC, 2000). The ash content was calculated as:

$$\text{Ash (\%)} = \frac{W_2 - W_3}{W_2 - W_1} \quad 2$$

Where:

W_1 = weight of empty dish (g)

W_2 = weight of dish + sample before ashing (g)

W_3 = weight of dish + sample after drying (g)

Crude protein:

Approximately 2.0 g sample was weighed into Kjeldahl flask and about 5 g anhydrous sodium sulphate was added followed by addition of 25 mL conc. H_2SO_4 with few boiling chips and heated in the fume chamber until solution becomes clear. The solution was cooled to room temperature after which it was transferred into a 250 mL volumetric flask and made up to the level with distilled water. The distillation unit was cleaned and the apparatus set up. A 100 mL conical flask, (receiving flask) containing 5 mL of 2 % boric acid was placed under the condenser with addition of drops of methyl red indicator. 5 mL of the digest was pipetted into the apparatus through the small funnel, which was washed down with distilled water followed by addition of 5 mL of 40 % sodium hydroxide solution. The solution in the receiving flask was titrated with 0.049 M H_2SO_4 to obtain a pink color (AOAC, 2000). The percentage crude protein was calculated as:

$$\text{Nitrogen in sample (\%)} = \frac{Titre - Blanl \times Normality\ of\ acid \times N_2 factor\ (1.4)}{Weight\ of\ sample} \times 100 \qquad 3$$

Crude protein (%) = Nitrogen in sample × 6.25 4

Crude fat:

Exactly 2.0 g of the sample was weighed into a labeled thimble and filled with 300 mL of Petroleum ether a round bottom flask and the extractor thimble sealed with cotton wool. The Soxhlet apparatus was allowed to reflux for 6. The solvent was evaporated using a rotary evaporator and the extraction flask was dried at 105°C for 1 hour in an oven, then cooled in a desiccator and weighed (AOAC, 2000). The fat content was calculated as:

$$\text{Fat (\%)} = \frac{weight\ of\ fat\ (g)}{Weight\ of\ sample\ (g)} \times 100 \qquad 5$$

Crude fibre:

The crude fiber of the samples was determined by an approach as described by AOAC. (2000), about 5 g of sample was measured in an Erlenmeyer 500 ml flask, and 100 mL of trichloroacetic acid added. The mixture was then boiled and allowed to reflux for about 40 minutes. It was then allowed to cool, filtered through Whiteman paper of 15.0 cm number 4. The remnant was rinsed with hot water and transferred into a porcelain dish, and then oven dried at 105ºC. The sample was then cooled in a desiccator and weighed as W_1. After that, it was incinerated at 500°C in a soundproofed furnace for 6 hours, cooled and weighed as W_2.

Thus:

% crude fibre was calculated as:

$$\text{Crude fibre (\%)} = \frac{W_1 - W_2}{Weight\ of\ sample} \times 100 \qquad 6$$

The carbohydrate content of the sample was determined by the difference using (AOAC, 2000):

Carbohydrate (%) = 100 – (% moisture + % ash + % protein + % crude fibre + % crude fat) 7

X-IRRADIATION OF SAMPLES

X-irradiation was conducted on a total of 10 distinct samples of Dioscorea *rotundata* at the Radiology Department located within the Benue State University Teaching Hospital, utilizing a highly calibrated single-phase X-ray machine. The primary objective of this intricate procedure was to evaluate and analyse the various effects that X-irradiation would have on the proximate nutritional profile and at which absorbed doses, which encompasses the fundamental nutritional components, of both un-fertilized and inorganically fertilized varieties of *Dioscorea rotundata*, each sample was arranged in a single, flat layer on a tray, ensuring that every specimen received a uniform exposure to the X-rays. The X-ray machine was calibrated to operate at a range of varying kilovolt peaks and milliampere-seconds and optimize the irradiation dose to correspond effectively with each sample's unique thickness and density characteristics. The procedure was carefully repeated for each of the 10 samples.

DOSE MEASUREMENT

Absorbed dose of radiation for each of the ten samples was measured using a thermoluminescent dosimetry (TLD) technique with a Harshaw 4500 TLD reader. This method enabled accurate quantification of the radiation dose absorbed by each sample. The calibrated X-ray machine was confirmed to be operating at optimal functionality prior to its application, and strict safety protocols were followed during the handling of both the X-ray machine and the irradiated yams. To guarantee optimal radiation dose, adjustments were made to the kilovolt peak (kVp) and milliampere (mA) settings based on the size and density of each sample, ensuring that each yam received the precise radiation dose necessary for effective treatment.

RESULTS AND DISCUSSION

The result of the experimental procedure as are presented in this section

Table 1: Proximate Analysis for Unfertilized Samples Before and After four weeks of Irradiation

Sample name	Absorbed Dose (kGy)	Ash Content (%) (Before Irradiation)	Ash Content (%) After four weeks	Moisture (%) (Before Irradiation)	Moisture (%) After four weeks	Crude Fat (%) (Before Irradiation	Crude Fat (%) After four weeks	Crude Fibre (%) (Before Irradiation	Crude Fibre (%) After four weeks	Crude protein (%) Before Irradiation	Crude protein (%) After four weeks	Carbohydrate Before Irradiation	Carbohydrate (%) After four weeks
Gbangu	0.45	1.17	1.17	46.51	52.51	0.98	0.95	0.66	0.66	1.64	1.65	50.50	50.51
Amula	0.38	0.60	0.61	67.58	71.57	0.53	0.50	0.93	0.92	1.33	1.32	23.30	23.29
Faketsa	0.39	0.82	0.81	58.69	65.58	0.70	0.72	0.69	0.68	1.49	1,43	26.64	26.65
Hembam kwase	0.86	0.79	0. 78	64.98	68.17	0.63	0.62	0.73	0.73	1.47	1,47	24.85	24.83
Ayam Ayua	0.64	1.03	1.02	53.20	57.50	0.75	0,72	0.66	0.64	1.50	1.48	33.70	33.71

Table 2: Proximate Analysis for Inorganically fertilised Samples Before and After four weeks of Irradiation

Sample name	Absorbed Dose (kGy)	Ash Content (%) (Before Irradiation)	Ash Content (%) After four weeks	Moisture (%) (Before Irradiation)	Moisture (%) After four weeks	Crude Fat (%) (Before Irradiation	Crude Fat (%) After four weeks	Crude Fibre (%) (Before Irradiation	Crude Fibre (%) After four weeks	Crude protein (%) Before Irradiation	Crude protein (%) After four weeks	Carbohydrate (%) Before Irradiation	Carbohydrate (%) After four weeks
Gbangu	0.41	1.41	1.39	52.86	56.54	0.89	0.80	0.64	0.62	1.71	1.72	48.78	51.5
Amula	0.49	0.56	0. 53	66.32	72.17	0.55	0.44	0.84	0.82	1.31	1.31	19.36	17.24
Faketsa	0.67	1.17	0.14	52.60	67.12	0.66	0.52	0.69	0.68	1.57	1,56	23.36	23.35
Hembam kwase	0.94	0.91	0. 97	64.58	70.27	0.60	0.61	0.70	0.71	1.55	1,57	22.23	25.21
Ayam Ayua	0.32	1.13	1.13	55.57	58.40	0.74	0.69	0.67	0.62	1.31	1.32	31.40	30.41

Table 3: Probability values of Proximate Nutrients profile for Unfertilized Samples

Sample	(Ash) P-value	(Moisture) P-value	(Crude fat) P-value	(Crude Fibre) P-value	(Crude protein) P-value	(Carbohydrate) P-value
Gangu	0.99	0.01	0.03	0.99	0.89	0.98
Amula	0.03	0.00	0.00	0.35	0.65	0.91
Faketsa	0.34	0.00	0.51	0.83	0.21	0.99
Hembam kwase	0.56	0.01	0.45	0.99	0.99	0.02
Anyam Ayua	0.83	0.00	0.01	0.56	0.73	0.95

Table 4: Probability values of Proximate Nutrients profile for inorganically Fertilized Samples

Sample	(Ash) P-value	(Moisture) P-value	(Crude fat) P-value	(Crude Fibre) P-value	(Crude protein) P-value	(Carbohydrate) P-value
Gangu	0.63	0.01	0.01	0.35	0.89	0.01
Amula	0.02	0.00	0.00	0.45	0.99	0.00
Faketsa	0.00	0.00	0.01	0.83	0.95	0.99
Hembam kwase	0.95	0.00	0.99	0.99	0.78	0.00
Anyam Ayua	0.99	0.01	0.03	0.12	0.83	0.63

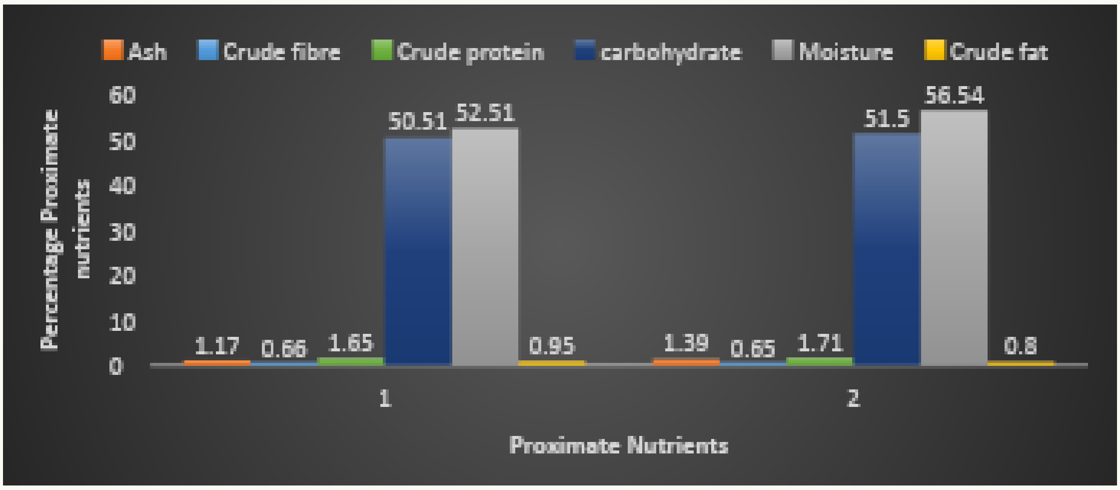

Figure 2; Percentage Proximate Nutrients of Un-Fertilized and inorganically fertilized samples after four weeks of irradiation

DISCUSSION

The results of the proximate analyses conducted for X-irradiation are shown in Tables 1 and 2 respectively.

Table 1, shows the results for unfertilized samples before and after four weeks of Irradiation while table 2 is the results for the analysis of inorganically fertilised samples before and after four weeks of Irradiation.

The ash content of the samples displayed a degree of stability following irradiation, with only minimal variations noted. For example, the ash content of *Gbangu* remained at 1.17% after irradiation, while Amula's content changed from 0.60% - 0.61%. The moisture content of the samples showed an increase after irradiation, particularly in Amula (rising from 67.58% to 71.57%). The crude fat content of the samples experienced a decline, with *Amula* showing a slight decrease of 0.03 post-irradiation (from 0.53% to 0.50%) as published by (Imeh *et al*., 2012). The crude fibre in the samples showed consistent stability after irradiation, with only litle fluctuations noted, this corroborated with the findings of Wang et al. (2022). The overall protein concentrations in the samples exhibited a steady trend after X-irradiation, with only minimal fluctuations. The carbohydrate levels in the samples remained relatively stable after irradiation, with just minor changes identified as reported by Falade et al. (2011).

The low absorbed dose is attributed to a small amount of radiation energy deposited in the yam tissue as shown in the Tables 1 and 2 before and after irradiation. Therefore, the proximate analysis (moisture, protein, fat, fibre, ash, carbohydrate) were not significantly altered. In other words, the yams retain their natural nutritional quality. Our research shows that irradiation at certain doses does not significantly change the proximate composition of yam, particularly protein, ash and carbohydrate levels but could affect the moisture content as shown in our study Table The change in moisture content after irradiation is primarily due to the treatment's ability to inhibit sprouting and reduce metabolic activity, which effectively locks in moisture that would otherwise be lost during natural aging

The findings reveal an appreciable increase in moisture levels after irradiation (p-value < 0.05), associated with the alterations within the starch granules of *Dioscorea rotundata*, which influence moisture retention and absorption characteristics. These findings are consistent with the research published by Wang et al. (2022) and Tanimola et al. (2022).

Table 2 shows the results of inorganic fertilized samples and after four weeks of irradiation. The ash content showed a minimal percentage decrease following irradiation, with the largest drop noted in *Faketsa* (from 1.17% to 0.14%), which may be attributed to variations in the experimental period as suggested by Armah et al. (2024). The moisture content rose following irradiation, with the significant rise seen in *Faketsa* (from 52.60%- 67.12%), which shares the same explanation as observed in the unfertilized samples. The crude fat content dropped after irradiation, with the highest reduction recorded in Amula (from 0.55% to 0.44%). The crude fibre content of the samples remained relatively stable following irradiation, with only minimal detection. The crude protein content of the samples exhibited relative stability after irradiation, with only minor variations observed. The carbohydrate content of the samples demonstrated diverse changes post-irradiation, with some samples exhibiting an increase, while others displayed a decrease. The findings reveal negligible reductions in ash content and crude fat content subsequent to irradiation (p-value < 0.05), alongside a significant increase in moisture content (p-value < 0.05) as shown in table 4 (Tanimola *et al*., 2022).

Considering the results of Tables 1-2, the ash content of the inorganically fertilized samples (Table 2) declined following irradiation, whereas that of the unfertilized samples (Table 1) remained relatively stable. The moisture content of the inorganically fertilized samples exhibited a more pronounced increase following irradiation in comparison to the unfertilized samples. This is attributed to the enhanced moisture retention in samples after irradiation capabilities resulting from the structural alterations in starch granules (Rostamabadi *et al.,* 2023) which appear to be more pronounced in inorganically fertilized samples.

The crude fat content of the inorganically fertilized samples experienced a more substantial decrease post-irradiation relative to the unfertilized samples. These results imply that the fertilization status of the samples may significantly influence their response to irradiation, particularly regarding ash, moisture and crude fat content. However, to gain a comprehensive understanding of how both fertilization and irradiation interact and affect these nutritional aspects, it is imperative to conduct further analytical investigations and experimental validations. Such studies will be crucial in clarifying the underlying mechanisms at play and in determining the broader implications for food science related to this important tube. The findings show a notable difference in ash content between the unfertilized and inorganically fertilized samples with (p-value = 0.03).

CONCLUSION

Analysis of the samples shows that; ash content of the inorganically fertilized samples decreased after irradiation, while the ash content of the unfertilized samples remained fairly stable. The moisture content of the inorganically fertilized samples showed a more significant increase after irradiation compared to the unfertilized samples. The crude fat content of the inorganically fertilized samples experienced a more considerable decrease after irradiation in contrast to the unfertilized samples. These results suggest that the interactions between fertilization and irradiation may modify the proximate nutrient composition of the Dioscorea rotundata varieties investigated.

References

AOAC, (2000). *Official method of analysis*, *14*th edition, the William Byrd press, Richmond VA USA. 332-333

Armah, O.J., Appiah, V., Egblewogbe, M. & Ocloo, K.C.F. (2024). Characterization of flour produced from gamma irradiated dried cassava (*Manihot esculenta*) chips. Radiation Physics and Chemistry, 218(12): 111651Doi:10.1016/j.radphyschem.2024.111651

Bakayoko, Y., Emmanuel, A.E., Bakayoko, L., Dibi, B.E.K., Agre, P., Sidoine, B.E., Asfaw, A.,Adebola, O.P., Dufour, D. & Kouakou, M.A. (2026). Participatory selection of white guinea yam (*Dioscorea rotundata p*) elite cultivars using organileptic and sensory quality-related traits of boiled and pounded tubers. Advances in Agriculture, 2026: 2026.6686087https://doi.org/10.1155/aia/6686087

Bevelacqua, J. J., & Mortazavi, S. M. J. (2020). Can irradiated food have an influence on people's health? 243–257. https://doi.org/10.1016/B978-0-12-817240-7.00015-2

Bhatnagar, P.,Gururani, P., Bisht, B., Kumar, V., Kumar, N., Joshi, R. & Vlaskin, S.M. (2022). Impact of irradiation on physic-chemical and nutritional properties of fruits and vegetables: a mini review. *Heliyon,* 8(10): 1-12

Bradely, R. L. (2003). Moisture and total solids analysis.In food analysis 3rd edition. Eds. Harbers, L. H. and Nielsen, S. S. 2003, p. 81-101.

Chen, Y., Michalak, M. & Agellon, B.L. (2018). Importance of nutrients and nutrient metabolism on human health. *Yale Journal of Biology and Medicine*, *91*(2): 95-103

Danyo, E. K., Ivantsova, M., & Selezneva, I. (2023). Ionizing radiation effects on microorganisms and its applications in the food industry. Foods and Raw Materials. https://doi.org/10.21603/2308-4057-2024-1-583

Demirpence, H. & Beyaz, D. (2025). Effect of gamma irradiation on the microbial load and quality of foods. *Animal Health Production and Hygiene*, *14*(1): 31-36

Dibi, E. B. K., Kouame, N., N'goran, E. K., Kouakou, M. A., Kouame, J. M. Y., Essis, B. S., & N'zue, B. (2021). Response of the Yam Variety Krengle (Dioscorea rotundata) to Organo-mineral Fertilisation at Bouaké in Central of Côte d'Ivoire. *The Journal of Agricultural Science*, *13*(6), 123. https://doi.org/10.5539/JAS.V13N6P123

Edu, N. E., Agu, R. C., Nwachukwu, A. A., Osondu-Anyanwu, C., Nkang, N. A., & Egbaji, C. I. (2023). Assessment of X-ray Irradiation on the Morphological Performance of Sweet Potato (Ipomoea batatas [L.] Lam). *Journal of Advances in Biology & Biotechnology*, *26*(3), 17–21. https://doi.org/10.9734/jabb/2023/v26i3624

Falade, K.O., Ighravwe, E. & Ikoyo, S.S. (2011). Physico‐chemical characteristics of non‐irradiated and γ‐irradiated yams cultivars (Dioscorea rotundata, Dioscorea alata) and sweet potato (Ipomoea batatas (L) Lam). International Journal of Food Science and Technology 46(6): 1186–1193.

Imeh, J., Onimisi, M.Y. & Jonah, S.A. (2012). Effect of Irradiation on Sprouting of Water Yam (Dioscorea Alata) Using Different Doses of Gamma Radiation. Chemistry: A European Journal 2(3): 137–141.

Indiarto, R., Pratama, A.W., Sari, T.I. & Theodora, H.C. (2020). Food irradiation technology: a review of the uses and their capabilities. *International Journal of Engineering Trends and technology*, *68*(12):91-98

Mshelia, D.R., Dibal, I.N. & Chiroma, S. (2022). Food irradiation: an effective but under-utilized technique for food preservation. *Journal of Food Science and Technology,* 60(10): 2517-2525

Obidiegwu, E.J., Lyons, B.J. & Chilaka, A.C. (2020). The Dioscorea Genus (Yam): An appraisal of nutritional and therapeutic potentials. *Foods*, 9(9): 1-45

Raza, A., Abdullah, M.H., Wasiq, M., Butt, U.M., Afzaal, M., Singh, A., Panigrahi, R. & Shah, A.M. (2026). A comprehensive review on non-thermal techniques in food processing and implementation in different food industries: limitations and challenges. *Food Science and Nutrition,* 14: 1-18

Rostamabadi, H., Demirkesen, I., Taze, .BH., Karaca, C.A., Habib, M., Jan, K., Bashir, K., Nemtanu, M., Colussi, R. & Falsafi, R.S. (2023). Ionizing and nonionizing radiations can change physicochemical, technofunctional, and nutritional attributes of starch. *Food Chemistry*, *19*:100771.doi:10106/j.fochx.2023.100771

Tanimola, A.R., Otegbayo, B. & Akinoso, R. (2022). Physicochemical properties of yam starches from fifty-five lines of Dioscorea species. Food Research 6(3): 49–61.

Wang, G., Wang, D., Qing C., Chen, L., Gao, P. and Huang, M. (2022). Impacts of electron-beam-irradiation on microstructure and physical properties of yam (Dioscorea opposita Thunb.) flour. *Food Science and Technology*, *163*:1-7

Zehi, Z.B., Afshari, A., Noori, S.M.A., Jannat, B. & Hashemi, M. (2020). The effect of X-ray irradiation on safety and nutritional value of food: a systematic review article. *Current Pharmaceutical Biotechnology*, *21*(10): 919-926