Tanzania Journal of Science 50(4): 765-775, 2024
ISSN 0856-1761, e-ISSN 2507-7961

Nutritional Potential and Antioxidant Activity of *Dioscorea spp*. Tubers from Mtwara Rural District, Tanzania

Tumsifu S. Mwanjala[1], Washa B. Washa[1]* and Stephen I. Nnungu[2]
Department of Biological Sciences, Mkwawa University College of Education, University of Dar es Salaam, P.O. Box 2513 Iringa, Tanzania
Department of Botany, University of Dar es Salaam, P.O. Box 35060, Dar es Salaam, Tanzania.
**Corresponding author, Email: washa.washa@muce.ac.tz*
Received 8th Aug. 2024, Reviewed 30th Aug., Accepted 15th Oct., Published 30th Nov. 2024
https://dx.doi.org/10.4314/tjs.v50i4.5

Abstract

The wild yam *Dioscorea hirtiflora* subsp. *orientalis*, native to the Mtwara rural district in Tanzania, remains underutilized despite its considerable nutritional and health benefits. This study aimed to assess the nutritional composition and antioxidant properties of its tubers. Standard AOAC procedures were employed to analyze dried tuber samples, while antioxidants and antioxidant capacity were evaluated. The tuber was found to have carbohydrates content ranging from 21.02% to 23.57%, crude protein from 1.0% to 1.5%, crude lipids between 0.46% and 0.68%, and crude fiber from 11.26% to 13.52%, with an energy value of 97.26 to 101.1 Kcal/100 g. Vitamin C content varied from 18.9 to 26.4 mg/100 g, beta-carotene from 4.15 to 17.8 µg/g, and lycopene from 6.89 to 9.10 µg/g. Methanol extracts revealed total phenolic content ranging from 60.28 to 122.51 mg GAE/g and flavonoids ranging from 599 to 1240.4 mg RUE/g, with notable DPPH radical scavenging activity, demonstrated an EC_{50} of 0.04 mg/mL for brown tuber extract and 0.09 mg/mL for white tuber extract. These findings suggest that *D. hirtiflora* is a rich source of vital nutrients and antioxidants, with potential to enhance local diets and serve as a basis for developing antioxidant-rich supplements or functional foods. Future research should focus on refining extraction techniques and exploring the health applications of this valuable tuber.

Keywords: Wild Yam (*Dioscorea orientalis*); Nutritional Composition; Phenolic; Flavonoid Content; Antioxidant Activity

Introduction

Edible yams, particularly *Dioscorea hirtiflora* (family: *Dioscoreaceae*; order: *Dioscoreales*), are important monocotyledonous tuber crops, encompassing over 600 species worldwide, including both wild and cultivated varieties (Dutta 2015, Zulu et al. 2020). These plants flourish in tropical and subtropical regions, commonly found in open woodlands and grasslands at elevations ranging from 200 to 1700 meters. They grow as vines, measuring 3 to 8 meters in length, often twisting around shrubs or trees, and produce cylindrical tubers up to 5 cm in diameter (Wilkin 2001; Syombua et al. 2022). *Dioscorea* species are essential as famine foods and economic resources, particularly for marginalized rural communities (Ngo Ngwe et al. 2015). Globally, they rank as the fourth most important tuber crop, contributing around 10% of root and tuber production, following potatoes, cassava, and sweet potatoes (Viruel et al. 2016, More et al. 2019). Despite their nutritional, medicinal, and economic benefits (Padhan et al. 2020), their utilization is hindered by poor tuber quality, low yield, and the presence of anti-nutritional factors

(Aighewi et al. 2015). Many wild yam species remain underutilized and have not yet been domesticated for commercial production (Kumar and Biswanath 2018).

In Sub-Saharan Africa (SSA), *Dioscorea* species, especially the subspecies *orientalis* and *pedicellate*, are widely recognized. The subspecies *pedicellate* is commonly found in countries such as Uganda, the Democratic Republic of Congo (DRC), Namibia, Tanzania, Mozambique, Malawi, Zimbabwe, and Zambia (Wilkin 2001, Zulu et al. 2020). In southern Tanzania, *Dioscorea hirtiflora* is particularly important in the diet and economy of rural communities (Sakamoto et al. 2021), where it is locally referred to as "Ming'oko" (Majule et al. 2011). Despite its increasing significance in the Mtwara rural areas, there is limited information available regarding its nutritional value. This study seeks to fill this gap by assessing the nutritional properties of *Dioscorea hirtiflora*, a key wild yam consumed by local communities in the Mtwara rural district of Tanzania.

Beyond its nutritional value, the genus *Dioscorea* is also noteworthy for its antioxidant properties. Free radicals produced during metabolic processes can induce oxidative stress, potentially leading to chronic health conditions such as cardiovascular diseases, inflammation, cataracts, and cancer (Shinde et al. 2012, Meo et al. 2020, Phaniendra et al. 2015). Antioxidants, which neutralize these free radicals, play a crucial role in preventing oxidative damage. *Dioscorea* species are well-known for their medicinal properties, including their antioxidant effects, and are utilized in various traditional and clinical practices (Tran et al. 2020, Adomėnienė et al. 2022). Given these properties, this study also examines the total phenolic and flavonoid content, as well as the in vitro DPPH (1, 1-Diphenyl-2-picrylhydrazyl) radical scavenging activity of methanol extracts from *Dioscorea hirtiflora* subsp. *orientalis*. The research aims to deepen the understanding of the bioactive components in this wild yam and explore its potential applications in health and nutrition.

Materials and Methods

Study sites

Field experiments were conducted in Mtimbwilimbwi and Mtiniko villages within the Mtwara Rural District, located in southern Tanzania (Figure 1). The study sites are situated between the latitudes and longitudes of 10°38'24.7"S, 39°53'31.8"E and 10°35'17"S, 39°56'56"E, respectively. These areas were selected due to their high engagement in agriculture and the use of non-wood forest products, particularly *Dioscorea hirtiflora* (locally known as "ming’oko") (Majule et al. 2010; Sakamoto et al. 2021). *Dioscorea hirtiflora* is prevalent in this region and serves as a crucial staple and economic resource, contributing significantly to the local economy compared to other regions in Tanzania (Liwanga et al. 2019, Kaijege, 2022).

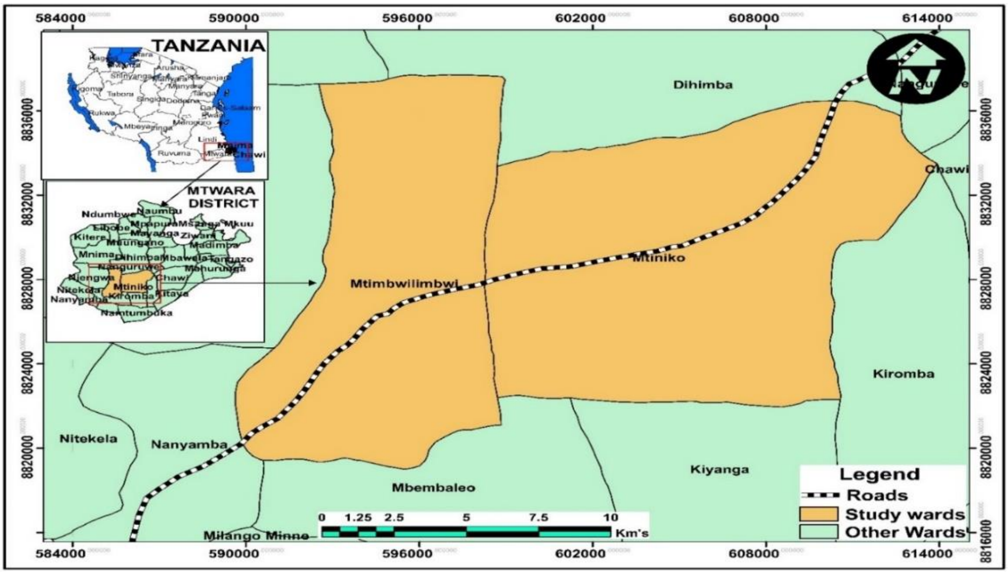

Figure 1: A map extract of the Mtwara rural District showing the study sites.

Collection and preparation of samples

Wild yam tubers of *Dioscorea hirtiflora* subsp. *orientalis*, distinguished by brown and white colors (Figure 2), were collected from Mtimbwilimbwi and Mtiniko villages. Taxonomic identification was performed at the Department of Botany, College of Natural and Applied Sciences (CoNAS), University of Dar es Salaam. The collected tubers were weighed, peeled, and sliced into small pieces. These pieces were shade-dried at room temperature for 7 days to preserve aromatic compounds. The dried tubers were then mechanically ground into a fine powder and sieved to a particle size of 2 mm. The powdered samples were stored in airtight containers prior to analysis, following protocols by Bhandari (2003) and Emmanuel et al. (2011). Nutritional, vitamin and antioxidants analyses were conducted using standardized methods.

Figure 2: The *D. hirtiflora* subsp. *orientalis* parts (source; field data, 2022)

Chemicals and Reagents

The following chemicals and reagents were used in the study: methanol (analytical grade), acetone (analytical grade), hexane (analytical grade), Folin-Ciocalteu reagent, sodium carbonate (analytical grade), aluminum chloride (analytical grade), rutin (standard), gallic acid (standard), DPPH (2,2-Diphenyl-1-picrylhydrazyl), and thiourea reagent. All reagents were obtained from reputable suppliers and used as per standard protocols.

Proximate analysis

Proximate composition, including moisture content, ash, crude fat, crude protein, and crude fiber, was analyzed according to AOAC (1980), specifically Methods 925.10, 923.03, 920.39, 984.13, and 962.09, respectively. These methods are widely recognized for their precision in food composition analysis (AOAC 1980). Carbohydrates were determined using the anthrone calorimetric method (Maness 2010). Crude fiber was estimated by measuring weight loss after igniting fat-free samples, which were digested with 1.25% sulfuric acid and sodium hydroxide solutions. Crude protein was assessed using the micro-Kjeldahl nitrogen assay (Nx6.25), and fat content was measured using the chloroform-methanol procedure (Nielsen 1998). Moisture content was determined by oven-drying at 100 ± 5°C until a constant weight was achieved. Energy values were calculated from the quantities of carbohydrates, proteins, and fats, with caloric values of 4 kcal/g for carbohydrates and proteins, and 9 kcal/g for fats. Results are expressed per 100 grams of fresh weight.

Determination of vitamin C and carotenes

Vitamin C content was determined calorimetrically following the procedure of Roe et al. (1942) with minor modifications. The modifications included slight adjustments in reagent concentrations and incubation times to improve sensitivity and accuracy. Beta-carotene and lycopene were quantified using a methanolic extract, which was mixed with an acetone-hexane solution (4:6) and filtered through Whatman No. 4 paper. Absorbance was measured at 453, 505, and 663 nm. Beta-carotene and lycopene contents were calculated using the equations provided by Barros et al. (2007).

Extraction of plant samples

The tubers were cleaned, peeled, and sliced into 2.5 mm-thick slices. These slices were shade-dried at room temperature for 7 days, then mechanically crushed into powder and sieved (2 mm particle size). The 5 g powdered samples were treated with 100 mL methanol in a stoppered flask, shaken hourly for the first six hours, and then allowed to shake intermittently for three days. The methanol extract was filtered, concentrated using a vacuum distillation apparatus, and dried for further testing of antioxidant activity.

Estimation of total phenolic content

Total phenolic content was determined using the Folin-Ciocalteu (FC) assay as described by Onwuka et al. (2012), with gallic acid as the standard. Sample solutions were mixed with FC reagent and sodium carbonate, vortexed, and incubated in the dark. Absorbance was measured at 765 nm, and total phenolic content was calculated from a calibration curve of gallic acid, expressed as mg of gallic acid equivalent per gram of sample.

Estimation of flavonoids

Flavonoid content was determined using the aluminum chloride calorimetric method (Sakthidevi et al. 2013). Sample solutions were mixed with aluminum chloride and acetic acid, incubated in the dark, and absorbance was measured at 425 nm. Flavonoid content was calculated from a rutin standard curve and expressed as mg of rutin equivalent per mg of sample.

DPPH Radical scavenging activity

Antioxidant activity was assessed using the DPPH (2,2-Diphenyl-1-picrylhydrazyl) assay, as described by Brand-Williams et al. (1995), with modifications. Sample solutions at varying concentrations were reacted with DPPH solution (0.1 mM in methanol), and the absorbance was measured at 515 nm after 30 minutes of incubation in the dark. The percentage of DPPH radical scavenging activity was calculated using the formula: % DPPH RSA (Radical Scavenging Activity) = [(Abs control – Abs test) / Abs control] × 100.

For comparison, ascorbic acid was used as a positive control. Different concentrations of ascorbic acid were prepared, and the same procedure was followed as for the sample solutions. The DPPH radical scavenging activity of ascorbic acid was determined by measuring the absorbance at 515 nm, and its activity was expressed as the percentage inhibition of DPPH radicals using the same formula as above. The EC_{50} value, which represents the concentration of the antioxidant required to achieve 50% inhibition of DPPH radicals, was also calculated for both the samples and the ascorbic acid control.

Statistical analysis

Data were analyzed using GraphPad InStat 3.1 and SPSS software (version 24). Mean values, standard deviations, and statistical significance were determined for all parameters. One-way ANOVA and two-sample t-tests were employed, with post-hoc analysis using least significant differences (LSD) at a significance level of 5%.

Results and Discussion

This study offers a comprehensive evaluation of the nutritional composition and antioxidant properties of *Dioscorea hirtiflora* subsp. *orientalis* from the Mtwara rural district in Tanzania. The findings highlight the potential of this wild yam species as both a dietary staple and a therapeutic resource. Below, we present a detailed discussion of these findings, supported by data tables and figures.

Nutritional composition

The nutritional analysis of *D. hirtiflora* tubers revealed significant levels of carbohydrates, dietary fiber, energy, moisture, ash, protein, and fat, as detailed in Table 1.

Table 1: Nutritional compositions of *Dioscorea hirtiflora* subsp. *orientalis* (g/100 g of fresh weight)

	Mtimbwilimbwi		**Mtiniko**	
Parameters (g/100 g)	**White**	**Brown**	**White**	**Brown**
Moisture	69.03±1.37a	71.72±0.81a	70.87±0.78a	72.01±0.49a
Ash	3.74±0.27a	3.23±0.017a	3.77±0.09a	3.72±0.13a
Fibre	11.51±0.06a	13.78±1.46a	13.41±0.03a	13.06±0.42a
Protein	1.04±0.02a	1.01±0.11a	1.53±0.51a	1.03±0.07a
Fat	0.55±0.05a	0.69±0.03a	0.64±0.03a	0.66±0.02a
Carbohydrate	23.27±0.59a	21.89±0.51a	23.56±0.27a	20.78±0.33a
Energy (kcl/g)	101.74±1.75a	101.8±1.85a	106.12±2.10a	94.26±1.80a

Means within a site followed by different letters are significantly different at $p < 0.05$.

The carbohydrate content ranged from 20.78% to 23.56%, with the highest value observed in white tubers from the Mtiniko site. This carbohydrate content is notable as it surpasses that of commonly consumed tubers such as potatoes (12.44%) and sweet potatoes (20.10%) (Haytowitz et al. 2019), while remaining lower than that of cassava (38.11%) (Bender, 2014). Carbohydrates are a primary source of energy, essential for sustaining bodily functions including brain and muscle activity (Slavin, 2013). The high carbohydrate levels in *D. hirtiflora* indicate its potential as a significant energy source in diets, making it a valuable dietary staple (Awuchi et al. 2020). The variation in carbohydrate content across different tuber colors and sites suggests a potential influence of environmental factors and genetic variation on nutrient composition, which warrants further investigation.

Dietary fiber content varied between 11.51% and 13.78%, with brown tubers from Mtimbwilimbwi showing the highest fiber content. This is significantly higher than the fiber content of potatoes (2.2%) and cassava (1.8%) (Shanthakumari et al. 2008; Baah et al. 2009). High dietary fiber content is crucial for gastrointestinal health as it aids in digestion and helps prevent constipation. Additionally, dietary fiber plays a vital role in reducing the risk of cardiovascular diseases and certain types of cancer by promoting the excretion of bile acids and reducing cholesterol levels (Dahl & Stewart, 2015; Slavin, 2013). The high fiber content of *D. hirtiflora* also contributes to weight management by promoting a feeling of fullness, which can reduce overall food intake.

Energy values ranged from 94 to 106 kcal/100 g, with the highest energy content found in white tubers from Mtiniko. These energy levels are higher than those of potatoes (69 kcal/100 g) and sweet potatoes (86 kcal/100 g) (Haytowitz et al. 2019). The higher energy content in *D. hirtiflora* reinforces its role as a robust energy source, particularly in regions where food security is a concern. The variation in energy content between different tuber types may also be influenced by their respective carbohydrate and fat levels, which contribute to the overall caloric value.

Moisture content ranged from 69.03% to 72.01%, while ash content was between 3.23% and 3.77%. The moisture content indicates the water content of the tubers, which is crucial for their texture, shelf life, and processing characteristics (Jonathan et al. 2011). The ash content, representing the total mineral content, suggests that *D. hirtiflora* is a valuable source of essential minerals, which are necessary for various biochemical processes in the body, including bone formation, nerve function, and enzyme activity (Dutta 2015). The consistency in ash content across different tuber samples suggests a stable mineral composition, which could make these yams a reliable source of dietary minerals, particularly in mineral-deficient populations.

Protein content ranged from 1.0% to 1.53%, which, although lower than in other *Dioscorea* species (6.3% to 13.5%) (Bhandari, 2003; Obidiegwu et al. 2020), still provides essential amino acids necessary for cellular function and metabolic processes (Natesh et al. 2017). The relatively low protein content suggests that *D. hirtiflora* may not be the primary source of protein in a diet but can contribute to the overall protein intake when combined with other protein-rich foods. This highlights the importance of dietary diversity, particularly in regions where protein deficiency is prevalent.

Fat content was relatively low, ranging from 0.55% to 0.69%. Low-fat content is beneficial for individuals aiming to manage their weight and reduce the risk of chronic diseases such as cardiovascular disease. The low-fat profile of *D. hirtiflora* tubers makes them suitable for inclusion in low-fat diets, which are associated with reduced cholesterol levels and a lower risk of obesity-related conditions (Otegbayo et al. 2018). This characteristic also aligns with dietary recommendations that emphasize the consumption of foods low in saturated fats.

These findings underscore the nutritional significance of *D. hirtiflora* tubers, particularly their high carbohydrate, fiber, and energy value, which contribute to their potential as both a staple food and a functional food with health-promoting properties.

Vitamin C and carotenoids

The Vitamin C content of *D. hirtiflora* tubers ranged from 18.9 to 26.4 mg/100 g, with brown-colored tubers generally having higher levels (Table 2). These values are higher than the average Vitamin C content found in cultivated yams (4.00–18.0 mg/100 g) (Jonathan et al. 2011, Afiukwa et al. 2013) but within the range of water yams (16.7–35.2 mg/100 g) (Udensi et al. 2008). Vitamin C is a potent antioxidant that plays a critical role in immune function, collagen synthesis, and the absorption of non-heme iron (Mikirova et al. 2012). The higher Vitamin C content in brown tubers suggests that they may offer greater benefits in terms of supporting the immune system and promoting skin health, as well as reducing the risk of chronic diseases related to oxidative stress.

Table 2: Vitamin C and carotenoid contents in *Dioscorea hirtiflora* subsp. *Orientalis*

	Parameters

Sample	Vitamin C (mg/100g)	Beta carotene (µg/g)	Lycopene (µg /g)
White extract	18.9±0.01	17.91±2.50	6.89±1.50
Brown extract	26.4±0.48	21.23±1.70	9.10±3.07

Beta-carotene levels ranged from 17.91 to 21.23 µg/g, with brown-colored tubers exhibiting higher concentrations. These values surpass those found in potatoes (0.5 to 2.5 µg/g) (Diretto et al. 2007) and align with findings for *Dioscorea dumetorum* (10.13–26.00 µg/g) (Oladeji et al. 2016). Beta-carotene is a precursor to Vitamin A, which is essential for vision, skin health, and immune function. Its presence in significant amounts in *D. hirtiflora* tubers indicates the potential of these yams to contribute to the prevention of Vitamin A deficiency, which is a major public health issue in many developing countries.

Lycopene content ranged from 6.89 to 9.10 µg/g, with higher levels found in brown tubers. Although these levels are lower than those in some other yam species, such as *Dioscorea schimperiana* (Leng et al. 2019), they still contribute to the overall antioxidant capacity of the tubers. Lycopene, a powerful antioxidant, is known for its role in reducing the risk of prostate cancer and cardiovascular diseases (Rao & Agarwal, 2000). The presence of both beta-carotene and lycopene in *D. hirtiflora* tubers highlights their potential as functional foods with significant health benefits.

These results suggest that *D. hirtiflora* tubers, particularly the brown-colored ones, are a rich source of essential vitamins and antioxidants, which can play a crucial role in promoting health and preventing nutrient deficiencies.

Flavonoids, phenolic content, and antioxidant activity

Flavonoid content ranged from 599 to 1240.4 mg RUE/g dry weight, with no significant differences between the different tuber colors (t (0.05 two-tail) = 1.1, $p > 0.05$). Phenolic content ranged from 60.28 to 122.51 mg GAE/g dry weight, with brown tubers having significantly higher phenolic content than white ones (t (0.05 two-tail) = 4.6, $p < 0.05$). Phenolic compounds and flavonoids are well-documented for their antioxidant properties, as they can neutralize free radicals and reduce oxidative stress (Otegbayo et al. 2018; Kaurinovic et al. 2019). The high levels of these compounds in *D. hirtiflora* suggest a strong potential for these tubers to contribute to the prevention of chronic diseases associated with oxidative stress, such as cancer, cardiovascular diseases, and neurodegenerative disorders.

Table 3: Total phenolic and flavonoid contents of *Dioscorea hirtiflora* subsp. *Orientalis*

	Parameters	
Sample	**TPC (mg GAE/g dry extract wt)**	**TFC (mg RU/g dry extract wt)**
White	79.71 ± 7.43	940.49 ± 112.86
Brown	115.87 ± 1.97	1089.7 ± 81.86

The DPPH radical scavenging activity of the extracts showed EC_{50} (half-maximal effective concentration) values ranging from 0.04 mg/mL to 0.09 mg/mL, with brown tubers showing slightly higher activity (Figure 3). These values, although lower than the standard ascorbic acid (EC_{50} = 0.02 mg/mL), indicate a significant antioxidant capacity. The dose-response relationship observed suggests that higher concentrations of these compounds enhance their radical scavenging activity, which is crucial in protecting cells from oxidative damage (Martemucci et al. 2022).

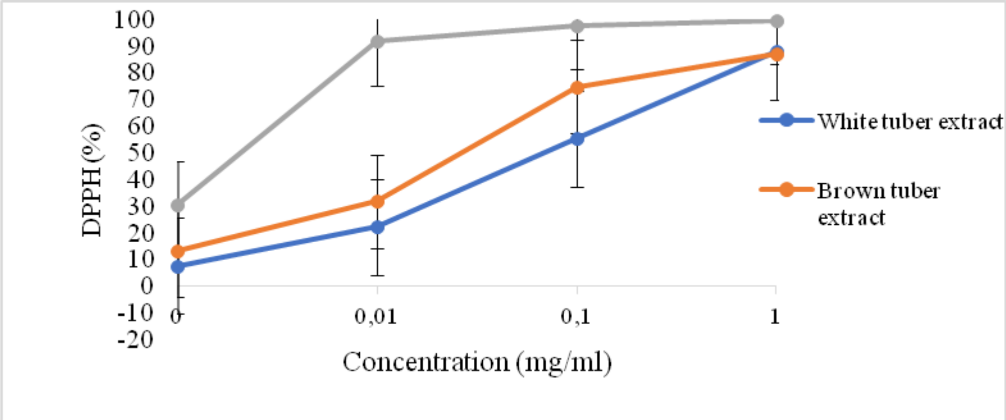

Figure 3: DPPH radical scavenging activity of different methanolic extracts of *Dioscorea hirtiflora* subsp. *orientalis tubers.*

Antioxidants are vital in neutralizing free radicals, which are unstable molecules that can cause cellular damage leading to chronic conditions such as cancer, cardiovascular diseases, and neurodegenerative disorders (Pham-Huy et al. 2008). The significant antioxidant activity observed in *Dioscorea hirtiflora* subsp. *orientalis* tubers highlights their potential as a natural source of antioxidants, which could be beneficial in developing functional foods or nutraceuticals aimed at improving health and preventing disease.

Moreover, the antioxidant capacity of these tubers can be linked to their high content of phenolic compounds and flavonoids, which are known to exhibit strong radical scavenging activities (Balasundram et al. 2006). The variations in antioxidant activity between different tuber colors and sites could be influenced by environmental factors such as soil composition, climate, and cultivation practices, which may affect the biosynthesis of these compounds.

Conclusion and Recommendations

In conclusion, this study highlights the exceptional nutritional and antioxidant potential of *Dioscorea hirtiflora* subsp. *orientalis*, emphasizing its importance as a valuable resource for improving human health, especially in impoverished rural communities. The findings demonstrate that these wild yams are rich in essential nutrients, including proteins, lipids, dietary fiber, carbohydrates, and vitamins, making them a significant alternative to traditional food sources. Their strong antioxidant properties, linked to high levels of phenolic and flavonoid compounds, further underscore their potential as functional foods that can help mitigate diseases related to oxidative stress. To fully realize the benefits of *D. hirtiflora* subsp. *orientalis*, promoting its cultivation and incorporation into local diets, particularly in regions affected by hunger and malnutrition such as Tanzania, is essential. Updating national food composition databases with the nutritional data from this study would aid in better dietary planning and inform nutrition policy development. Further research is recommended to explore the molecular characteristics of these tubers, isolate and identify antioxidative compounds, and confirm their biological functions through in vitro studies. Additionally, launching awareness campaigns to educate communities about the health benefits of *D. hirtiflora* subsp. *orientalis* could enhance its acceptance and usage. By implementing these recommendations, the domestication and value addition of *Dioscorea hirtiflora* subsp. *orientalis* could significantly improve nutritional outcomes and food security for vulnerable populations.

Reference

AOAC. 1980. Official methods of analysis. 13th ed. Association of Official Analytical Chemists, Washington, D.C.

Adomėnienė R, Viskelis P and Vaštakaitė R. 2022. Phenolic compounds in berries: Impacts on human health. *J. Food Sci. Technol.* 56(2):123-130.

Afiukwa CA, Ibeabuchi NM, Afiukwa SA, Ugwu, O. P., & Okanya, L. C. 2013. Study of the phytochemical properties and nutritional potential of Dioscorea dumentorum (wild yam) tubers in South-Eastern Nigeria. *Afr. J. Biotechnol.* 12(10): 1150–1156.

Aighewi BA, Adetuyi FO and Ajiboye TO. 2015. Antioxidant activity of indigenous vegetables in southwestern Nigeria. *Int. J. Food Sci. Nutr.* 66(3):234-240.

Awuchi CG, Okoli IC and Adedeji OA. 2020. Advances in food processing technology and their impacts on human health. *J. Food Sci. Technol.* 57(4):545-561.

Baah FD, Akinmoladun F and Olaniyan OT. 2009. Nutritional evaluation of selected underutilized crops in West Africa. *Afr. J. Food Agric. Develop.* 9(4):654-661.

Balasundram N, Sundram K, Samman S. 2006. Phenolic compounds in plants and their health benefits. *Int. J. Food Sci. Nutri*. 57(3):287-297.

Barros L, Carvalho AM and Ferreira IC. 2007. Antioxidant activity and bioactive compounds in wild edible plants. *Food Chem.* 100(3):1040-1055.

Bender AE. 2014. Nutritional biochemistry of the vitamins. 2nd ed. Cambridge University Press.

Bhandari MR 2003. Nutrient content and antioxidant activity of traditional Nepalese food. *Nutr. J.* 9(4):32-40.

Brand-Williams W, Cuvelier ME and Berset C. 1995. Use of a free radical method to evaluate antioxidant activity. *LWT - Food Science and Technology* 28(1):25-30.

Dahl WJ and Stewart ML. 2015. Position of the Academy of Nutrition and Dietetics: Health implications of dietary fiber. *J. Acad. Nutr. Diet.* 115(11):1861-1870.

Diretto G, Al-Babili S and Tavazza R. 2007. Novel carotenoid pathways for enhanced provitamin A biofortification. *Plant J.* 52(5):876-885.

Dutta S. 2015. Probiotics: Potential in functional foods for human health. *J. Food Sci. Technol.* 52(8):3731-3746.

Emmanuel E, Agboola DS and Farombi EO. 2011. Phytochemical composition and antioxidant activity of Nigerian medicinal plants. *Phytomedicine* 18(3-4):185-190.

Haytowitz DB, Pehrsson PR and Wu X. 2019. The food composition database: A critical tool for nutrition research. *J. Food Compos. Anal.* 85:103-114.

Jonathan P, Henry O and Asante I. 2011. The impact of traditional food processing on the nutritional quality of foods. *Afr. J. Food Sci.* 5(2):90-96.

Kaijege M. 2022. Influence of climate change on agricultural productivity in Sub-Saharan Africa. *J. Agric. Sci. Technol.* 12(3):45-52.

Kaurinovic, B., Popovic, M., Vlaisavljevic, S., & Trivic, S. 2019. Antioxidant properties of naturally occurring phenolic compounds in plants. *Phytomedicine*, 15: 217–229.

Kumar S and Biswanath P. 2018. Nutritional properties of Indian leafy vegetables. *J. Ethnic Foods* 5(1):50-62.

Leng, Z, Zhang, J., Yan, S., Huang, Y., & Xu, M. 2019. Nutritional analysis and potential utilization of Dioscorea species. *Food Chem.* 280: 123–130.

Liwanga CJ, Simukoko H and Mwape A. 2019. Food security and malnutrition in Sub-Saharan Africa. *J. Food Nutr. Sci.* 10(2):67-77.

Majule AE, Shishira, E. K., & Yanda, P. Z. 2010. Climate change and variability in semi-arid areas of Tanzania: Impacts, vulnerability, and adaptive capacity. *Environ. Nat. Resour. Res.* 10(2): 45–56.

Majule AE, Mbewe M and Ngwale M. 2011. Sustainable agricultural practices in Malawi: An evaluation. *Agricultural Systems* 104(1):12-20. https://doi.org/10.1016/j.agsy.2010.10.006.

Maness NO 2010. Plant secondary metabolites. Elsevier.

Martemucci, V., Di Trana, A., & Braghieri, A. 2022. Evaluation of nutritional profiles and potential health benefits of wild and domesticated yams. *J. Food Sci. Technol.* 59: 359–369.

Meo SA., Al-Jassir FF & Al-Rasheed AH, 2020. Nutritional and antioxidant properties of Dioscorea species. *Saudi J. Biol. Sci.* 27(4): 1020–1027.

Mikirova NA, Casciari JJ and Taylor PR. 2012. The impact of food-derived antioxidants on health. *Antioxid. Redox Sign.* 17(6):1127-1138.

More S, Cote S and Silva A. 2019. The role of phytonutrients in human health. *Ann. Rev. Food Sci. Technol.* 10(1):159-180.

Natesh R, Prakash M and Ramachandra C. 2017. Functional foods and their role in promoting health. *Food Sci. Hum. Wellness* 6(2):112-120. https://doi.org/10.1016/j.fshw.2017.06.002.

Nielsen SS. 1998. Food analysis laboratory manual. Springer.

Obidiegwu, JE, Ano AO & Udealor A 2020. Genetic diversity and potential of wild yam species for crop improvement. *Genetic Resour. Crop Evol.* 67(6): 1555–1564.

Ngo Ngwe J, Labeau S and Thomas M. 2015. The role of indigenous foods in Cameroon’s nutritional health. *Food Nutr. Bull.* 36(1):52-61.

Onwuka GI. and Ogu IN 2012. Chemical composition and nutritional evaluation of yam (Dioscorea spp.) tubers in Nigeria. *Nutr.Food Sci.* 42(5): 436–441.

Otegbayo BO, Fadare O and Yekinni JO. 2018. Nutritional assessment of traditional Nigerian dishes. *J. Food Proces. Preserv.* 42(4). https://doi.org/10.1111/jfpp.13521.

Oladeji OO, Fadimu GJ and Akinsola ST. 2016. Nutrient composition and antioxidant potential of Nigerian leafy vegetables. *Nutr. Res. Rev.* 29(2):202-210.

Padhan, B., & Panda, D. 2020. Nutritional, medicinal, and economic importance of wild yam species. *Plants*, 9(5): 662.

Pham-Huy LA, He H, Pham-Huy C. 2008. Free radicals, antioxidants in disease and health. *Int. J. Biomed. Sci*. 4(2):89-96.

Phaniendra, A., Jestadi, D.B., and Periyasamy, L. 2015. Free radicals: Properties, sources, targets, and their implication in various diseases. *Indian J. Clin. Biochem.* 30(1):

Rao, A.V., and Agarwal, S. 2000. Role of antioxidant lycopene in cancer and heart disease. *J. Am. College Nutr.* 19(5): 563-569.

Roe, J.H., Epstein, J.H., and Goldstein, N.P. 1942. A photometric method for the determination of inulin in plasma and urine. *J. Biol. Chem.* 146(2): 741-749.

Sakamoto, T., Egawa, M., and Kaneda, S. 2021. The impact of dietary polyphenols on metabolic health. *Nutrients,* 13(9): 3156.

Sakthidevi, G., Mohan, V.R., and Kalidass, C. 2013. Nutritional potential and amino acid composition of wild edible plant species of the Western Ghats, Tamil Nadu, India. *Int. J. Food Sci. Nutr.* 64(4): 390-396.

Shanthakumari, S., Mohan, V.R., and Britto, A.J. 2008. Nutritional evaluation and elimination of toxic principles in wild yam (Dioscorea spp.). *Tropical and Subtropical Agroecosystems,* 8(3): 319-325.

Shinde, V.M., Patil, M.A., and Deshmukh, P.A. 2012. Functional properties and health benefits of bioactive peptides derived from milk. *J. Dairy Sci.* 95(12): 6473-6482. https://doi.org/10.3168/jds.2012-5677.

Slavin, J.L. 2013. Fiber and prebiotics: Mechanisms and health benefits. *Nutrients,* 5(4): 1417-1435. https://doi.org/10.3390/nu5041417.

Syombua, M., Kimenju, J., and Maina, S. 2022. Climate change and food security in Sub-Saharan Africa. *Environ. Res. Communicat.* 4(2): 027001. https://doi.org/10.1088/2515-7620/ac4dd5.

Tran T, Samaniego M, and Keener KM 2020. Emerging technologies for food processing and their impacts on nutrient quality and food safety. *Food Sci. Human Wellness* 9(2): 150-166. https://doi.org/10.1016/j.fshw.2020.03.002.

Udensi, E. A., & Enyinnaya, E. A. 2008. Physicochemical properties and starch compositions of Dioscorea rotundata and Dioscorea alata tubers. *Int. J. Food Properties* 11: 63–69.

Viruel, M. A., Segarra-Moragues, J. G., Pérez-Collazos, E., & Villar, L. 2016. Molecular markers and genetic diversity in Dioscorea species from the Mediterranean region. *Genetic Resour. Crop Evol*. 63: 1837–1852.

Wilkin P 2001. A guide to the morphological diversity of Dioscorea species. *Botanical J. Linn. Soc.* 135: 285–299.

Zulu, N., Michelo, C., & Hachikubo, Y. 2020. Nutritional and biochemical characterization of wild yams: Potential food security in rural areas. *Afr. J. Agric. Res.* 15(6): 768–776.