


Effect of Traditional Food Processing Methods on The Nutrient and Anti-Nutrient Composition of Aerial Yam (*Dioscorea bulbifera*) Flour

*Cyril, O. Anoshirike¹ , Elizabeth, N. Chukwuemeka², Ngozi M. Nnam¹, Elizabeth, A. Udentia¹, Kelechi, M. Anoshirike³

1. Department of Nutrition and Dietetics, University of Nigeria, Nsukka.
2. Department of Home Economics, Federal College of Education Iha-amufu Enugu State.
3. Department of Nutrition and Dietetics, Imo State Polytechnic Umuagwo Imo State, Nigeria.

* Corresponding author: Cyril O. Anoshirike¹

Email: cyril.anoshirike@unn.edu.ng

DOI: <https://dx.doi.org/10.4314/jdan.v13ii1.5>

ABSTRACT

Background: Aerial yam bulbil is one of the high-yielding food crops with quality nutrients. It has great potential to contribute to food security. However, this food crop is often underutilized. Therefore, the traditional methods of processing it into flour to increase food diversity, reduce post-harvest loss, improve nutrient quality, and reduces anti-nutrients are often unexploited in Nigeria.

Objective: The study evaluated the effect of traditional food processing methods on the nutrient and anti-nutrient composition of Aerial Yam bulbil flours.

Methods: The aerial yam bulbil was harvested from a farm in Ovoko, Igbo-Eze South LGA Enugu State, Nigeria, and was divided into three portions as follows: Unprocessed; germinated for 72 hours only; germinated for 72 hours and fermented for 48 hrs. After, the three portions of the Aerial yam bulbils were separately peeled, cut into small pieces, washed, drained, sundried, and milled into flours such as Unprocessed aerial yam flour (UAYF); germinated aerial yam flour (GAYF); germinated and fermented aerial yam flour (GFAYF). The flour samples were subjected to nutrient and anti-nutrient analysis using standard methods. The data were analyzed using IBM-SPSS version 22. Statistical analysis was carried out using Analysis of Variance (ANOVA) and the means were compared using post hoc tests; Duncan's multiple tests and Fisher's least significant difference test.

Results: Germinated and fermented aerial yam flour had higher Protein (21.30%) and Fat (3.32%) and least carbohydrate (65.78%) and ash (3.95%), while sample UAYF and GFAYF had higher fibre (3.95%). GFAYF had higher zinc (0.13mg), iron (3.55mg), calcium (3.34mg), and phosphorous (84.39mg). GFAYF had reduced Phytate 4.73mg; Tannins (1.24mg); Hydrogen Cyanide (4.16mg); Oxalate (2.38mg); but increased Saponin (0.12mg) respectively.

Conclusion: Combined germination and fermentation improved nutritional quality and decreased the anti-nutritional content of Aerial yam flour. This product can be used for the preparation of healthy and therapeutic dishes.

Keywords: Aerial yam flour, Germination, Fermentation, Nutrient composition

INTRODUCTION

Aerial yam (*Dioscorea bulbifera*) is an edible aerial "bulbil" usually known as the air potato and a member of the *Dioscoreaceae* family which consists of several varieties that originate and grow extensively in Africa and South Asia. The aerial "bulbils" are under-utilized and not commercially grown; but are cultivated and consumed among rural dwellers in parts of Western Nigeria (1). The Aerial yam bulbil is called "adu" in Igbo language, *ewuraesi* in Yoruba and *doyarbisa* in Hausa languages. It can grow in wild forms or be cultivated for food. Aerial yam bulbil provides sufficient number of calories from Carbohydrates. It also

contributes protein, fiber, and some minerals and essential vitamins in human diets (2, 1). Aerial yam bulbil can be boiled, roasted, or fried alone or in combination with other food crops for food, and their consumption may provide adequate nutrients to maintain good health. Seasonality precipitates micronutrients and general nutrient deficiencies. Yam is one of the stable food crops which serve as an integral vehicle for food security not only in Nigeria but in West Africa (3), a source of income and employers of labour in the producing areas. Different varieties of yams such as: *D. rotundata*, *D. cayenensis*, *D. bulbifera*, *D. dumentorum* and *D. esculenta* that are cultivated and produced in lesser

quantity for domestic use in Nigeria are due to constraints such as lack of finance, high cost of labour and storage facilities, hard-to-cook property as well as the presence of some anti-nutrients.

Traditional food processing methods such as soaking, germination, and fermentation could reduce the level of anti-nutrients thereby improving the nutritional qualities of food products (4). Eliminating or reducing of Anti-nutrients may be more effective by a combination of processing methods than single techniques (5). During fermentation and germination, phytates are degraded by the activation of inherent phytases (6). Food fermentation enriches food substrates with protein, essential amino acids, and vitamins; and the diet through the development of a diversity of flavors, aromas, and textures in food substrates; eliminates anti-nutrients; reduces the Post-harvest loss, cooking difficulties and provides a desirable taste on the food product (7). Reduction of anti-nutritional factors in roots and tubers (aerial yam), legumes, and cereals are very important in food processing, preparation, and formulation of not only complementary foods but other foods to ensure nutrient bioavailability. Fermentation and germination are traditional food processing techniques used to produce *ogi* (7) from sorghum, maize, or millet; *garri* or *fufu* from cassava; *ogiri* from melon seed, castor oil seed, which are widely consumed across West Africa (8) and in Nigeria. Fermentation and germination of food not only enhance nutrient availability and reduce anti-nutritional factors (9) but also reduce post-harvest losses and increase the shelf life of the food.

Aerial yam bulbil processing and cultivation have received minimal interest and attention from food processors in Nigeria. Moreso the health benefits of aerial yam bulbils in lowering blood cholesterol levels, and blood pressure, and treatment of other diseases are underexploited. Aerial yam flour may create convenience in the diverse use of this food product as food in Nigeria, it can also create jobs for people that produce the flour (10, 11). Aerial yam bulbil referred to as 'potato yam' or 'air potato' is cultivated for food, though with constricted consumption even during periods of food shortage, due to its hard-to-cook property and possession of antinutrient content (12). It is highly under-exploited (13), especially in Nigeria. Improving the nutrient quality of aerial yam through

germination and combining germination and fermentation and the production of aerial yam flour has not been fully explored. Bridging the nutrition gap has become imperative with a view to providing information on the effect of processing on the nutrient profiles of aerial yams, and its diverse use both in solving nutrition problems and the food industry. It is, therefore, the objective of this work to evaluate the effect of some traditional food processing methods on the nutrient and anti-nutrient composition of Aerial Yam bulbil (*Discorea bulbifera*) flours.

MATERIALS AND METHODS:

Materials: Aerial yam bulbil (*Discorea bulbifera*) that is used for this study was obtained from a family farm in Ovoko, Igbo-Eze South Local Government Area, Enugu State, Nigeria.

Sample preparation

A large quantity (4kg) of aerial yam bulbil (*Discorea bulbifera*) was harvested, cleaned, washed, allowed the water to drain, and then divided into three portions. The first portion was peeled, cut into small round sizes, spread out in a wide wooden basket, and sun-dried to 96% dry matter, milled, packaged in cellophane bags, labeled, and stored in the refrigerator until used for nutrient and anti-nutrient analyses. The remaining two portions were soaked in tap water in a ratio of 1:3 (w/v), drained and spread on a wet jute bag, covered completely with another wet jute bag, and allowed to germinate for 72 hours (3 days). After germination, the aerial yam was divided into two portions. The first portion was peeled, cut into small round pieces and sun-dried to 96% dry matter, milled, packaged in cellophane bags, labeled, and stored in a refrigerator for nutrient and anti-nutrient analyses. The third portion was soaked in a plastic container in tap water in a ratio of 1:3 (w/v) and left to ferment for 48 hours by inherent microflora. When the bubbles that indicate initial fermentation appeared, the fermenting aerial yam was drained in a stainless sieve, peeled, cut into small round pieces, and spread evenly in a wide wooden basket; labeled, and set out for sun drying. After sun drying, the samples were milled, packaged, labeled, and stored as the other samples. The sample preparation flow chart is represented in Figure 1.

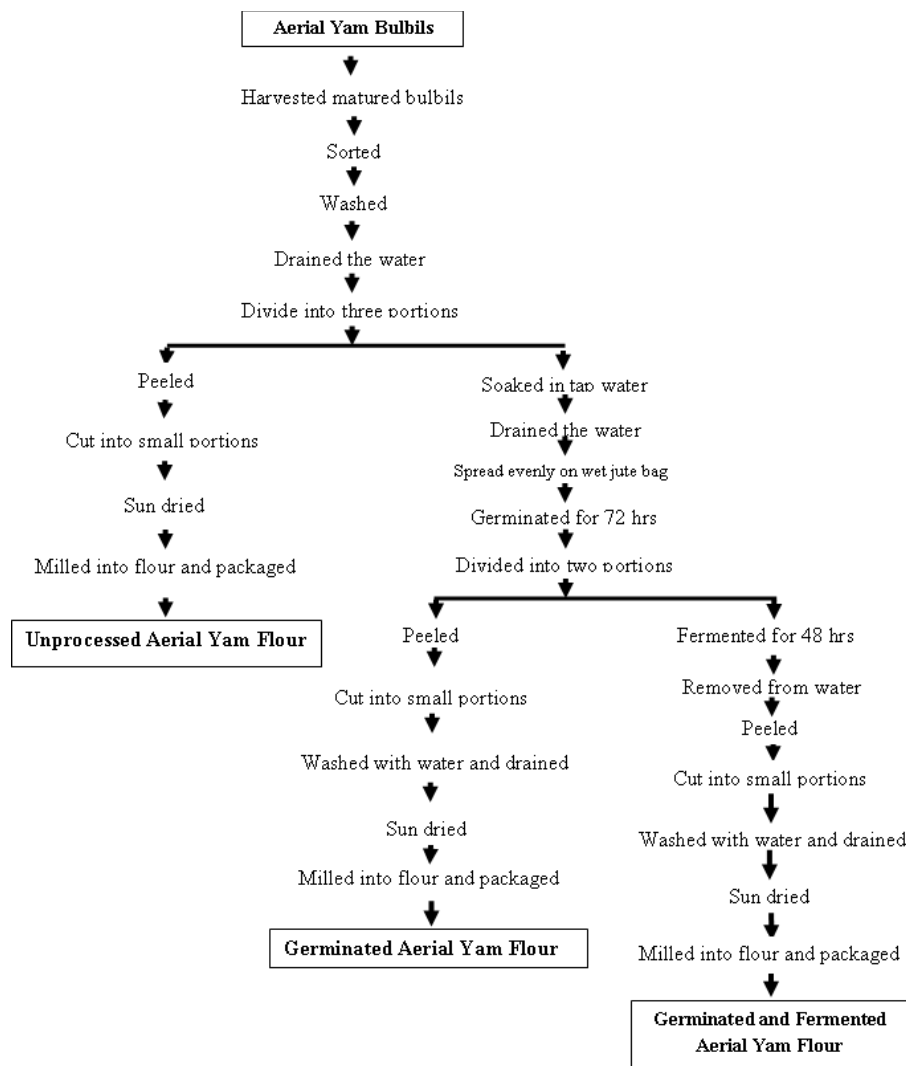


Figure 1: Systematic procedure for the selection and traditional processing of aerial yam (*Dioscorea bulbifera*) into flours.

Nutrients and anti-nutrient analysis

Proximate analysis

The moisture content of samples of Aerial yam flour was determined using the oven-drying method described by the Association of Official Analytical Chemistry (AOAC) (14). The percentage of dry matter was determined by subtracting the moisture content from 100%. The protein content of the samples was determined using the Kjeldahl method as described by AOAC (15, 16). Fat content determination was done by Soxhlet extraction technique using petroleum ether (40-50°C) as described by Folchet et al. (17). The crude fibre was determined by the method of AOAC International, (14) and McCleary and Prosky, (18). The Ash content was determined using incineration of 2 g of each sample in a muffle furnace at 500°C for 2 hours as described by AOAC (14). The carbohydrate

content of the flour samples was determined by difference. Carbohydrate (%) = 100% - [Moisture (%) + Crude Protein (%) + Ash (%) + Fat (%) + Crude fibre (%)].

Minerals content of the aerial yam flour samples

Mineral compositions of the aerial yam flour samples were determined according to methods recommended by AOAC International (14,16,19) using an absorption spectrophotometer. Iron, zinc, calcium, and magnesium contents were analyzed by Atomic Absorption Spectrophotometer (20, 21, 22). All the analyses were in triplicate determinations.

Determination of anti-nutrient properties of the aerial yam flour

Phytate determination was carried out by the method of Makkar and Becker (23). Tannin was determined by the method of Kirk and Sawyer (24). Oxalate was determined by spectrometric method by Dye, (25).

Saponin was determined by the modified method of Makkar and Becker, (23). Hydrogen cyanide (HCN) was determined by the method of AOAC International (14).

Statistical analyses

The data obtained from the chemical evaluations of the flour samples were statistically analyzed using SPSS version 22. Analysis of variance (ANOVA) and means were separated and compared using post hoc tests such as Duncan’s new multiple range test and Fisher’s least significance difference (LSD) were used to determine the significant differences between the means and separation of the means where significant differences existed at P < 0.05.

RESULTS

The results of the proximate composition of unprocessed, germinated, germinated, and fermented aerial yam flour on a dry matter basis are presented in Table 1. The germinated aerial yam flour had the highest protein and fat content values of 21.30% and 3.32%, respectively. The germinated and fermented aerial yam flour had the highest ash and fiber content value of 3.95% each, respectively, as well as the lowest carbohydrate content value of 65.78%. The unprocessed aerial yam flour had the highest carbohydrate content of 70.80%.

Table 1: Proximate composition of unprocessed, germinated and germinated and fermented aerial yam flour (%) in dry matter base.

Flour Samples	Protein	Fat	Ash	Fiber	Carbohydrate	Dry Matter
UAYF	19.24 ^a	2.94 ^a	2.98 ^a	3.95 ^b	70.80 ^c	91.32
GAYF	21.30 ^c	3.32 ^b	3.01 ^b	3.33 ^a	67.95 ^b	91.22
GFAYF	20.11 ^b	3.19 ^b	3.95 ^c	3.95 ^b	65.78 ^a	91.37
LSD	1.0832	1.0922	1.0945	1.0844	1.0886	1.0817

Dry matter meant SD of triplicate determination; values with the same alphabet superscript indicate no significant difference in the mean values of samples across the column, while values with different alphabet superscripts indicate a significant difference in the mean values of samples across the column. UAYF = Unprocessed aerial yam flour
 GAYF = Germinated aerial yam flour
 GFAYF = Germinated fermented aerial yam flour.

The mineral composition of unprocessed, germinated, and fermented aerial yam flours on a dry matter basis (mg/100g) is presented in Table 2. Germinated and fermented aerial yam flour (GFAYF) was significantly higher in zinc, iron, calcium, and

phosphorus content of 0.13mg, 3.55mg, 3.34mg, and 84.39mg per 100g, respectively, compared to the unprocessed aerial yam flour and germinated aerial yam flour.

Table 2: Mineral composition of unprocessed, germinated, germinated, and fermented aerial yam flours on a dry matter basis (mg/100g).

Minerals	UAYF	GAYF	GFAYF
Zinc	0.09 ^b	0.05 ^a	0.13 ^c
Iron	3.40 ^a	3.47 ^{ab}	3.55 ^b
Calcium	2.86 ^a	3.01 ^b	3.34 ^c
Phosphorus	65.15 ^a	74.95 ^b	84.39 ^c

Values with the same alphabet superscript indicate no significant difference in the mean values of samples across the column, while values with a different alphabet superscript indicate a significant difference in the mean values of samples across the column.
 UAYF = Unprocessed aerial yam flour
 GAYF = Germinated aerial yam flour
 GFAYF = Germinated fermented aerial yam flour

Table 3 presented the anti-nutrient content of unprocessed, germinated, and fermented aerial yam flours on a dry matter basis (mg/100g). Germinated and fermented aerial yam flour (GFAYF) had significantly least phytate, tannins, hydrogen cyanide

(HCN), and oxalate value of 4.73mg, 1.24mg, 4.16mg, and 2.38mg, respectively, and with significantly increased saponin value of 0.12mg as compared to other samples.

Table 3: Anti-nutrient content of unprocessed, germinated, germinated and fermented aerial yam flours on dry matter basis (mg/100g)

Anti-nutrient	UAYF	GAYF	GFAYF
Phytate	5.28 ^b	5.22 ^b	4.73 ^a
Tannins	1.28 ^b	1.26 ^b	1.24 ^a
Hydrogen cyanide (HCN)	4.66 ^b	5.26 ^c	4.16 ^a
Oxalate	5.55 ^b	5.26 ^b	2.38 ^a
Saponin	0.05 ^a	0.08 ^b	0.12 ^c

Values with the same alphabet superscript indicate no significant difference in the mean values of samples across the column; while values with a different alphabet superscript indicate a significant difference in the mean values of samples across the column.

UAYF = Unprocessed aerial yam flour

GAYF = Germinated aerial yam flour

GFAYF = Germinated fermented aerial yam flour

DISCUSSION

This study has revealed that aerial yam, both processed and unprocessed, contained an appreciable quantity of protein. The protein content of aerial yam flour contributes more than 20% as against 12% of the total caloric value of the food that is considered a good source of protein diet (26). The protein content is, however, higher in the processed than the unprocessed aerial yam flour. This could be attributed to the activities of the enzymes (proteases) that are activated during the germination process which hydrolyze the bonds between protein and anti-nutrients to release more free amino acids to synthesize new protein. The findings in this study are similar to a previous study by Ghavidel and Prakash, (27) that reported an increase in protein in green gram, cowpea, lentil, and chickpea (soaking in water for 12 hr at 22–25°C, and germination for 24 hr). Moreover the higher protein content could be attributed to an increased number of free amino acids released during germination (28). This protein content is higher compared to that reported by Kayode et al. (1) of protein content between 4.42% to 5.07% for aerial yam flour blanched, fermented, and unfermented or sundried or solar dried; and 2.40% raw water yam; 1.8% raw Irish potato; 1.04% raw cassava (29). This could be due to the low moisture content in the aerial yam flour. An appreciable amount of protein in aerial yam could indicate that aerial yam flour is an important and nutritious food for fighting malnutrition, especially severe acute malnutrition in children.

Dietary fats help in the absorption of fat-soluble vitamins, and retention of flavors during cooking and contribute to increase palatability of the diet (26). The dietary fats of Aerial yam flour contributed to about 7% of the caloric value. This finding is higher than that reported by Otegbayo et al. (26) on dietary fats contribution of 1%-2% caloric value of food which is sufficient for the diet. This could be due to the hydrolysis of fat to fatty acids and glycerol for the synthesis of new fat. This finding is like that reported

by Chukwuemeka et al (30) on germinated and fermented cowpea flour had higher fat and protein content than unprocessed and germinated cowpea flour. The ash content of the Aerial yam flour determines the presence of important dietary minerals and is useful for the development of the body (26).

The dietary fiber of food reduces the threat of colon cancer and cardiovascular diseases and protects the beneficial microflora of the intestine (26). The high fiber in the diet improves the digestion and absorption process of the large intestine, which helps to prevent constipation (31). The fiber content of aerial yam flour could be attributed to its low glycemic index property which makes it suitable for the management of diabetes mellitus.

Germination and fermentation of aerial yam flour had an increased ash and fiber content, indicating that both germination and fermentation activate enzymes and microorganism activities that hydrolyze and degrade the complex bonds between anti-nutrients and nutrients in aerial yam to release the minerals that are in ash form. More so, complex carbohydrates are broken down into simple sugar and are utilized for the growth of bacteria responsible for the fermentation process. The increase in fiber content and the decrease in carbohydrates are attributed to the above-mentioned activity.

The study also observed that germinated and fermented aerial yam flour had the highest zinc, iron, calcium, and phosphorus content. The germination and fermentation process increases the minerals and fiber content and decreases the carbohydrate content and could be suitable for the preparation of low glycemic food products for diabetics, and micronutrient quality food for the prevention and treatment of micronutrient deficiencies. The presence of phytate in Aerial yam limits the bioavailability and utilization of minerals such as iron, calcium, and zinc by forming indigestible insoluble complexes with these minerals (32, 26).

The study revealed that Aerial yam flour contains significant levels of anti-nutrients such as phytate, tannins, hydrogen cyanide (HCN) and oxalate, which decreased by the processing methods used. Anti-nutrient contents of Aerial yam flour could form complex bonds or complex compounds with the minerals and nutrients which affect its absorption in the human body. The combined processing methods of germination and fermentation reduced the anti-nutrient contents of Aerial yam flour more than single processing method. This implies that the complex bonds or complex formation between nutrients and anti-nutrients which make them unavailable have been hydrolyzed by the enzymes and microflora that are responsible for germination and fermentation process, respectively. A study by Iyang and Zakari, (5) reported that combination of processing methods may be more effective in eliminating or reducing anti-nutrients than single techniques. Germination and fermentation have been shown to reduce anti-nutrients that are bound with nutrients and make the nutrients inaccessible and limit their bioavailability during absorption. This is supported by a previous study by Yasmin et al., (33) that reported a decrease in cyanide, tannins, polyphenols, and phytic acid in red kidney beans that were processed by germination.

CONCLUSION

Aerial yam flour produced from combined germination and fermentation process has improved nutritional value (protein, fat, fiber, ash, and minerals) and reduces the anti-nutrient contents. The processing of aerial yam flour shows improved in nutrient quality and can be used to prepare varieties of healthy dishes for both healthy individual, diabetic, and malnourished children requiring quality nutrients to improve their health and nutritional status.

Ethical Clearance: Not applicable

Conflict of interests: No conflict of interest

Funding: The study was self-sponsored by the shared contribution of the authors

Authors' Contributions: All the authors listed in the articles contributed in one way or the other in the identification of the title, study design; Literature review; Supervision of the work; Principal Investigation; data collection; data analysis; and writing of the manuscript; reviewing of the manuscript and funding. Cyril, O. Anoshirike, the corresponding author; writing of the manuscript; data analysis and funding. Elizabeth, N. Chukwuemeka., Principal Investigation; data collection; identification

of the title; study design; Literature review; and funding. Ngozi M. Nnam, Supervision of the work; study design; Literature review; and funding. Elizabeth, A. Udentia, reviewing of the manuscript and funding. Kelechi, M. Anoshirike reviewing the manuscript and funding.

REFERENCES

1. Kayode RMO, Buhari OJ, Otutu LO, Ajibola TB, Oyeyinka SA, Opaleke DO, Akeem SA. Physicochemical Properties of Processed Aerial Yam (*Dioscorea bulbifera*) and Sensory Properties of Paste (*Amala*) Prepared with Cassava Flour. *The Journal of Agricultural Sciences*, 2017; 12 (2). Pp 84-94. <http://dx.doi.org/10.4038/jas.v12i2.8227>
2. Hahn SK. Yams: Dioscorea species (Dioscoreaceae), 1995; in Kambaska K., Sahoo S, Prusti A. Effect of plant growth regulator on in-vitro micro propagation of 'bitter yam' (*Dioscorea hispida* Dennst). *International Journal of Integrated Biology*, 2008; 4(1):50. DOI: <http://dx.doi.org/10.1038/1681090a0>
3. Zannou A. Socio-economic, agronomic and molecular analysis of yam and cowpea diversity in the Guinea-Sudan transition zone of Benin. Ph.D. Thesis, Wageningen University. 2006. DOI: [http://dx.doi.org/10.1016/s1573-5214\(04\)80023-x](http://dx.doi.org/10.1016/s1573-5214(04)80023-x)
4. Agostini JDS, Nogueira RB, Ida EI, Lowering of phytic acid content by enhancement of phytase and acid phosphatase activities during sunflower germination. *Braz. Arch. Bio. Technol.* 2010; 53: 975-980
5. Inyang CU, Zakari UM. Effect of germination of pearl millet on proximate, chemical and sensory properties of instant Fura: A Nigerian cereal food, *Pak. of J. Nutr.*, 2008; 7; 9-12.
6. Temesgen M. Nutritional status of Ethiopian weaning and complementary foods: A Review. *Open Access Scientific Reports*. 2013; 2(2): 621.
7. Cooper G. *Food Microbiology*. Library Press, 2018.
8. Omemu AM. Fermentation dynamics during production of ogi, a Nigerian fermented cereal porridge. *Report and Opinion*, 2011; 3, 8-17.
9. Hotz C, Gibson RS. Traditional food-processing and preparation practices to enhance the bioavailability of micronutrients in plants-based diets. *Journal of Nutrition*, 2007; 137, 1097-1100. <https://doi.org/https://doi.org/10.1093/jn/137.4.1097>.
10. Ddungu SP, Ekere W, Bisikwa J, Kawooya R, Okello K D, Biruma M. Marketing and market integration of cowpea (*Vigna unguiculata* L. Walp) in Uganda. *Journal of Development and*

- Agricultural Economics, 2015; 7(1), pp.1-11, DOI: 10.5897/JDAE14.0577.
11. Food and Agriculture Organization of the United Nations (FAO)/FAOSTAT. Statistical Database, Statistical Division Rome. Rome: Food and Agriculture Organization of the United Nations. 2019.
 12. Ogbuagu MN. Nutritive and anti nutritive composition of the wild (inedible) species of *Dioscorea bulbifera* (Potato Yam) and *Dioscorea dumetorum* (Bitter Yam). *Pac. J. Sci. Technol.* 2008; 9(1), 112-118.
 13. Achy YJ, Koffi HKP, Konan KH, Kouame PL. Assessment of phytochemical properties and anti-nutritional factors of flour from yam (*Dioscorea bulbifera*) bulbils in southeast Cote d'Ivoire. *Int. J. Adv. Res.* 2016; 4(12): 871-887.
 14. AOAC International. *Official methods of analysis* (20th edn.). AOAC International. 2016.
 15. Wiles P, Gray I, Kissling R. Routine analysis of proteins by Kjeldahl and Dumas methods: review and interlaboratory study using dairy products. *J AOAC Int*, 1998; 81, 620–632.
 16. Pearson DA. *Chemical Analysis of Food* (7th ed). Churchill Living Stone. 1976.
 17. Folch J, Lees M, Stanley G. A simple method for the isolation and purification of total lipids from animal tissues. *J Biol Chem*, 1957; 226, 297–509.
 18. McCleary B. Prosky L. *Advanced dietary fibre technology*. Blackwell Science, 2001.
 19. Onwuka G. *Food Analysis and instrumentation; Theory and practice*. Naphtali Prints, 2005.
 20. Beatty R, Kerber J. *Concepts, instrumentation and techniques in atomic absorption spectrophotometry* (2nd ed.). The Perkin-Elmer Corporation, 1993.
 21. Welz B. *Atomic Absorption Spectrometry*. VCH, 1985.
 22. Yeung V, Miller DD, Rutzke MA. Atomic Absorption Emission Spectroscopy, Spectroscopy, Atomic Coupled Plasma-Mass and Inductively Spectrometry. In S. Nielsen (Ed.), *Food Analysis, Food Science Text Series*. Springer International Publishing, 2017; (ed), p. 129). https://doi.org/DOI/10.1007/978-3-319-45776-5_9
 23. Makkar HPS, Becker K. Nutritional Value and anti-nutritional components of and ethanol extracted moringa oleifera leaves. *Animal Feed Science Technology*, 1996; 63, 211–238.
 24. Kirk R, Sawyer R. *Pearson composition and analysis of foods*. Longman Scientific and Technical, 1991.
 25. Dye G. *The Chemical Analysis of Food* (7th ed.). Churchill, Living Stone, 1956.
 26. Otegbayo BO, Ogunniyan DJ, Olunlade BA, Oroniran OO, Atobatele OE. Characterizing genotypic variation in biochemical composition, anti-nutritional and mineral bioavailability of some Nigerian yam (*Dioscorea* spp.) land races. *Journal of Food Science & Technology*, 2018; 55,(1); 205-216.
 27. Ghavidel RA, Prakash J. The impact of germination and de- hulling on nutrients, anti-nutrients, in- vitro iron and calcium bioavailability and in- vitro starch and protein digestibility of some legume seeds. *LWT – Food Science and Technology*, 2007; 40(7), 1292–1299. <https://doi.org/https://doi.org/10.1016/j.lwt.2006.08.002>.
 28. Ruiz C, Bressani R.. Effect of Germination on the Chemical Composition and Nutritive Value of Amaranth Grain. *Cereal Chem.*,1990; 67(6), 519–522.
 29. Sanusi RA, Akinyele IO, Ene-Obong HN, Enujughu V. Nigerian Food Composition Table. (Harmonized edition 2017).
 30. Chukwuemeka EN, Anoshirike CO, Nnam MN, Chikwendu JU. Anoshirike KC. Nutrient and Anti-Nutrient Composition of Cowpea (*Vigna Biflora*) Flours Produced from Germination and Fermentation Process. *Nigerian Journal of Nutritional Sciences*, 2022; 43(2); 80-87.
 31. Baah FD, Maziya-Dixon B, Asiedu R, Oduro I, Ellis WO. Nutritional and biochemical composition of *D. alata* (*Dioscorea* spp.) tubers. *J. Food Agr. Environ.* 2009; 7 (2), 373–378.
 32. Gibson RS, Perlas L, Hatz C. Improving the bioavailability of nutrients in plant foods at the household level. *Proceedings of the Nutrition Society*, 2006; 65, (2) 160-168.
 33. Yasmin A, Zeb A, Khalil AW, Paracha GM, Khattak AB.. Effect of processing on anti-nutritional factors of red kidney bean (*Phaseolus vulgaris*) grains. *Food and Bioprocess Technology*, 2008; 1, 415– 419.