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RESEACH ARTICLE

PROXIMATE COMPOSITION AND HYDROCYANIC ACID CONTENT OF THREE VARIETIES OF CASSAVA CULTIVATED IN GAYA TOWN

Sadiq, B.B.,[1*] Idris, F.Z.,[1] Okpanachi, O.N.,[2] Aliyu, A.,[3] Zulaihat, L.,[4] and Nasiru, S.[5]

[1]Department of Biochemistry, Faculty of Science and Computing, Khalifa Isyaku Rabiu University Kano.
[2]Department of Biochemistry, Faculty of Basic medical Science, University of Nigeria, Nsukka.
[3]Department of Biochemistry, Aliko Dangote University of Science and Technology, Wudil, Kano.
[4]Department of Biochemistry, Faculty of Basic medical Science, Bayero University Kano
[5]Department of Biochemistry, Faculty of Science, Federal University Dutse.

Abstract
Background: This study was conducted to obtain comprehensive data on the nutritional composition and hydrocyanic acid content of three cassava varieties sold in Gaya town of Kano state, Nigeria, which can be used for nutritional evaluation, food processing, safety and to focus on the future development of the food product with an excellent health benefit. **Methods:** Fresh Cassava Manihot *esculentus Crantz* **(**also called *Rogo in Hausa***)** samples were collected in a clean labelled polyethene sample bag in the month of September, 2023. The cassava varieties were analyzed for their proximate composition and hydrocyanic content. **Results:** It was observed that starch cassava variety had a moisture (59.692± 0.391), ash (0.763±0.032) and fat (2.418±0.025) content higher than sweet (56.444± 0.750, 0.578±0.011, 2.140±0.035) and bitter cassava variety (58.063±0.084, 0.669±0.012, 2.395±0.339) and all the values were higher than the recent recommended moisture content limits by WHO/FAO. The carbohydrate content determined for sweet cassava was higher than the starch cassava and bitter cassava variety. These values were within the recent recommended limits by WHO/FAO. The bitter cassava variety had a protein content higher than the sweet cassava and starch cassava variety at p value <0.05. The total hydrogen cyanide present in the cassava samples shows that the bitter cassava Variety had more hydrogen cyanide with a mean value of 0.552±0.011 mol/dm^3, while the sweet cassava variety had a value of 0.304±0.023 mol/dm^3 and the starch variety had a value of 0.248±0.011. These values were higher than the recent recommended hydrogen cyanide content limits by WHO/FAO. The study reveals nutritional differences among three cassava varieties in Gaya, with starch having higher moisture, ash, fat, and hydrocyanide levels, emphasizing the need for improved processing techniques and health education. **Conclusion:**The study reveals nutritional differences among three cassava varieties in Gaya, with starch having higher moisture, ash, fat, and hydrocyanide levels, emphasizing the need for improved processing techniques and health education.

Keywords: Cassava, Hydrocyanic acid, Proximate analysis, Nutritional composition.

INTRODUCTION

Cassava (*Manihot esculentus* Crantz) is a staple crop widely grown and consumed in many parts of the world, particularly in tropical and subtropical regions belonging to the family myrtaceae or euphorbiaceous (Yadav *et al.*, 2011). Starch cassava refers to cassava varieties specifically cultivated and processed for their high starch content, which makes them ideal for industrial applications. Cassava starch, extracted from the tuberous roots, is a versatile carbohydrate used in food production, pharmaceuticals, textiles, and bioethanol industries. This type of cassava typically has a high dry matter content, enhancing starch yield and quality. Sweet cassava refers

* **Corresponding Author** Sadiq, B.B.,
E-mail: sadiq.bb.bch@khairun.edu.ng

to cassava varieties with low levels of cyanogenic glucosides, typically less than 50 mg per kilogram, making them safer for direct consumption with minimal processing. These varieties are characterized by their mildly sweet taste and are commonly eaten boiled, roasted, or fried. Sweet cassava is also used in making various dishes, including desserts and snacks, especially in regions where it is a dietary staple. Due to its lower cyanide content, it is more consumer-friendly compared to bitter cassava, though proper cooking is still recommended to eliminate residual toxins (Fao.org, 2021). Sweet cassava's nutritional profile includes carbohydrates as the primary energy source, along with small amounts of vitamins and minerals, making it an important food crop in tropical and subtropical regions (Okigbo, 2020). Bitter cassava refers to cassava varieties with high levels of cyanogenic glucosides, often exceeding 50 mg per kilogram, which necessitates thorough processing to remove toxic hydrogen cyanide compounds. This variety is typically cultivated for its high yield and adaptability to harsh growing conditions. Bitter cassava is commonly processed into starch, flour, or fermented products such as garri, fufu, and tapioca, which are staples in many African, Asian, and Latin American diets. The extensive processing—such as soaking, drying, and cooking—detoxifies the cassava and enhances its storability and versatility (Cardoso et al., 2020). Despite the extra effort required for safe consumption, bitter cassava is a critical food security crop due to its resilience and ability to thrive in poor soils and drought conditions (FAO, 2021).

It is widely consumed by millions of people in many tropical and subtropical regions of the world (Fukagawa and Ziska, 2019). Cassava, a staple root crop in tropical regions, is classified into bitter cassava starch cassava and sweet cassava, based on their cyanogenic glucoside content. Sweet cassava contains lower levels of these compounds (<50 mg/kg), making it suitable for direct consumption after minimal processing, while bitter cassava has higher cyanogenic glucosides (>50 mg/kg) and requires extensive processing to ensure safety (Fao.org, 2021). Both types are versatile, with sweet cassava often used in fresh or boiled forms and bitter cassava predominantly processed into starch, flour, or fermented products (Okezie & Kosikowski, 2020). It contains carbohydrates, essential minerals, and vitamins, which are valuable resources needed by the body (Tardy *et al*., 2020) and also serving as a contributor to food security (Pawlak and Kołodziejczak, 2020). In addition to its culinary uses, cassava also has several industrial applications. It can be processed into starch or used to production of bioethanol, biodegradable packaging, and textile manufacturing (Li *et al*., 2017), creating opportunities for economic growth in regions where cassava is cultivated (Mbanjo *et al*., 2021). They can be prepared and consumed in various ways, including boiling, baking, frying, or grinding into flour. Cassava flour, in particular, is widely used as a gluten-free alternative in baking and cooking (Guo *et al*., 2017). Being widely known as a good source of energy, it is important to note that cassava should be properly processed before consumption, as it contains potentially harmful substance (Shilpa *et al*., 2024).

MATERIALS AND METHOD

CASSAVA SAMPLE IDENTIFICATION, AUTHENTICATION AND COLLECTION

Fresh Cassava Manihot *esculentus Crantz* **(**also called *Rogo in Hausa***)** samples were collected in a clean labelled polyethene sample bag in the month of September, 2023 from different farm lands at Gaya Local Government Area of Kano State, Nigeria. The cassava samples were identified using standard identification procedure (Augusto *et al*., 2021) at Department of Plant Biology, Bayero University Kano. The cassava sample were identified prior to collection using standard identification procedure by Augusto *et al*. (2021) at Department of Plant Biology, Bayero University Kano and a voucher number was given as BUKHAN 0899. The samples were transported to Department of Biochemistry Laboratory, Federal University Dutse Jigawa State, Nigeria for analysis.

DETERMINATION OF PROXIMATE COMPOSITION

AOAC, (1990) method was used to determine the proximate (Moisture, Ash, Lipids, Protein, Carbohydrate and Crude fiber) compositions of the samples.

DETERMINATION OF HYDROCYNIC (PRUSSIC) ACID IN FRESH CASSAVA TUBER

About 100g of raw cassava tubers were grated and transferred to a conical flask, and 200ml distilled water was added shaken vigorously and allowed to stand for

30minutes. The supernatant of the samples was collected in different labeled beakers. 25 mL of the whole sweet cassava supernatant was pipette into a conical flask and 2 drops of phenolphthalein indicator was added. The solution was titrated against the standard 0.1N NaOH. Two more accurate titration were carried out and recorded (Onwuka, 2005).

The concentration of the Hydrocyanic acid was calculated using the following equation:

$$\frac{MA \times VA}{MB \times VB} = Mole\ ratio\ of\ \frac{acid}{base}$$

Where MA = Molarity of acid, VA = Volume of acid, MB = Molarity of base, VB= Volume of base.

STATISTICAL ANALYSIS

The Data collected were statistically analyzed using SPSS version 20.0. The results were expressed as mean ± standard deviation (SD). The data were analyzed statistically using One-way Analysis of Variance (ANOVA). Differences were considered statistically significant at $p<0.05$.

RESULTS

The results for the proximate composition of the different varieties of cassava is presented in the Table 1 below. The results show that there was no significant difference between the moisture content of the three samples analyzed at ($p<0.465$). However, all the samples differ significantly in term of their ash content, carbohydrate and crude fiber content. The results also show that there is no significant difference between the fat, protein and total dry matter content of the three samples analyzed at ($p<0.05$).

Table 1. Proximate composition and hydrogen cyanide content

CASSAVA VARIETIES	Moisture (%)	Ash (%)	Fat (%)	Protein (%)	Carbo-Hydrate (%)	Crude-Fiber (%)	Dry Matter (%)
Sweet Cassava (Farin Iri)	56.444± 0.750[a]	0.578±0.011[c]	2.140±0.035[a]	3.281±0.000[a]	37.557±0.795[a]	4.638±0.202[c]	43.556±0.750[a]
Bitter Cassava (Bakin Iri)	58.063±0.084[a]	0.669±0.012[b]	2.395±0.339[a]	4.922±0.774[a]	33.951±1.017[b]	11.200±0.120[a]	41.937±0.084[a]
Starch Cassava (Dakata)	59.692± 0.391[a]	0.763±0.032[a]	2.418±0.025[a]	3.828±0.774[a]	33.414±0.407[b]	5.550±0.028[b]	44.92± 6.720[a]
WHO/FAO PERMISSIBLE LIMIT	13%	3%	20-35%	10-35%	45-65%	15%	59%

Values presented as mean±SD. Values with the same superscripts along the same column, with different subscript are significantly different ($p<0.05$)

HYDROGEN CYANIDE CONTENT

The hydrocyanic composition of the different varieties of cassava is presented in Table 2 below. The results show that there is no significant difference between the hydrocyanic composition of sample a, which is sweet cassava and sample c, which is starch cassava analyzed at ($p<0.001$). However, sample b which is bitter cassava differ significantly in term of their hydrocyanic composition content at ($\alpha=0.001$).

TABLE 2: HYDROGEN CYANIDE CONTENT

CASSAVA VARIETIES	Hydrocyanic acid (mg/kg)
Sweet Cassava (Farin Iri)	206.60 ±17.10[b]
Bitter Cassava (Bakin Iri)	372.95 ±7.64[a]
Starch Cassava (Dakata)	167.56 ±7.64[b]
WHO/FAO PERMISSIBLE LIMIT	10 (mg/kg)

Values presented as mean±SD. Values on the same column, with different subscript are significantly different ($p<0.05$).

DISCUSSION

The starch cassava variety had a moisture content higher than sweet and bitter cassava variety and bitter cassava. These values were higher than the recent recommended moisture content limits by WHO/FAO as shown in Table 1 above. The consequence of having higher moisture content is that the cassava samples can't be stored for a long period of time, due to microbial contamination relevant to the work done by Akpabio *et al*., (2012), reported a higher moisture content value of 71.53% and 72.07% for sweet and bitter cassava cultivated in Abia

State, Nigeria. In separate research by Somendrika *et al*. (2017), which reported a moisture content value of 52.70±0.52% for sweet cassava and 58.88±0.25% for bitter cassava variety in Gannoruwa, Sri-Lanka. Moisture content of Cassava is influenced by type, variety and storage condition. The low moisture content of Sweet cassava would enhance its storage stability by avoiding mold growth, biochemical reactions and extend the shelf life of the final product (Guinee *et al*., 2002).

It was observed that starch cassava variety had a higher ash content than the bitter and sweet cassava variety as presented in table 1 above, related to the high ash content in some reviewed literature studies in Nigeria, as Emmanuel *et al*. (2012) reported an ash content in six cassava cultivars in Ghana ranging from 1.71±0.32 – 2.34± 0.15. Eleazu *et al*., (2012) also reported an ash content value ranging from 1.44±0.52 – 2.35±0.35 from 6 yellow and white cassava variety cultivated in Umudike, Abia State, Nigeria. Ash content represents the total mineral content in food after it has been burned at a very high temperature. The variance in the ash content values of the cassava in study and the reviewed cassava could be as a result of environmental factors and location of harvesting. The differences in ash content may be due to the differences in soil characteristics, climate conditions and genetic variations. Ash content is an indication of mineral content of a food. Therefore, this suggests that Starch cassava could be important sources of minerals than the common sweet and bitter cassava.

It was observed that the starch cassava variety had a higher fat content than the bitter and sweet cassava variety as presented in the Table 1 in compliance with the results obtained by Devendra *et al*. (2013) and Ifeabunike *et al*. (2017) who reported percentage fat contents of 1.2% and 0.33%, respectively for cassava cultivars cultivated from Umudike, Abia. The differences in fat content may be due to location and varietal differences (Meijaard *et al*., 2022). Diets with high fat content contribute significantly to the energy requirement for humans. The high fat content of Starch cassava in this study would make it a better source of fat than the other varieties of cassava (sweet and bitter cassava). High fat cassava is also good for flavor enhancers and useful in improving palatability of foods in which it is incorporated (Guo *et al*., 2017).

It was observed that the starch cassava variety had a higher fat content than bitter and sweet cassava variety shown in Table 1 above. These values are very good as Nigerian cassava have been reported to have higher dry matter percentage in cassava varieties. Ngiki *et al.,* 2014), reported a dry matter value of 92.50% for cassava roots and 90.90% for cassava leaves which is been used for livestock feeds. Dry matter determination in different Varieties of cassava is important since nutrition and energy calculation is based on magnitude and nature of dry matter content. Higher dry matter content naturally would provide greater yield.

It was observed that the sweet cassava variety had a carbohydrate content higher than the starch cassava and bitter cassava variety as shown in Table 1 above. Carbohydrates are good sources of energy and that a high concentration of this is desirable in breakfast meals and weaning food formulas. In this regard, therefore, the high carbohydrate content of the sweet cassava would make it a good source of energy and use in breakfast formulations.

It was observed that the bitter cassava variety had a protein content which was higher than the sweet cassava and starch cassava variety as shown in Table 1 above. The protein content differences can be attributed to the geographical location of soil fertility. Since soils with low nitrogen levels can influence protein levels reported by Tenorio *et al*., (2018). The protein content of the Bitter cassava in this study suggests that it may be useful in food formulation systems, especially with higher protein content of legume crops.

It was observed that the bitter cassava variety had a crude fiber content higher than the sweet cassava and starch cassava variety as shown in Table 1 above. Crude fiber helps in the prevention of heart diseases, colon cancer, diabetes, etc. Bitter cassava would be a better source of fiber content; since it had significantly higher crude fiber content as compared to sweet and starch cassava. Therefore, it will be useful if bitter cassava is added to meal diet and used in food formulation to help relieve constipation.

Hydrocyanic acid (HCN) is a potent toxin produced from the enzymatic breakdown of cyanogenic glycosides present in cassava. It's a colorless and highly toxic compound, is naturally present in cassava plants. The HCN content in cassava can vary among different varieties and is influenced by factors such as plant age, processing methods, and environmental conditions.

Cyanide is the most toxic factor restricting the consumption of cassava. There are three different forms of cyanogen's present in cassava and these include linamarin, acetonehydrin (lotaustralin) and free HCN. The linamarin and lotaustralin undergo a sequential enzymatic breakdown and the final form is a toxic free cyanide. The total of these three forms is called Cyanogenic potential. Cyanogenic glycosides are effective defense agents against generalist herbivores (Emmanuel *et al*., 2012), including humans. Cassava leaves have a cyanide content ranging from 53 to 1,300 mg cyanide equivalents/kg of DW (Ndubuisi and Chidiebere, 2018), and cassava root parenchyma has a range of 10 to 500 mg cyanide equivalents/kg dry matter (Cardoso *et al*., 2005) both of these are much higher than what is recommended. Bitter cassava varieties, have cyanide levels higher than the FAO/ WHO (1991) recommendations, which is < 10 mg cyanide equivalents/kg DM, to prevent acute toxicity in humans. It was reported by Charles *et al*. (2005) that 15–61 mg HCN/kg in various food products containing cassava.

The total hydrogen cyanide present in the cassava samples as shown in Table 2 shows that the bitter cassava Variety had more hydrogen cyanide with a mean value of 372.95±7.64 (mg/Kg), while the sweet cassava variety had a value of 206.60±17.10 (mg/Kg) and the starch variety had a value of 167.56±7.64 (mg/Kg). These values were higher than the recent recommended hydrocyanic acid limits by WHO/FAO. This supports the fact that the bitter cassava variety has a higher HCN content than the sweet and starch cassava varieties. The result also shows why it is harmful for people to eat cassava raw without any fermentation and processing method, in order to detoxify the large amount of hydrogen cyanide from cassava as reported by (Adindu *et al*., 2015). Reports have shown that age, variety and environmental conditions influence the occurrence and concentration of hydrogen cyanide in various parts of the cassava plant and at different stages of development respectively (Albert *et a*l., 2005). This means that some varieties generally considered starch cassava (low cyanide content) can have a high cyanogenic potential under certain conditions (Westby *et al*., 2012). Cardoso *et al*. (2015) reported that in Amazonia (the original source of cassava) and in Africa different varieties have a range of total cyanide contents in the parenchyma from very low to very high (1–1550 mg/Kg). Classical examples of variations in HCN content in cassava varieties can be seen as Seri *et al*., (2013) reported an HCN value of different varieties with Nigerian origin harvested in Senegal, Soya cassava variety had a value of 231.20±10.2 mg/Kg, Kombo cassava variety had 104.20±3.9 mg/Kg, Gniargui cassava variety had 270.80±120 mg/Kg and TMS 30572 cassava variety had 171.6±5.4 mg/Kg. Improved cassava variety HCN value with 10, 13 and 16 months of harvesting with TMS 98/0505 having a value of 43.68±3 (Agriga *et al*., 2015). Bitter cassava varieties, have cyanide levels higher than the FAO/ WHO (1991) recommendations, which is < 10 mg cyanide equivalents/kg DM, to prevent acute toxicity in humans.

CONCLUSION

The study found significant differences in nutritional composition and hydrocyanic acid content among three cassava varieties in Gaya. Starch cassava had higher moisture, ash, and fat content, while sweet and bitter cassava had higher carbohydrate and protein content. Hydrocyanide levels exceeded WHO/FAO safety thresholds. The study highlights the necessity of effective processing techniques and health education initiatives to improve the nutritional advantages and lower the health hazards associated with the region's consumption of cassava.

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REFERENCES

Adindu, M.N., Olayemi, F.F. and Nze-Dike, O.U. (2015). The cyanogenic potential of some cassava products in Port Harcourt markets in Nigeria. *Journal of Food Composition Analysis*; 16:21–24. 44.

Agriga, A.N. and Iwe, M.O. (2015). Optimization of chemical properties of cassava varieties harvested at different times using response surface methodology. *American Journal of Advanced Food Science and Technology;* 4(1):10-21.

Akpabio, U.D., Akpakpani, A. and Nwokocha, G.C. (2012). Comparative study on the physicochemical properties of two varieties of cassava peels. *International Journal of Environment and Bioenergy.* 2(1):19-32.

Albert, L.C., Klanarong, S.T. and Zou-chi, H. Proximate composition, mineral contents, hydrogen cyanide and phytic acid of five cassava genotypes. *Food Chemistry*. 92(4):615-620.

AOAC. (1990). *Official methods of analysis of the Association of Official Analytical Chemists* (14th ed.). Association of Official Analytical Chemists. Pp. 223-225, 992-995.

Augusto, L., Bohorquez-Chaux, A., and Zhang, X. (2021). Identification of Cassava Varieties in Ex-Situ Collections and Global Farmer's Fields: An Update from 1990 to 2020. *IntechOpen EBooks*. https://doi.org/10.5772/intechopen.99110

Cardoso, A. P., Mirione, E., Ernesto, M., Massaza, F., Cliff, J., Haque, M. R., & Bradbury, J. H. (2020). Processing of bitter cassava varieties for safe consumption. *Food Chemistry, 101*(3), 894-897.

Cardoso, A.P., Mirione, E., Ernesto, M., Massaza, F., Cliff, J. and Hague, M.R. (2015). Processing of cassava roots to remove cyanogens. *Journal Food Comp Anal*.; 18:451–460.

Chandra, H., Gupta, B.N. and Ghagawa, S.K. (2017). Chronic cyanide exposure. A biochemistry and industrial hygiene study. *Journal of Anl Toxicol*.; 4:161-165.

D'Angelo, A., Petrella, C., Greco, A., Ralli, M., Vitali, M., Giovagnoli, R., De Persis, S., Fiore, M., Ceccanti, M., and Messina, M. P. (2022). Acute alcohol intoxication: a clinical overview. *La Clinica Terapeutica*, *173*(3), 280–291. https://doi.org/10.7417/CT.2022.2432

Devendra, C. (2011). Cassava as a feed source for ruminants. In Cassava as Animal Feed, Mestle, B, and Graham, M. (Eds). IDRC, Canada; 107-119.

Dje, K. M., Ebah-Djedj, B. C., B.N`ue, Zohouri, G. P., and Amani, N. G. (2012). Effect of Harvest Period on Starch Yield and Dry Matter Content from the Tuberous Roots of Improved Cassava (Manihot esculenta Crantz) Varieties. *Pakistan Journal of Nutrition*, *11*(5), 414–418. https://doi.org/10.3923/pjn.2012.414.418

Eleazu, C.O. and Eleazu, K.C. (2012). Determination of the proximate composition, total carotenoid, reducing sugars and residual cyanide levels of flours of 6 new yellow and white cassava (Manihot esculenta Crantz) varieties*. American Journal of Food Technology*; 7:642-649.

Emmanuel, O. A., Clement, A., Agnes, S. B., L. Chiwona-Karltun, and Drinah, B. N. (2012). Chemical composition and cyanogenic potential of traditional and high yielding CMD resistant cassava (Manihot esculenta Crantz) varieties. *International Food Research Journal*, 19 (1), 175–181.

Falade, K. O., and Akingbala, J. O. (2010). Utilization of cassava for food. *Food Reviews International,* 26(1), 51-67.

FAO (Food and Agriculture Organization of the United Nations) (2017). Available: www.fao.org (Accessed on the 12th May 2017).

FAO. (2021). *Cassava: Post-harvest operations*. Food and Agriculture Organization of the United Nations. http://www.fao.org

Fukagawa, N. K., and Ziska, L. H. (2019). Rice: Importance for Global Nutrition. *Journal of Nutritional Science and Vitaminology*, *65*(Supplement), S2–S3. https://doi.org/10.3177/jnsv.65.S2.

Guinee, T. P., Feeney, E. P., Auty, M. A. E., and Fox, P. F. (2002). Effect of pH and Calcium Concentration on Some Textural and Functional Properties of Mozzarella Cheese. *Journal of Dairy Science*, *85*(7), 1655–1669. https://doi.org/10.3168/jds.s0022-0302(02)74238-0.

Guo, Q., Sun, D.-W., Cheng, J.-H., and Han, Z. (2017). Microwave processing techniques and their recent applications in the food industry. *Trends in Food Science & Technology*, *67*, 236–247.

Ifeabunike, O., Nwaedozie, J., and Aghanwa, C. (2017). Proximate Analysis, Hydrogen Cyanide and Some Essential Mineral Content of Sweet Cassava Variety (Manihot utilisima) and Bitter Cassava Variety (Manihot palmata) Cultivated in Kachia Local Government Area of Kaduna State, Nigeria. *International Journal of Biochemistry Research & Review*, *19*(1), 1–12. https://doi.org/10.9734/ijbcrr/2017/36215.

Li, S., Cui, Y., Zhou, Y., Luo, Z., Liu, J., and Zhao, M. (2017). The industrial applications of cassava: current status, opportunities and prospects. *Journal of the Science of Food and Agriculture*, *97*(8), 2282–2290. https://doi.org/10.1002/jsfa.8287.

Mbanjo, E. G. N., Rabbi, I. Y., Ferguson, M. E., Kayondo, S. I., Eng, N. H., Tripathi, L., Kulakow, P., and Egesi, C. (2021). Technological Innovations for Improving Cassava Production in Sub-Saharan Africa. *Frontiers in Genetics*, *11*. https://doi.org/10.3389/fgene.2020.623736

Meijaard, E., Abrams, J. F., Slavin, J. L., and Sheil, D. (2022). Dietary Fats, Human Nutrition and the Environment: Balance and Sustainability. *Frontiers in Nutrition*, *9*(1), 878644. https://doi.org/10.3389/fnut.2022.878644

Ndubuisi, N. D., & Chidiebere, A. C. U. (2018). Cyanide in Cassava: A Review. *International Journal of Genomics and Data Mining*, *3*(1). https://doi.org/10.29011/2577-0616.000118.

Ngiki, Y.K., Igwebuike, J.U. and Morph, S.M. (2014). Effect of replacing maize with cassava root- leaf mixture on the performance of broiler chickens. *International Journal for Ifeabunike Science and Technology*; 3(6):352- 362.

Okezie, B. O., and Kosikowski, F. V. (2020). Cassava in the tropics. *Journal of Food Science and Technology, 35*(3), 345–350.

Okigbo, B. N. (2020). Sweet cassava and its potential. *Journal of Root Crops Research, 32*(2), 45–54.

Onwuka, G. I. (2005). *Food analysis and instrumentation: Theory and practice*. Naphathali Prints. pp. 95-96.

Otubogun, F. M., Akinyemi, R. O., and Ogunniyi, A. O. (2019). Tropical ataxic neuropathy: Findings of a neuro-epidemiological survey of Odeda, southwest Nigeria. *Journal of the Neurological Sciences*, *405*, 116434. https://doi.org/10.1016/j.jns.2019.116434

Pawlak, K., and Kołodziejczak, M. (2020). The Role of Agriculture in Ensuring Food Security in Developing Countries: Considerations in the Context of the Problem of Sustainable Food Production. *Sustainability*, *12*(13), 5488. MDPI. https://doi.org/10.3390/su12135488

Seri, S.G., Souleymane, T. and Kouakou, B. (2013). Assessment of cyanide content in cassava varieties and derived products from Senegal. *International Journal of Nutrition and Food Sciences.* 2(5):225–231.

Shilpa Susan Scaria, Balasubramanian, B., Arun Meyyazhagan, Jaya Gangwar, Juhi Puthukulangara Jaison, Jissa Theresa Kurian, Karthika Pushparaj, Manikanatan Pappuswamy, Park, S., and Kadanthottu Sebastian Joseph. (2024). Cassava (*Manihot esculenta* Crantz)—A potential source of phytochemicals, food, and nutrition—An updated review. *EFood*, *5*(1). https://doi.org/10.1002/efd2.127

Somendrika, M.A.D., Wickramasinghe, l., Wansapala MAJ, and Peiris S. Nutritional composition of cassava cultivar "CARI555". *Pakistan Journal of Nutrition*. 2017; 16:216-220.

Tamayo Tenorio, A., Kyriakopoulou, K. E., Suarez-Garcia, E., van den Berg, C., and van der Goot, A. J. (2018). Understanding differences in protein fractionation from conventional crops, and herbaceous and aquatic biomass - Consequences for industrial use. *Trends in Food Science & Technology*, *71*, 235–245. https://doi.org/10.1016/j.tifs.2017.11.010

Tardy, A.-L., Pouteau, E., Marquez, D., Yilmaz, C., and Scholey, A. (2020). Vitamins and minerals for energy, fatigue and cognition: A narrative review of the biochemical and clinical evidence. *Nutrients*, *12*(1), 228. https://doi.org/10.3390/nu12010228

Westby, A. (2012). Cassava utilization, storage and small scale processing. In: Hillocks RJ, Thresh JM, Belloti, A.C. (Eds.). Cassava: Biology, Production and Utilization; 281-300.

Yadav, J. S., Ogwok, E., Wagaba, H., Patil, B. L., Bagewadi, B., Alicai, T., Gaitan-Solis, E., Taylor, N. J., and Fauquet, C. M. (2011). RNAi-mediated resistance to Cassava brown streak Uganda virus in transgenic cassava. *Molecular Plant Pathology*, *12*(7), 677–687. https://doi.org/10.1111/j.1364-3703.2010.00700.x