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Original Research Article

ASSESSMENT OF HYDROGEN CYANIDE LEVELS IN PROCESSED CASSAVA PRODUCTS FROM LAFIA TOWN, NIGERIA, DURING JANUARY TO MARCH, 2023

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ABSTRACT

The expanding use of cassava and its derivatives across industries in Nigeria has raised concerns about potential hydrogen cyanide (HCN) toxicity in inadequately processed cassava products. This study aimed to investigate and compare the hydrogen cyanide concentration in eight processed cassava product samples sourced within the period from January to March, 2023 from supermarkets and local markets in Lafia town, Nigeria, using the picrate in solution method. The samples included Niji® Foods Cassava Flour, IFGREEN® Odourless Fufu Flour, Ayoola® Fufu Flour, Aiteefills® Fufu flour, Niji® Foods Garri, Golden Penny Garri, GGEE® foods Ijebu Garri, and local brand cassava starch. Spectrophotometric measurements at 535 nm were used to determine the total cyanide content in mg HCN equivalents/kg dry weight, calculated as ppm by multiplying the absorbance by 396. The results were analyzed using Minitab version 20.0, employing one-way ANOVA, and pair-wise comparisons were made post hoc using Tukey t-tests. HCN concentrations in all samples ranged from 4.13 to 21.47 mg HCN equivalents/kg dry weight, exhibiting significant variation ($p \leq 0.05$) among the samples.

Except for Niji® Foods Garri and Ayoola® Fufu Flour, all samples surpassed the benchmark limit set by FAO/WHO and SON (10 mg HCN/kg body weight). However, all samples were deemed safe for consumption as the hydrogen cyanide concentration did not exceed the lethal dose threshold (50 - 100 mg HCN/kg body weight).This study provides valuable insights into the hydrogen cyanide content of various processed cassava products and confirms their safety for consumption when adequately processed. The findings can guide industry practices and ensure the production of safe cassava-based products for consumers in Nigeria.

Keywords: Cassava, hydrogen cyanide concentration, processed, safety

Introduction

Cassava, scientifically known as *Manihot esculanta* Crantz, has become extensively cultivated in the Pacific region. It is a domesticated plant originating from one or more species within the Genus *Manihot*, belonging to the Euphorbiaceae family [1]. Among the various parts of the cassava plant utilized, the storage root (tuber) and leaves are the most commonly used. The *Manihot* genus comprises approximately 100 species, with *Manihot esculenta* Crantz being the sole commercially cultivated species [2]. It is one of the most perishable tuber crops with a high postharvest loss [3, 4].

As of the most recent data, global cassava production has reached a significant milestone, totaling 302.66 million metric tonnes [5]. The top-producing countries include Nigeria, ranking 1st, followed by Congo DR, Thailand, and Indonesia, ranked 2nd, 3rd, and 4th, respectively [5]. Notably, Africa has emerged as the world's largest cassava growing region, with a remarkable production of 193.62 million metric tonnes in 2020. Within Africa, Nigeria remains the unequivocal leader, contributing about 60 million metric tonnes to the global cassava production in the same year [5]. Cassava plays a crucial role as a staple crop, nourishing millions of people globally. However, its inherent composition of cyanogenic glucosides raises concerns about potential toxicity due to the release of hydrogen cyanide (HCN) during metabolism [6].

Ensuring safe consumption of cassava necessitates proper processing techniques to reduce cyanide levels. This versatile tuber, undergoes various local processing techniques to yield a range of products, including tapioca, farina, garri, fufu, and starch which serve as essential and affordable staple foods in Africa, with Nigeria being a prominent consumer, utilizing most of its domestic production [7, 8]. In the context of cassava processing, distinct methods such as soaking, fermentation, cooking, steaming and chipping, frying, drying, and roasting are traditionally employed [9]. Each of these techniques significantly impacts the chemical composition of the final cassava products. Both traditional and modern methods are employed for cassava detoxification, yet the effectiveness of these methods in mitigating HCN toxicity remains a topic of ongoing investigation [10, 11]. In recent years, there has been growing concern regarding the safety and nutritional quality of processed cassava products. While some studies [11, 12, 13] have explored the impact of processing techniques on cyanide reduction, there remains a lack of comprehensive research comparing the HCN concentrations among different forms of processed cassava products. This study aims to address this gap by conducting a comparative analysis of the HCN concentration in various processed cassava products.

In this study, we present the results of a comprehensive analysis of HCN concentrations in processed cassava products, including garri, fufu flour, high quality cassava flour and starch. The investigation involved the determination of hydrogen cyanide concentration in eight locally sourced processed cassava products ((Niji® Foods Garri, Golden Penny Garri, GGEE® foods Ijebu Garri, IFGREEN® Odourless Fufu Flour, Ayoola® Fufu Flour, Aiteefills® Fufu flour, Niji® Foods Cassava Flour and Local Brand Cassava starch) available in local markets and supermarkets in the city of Lafia, Nassarawa State, Nigeria for comparative analysis in order to evaluate the safety of these products for consumption. Recent advances in analytical techniques and equipment have enabled more accurate and sensitive measurement of HCN levels [14, 15], providing an opportunity to gain deeper insights into the variations in cyanide content among processed cassava products. Additionally, this research is of significant importance for food safety and public health, especially in regions heavily reliant on cassava as a dietary staple.

2. Experimental

2.1 Study Site and Sample collection

This study was carried out during the months of January to March in 2023 in the captivating and vibrant town of Lafia. Nestled in the heart of Nassarawa State's lush Guinea Savanna region in north-central Nigeria, Lafia serves as both the headquarters of the Lafia Local Government Area and the state capital. Positioned between latitudes 80 28’ N and 80 30’ N and longitudes 80 29’ E and 80 32’ E, this town boasts a strategic and picturesque location. With a population of 361,000

[16], the Lafia Local Government Area is home to diverse communities and is bordered by three neighboring local government areas: Wamba to the north, Nassarawa Eggon to the north-west, Obi to the south, Doma to the south-west, and Plateau State to the east (Figure 1). Geologically, Lafia is an integral part of the lower Benue trough, lending unique characteristics to its landscape and natural resources. The people here engage in a variety of occupations, including civil service, farming, mining, artisanry, and fishing, which together weave the colorful fabric of their livelihoods. Samples consisting of products containing cassava as primary ingredients were randomly obtained directly from supermarkets and local markets in Lafia town from January to March, 2023. The eight samples of processed cassava products were divided into four groups based on the method of processing: garri samples, fufu flour, high quality cassava flour and locally processed starch. The samples include Niji® Foods Cassava Flour, IFGREEN® Odourless Fufu Flour, Ayoola® Fufu Flour, Aiteefills® Fufu flour, Niji® Foods Garri, Golden Penny Garri, GGEE® foods Ijebu Garri and local brand cassava starch. They were designated as NFCF, IGFF, AYFF, ATFF, NFG, GPG, GIG and LBCS respectively. The samples were transported directly to the Chemistry laboratory, Faculty of Agriculture, Nassarawa State University, Shabu Campus, for analysis.

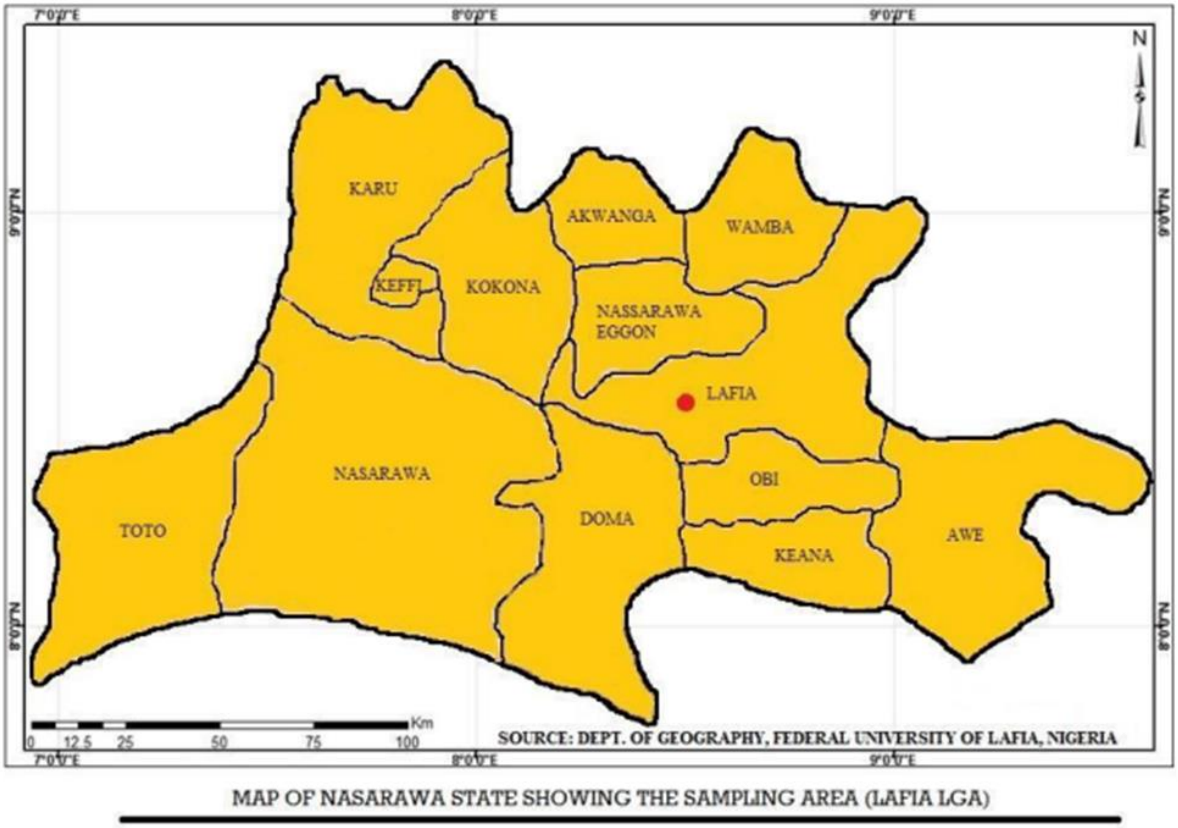

Figure 1: Map of Nassarawa state showing Lafia Local Government Area [17]

2.2 Preparation of samples

100g of each processed cassava product sample was put in tightly sealed plastic envelopes and kept in field cellophane bags before analysis to prevent environmental contamination.

2.3 Preparation of reagents

2.3.1 Preparation of alkaline picrate solution

Equal volumes of picric acid obtained by diluting 2.56 g of picric acid in 100 ml of distilled water and 5% sodium carbonate solution obtained from 5 g of sodium carbonate dissolved in 100 ml of distilled water were mixed to have alkaline picrate for the analysis.

2.3.2 Standard potassium cyanide stock solution (picrate in solution)

6.5 g of potassium cyanide was diluted in distilled water and completed to 1000 ml with 0.01 M H_2SO_4. This stock solution containing 2.6 g of CN^- per ml was obtained with the purity of KCN (see appendix II, table B.1). The obtained stock solutions were diluted with a 0.01 M H_2SO_4 to yield eight dilute solutions which were further diluted serially with alkaline picrate solution in distilled water to give eight solutions (see appendix II, table B.2), whose absorbance at 535 nm was used to draw a calibration curve (see appendix II, figure A.1).

2.4 Determination of cyanide using picrate in solution

The investigation into cyanide levels took place by extracting samples from eight distinct processed cassava products, each uniquely labeled. The methodology employed was the picrate in solution method, which was detailed in [18].

To initiate the determination process, 3.0 grams of each sample were accurately weighed and then immersed in 50 ml of distilled water for a duration of 60 seconds. Afterward, the extracts underwent filtration using filter paper. Subsequently, 0.04 ml of the extract was carefully taken and subjected to specific treatments as outlined in the table provided in appendix I, table A.2.

The prepared test tubes containing the samples and color reagents were then incubated in a water bath at a temperature of 37 degrees Celsius for a period of 15 minutes. Before readings were recorded, 15 µL of sulfuric acid (H_2SO_4) was introduced to halt the reaction and enhance the stability of the readings. To gauge the cyanide content accurately, the UV absorption readings of the distillate were meticulously measured, and based on these readings, a standard curve was constructed (see appendix II, figure A.1).

2.5 Data Analysis

Data was analyzed using a one-way analysis of variance (ANOVA). The mean differences were determined using the Tukey's Least Significance Difference test at 5% significant level. Values of $p \leq .05$ were considered statistically significant. All data were expressed as the mean ± standard deviation (SD) of three observations. All calculations were done using the Minitab version 20 software.

3. Results and discussion

Figure 2 provides a comprehensive display of the hydrogen cyanide concentration found in various cassava products. For this study, a set of eight diverse processed cassava samples were thoughtfully chosen from the local markets in Lafia town, situated in Nassarawa State, Nigeria. The cyanide content of these samples was meticulously assessed, employing the well-established picrate in solution method.

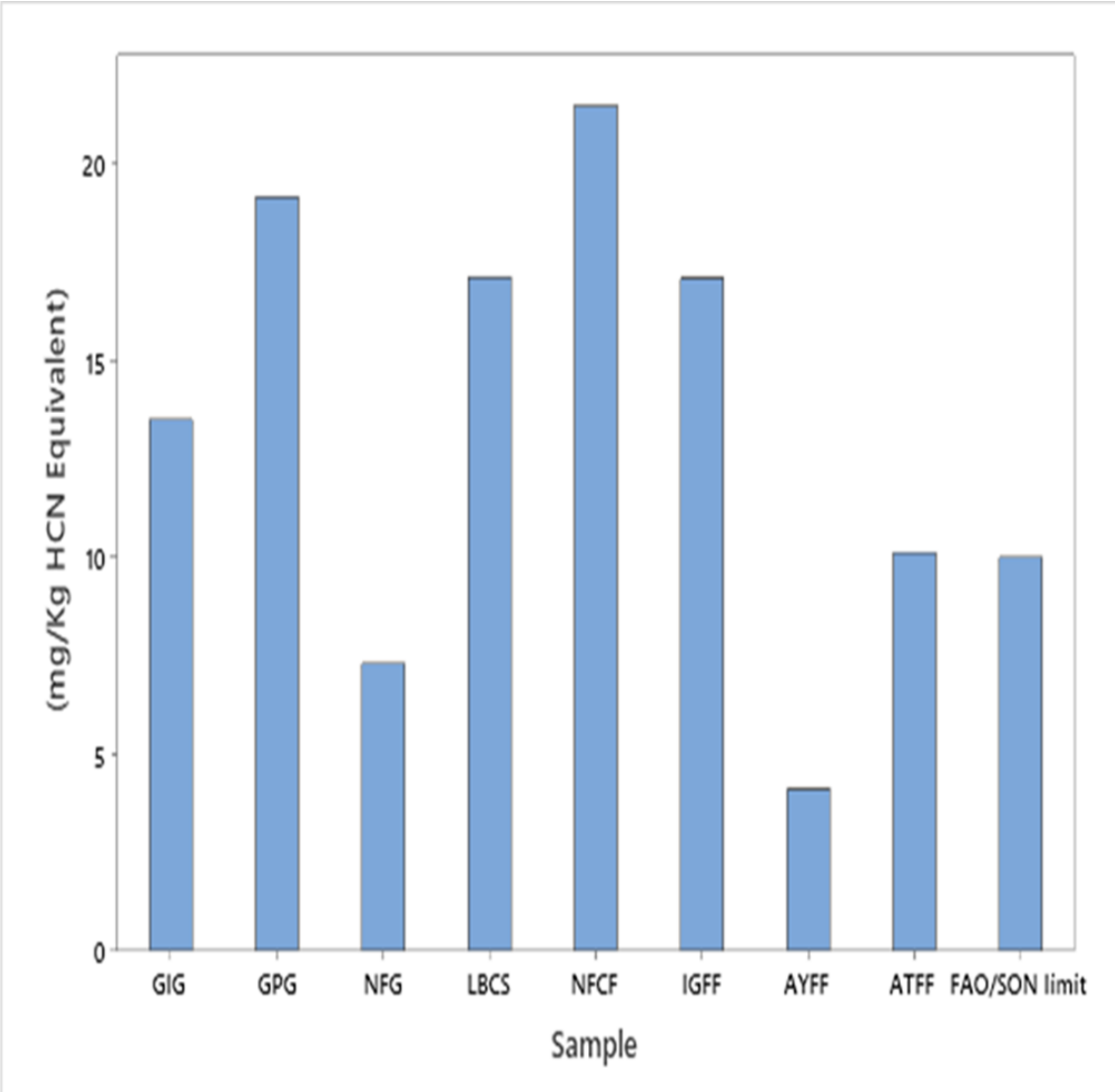

Figure 2: Hydrogen cyanide concentration in the eight processed cassava products

3.1 Variation of cyanide in the different cassava products

The processed cassava product samples were subjected to analysis, revealing cyanide contents ranging from 4.13±0.12 ppm to 21.47±0.55 ppm Total cyanide, as depicted in Figure 2. It is important to note that these cyanide levels exhibited significant variations ($p = .05$) among the samples. Particularly, AYFF demonstrated the lowest cyanide content (4.13±0.12 ppm) and significantly differed ($p \leq 0.05$) from the other samples. On the other hand, when compared to AYFF, NFG, and ATFF, GIG, GPG, LBCS, NFCF, and IGFF displayed significantly higher cyanide levels. These differences in cyanide content can be attributed to the distinct processing methods employed. The traditional processing techniques, including grating, dewatering (pressing), fermenting, drying, and frying, are effective in reducing cyanide content [19]. Among the samples, NFCF exhibited the highest cyanide retention, suggesting the presence of chemically bound glycoside linamarin. Conversely, lower cyanide levels may indicate the presence of free cyanides such as hydrogen cyanide and cyanohydride. Since cyanide is soluble in water and volatile (with a boiling point of 25°C), soaking and air drying at temperatures ranging from 28°C to 40°C can effectively remove cyanide [20]. These findings highlight the significance of processing methods in determining the cyanide content of cassava products and underscore the need for appropriate processing techniques to minimize cyanide levels effectively. Cassava varieties are classified as sweet variety when cyanide values are in the range 15 – 50 ppm and bitter variety when values are from 15 – 400 ppm of fresh cassava [21]. The cyanide levels of AYFF (4.13±0.12 ppm Total cyanide) and NFG (7.30±0.15 ppm Total cyanide) cassava products fall within the acceptable limits of 10 ppm dry weight recommended by FAO/WHO and SON for safe cassava products. However, the level of cyanide in ATFF (10.13±0.06) is slightly higher than the recommended safe level.

The recommended safe levels in a final product is 10 ppm [22]. Since all the samples are processed products, the cyanide levels are expected to be low. However, the cassava flour sample, NFCF having the highest cyanide content, is a raw material, hence, it is expected that the cyanide level will reduce further down the processing stream. The temperatures for proofing (30 - 32 ºC) and baking (178 – 193 ºC) for bread making can significantly reduce cyanides in the final product [20].

The findings of this study exhibit remarkable disparities when compared to previous research. Burn *et al.* [23] reported cyanide analysis of cassava chips samples from Melbourne, with a six-year study period yielding 91 mg HCN equivalent, except for one sample which showed 7.00 mg HCN equivalent per kilogram of dry weight. On the other hand, the results closely aligned with Bandna's [24] investigation on fried cassava products, which indicated cyanide content ranging from 8.13±4.30 to 37.02±5.59 ppm.

Interestingly, the cyanide contents observed in the studied Gari products (GPG, GIG, and NFG) remained notably lower when compared to Alhassan *et al.*'s [25] research on "Gari" sourced from 25 locations in Cameroon (114±16 ppm) and the total cyanide contents of "Gari" samples sold in Port-Harcourt markets, Nigeria, reaching 30 ppm [26]. Notably, none of these studies specified the cassava cultivar utilized.

These significant variations in cyanide levels emphasize the necessity of considering various factors that might impact the cyanide content in cassava products, including processing methods, geographical location, and cassava cultivars employed in each study. Also, previous studies had shown that roasting of cassava mash in the presence of palm oil engendered rapid volatilization of hydrocyanic acid [27, 28, 29] and may have also accounted for relatively moderate cyanide contents in the garri samples (GIG, GPG and NFG). Accordingly, from toxicological standpoint, the consumption of eba is safer and should be preferred to intake of garri or garri dispersed and soaked in cold water, which is a common snacking habit among Nigerians since the boiling stage will further reduce the cyanide level through volatilization. Due to the increasing demand of “gari” in local markets, producers often shorten certain steps in the production process [30].

In the cassava fufu flour samples, apart from IGFF (17.10±0.10), cyanide contents of AYFF (4.13±0.12 ppm Total cyanide) and slightly ATFF (10.13±0.06 ppm Total cyanide) are in conformity with the recommended limit by FAO/WHO and SON (10 ppm Total cyanide per Kg dry wt). Cyanide elimination rates of the present study was similar to those reported by Ndam *et al.* [31] who reported 9.8 ± 6.95 ppm and 6.54±7.22 ppm for cassava fufu made from local and improved cultivars respectively. Also, Iwuoha *et al.* [32] showed that soaking for five to six days at a pH of 4 to 4.5 reduced the cyanide up to 94.7%. [33] obtained a reduction of cyanide content of 90% after soaking for 72 h. Soaked Cassava increases the process of cyanide elimination because the roots which are completely submerged in water can support bacterial growth allowing the production of linamarase [34]. Moreover, since cyanide is water soluble and volatile, the operations of soaking, followed by manual crushing and then sun/oven drying could have resulted in the lowest cyanide content observed in AYFF [35], although “Fufu” of higher cyanide contents have been sampled in certain villages of Cameroon and markets of Nigeria [25, 26]. This was usually due to high demand in local markets, causing the producers to neglect the various steps of fermentation, which according to them, was regarded as a waste of time with little effect on cassava detoxification [30]. However, it should be noted that these products were locally made and not packaged or branded as the case is with samples used in the present study.

Orjiekwe *et al.* [18] reported cyanide levels of 6.0 ppm in cassava flour, 10.0 ppm in fufu flour and 5.0 ppm in garri samples obtained from Okada community in Edo state, Nigeria. The reported values of cyanide in the present study for flour and garri samples were significantly higher than that reported by Orjiekwe *et al.* [18]. However values of cyanide in AYFF and ATFF agreed with the value reported for Fufu flour in the previous study. The cyanide level in the previous study were significantly lower than the lethal dose of cyanide intoxication of human which has been reported as 200 to 300 mg/kg and the oral toxicity standard of 50 to 90 mg HCN equivalent/kg body weight [36]. Although some of the cyanide levels of the test samples (NFG, AYFF and slightly ATFF) employed in this work are within the acceptable levels recommended by FAO/WHO and SON, epidemiological studies have shown that exposure to small doses over a long period of time can result in increased blood cyanide levels which is associated with the following symptoms: dizziness, headache, nausea and vomiting, rapid breathing, restlessness, weakness and in severe cases paralysis, nerve lesions, hypothyroidism and miscarriage [37, 38].

Traditionally, the focus has been on reducing and, if possible, eliminating cyanide from raw cassava roots by employing various processing schemes [39, 40]. Research investigations have revealed that the ultimate level of residual cyanide in cassava-based products hinges on both the initial cyanide load and the processing methods utilized for raw cassava roots [41, 42].

All these processing techniques involve specific operations designed to facilitate the breakdown of cyanogenic glycosides through the activity of endogenous hydrolyzing enzymes like linamarase. This enzymatic activity converts cyanogenic glycosides into hydrogen cyanide, which is subsequently volatilized through roasting or boiling. In certain instances where it might be challenging to entirely eliminate cyanide from cassava products, levels below 50 mg/kg are deemed safe [43].

As a result, before being consumed, the cassava products labeled NFCF, LBCS, IGFF, AYFF, and ATFF will undergo further processing techniques, such as boiling or high-temperature mixing, to further reduce the cyanide concentration. It is worth considering that variations in cyanide levels might be attributable to the efficiency and adequacy of the chosen processing methods.

3.2 Evaluation of Processed products' Suitability for consumption

The selected samples of processed cassava products were subjected to analysis to determine the concentration of hydrogen cyanide. Based on the standard health rating index, FAO/WHO and SON recommends that cyanide content in the final processed cassava product must not be greater than 10 ppm. However, consumption of 50 to 100 mg of cyanide in meals has been associated with acute poisoning which is lethal to humans. Long term consumption of small amounts of cyanide can cause severe health problems such as tropical neuropathy, konzo [44] and fibrocalculous pancreatic diabetes (FCPD), also known as tropical calcific pancreatitis [45], glucose intolerance and coupled with iodine deficiency goiter and cretinism also results. Cyanide toxicity is aggravated by low protein content of cassava and a deficiency of sulfur containing amino acids in the diet. Therefore, it is necessary to evaluate the different processed products' suitability for consumption.

3.2.1 Garri products

This study focused on three garri products, namely GIG, GPG, and NFG, which are widely available in both supermarkets and local markets within Lafia town. These products undergo meticulous processing and are carefully packaged as fine granules, available in various sizes. For analysis, 1 kg net weight packs of each product were obtained. In the local households of Lafia, these garri products are commonly consumed by either soaking them in room temperature water or mixing them with boiled water to create a dough known locally as 'eba.' This dough can be savored alongside protein-rich soup delicacies. Throughout the analysis, the cyanide concentration in the three garri products ranged from 7.30±0.15 to 19.70±0.52 ppm Total cyanide, as illustrated in Figure 2. The higher cyanide content in GIG and GPG can be attributed to the insolubility of cyanide in oil/fats, preventing leaching of the cyanide [46].

Considering a typical meal where an individual consumes 100-200 g of the soaked or hot water-mixed garri product, the amount of cyanide ingested would range from 1.5 mg to 3.9 mg. Consequently, consuming these garri products in a meal does not pose a risk of reaching the lethal dose of cyanide. Hence, GIG, GPG, and NFG are considered safe for direct consumption by households in Lafia town.

3.2.2 Cassava Fufu flour samples

The study's analysis included three Fufu flour samples: AYFF, ATFF, and IGFF, all conveniently packaged in 1 kg net weight packs, readily available at local supermarkets and markets in Lafia town. Similar to Garri, Fufu flour is prepared by stirring the flour paste (created by dissolving the flour in normal temperature water) into boiling water until a smooth dough is achieved. This versatile Fufu dough complements various local soup delicacies. During the analysis, the Fufu flour samples displayed cyanide levels ranging from 4.13±0.12 to 17.10±0.10 ppm Total cyanide, as depicted in Figure 2. In accordance with the benchmarks established in this study, IGFF exhibited cyanide levels exceeding the recommended limit, with ATFF slightly surpassing the limit (10.13±0.06 ppm Total cyanide). On the other hand, AYFF's cyanide content (4.13±0.12 ppm Total cyanide) remained within an acceptable range. This indicates that the drying method employed for cassava in both AYFF and ATFF is efficient, rendering them safe for consumption. Notably, since the products are not manufactured in Lafia, it is possible that the cassava flour samples (AYFF and ATFF) are solely derived from the pulp and not the peels of cassava, resulting in a lower amount of cyanide. Considering a typical meal, where an adult consumes 100-200 g of the cooked Fufu product, the amount of cyanide ingested would range from 0.83 mg to 3.42 mg. Consequently, consuming cassava Fufu flour products in a meal poses no risk of reaching a lethal dose of cyanide.

3.2.3 High Quality Cassava Flour

The sole sample analyzed in this category was NFCF, as sourcing other packaged high-quality cassava flour proved challenging in Lafia town. NFCF can be obtained from local markets and primarily serves as a crucial raw material for confectioneries and baking industries, undergoing further processing within the production stage. The cyanide content in NFCF was measured at 21.47±0.55 ppm Total cyanide, as indicated in Figure 2, which exceeds the recommended limit. This elevated cyanide level may be attributed to inefficient drying during the processing stage. Nevertheless, as NFCF is not directly consumed but rather subjected to additional processing, it is expected that the cyanide level will further diminish during these subsequent stages [1]. In a typical final product made from NFCF, containing 100-200 g of the flour, the amount of cyanide consumed per meal would range from 2.15 to 4.29 mg. Consequently, consuming products derived from high-quality cassava flour (NFCF) does not pose a risk of reaching a lethal dose of cyanide.

3.2.4 Local brand cassava starch

The locally branded cassava starch sample (LBCS) was directly obtained from manufacturers in Lafia town. This versatile product finds application as a thickening agent, binding agent, texturizer, and stabilizer in a wide range of food products, including canned foods, frozen foods, salad dressings, sauces, and infant foods. Additionally, glucose and fructose derived from starch serve as alternative sweeteners to sucrose in canned fruits and jams. Moreover, LBCS can be used as a biodegradable polymer to replace plastics in packaging materials, among other applications. Typically, this product undergoes further processing stages along the production line before its incorporation into the final product.

In the present study, the cyanide content of LBCS measured 17.13±0.06 ppm Total cyanide (see Figure 2), surpassing the benchmark used in this investigation. The impact of processing on the cyanide level is evident. The elevated cyanide level in LBCS could be attributed to inadequate dewatering and drying during the processing stage, as cyanide is more soluble in neutral water and can dissipate into the atmosphere during sun-drying [47, 48]. For final products containing 100-200 g of starch, the cyanide content would range from 1.7 to 3.4 mg. Consequently, it can be confidently concluded that consuming products made from LBCS is safe, as the cyanide levels remain far below the lethal dose threshold.

4. Conclusion

The study revealed significant variations in cyanide content among the samples, indicating the influence of diverse processing methods. While some products like NFG and AYFF exhibited cyanide levels within safe limits, all others surpassed recommended thresholds. However, all samples are safe for consumption since the lethal dose of cyanide toxicity in human was not exceeded in all the samples. Notably, further processing stages and culinary practices play essential roles in mitigating cyanide consumption in these products. Our findings highlight the importance of employing efficient processing techniques to ensure the safety of cassava-based products for consumption. The present study contributes to our understanding of cyanide content in processed cassava products and emphasizes the significance of quality control measures during manufacturing. These insights are relevant for both local communities and regulatory authorities to promote the safe consumption of cassava products and safeguard public health. Further studies can explore additional factors impacting cyanide levels and potential mitigation strategies to ensure food safety and enhance the quality of cassava-based products in the market.

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6. Conflict of interest

The author(s) declares no conflict of interest.

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APPENDIX I

Table A.1: FAO/WHO and SON nutritional standards for processed cassava products

PRODUCT TYPE	(%)MD (MAX)	(%)ASH (MAX)	(%)CP (MIN)	(%)FAT (MAX)	(%)CF (MAX)	(%)NFE (MIN)
STARCH	12.0	0.1	0.5	-	0.2	85
FUFU FLOUR	10.0	0.6	1.0	-	2.0	65 – 70
GARRI	7.0	1.5	1.0	-	2.0	65 – 70
HIGH QUALITY CASSAVA FLOUR	12.0	0.7	1.0	-	1.5	65 - 70

Max = Maximum; Min = Minimum *[49]*

APPENDIX II

Table B.1: Stock solution Of HCN Equivalent in acid conditions (H_2SO_4)

Flasks	Stock solutions	H_2SO_4	HCN^- Concentration
	Ml	ml	mg HCN^-ml^- Equivalent
0	0	100	0
1	1	99	0.026
2	2	98	0.054
3	5	95	0.135
4	10	90	0.27
5	15	85	0.405
6	25	75	0.675
7	50	50	1.35

Table B.2: Standards preparation for picric in solution method

Test tubes	Stock solution	Alkaline Picric	Distilled water	mg CN	Absorbance
0	0	2	2	0	0.011
1	0.04	2	1.96	0.001104	0.005
2	0.04	2	1.96	0.00208	0.018
3	0.04	2	1.96	0.0052	0.052
4	0.04	2	1.96	0.0104	0.11
5	0.04	2	1.96	0.0156	0.045
6	0.04	2	1.96	0.026	0.44
7	0.04	2	1.96	0.052	0.847

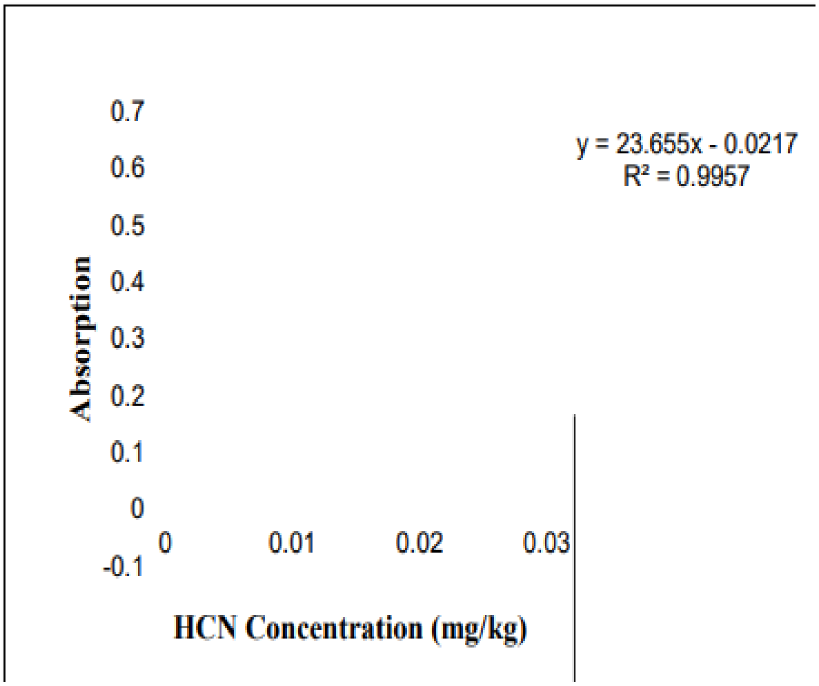

Figure A.1: HCN UV-visible calibration curve for picrate solution method

APPENDIX III

Table C.1: Total cyanide content (mg HCN equivalents/kg dry weight (wt) = ppm) of the eight processed cassava products.

Sample	Processing method	N	Mean±SD (mg HCN Equivalents/kg dry wt)	Minimum	Maximum
GIG	Grating, fermenting and roasting	3	13.50^{d}±0.52	13.20	14.10
GPG	Grating, fermenting and roasting	3	19.17^{b}±0.06	19.10	19.20
NFG	Grating, fermenting and roasting	3	7.30^{f}±0.15	7.00	7.30
LBCS	Crushing, slurry screening, dewatering, drying and sieving	3	17.13^{c}±0.06	17.10	17.20
NFCF	Slicing, drying, pounding/milling and sieving	3	21.47^{a}±0.55	21.10	22.10
IGFF	Fermenting, dewatering drying and milling	3	17.10^{c}±0.10	17.00	17.20
AYFF	Fermenting, dewatering drying and milling	3	4.13^{e}±0.12	4.00	4.20
ATFF	Fermenting, dewatering drying and milling	3	10.13^{g}±0.06	10.10	10.20
FAO/SON limit			**10.00**		
FAO/SON Lethal dose per Kg dry wt			**50 -100 mg**		

Keys: GIG, GPG, NFG, LBCS, NFCF, IGFF, AYFF and ATFF: Different samples.