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Impact of Selected Processing Methods of High-Level Cyanide in Cassava on Optic Neuropathy in Wistar Albino Rats—An Experimental Study

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Abstract

Background: Cassava tuber crop is a staple food rich in carbohydrates and utilized in various forms by millions of Nigerians. The storage root of the cassava contains linamarin, a cyanogenic glycoside that is easily hydrolyzed to release cyanide salt compounds which is toxic to the nervous system especially the optic nerve, sometimes leading to optic neuropathy and visual impairment. **Aim:** The aim of this study is to find out the impact of selected processing methods of high-level cyanide in cassava on optic neuropathy in Wistar albino rats. **Methodology:** Twenty-four Wistar albino rats were fed with different concentration and duration of predetermined high-cyanide content cassava root cultivar which was processed using different processing methods adopted by various communities in Rivers State, Nigeria (for human consumption). A control group of 3 Wistar albino rats was fed with normal "Growth Mesh" meals. The pre and post weights of the animals and the fundoscopic optic nerve status of the rats were evaluated after 30 and 60 days. SPSS Version 25 was employed for descriptive and inferential statistical analyses. A p-value of ≤0.05 was considered statistically significant. **Results:** The Cassava species available in Rivers State have high cyanide content (2336.79 mg CN^-/kg dry weight of cassava). There was statistically significant reduction in the cyanide content ($p = 0.000$) depending on the various common processing methods (into garri for human consumption): 24 hours, 48 hours, fermentation; with and without red palm oil additive. The individual weights as well as the mean weight of the 24 rats in the experimental group increased gradually from the first week to the 9th week with a slight weight reduction on the third and fourth weeks which was not statistically significant ($p = 0.092$).

However, there was a steady increase in the weights of the animals in the control group throughout the 9 weeks. Varying degrees of optic neuropathy occurred, worse with the rats that had 24-hour fermented cassava twice daily for 60 days. The intra and inter group differences in the optic disc changes was statistically significant ($p = 0.000$). **Conclusion:** Longer duration of processing cassava roots into garri for human consumption reduces its cyanide content and minimizes the adverse impact on the optic nerve.

Keywords

Cassava Processing Methods, Cyanide in Cassava, Optic Neuropathy, Wistar Albino Rats

1. Introduction

Cassava (Manihot esculenta Crantz) is a widely cultivated tuber crop, a staple food rich in carbohydrates and utilized in various forms by millions of Nigerians. The storage root of the cassava plant contains linamarin, a cyanogenic glycoside that is easily hydrolyzed by the enzyme linamarase (a β glucosidase) to release cyanide salt compounds (HCN) [1].

Different processing methods are adopted by various communities and cultural settings such as 24-hour fermentation with or without the addition of fresh red palm oil, 48-hour fermentation with or without the addition of fresh red palm oil etc. The different methods usually determine the amount of cyanide available for ingestion during consumption. In many parts of Nigeria, including Rivers State, cassava is consumed in different forms: Garri, Fufu, Cooked cassava slices, Cassava flour, Macaroni, bread, indomine and candies.

The consumption of insufficiently processed root cassava tuber with varying levels of cyanide salt compounds can result in dietary cyanide poisoning and this has been implicated in optic neuropathy [2]. Exposure to toxic substances such as high cyanide concentration could disrupt the functions of the optic nerve resulting in various degrees of optic neuropathy and subsequent visual impairment and blindness [3] [4].

Optic atrophy and/or optic neuropathy have been reported as causes of visual impairment and blindness in Rivers State [5]. Nutritional optic neuropathy from cyanide toxicity in cassava (a staple food) for human consumption could significantly contribute to visual impairment in Nigeria. This work, therefore, examines the impact of selected processing methods-duration of fermentation cassava on the cyanide content and consequent effect on optic neuropathy in Wistar Albino Rats. This experimental study could serve as a transition into invaluable clinical practice especially in the field of neuro-ophthalmology.

2. Materials and Methods

This was an experimental study on 24 male Wistar Albino Rats that were fed

with differently processed high level cyanide cassava (higher than FAO/WHO recommended level of 15 - 1000 mg CN^-/kg dry weight) [6] into garri (of predetermined varying concentrations of cyanide for different frequencies and duration (once and twice daily for 30 days and 60 days). There was a control group of 3 Wistar Albino Rats that were treated with exclusively normal rat-feeds "Grower Mash" (composed of Crude Protein −15.5%, Fat −3.6%, Crude Fiber −4.6%, Calcium −1.1%, Phosphorus -0.4%, Methionine −0.37%, Lysine 0.75%, Metabolizable Energy −2550 kcal/g) for the same number of days. Ingredients that composed the "Grower Mash" were cereals/grains, vegetable protein, premix (vitamins/minerals), essential amino acids, galt, antioxidants, prebiotics and anti-toxins.

The rats were divided into 8 groups of 3 and fed with corresponding weight of fried garri for 30 and 60 days either once daily or twice daily with a control group (of 3 rats) on normal rat-feeds for the same duration. Each rat in the various groups was marked with permanent ink: on the head (HM), at the back (BK), and unmarked (UM) for identification and subsequent follow up.

2.1. Collection and Processing Fresh Cassava Roots

Fresh tubers of cassava from known heavy cassava producing and consuming communities in Rivers State, Nigeria: Etche, Omuma, Khana, Gokhana, Ikwerre, Emohua, Eleme, Tai, Oyigbo, Ahoada-East, Ahoada-West, Ogba/Egbema/Ndoni, Port Harcourt and Obio-Akpor Local Government Areas of Rivers state were purchased from the open markets and analyzed for their cyanide contents.

Tubers of cassava with high content of cyanide (>400 mg HCN/kg as recommended by FAO) (FAO/WHO, Joint FAO/WHO Food Standards Programme, Codex Alimentarius Commission XII, Supplement 4, FAO, Rome [7] were processed using the usual most popular methods in Southern Nigeria and fed the rats for 30 and 60 days in their various groups. The popular durations of fermentation and processing methods used in the various communities in Rivers State were: 24-hour, 48 hours, fermentation; with and without red palm oil additive. The commonest frequencies of garri consumption (once and twice daily were also employed to treat the animals).

2.2. Determination of Cyanogenic Glycoside Content in the Various Varieties of Cassava Samples

The Cyanogenic glycoside of the purchased cassava roots was determined using alkaline picrate method of Onwuka [8]. Ground sample (5.0 g) was weighed and dissolved in 50 cm^3 distilled water. The cyanide extraction was allowed to stay overnight and then filtered.

Preparation of cyanide standard curve: Different concentrations of KCN solution containing 0.1 to 1.0 mg/mL cyanide were prepared. To 1 mL of the sample filtrate and standard cyanide solution in test tubes, 4 mL of alkaline picrate solution (1 g of picrate and 5 g of Na_2CO_3 in 200 cm^3 distilled water) was added and incubated in water bath for 15 min at room temperature (34˚C). After colour development, the absorbance was read at 490 nm against a blank containing only

1 mL distilled water and 4 cm^3 alkaline picrate solution. The cyanide content was extrapolated from the cyanide standard curve.

Cassava species (Sample 7 above) having the highest cyanide content (2336.79 mg CN^-/kg dry weight of cassava) were processed using different durations of fermentation and processing methods that are popularly used in the various communities in Rivers State, viz: 24-hour, 48 hours, fermentation; with and without red palm oil additive.

2.3. Experiment on Rats

A total of 24 rats (3 rats per group of 8) with a control group of 3 rats were fed with the determined cyanide content for 30-days and 60-days. The control group (sub group) was fed on normal rat-feeds "Grower Mash".

The quantity of cyanide in cassava-product consumed by an average adult weighing approximately 70 kg was determined and the equivalent in weight for the rats determined. For instance, if an average 70 kg adult consumes an average of 5 cups of garri/day (45 units of cyanide) then 2 kg rat was administered with 1.3 units of cyanide contained in the processed cassava (garri) in three divided

Table 1. Results of the cyanide contents of the various raw cassava cultivars.

Samples	mg CN^-/kg dry weight of cassava	FAO/WHO recommended level (mg CN^-/kg dry weight of cassava)	Percentage Increase (%)
1	1286.00		28.6
2	2486.39		148.6
3	1791.80		79.2
4	1204.07	15 - 1000	20.4
5	1734.81		73.4
6	1417.79		41.8
7	2386.0		133.0

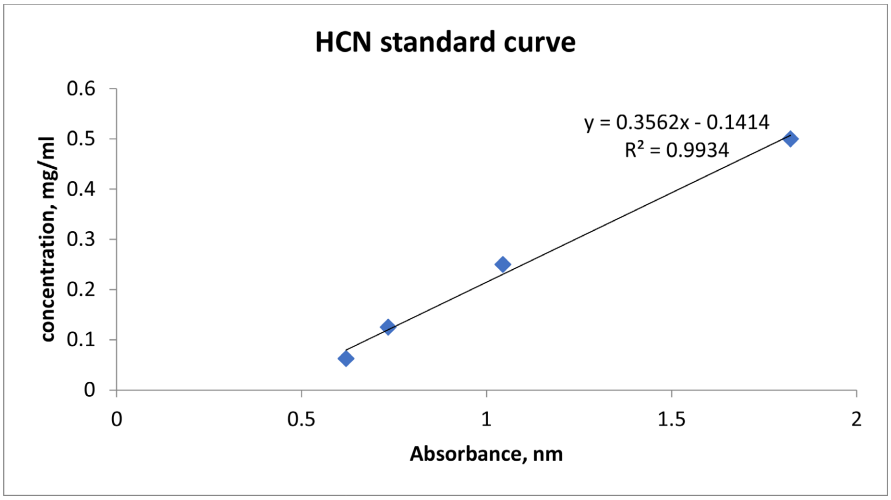

Figure 1. Determination of cyanide contents of various cassava processing methods.

doses/day. We ensured that the rat consumed all the measured-out quantity of garri before it was given any other meal for the day. At the end of specified period, the rats were sacrificed and examined for changes in the optic nerve.

2.4. Assessment of Optic Neuropathy in Experimental Rat Subjects

Pre- and post-experimental optic nerve status of the rats were assessed clinically—fundoscopy of the optic disc, optical coherence tomography (OCT) analysis of the optic disc head and the histopathological analyses of the optic nerve head.

All the analyses were carried out in the analytical chemistry laboratory of the University of Port Harcourt. Histopathological sections were analyzed at the Histopathology laboratory of the University of Port Harcourt Teaching Hospital, while the clinical assessment was done at the ophthalmology department of the University of Port Harcourt Teaching Hospital.

3. Statistical Analysis

The data obtained were entered into Microsoft Excel sheet, cleansed and later exported to IBM Statistical Package for Social Sciences (SPSS) version 25 software (SPSS) Inc; Chicago, IL, USA was employed for descriptive and inferential statistical analyses Relevant data were presented in tables and charts. Statistical significance was performed using Chi-square and independent T-test. Statistical significance was set at $p \leq 0.05$.

4. Results

A total of 27 Wistar Albino Rats were studied between March 2022 and June 2022. The rats were divided into Experimental and Control groups of 3 animals in each group. In the Experimental Group were 8 sub-groups depending on the cassava processing method and the feeding regimen, thus there were the following sub-groups:

Group 1—Experimental Group

Sub-group 1—Wistar Albino Rats treated with 24-hr fermented cassava daily for 30 days

Sub-group 2—Wistar Albino Rats treated with 24-hr fermented cassava twice daily for 30 days

Sub-group 3—Wistar Albino Rats treated with 24-hr fermented cassava daily for 60 days

Sub-group 4—Wistar Albino Rats treated with 24-hr fermented cassava twice daily for 60 days

Sub-group 5—Wistar Albino Rats treated with 48-hr fermented cassava daily for 30 days

Sub-group 6—Wistar Albino Rats treated with 48-hr fermented cassava twice daily for 30 days

Sub-group 7—Wistar Albino Rats treated with 48-hr fermented cassava daily for 60 days

Sub-group 8—Wistar Albino Rats treated with 48-hr fermented cassava twice daily for 60 days

Group 2 (Control Group)—Wistar Albino Rats treated with normal rat-feeds "Grower Mash" for 60 days.

The individual weight and mean group weight are presented in Table 2. The mean weight of all the animals in the experimental group at the beginning of the experiment was 68.5 gm and at the end of the experiment was 74.5 grams while the mean weight of the rats in the control group at the beginning of the experiment was 48.8 gm and at the end of the experiment was 120.2 grams (Table 2).

Table 2. Weight dynamics of the 27 Wistar albino rats in the experimental study.

Group 1	Baseline (WK 0)	WK 1	WK 2	WK 3	WK 4	WK 5	WK 6	WK 7	WK 8	Mean Weight (Grams)
Sub-group 1										
HD	71	76	73	82	85					79.0
BK	64	70	68	77	77					73.0
UM	50	48	47	53	58					51.5
Mean Grp Wt	61.6	64.6	62.6	72.3	73.3					67.8
Sub-group 2										
HD	71	68	72	75	83					74.5
BK	65	64	66	71	81					70.5
UM	65	64	63	72	74					68.2
Mean Grp Wt	67.0	65.3	67.0	72.6	79.3					71.1
Sub-group 3										
HD	60	60	61	67	73	79	86	91	106	77.9
BK	74	79	94	105	120	131	141	148	152	121.2
UM	73	99	81	99	106	111	119	122	131	108.5
Mean Grp Wt	69.0	79.3	78.6	90.3	99.6	107.0	115.3	120.3	129.6	102.5
Sub-group 4										
HD	79	74	88	92	107	116	122	127	131	107.1
BK	70	71	79	82	98	104	113	115	130	99.0
UM	63	60	74	74	81	88	91	93	102	82.9
Mean Grp Wt	70.6	68.3	80.3	82.6	95.3	102.6	108.6	111.6	121.0	96.3
Sub-group 5										
HD	74	79	77	79	88	98	102	109	112	93.0
BK	60	61	59	64	78	81	84	91	102	77.5
UM	68	72	74	77	87	98	101	107	121	92.1
Mean Grp Wt	67.3	70.6	70.0	73.3	84.3	92.3	95.6	102.3	111.6	85.0

Continued

Sub-group 6										
HD	68	98	106	108	116					107.0
BK	72	74	77	79	89					79.7
UM	67	77	82	86	93					84.5
Mean Grp Wt	69.0	83.0	88.3	91.0	99.3					90.4
Sub-group 7										
HD	63	76	74	81	87					79.5
BK	75	89	90	94	101					93.5
UM	77	75	63	80	88					76.5
Mean Grp Wt	71.6	80.0	75.6	75.0	92.0					83.2
Sub-group 8										
HD	63	84	86	90	100	97	102	108	112	97.4
BK	73	78	82	83	98	91	93	100	115	92.5
UM	80	83	82	88	99	92	95	102	118	94.8
Mean Grp Wt	72.0	81.6	83.3	87.0	99.0	93.3	96.6	103.3	115.0	94.9
Mean weight at the start of Experiment =					Mean weight at the end of experiment =					
Group 2 (Control Group)										
HD	51	68	83	98	118	132	147	153	167	120.7
BK	49	74	92	96	116	118	124	126	130	109.5
UM	46	74	113	128	138	140	146	150	155	130.5
Mean Grp Wt	48.6	72.0	96.0	107.3	124.0	130.0	139.0	143.0	150.6	120.2
Mean weight at the beginning of Experiment = 48.6;					Mean weight at the ebd of experiment = 120.2					

4.1. Changes in the Weights of Wistar Albino Rats in the Experimental and Control Groups

The individual weights as well as the mean weight of the 24 rats in the experimental group increased gradually from the first week to the 9th week of the experiment (Figure 2). However, a slight reduction of weight in most of the animals was observed on the third and fourth weeks. This observed difference was not statistically significant ($p = 0.092$).

There was a steady increase in the weights of the animals in the control group throughout the 9 weeks of this study (Figure 3).

4.2. Cyanide Contents of the Processed Cassava Cultivars Using Different Methods

The results of the cyanide contents of the processed cassava cultivars using different methods are presented in Table 3.

The high-cyanide cassava cultivar in this study exceeded the FAO/WHO

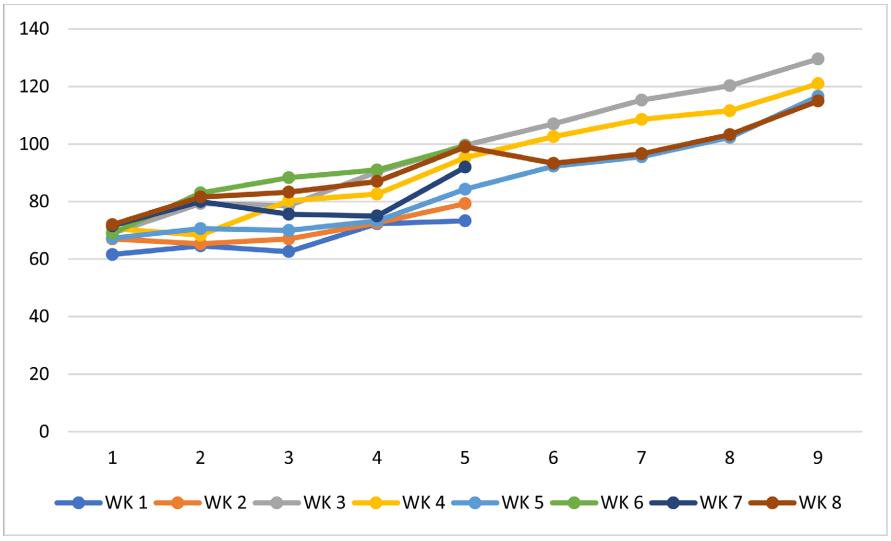

Figure 2. Changes in the Mean Weight of the Rats in the Experimental Groups during the period of the study.

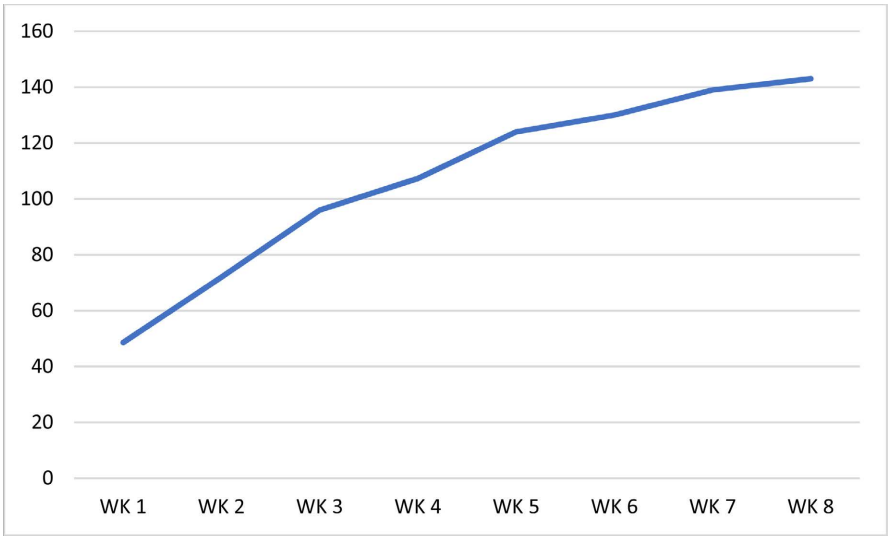

Figure 3. Changes in the Mean Weight of the Rats in the Control Group during the period of the study.

Table 3. Results of the cyanide contents of the processed cassava cultivar using different methods.

Samples	mg CN^-/kg dry weight of cassava	FAO/WHO recommended level (mg CN^-/kg dry weight of cassava)	Percentage Exceeded FOA/WHO Recommendation (%)	Percentage Reduction After Processing (%)
Raw Cassava	2486.39	15 - 1000	148.6	
24-hour Fermentation without Red Palm Oil	2386.65		138.7	4.2
24-hour Fermentation with Red Palm Oil	1791.8		79.2	27.9
48-hour Fermentation without Red Palm Oil	1204.07		20.4	51.6
48-hour Fermentation with Red Palm Oil	1034.81		3.5	58.4

Pearson Chi-Square value = 200.571, p-value = 0.000.

recommended cyanide in cassava level by over 148%. After undergoing different processing methods, the cyanide contents reduced considerably. The highest reduction was observed with 48-hour fermentation with red palm oil additive (58.4%), 48-hour fermentation without red palm oil (51.6%), 24-hour fermentation with red palm oil (27.9%) and the least reduction in cyanide content was with 24-hour fermentation without red palm oil additive (4.2%) (Table 3). This observed difference in the reduction of cyanide content with various processing methods was statistically significant (p = 0.000).

4.3. Processing Methods, Cyanide contents and Fundoscopic Findings in the Experimental Wistar Albino Rats

Wistar albino rats in the control group (fed with "Grower Mash" for 60 days) and the rats in sub-groups 5, 6, 7 & 8 (fed with 48-hour fermented cassava had normal optic disc findings on fundoscopy pre-, intra- and post-experimental duration. Rats treated with 24-hour fermented cassava (sub-groups 1, 2, 3 & 4) had varying degrees of papillitis, worse with the rats that had 24-hour fermented cassava twice daily for 60 days. The intra and inter group differences in the optic disc changes was statistically significant (p = 0.000) (Table 4).

5. Discussion

This experimental study sets out to breach the existing gap in knowledge of the relationship between optic neuropathy and cyanide content in the various common cassava cultivars available in Rivers State, Nigeria; and thereby probably serve

Table 4. Processing methods, cyanide contents and fundoscopic findings in the experimental Wistar albino rats.

Samples	mg CN^-/kg dry weight of cassava	FAO/WHO recommended level (mg CN^-/kg dry weight of cassava)	Percentage Exceeded FOA/WHO Recommendation (%)	Mean Significant Fundoscopic Findings in the Optic Nerve Head of each grp (Pre-Experiment)	Mean Significant Fundoscopic Findings in the Optic Nerve Head of each grp (post-Experiment)
Raw Cassava	2486.39		148.6		
24-hour Fermentation without Red Palm Oil	2386.65		138.7	Normal Disc	-Swollen Disc -Temporal Disc Pallor -Peripapillary haemorrhages
24-hour Fermentation with Red Palm Oil	1791.8	15 - 1000	79.2	Normal Disc	Mild papilledema
48-hour Fermentation without Red Palm Oil	1204.07		20.4	Normal Disc	-Mild papilledema -Temporal Disc Pallor
48-hour Fermentation with Red Palm Oil	1034.81		3.5	Normal Disc	Normal Disc findings
Control Group fed with "Grower Mash" for 60 days	Nil		Nil	Normal Disc findings	Normal Disc findings

Pearson Chi-Square value = 188.672, p-value = 0.000.

as a transitional study into clinical practice especially in the field of neuro-ophthalmology. Moreover, there are diverse methods of processing cassava roots for human consumption in Rivers State. The cyanide content in the various samples of cassava species were determined (**Figure 1**) and the highest cyanide content (2336.79 mg CN^-/kg dry weight of cassava) species was used to fed the rats in varying pre-determined concentrations relative to their weights. The results of the cyanide contents of the various raw cassava cultivars are depicted in **Table 1**. The cassava cultivar with 2386 mg CN^-/kg dry weight content exceeded the FAO/WHO recommended level by 133% (recommended content = 15 - 1000 mg CN^-/kg dry weight of cassava) [7]. This study sets out to show the impact of high cyanide in cassava roots and its various processing methods on the optic nerve integrity.

Cyanide is a potent and rapidly-acting asphyxiant which prevents tissue utilization of oxygen by inhibition of the cellular respiratory enzyme, cytochrome oxidase [9]. Cyanide exerts its toxic effects by binding to the ferric ion of cytochrome oxidase, an enzyme that accounts for about 90 percent of the total oxygen uptake in most cells via the electronic transport chain thereby inhibiting the electron transport chain and mitochondrial function, resulting in disruption of Adenosine Triphosphate (ATP) production and ultimately impairing the ATP-dependent axonal transport system in the optic nerve, leading to their ischemia, death and eventual atrophy [10]. The incidence of nutritional neuropathy from cyanide toxicity depends on the methods of processing, the amount of cyanide contained in the raw cassava tubers made into the different products consumed by human population [1] [11].

In this study, 24 Wistar Albino rats (3 rats per group of 8) with a control group of 3 rats were fed with the determined cyanide content for 30-days and 60-days. The control group (sub group) was fed on normal rat-feeds "Growers Mash". The individual weight and mean group weight of all the animals in the experimental group at the beginning of the experiment was 68.5gm and at the end of the experiment was 74.5 grams. There was a general decrease in the weight of the animals on the on the third and fourth weeks. This observed difference was not statistically significant ($p = 0.092$). This decline in weight could be as a result of the introduced new diet or as a result of cyanide poisoning or both. However, unlike the weight of the rats in the control group whose individual and group mean weight steadily increased from the first week to 9th week of the study (**Table 2**, **Figure 2** & **Figure 3**). Our observation in this study, compares well with the study by Blanc *et al.*, in 1985 who reported weight loss of 8% due to loss of appetite in about 50% of workers exposed to 15 ppm hydrogen cyanide (for an unspecified duration in a silver-reclaiming facility). Decreased body weight was also reported in rats exposed to 25 ppm cyanogen (12.5 ppm cyanide) 6 hours/day, 5 days/week for 6 months [12].

The processing methods influenced the reduction of the cyanide contents in this study. The highest reduction was observed with 48-hour fermentation with red palm oil (58.4%) and the least reduction in cyanide content was with

24-hour fermentation without red palm oil additive (4.2%) (Table 3). This observed difference in the reduction of cyanide content with various processing methods was statistically significant (p = 0.000).

In the tropics, cassava root deteriorates in air within a few days and it cyanogenic contents are lowered, the longer it stays, therefore, the higher is the reduction in its cyanide content [13]. Some processing methods remove nearly all the cyanogens [14], but others leave large amounts behind in the flour [1] [15].

The simplest process, called sun drying, involves peeling the root and drying in the sun. It is then ground up in a wooden pestle and mortar and sieved to produce white cassava flour. This removes two-thirds to three-quarters of the cyanide [1] [14].

In another method, called heap fermentation, a small heap of peeled cassava roots is left in the shade for 3 - 5 days, allowing fermentation inside the heap. The roots are then sun dried, pounded and sieved, producing a white grey flour. This method removes twice as much cyanogen as sun drying and is used by women processors in northern Mozambique when cyanide levels are high during drought [15].

However, although an improvement over sun drying, heap fermentation still leaves unacceptably high levels of cyanogen in the flour especially during drought, and does not stop the occurrence of konzo in eastern, southern and central Africa [15]. In West Africa the major processed cassava product is garri. To make garri the peeled root is ground up using a mechanical grinder and placed in a hessian bag for 2 - 3 days; there is extensive hydrolysis of linamarin to hydrogen cyanide catalysed by linamarase as well as lactic fermentation, which reduces the pH to about 4 (Joint FAO/WHO Food Standards Programme 1991) [7].

Excess water is squeezed out in a press and the product is roasted by heating over a wood fire in a metal pan with continuous stirring, which removes HCN and water and produces garri. The total cyanide content of gari is in the range 0 - 40 ppm, with an average of 20 ppm, 43 - 45 which is still twice the WHO safe level of 10 ppm (Joint FAO/WHO Food Standards Programme 1991) [7].

There are no reports of the occurrence of konzo in West Africa west of Cameroon, which is consistent with the assessment that konzo occurs after very high cyanide intake over a relatively short period. By contrast, TAN (or a similar syndrome) has been reported from West Africa (especially Nigeria), Tanzania, Uganda, Kenya, the West Indies and various parts of tropical Asia, amongst mainly older poor people who have consumed cyanide from cassava (mainly garri) over many years [16].

Optic nerve toxicity

Neurologic toxicity following cyanide ingestions differs depending on length of exposure, the amount ingested and the rate at which treatment is administered [17]. The central nervous system is usually the primary target of orally administered cyanide in animals. Tremors, convulsions, recumbency, and lethargy were observed in rats exposed to 7.8 mg CN^-/kg/day as potassium silver cyanide for 90 days by gavage [18]. Consumption of cassava and cassava products con-

taining large amounts of cyanide can cause acute intoxication, with symptoms of dizziness, headache, nausea, vomiting, stomach pains, diarrhea and sometimes death [19] [20].

Tropical ataxic neuropathy (TAN), causing instability in balance, loss of sensation in hands, loss of vision, deafness and weakness could occur in humans (especially among the elderly people who have consumed a monotonous cassava diet over years) [1].

In our findings, the rats in the control group (fed with "Growers Mash" for 60 days) and the rats in sub-groups 5, 6, 7 & 8 (fed with 48-hour fermented cassava) had normal optic disc findings on fundoscopy pre-, intra- and post-experimental duration. Rats treated with 24-hour fermented cassava (sub-groups 1, 2, 3 & 4) had varying degrees of optic neuropathies, worse with the rats that had 24-hour fermented cassava twice daily for 60 days. The intra and inter group differences in the optic disc changes was statistically significant ($p = 0.000$). There was no case of any death among the animals in this study. Our findings in this work are in tandem with the study of van Heijst *et al*., who reported that various degrees of optic neuritis and atrophy were noted in 20 West Africans that ingested cassava over an unspecified period [21].

6. Conclusion

Longer duration of processing cassava roots into garri for human consumption reduces its cyanide content and minimizes the adverse impact on the optic nerve with possible consequent visual impairment/loss from nutritional toxic optic neuropathy. Policy-makers, food processing industries and the public should therefore, be educated appropriately on the best way to process cassava into garri for human consumption.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Mlingi, N.L.V. and Bainbridge, Z. (1994) Reduction of Cyanogen Levels during Sun-Drying of Cassava in Tanzania. *Acta Horticulturae*, **375**, 233-239. https://doi.org/10.17660/ActaHortic.1994.375.23

[2] Reade, M.C., Davies, S.R., Morley, P.T., Dennett, J. and Jacobs, I.C., (2012) Management of Cyanide Poisoning. *Emergency Medicine Australasia*, **24**, 225-238. https://doi.org/10.1111/j.1742-6723.2012.01538.x

[3] Fukushima, A.R., Nicoletti, M.A., Rodrigues, A.J., Pressutti, C., Almeida, J., Brandão,

T., Ito, R.K., Leoni, A.B. and De Souza Spinosa, H. (2016) Cassava Flour: Quantification of Cyanide Content. *Food and Nutrition Sciences*, **7**, 592-599. https://doi.org/10.4236/fns.2016.77060

[4] World Health Organization and Food and Agriculture Organization of the United Nations (1992) Evaluation of Certain Food Additives and Naturally Occurring Toxicants: Thirty-Ninth Report of the Joint FAO/WHO Expert Committee on Food Additives. World Health Organization, Geneva.

[5] Pedro-Egbe, C.N., Cookey, S.A.H., Awoyesuku, E.A. and Ani N. (2011) Non-Glaucomatous Optic Neuropathies in Port Harcourt. *Clinical Ophthalmology*, **5**, 1447-1450. https://doi.org/10.2147/OPTH.S24934

[6] FAOSTAT. Food and Agriculture Organization of the United Nations (FAO). http://faostat.fao.org/site/345/default.aspx

[7] FAO/WHO (1991) Joint FAO/WHO Food Standards Programme. Codex Alimentarius Commission XII, Supplement 4. FAO, Rome.

[8] Onwuka, G.I. (2005) Food Analysis and Instrumentation. Theory and Practice. Napthali Prints, Lagos, 140-146.

[9] WHO (2004) Hydrogen Cyanide and Cyanides: Human Health Aspects. World Health Organization, Geneva, 1-67.

[10] Blanc, P., Hogan, M. and Mallin, K. (1985) Cyanide Intoxication among Silver-Reclaiming Workers. *Journal of the American Medical Association*, **253**, 367-371. https://doi.org/10.1001/jama.1985.03350270065023

[11] Johnson, O.R., Pleasant, O.N., Oloruntoba, A.C. and Grace Iyabo, A.-G. (2013) Evaluation of Cyanogen Contents of Cassava and Cassava Based Food Products in Karu, Nasarawa State, North Central Nigeria. *IOSR Journal of Environmental Science, Toxicology and Food Technology*, **6**, 47-50. https://doi.org/10.9790/2402-0614750

[12] Lewis, T.R., Anger, W.K. and Te Vault, R.K. (1984) Toxicity Evaluation of Sub-Chronic Exposures to Cyanogen in Monkeys and Rats. *Journal of Environmental Pathology, Toxicology, and Oncology*, **5**, 151-163.

[13] Padmaja, G. and Steinkraus, K.H. (1995) Cyanide Detoxification in Cassava for Food and Feed Uses. *Critical Reviews in Food Science and Nutrition*, **35**, 299-339. https://doi.org/10.1080/10408399509527703

[14] Nambisan, B. and Sundaresan, S. (1985) Effect of Processing on the Cyanoglucoside Content of Cassava. *Journal of the Science of Food and Agriculture*, **36**, 1197-1203. https://doi.org/10.1002/jsfa.2740361126

[15] Cardoso, A.P., Mirione, E., Ernesto, M., Massaza, F., Cliff, J. and Haque, M.R. (2005) Processing of Cassava Roots to Remove Cyanogens. *Journal of Food Composition and Analysis*, **18**, 451-460. https://doi.org/10.1016/j.jfca.2004.04.002

[16] Osuntokun, B.O. (1994) Chronic Cyanide Intoxication of Dietary Origin and a Degenerative Neuropathy in Nigerians. *Acta Horticulturae*, **375**, 311-321. https://doi.org/10.17660/ActaHortic.1994.375.31

[17] Chen, K.K. and Rose, C.L. (1952) Nitrite and Thiosulfate Therapy in Cyanide Poisoning. *Journal of the American Medical Association*, **149**, 113-119. https://doi.org/10.1001/jama.1952.02930190015004

[18] Gerhart, J.M. (1987) Ninety-Day Oral Toxicity Study of Copper Silver Cyanide [$KAg(CN)^2$] in Sprague Dawley Rats. IITRI Project No. L06183, Study No 4. The Dynamac Corporation, Chicago.

[19] Mlingi, N., Poulter, N.H. and Rosling, H. (1992) An Outbreak of Acute Intoxications from Consumption of Insufficiently Processed Cassava in Tanzania. *Nutrition*

Research, **12**, 677-687. https://doi.org/10.1016/S0271-5317(05)80565-2

[20] Akintonwa, A., Tunwashe, O. and Onifade, A. (1994) Fatal and Nonfatal Acute Poisoning Attributed to Cassava-Based Meal. *Acta Horticulturae*, **375**, 285-288. https://doi.org/10.17660/ActaHortic.1994.375.28

[21] van Heijst, A.N., Maes, R.A. and Mtanda, A.T. (1994) Chronic Cyanide Poisoning in Relation to Blindness and Tropical Neuropathy. *Journal of Toxicology*: *Clinical Toxicology*, **32**, 549-556. https://doi.org/10.3109/15563659409011059