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MANIHOT UTILISSIMA AND THE CHALLENGES AND IMPLICATIONS OF NUTRITIONAL TOXICITY TOWARDS NIGERIA AGRICULTURAL REVOLUTION

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ABSTRACT

The challenges and implications of nutritional toxicity which *Manihot utilissima* can pose on human health is the aim of this study. The production and utilization of M. utilissima as demonstrated in the sustained presidential initiative on M. utilissima production, processing and export is one of the most striking current issues in Nigeria national life. Based on this, the agricultural sector therefore, has become more attractive to a large number of Nigeria population hence the need to appropriately place within reach the knowledge of toxicity challenges associated with it. Generally, plants are chemical industries. They possess a plethora of chemicals that are toxic to animals and man, which inherently, they depend on to ward off predators. This is not at variance with M. utilissima. The principal toxic agent of M. utilissima is called linamarin. This is a cyanogenic glycoside and often coexists with its methyl homologue referred to as lotaustralin or methyl-linamarin. When linamarin interacts with an enzyme β-glucosidase (linamarase), it is converted to hydrocyanic acid (HCN). The enzyme is usually released when the cells of M. utilissima roots are ruptured. Many health disorders have been implicated with the toxic tendencies of M. utilissima. It has been confirmed for instance, in the pathological condition of acute cyanide intoxication as well as in goiter. HCN is detoxicated in the body in the presence of the enzyme rhodanase, to throcyanate (SCN) which

is a sulphur-containing compound with goitrogenic properties. There exist also, evidence linking tropical ataxic neuropathy and epidemic spastic paraparesis – two types of paralysis, to the combined effects of high cyanide and low sulphur intake. In these two unfortunate diseases, the spinal cord damage leads to paralysis. In the etiology of tropical diabetes, the role of cyanide toxicity has been established. This is also true in congenital malformation. Upon ingesting of huge amount of poorly processed high-cynogens M. utilissima, fatal poisoning becomes inevitable. However, the possibility of reducing or outrightly eliminating toxic effects from M. utilissima, even if poorly processed is there, if copious protein intake represents more than adequate for general metabolism and elimination by cyanide. By implication therefore, the lack of protein in M. utilissima roots accounts probably for most less-fatal incidences of cyanide poisoning that are associated with M. utilissima. The best prevention from M. utilissima toxicity remains proper processing to eliminate the toxic substances.

KEYWORDS: *Manihot utilissima*, cassava, nutritional toxicity, challenges, Nigerian agricultural revolution.

INTRODUCTION

Paradoxically, numerous toxic components from plants have fascinating medicinal value, though overdoses can be harmful and even kill.[1] A plant is considered harmful and poisonous if it causes chemical injury to a person who wittingly or unwittingly touches or swallows or even breathes its aroma.[2] In preponderance of cases, the poisonous substances are merely waste or by-products associated with the essential functions of the plant. Morphine from poppies and digitalis from foxgloves are classical examples.[3] M. utilissima is the scientific name of cassava. It belongs to the family of Euphorbiaceae with various common names such as tapioca, yucca, and manioc. Cassava is native to South America notably Brazil and Paraguay and probably brought into Africa by the Portuguese in the 16th century.[4] Hitherto, cassava known for nothing else but garri, tapioca, fufu and may be starch has turned out to be a source for making Nigeria nation and her citizens rich, courtesy of presidential initiative on cassava. Cassava has virtually turned to gold in Nigeria. This assertion is not a figurative statement nor based on abstract consideration but purely on analysis of historical and economic antecedence. In line with the Nigeria presidential Committee on cassava initiative, trade promotion policy, the Federal Government has created a very strong domestic demand and market, which consequently affected positively on the

stakeholders.[5] By any standard, so strong is cassava opportunities that it is one of the best thing, next only to the discovery of crude oil, to happen to Nigeria.

Presidential Initiative and Agencies on Cassava Project

The Federal government of Nigeria in her determined effort to ensure the success of the cassava initiative enlisted organizations and agencies to collaborate on the cassava project. These include:

- Federal Ministry of Agricultural and Rural development
- Federal Ministry of Industry and its Commerce counterpart
- International Institute of Tropical Agricultural, Ibadan
- National Special Programme for food security
- Post harvest unit, Food and Agriculture Organization (FAO)
- Raw Materials Research and Development Council
- Federal Institute of Industrial Research, Oshodi
- National Root Crops Research Institute, Umudike
- Nigeria Stored Product Research Institute, Ilorin (NSPRI)
- Root and Tuber Expansion Programme (RTEP)
- Flour Milling Association (FMA)
- Master Bakers Association (MBA)
- Standard Organization of Nigeria (SON)
- National Agency for Food and Drug Administration and Control (NAFDAC)
- Cassava Growers Association of Nigeria (CGAN)
- Cassava Processors Association of Nigeria (CAPAN)
- Cassava Equipment Fabricator Association of Nigeria (CEFAN)
- Small and Medium Enterprise Development Agency
- Nigerian Association of Small and Medium Enterprise
- Nigerian Association of Small Scale Industrialists (NASSI)
- State Ministries of Agriculture
- State Agricultural Development Programme (ADP)

Classification and Quality Criteria of Cassava

In line with the design of this report, cassava may be classified into two main types based on the cyanide concentration.

a. Sweet cassava with cyanide content less than 50 mg/kg fresh weight.

b. Bitter cassava with cyanide content more than 50 mg/kg fresh weight.[6]

The Canadian Food Safety Network stipulated that at HCN concentrations < 50 ppm, the cassava products are considered harmless.[6] Other sources have suggested different minimal levels for toxicity. Rosling for instance, suggested that intake of over 20 mg/100g of cassava is toxic.[7] Another source recognized the toxic HCN level at 50 – 60 mg daily for European adults[8], which it was opined that the minimal lethal HCN dose in humans is 35 mg.[9]

The verdict of Chinese officials who came on a return visit to Nigeria following an earlier market assessment mission to China embarked by the then Minister for commerce, Ambassador Idris Waziri in 2004 was "Nigeria Cassava has superior quality". The universal quality criteria for cassava root demand the following:

- About 300 g and above in weight and not less than 20 cm in length.
- Wholesome, not affected by rot. mould or deterioration.
- Practically free from mechanical damage and bruising
- Practically free of pests; and of course,
- Free of any foreign smell and/or taste, which our cassava varieties possess.

The Chinese officials took Nigeria Cassava samples, analyzed them and upon comparison with what they got from some Asian countries discovered and confirmed that it was better, mainly because Nigerian variety possess higher starch content with better quality in terms of colour, as well as the moisture content being lower than others.

Values, Opportunities, and Market for Cassava

The nutritional value of cassava is commendable. It is estimated that worldwide 400 million people consume cassava predominantly in Africa, India and Southeast Asia, South and Central America, a majority of which are African residence.[10,9] The leaves and tubers are used as sources of food. While the later provides a valuable source of carbohydrate, the former gives protein. Cassava tubers are rich in CHO predominantly starch hence a major source of energy, even, it is considered the highest source of carbohydrate with the exception of cane sugar.[11] The starch content of fresh cassava tubers is about 30%, however, are deficient in fat, protein and some minerals and vitamins. According to FAO, UN, after rice and corn, cassava is the third most important source of calories in the tropics.[12] However, he nutritional value is less than that of cereals, legumes and some other roots such as yam. The cassava leaves as a source of protein contains 8-10% protein but lacks the essential amino

acid, **methionine**; contains the highest concentration of cyanogenic glycosides than all other parts of the plant so for this reason only the young leaves are eaten but certainly after boiling. The opportunity which cassava offers in Nigeria is boundless. As far back as 2005, the Chinese order for a supply of five million metric tons of cassava chips translated into ₦5.6 billion annual income is of course, a good news for any cassava stakeholder. The cassava story is getting better on daily basis. It is a common knowledge that no aspect of cassava can be regarded as waste. Be it the leaves, the stem, the peel, and the tuber itself, there is always a ready commercial use for everything that comes out of cassava. As recorded by International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria, recognizing that 70 – 120% million population are into agriculture, the statistics of people that are engrossed into cassava production on 2005 alone is about 26,000.[13]

Cassava has a huge market both locally and internationally. The policy of the Federal Government of Nigeria for instance, on making composite bread flour mandatory has created an unprecedented ₦28 billion market for the product annually in the country. This estimated figure or size of the market for Nigeria alone is arrived at by simply multiplying 400,000 tons by ₦70,000. To ensure compliance to this directive SON and NAFDAC have the mandate of closing down defaulting flourmills and bakeries nationwide. Composite bread flour is a combination of 10 % High quality unfermented cassava flour (HQCF) with 90 % wheat flour. Among the benefits of this fantastic policy in Nigeria are

- ₦20 billion will be saved from expenditure on importation of wheat.
- And additional market for 1.2 million tons of fresh cassava annually will be created
- The dreaded cassava glut will be prevented and it will spur more production
- Private sector participation in form of establishment of modern cassava flour processing factories etc will be ensured cutting across all levels of players; micro, small, medium, and large scales.
- Thousands of jobs will concomitantly be created across the country.

There are many other industrial users of cassava who are even bigger than the bread industry, favouring the huge market for cassava. Among the industries using the product are:

- Pharmaccutical industries
- Flour mills
- Biscuits and confectionaries
- Plywood manufacturers

- Glue and Adhesive manufacturers, and of course, - Ethanol distilleries. It has become imperative that the world will have to develop alternatives, such as a shift from a hydrocarbon – based economy to a carbohydrate – based economy.

Cassava fills this need. Nigeria-made renewable cassava-based fuel, ethanol, will directly displace the amount of petrol and kerosene we need to import, offering our country the needed independence and security from foreign sources of energy. Cassava is the cheapest feedstock for ethanol production. It is cheaper than sugar, molasses and maize, which is the key feedstock currently in use. Therefore, ethanol production and use increases the demand for and of course, the price for cassava.

Toxicity of Cassava

The principal toxic agent of the cassava plant is called Linamarin.

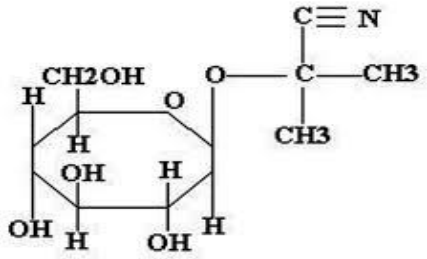

Fig. 1: Linamarin in *Manihot spp.*

It often coexists with methyl homologue called lotaustralin or methyl linamarin.

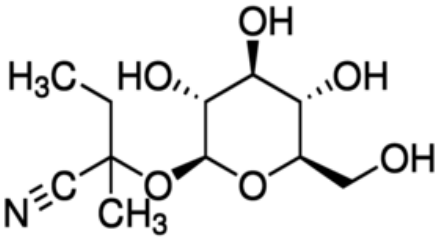

Fig. 2: Lotaustralin from *Manihot spp.*

Over 50 stable cyanogenic glycosides have been isolated from a similar number of plant species, several of which are used by humans for food [14]. Despite the fact that other food substance like sweet potato, yam, maize, bamboo, chickpea and sorghum are able to liberate HCN, documented causes of acute cyanide toxicity are linked to cassava and lima beans.[9]

Linamarin $\xrightarrow[\text{hydrolysis}]{\text{linamarase}}$ β-D-glucopyranose + acetone cyanohydrins (2– hydroxyisobutyronitrile)

Cyanohydrin $\xrightarrow[\text{Dissociation}]{\text{hydroxynitrile}}$ HCN (hydrocyanic acid or prussic acid)

Hydrocyanic acid (HCN) is a volatile compound and evaporates rapidly in the air at temperature over 28^{o}C, and dissolves readily in water. Loss can be experienced during transport, storage and analysis of specimens.

The normal range of cyanogens content of cassava tubers falls within 15-400mg HCN/Kg fresh weight.[15] The concentration of cyanogenic glycoside increases from centre of the tuber outwards. This explains why the cyanide content is substantially higher in the cassava peel. Concentration however, varies greatly between varieties and also with environmental and cultural conditions. All the same it should be noted that bitterness is not a reliable indicator of cyanide content but laboratory analysis.

Pathophysiology of Cyanide Intoxication

HCN + Sulfane sulpur Rhodanase thiocyanate (SCN)

Detoxification

Thiocyanate (SCN) is sulphur-containing compound with goitrogenic properties. Rhodanase (thiosulphate cyanide sulphur transferase) is present in most human tissues. Mecaptopyruvate cyanide sulphur transferase, which is present in red blood cells, is another enzyme that catalyze the reaction but to a lesser extent.[16] Thiosulphate and 3-mercaptopyruvate, derived mainly from cysteine, cystine (dicystcine, cys-cys) and methionine (the sulphur-containing amino acids, SAA) are essential substrates for conversion of HCN to SCN. Vitamin B_{12} has been reported to increase the urinary excretion of SCN in experimental animals given small doses of cyanide.[17] About 60 – 100% of the injected cyanide in the toxic concentration is converted to SCN within 20 hours. And enzymatic conversion accounts for more than 80% of cyanide detoxificationh.[18] In normal health situation, a dynamic equilibrium between HCN and SCN is maintained. A low protein diet particularly one that is deficient in sulfur-containing amino acids (SAA) may decrease the detoxification capacity and thus make a person more vulnerable to the toxic effect of cyanide.[19] Thiocyanate (SCN) is widely distributed throughout body fluids including saliva, in which it can readily be detected. Therefore, excessive intake of cassava especially as the sole source of dietary energy and main source of protein is an invitation to increased vulnerability to cyanide toxicity.

Protein link with cassava intake

Protein is essential for all the body's vital functions as well as for elimination of certain dietary toxins. The link between protein and cassava intake stems from the observation that whenever a chronic disease has been associated with cassava consumption, the victims have also been found to suffer from protein deficiency. The human body is naturally designed to detoxify cyanide by forming thiocyanide with the help of the enzyme rhodanase. But when the body is regularly exposed to cassava cyanogens, it requires an increased synthesis of rhodanase, which subsequently makes extra demands on the body's reserves of amino acids, the building blocks of proteins. For instance, to detoxify 1.0 mg HCN, the body also needs a daily supply of about 1.2 mg of dietary sulphur from SAA. As in the regular consumption of cassava where demand for rhodanase and SAA is prolonged yet the diet is inadequate, the consequence is that the synthesis of many proteins vital for bodily functions can be impaired, leading to the development of protein deficiency diseases or disorders.[20] The position of Padmaja is that cyanogens alone cannot be blamed for cassava toxicity because other cyanogenic crops like sorghum and lathyrus bean, which are consumed widely as food cause few toxicity.[20] But the fact remains that their protein contents, 11.0% and 18.7% respectively, are higher. To support this argument, Agbidye in experimental studies on cassava dependency, observed a positive linear relationship between blood cyanide and plasma cyanate in animals on SAA – free diet exposed to KCN through drinking water, but not in animals on balanced diet with adequate amount of cysteine and methionine. This led him to conclude that in SAA (cysteine and methionine) – deficient state, cyanide is converted to cyanate, a well known neurotoxic moiety.[5]

Disorders Associated with Cassava Toxicity

It is an established fact that cassava has a causative role in the pathological condition of acute cyanide intoxication and goiter. Also evidences exist linking two types of paralysis – tropical ataxic neuropathy and epidemic spastic paraparesis, to the combined outcome of a high cyanide and low sulphur (usually from SAA) intake.[21] What has not been established yet is the role of cyanide toxicity in the causation of tropical diabetes, and in congenital malformation. In the same vein, its supposed beneficial effects on sickle cell anaemia, schistosomiasis and malignancies are still at hypothetical stage.

Acute Cyanide Intoxication

This results from intake of raw or insufficiently processed cassava. The HCN is rapidly absorbed from the GIT. The mode of action is inhibition of cytochrome oxidase, an important enzyme in energy generation for the brain.[22,7] It produces recognizable effects in both fatal (0.5 – 3.5 mg / kg) and non-fatal dosages. Between 4 to 8 hours after ingestion symptoms which include vomiting, vertigo, and coma appear. In some cases this leads to death within 1 or 2 hour, with the possibility of concomitant brain damage expressed in the form of decayed – onset parkinsonism or dystonia among survivors for the 'bitter' variety. Intervention is quite effective and cheap, - increase the detoxicating capacity of the patient by administrating an IV injection of thiosulphate. This makes more sulphur available for conversion of HCN to SCN.

Endemic Goitre

SCN has the same molecular size as iodine and as such inhibit iodine by the thyroid gland.[23] The danger is that under conditions of high ingestion of poorly processed cassava, there is a tendency for chronic cyanide overloading leading to a high level of serum SCN of 1-3 mg/ 100ml as against the normal level of about 0.2 mg/100 ml. In such situations, there is an increased excretion of iodine and a reduced iodine uptake by the thyroid gland, resulting in a low SCN / Iodine ratio. Three seems to be the value of the threshold level of this ratio below which endemic goiter develops.[24] This tendency occurs only when the iodine intake is below about 100 mg/day. Indicating that at higher serum levels of SCN, i.e. SCN / iodine ratios of less than two, there exist abnormal level of thyrotropin stimulating hormone (TSH), which subsequently inhibit the formation of thyroxine (T_4) and related compounds, with a risk of endemic cretinism.[25] Cretinism is a condition characterized by severe mental retardation and severe neurologic abnormalities. Goiter was endemic in Eastern Nigeria in the 1960s when dry, unfermented cassava was a major component of the diet. But when iodine supplements are given usually, by adding potassium iodide (KI) to local supplies of salt, the incidence of goiter reduced in spite of a continued high intake of cassava products. And where salt intake remains small, iodized oil, given orally, provided protection for one or two years.

Neurologic disorders

Cassava consumption is recognized to be associated with neurodegenerative disease in adults so its effect on the nervous system is a major concern. But there is a consolation that this disease condition appears to be restricted to population that have poor protein diets associated

with heavy or exclusive cassava dependent.[9] Tropical Ataxia Neuropathy (TAN) and Epidemic spastic paraparsis are two forms of nutritional neuropathics in which cyanide intake from cassava-dominated diet has been proposed as a contributing factor[26],[27] TAN is the name given by Osuntokun to a neurological disorder found in rural population of Nigeria[26], where heavy cassava is consumed without the inclusion of sufficient protein-rich food supplement to take care of adequate supply of SAA for the detoxification of ingested cyanide. And the clinical manifestations include damage to one of the sensory tracts in the spinal cord resulting in an uncoordinated gait called ataxia; and increase in plasma SCN levels. The interventional measure is nutritional not medicinal. On admission, patients are subjected to highly nutritional diet, which includes cassava twice a week only. This leads to a return of plasma SCN level to normally within a short period, and the patients recover. Evidence shows that on discharge, they go back to their traditional cassava diet and so the condition reappears.[21] Epidemic spastic paraparesis is symmetrical, and the damage to the upper motor neuron is permanent but not progressive unlike TAN.[27],[28] Affected persons are unable to walk being left with a persistent crippling disease[9]; this is a situation emanating from depending on very toxic varieties of cassava as a food security crop.[27]

Tropical Diabetes Mellitus and Malignancy

There is a great possibility that cyanogenic glycosides enter and destroy B–islet cells. The principal metabolite of HCN which is SCN, is a particularly effective catalyst for the formation of carcinogenic nitrosamines through the action of sodium nitrite on a secondary amine.[29]

Cassava detoxification

Cyanide occurs in cassava and cassava products both as linamarin itself, glucosidic form, non-glucosidic or bound form (cyanohydrins). And the traditional methods of processing cassava involving soaking, drying, and crushing, can reduce the cyanide content to non-toxic levels but may leave residual glycoside or cyanohydrins which can result in acute HCN intoxication when ingested. An efficient processing method will release the enzyme linamarase by disintegrating the microstructure of the cassava root, which under normal conditions of hydrolysis the linamarin is hydrolysed to cyanohydrins. Upon decomposition, cyanohydrins gives HCN and acetone. But under acid conditions of pH 4.0 or less (as in some lactic acid fermentations of cassava, the cyanohydrins decomposition is impeded and it becomes stable. Relatively, it is easy to get rid of free cyanide, which is present at about 10%

both in peeled and fresh cassava especially in solution. The story is not the same with bound cyanohydrins which hydrolyse very slowly and result in a lot of residual cyanide in cassava products. Cassava root which is known to contain 38 mg HCN / 100 mg is eaten in Nigeria.[26] as: Garri (1.1 mg HCN/100g); Purupuru (4-6mg HCN/100g) quantities up to 750 g/day, corresponding to 8 mg and 30-45 mg HCN respectively. Fufu properly fermented for at least 3 days and cooked contains about 1.2 mg/kg HCN while garri, mashed, fermented and pressed for at least 48hours and fried contains about 25.8 mg/kg HCN. Meuser and Smolnik (1980) did a better job at improving garri production by washing the mash after fermentation to remove residual bound cyanide, present as cyanohydrins because of its higher stability at the lower $_{P}H$[30] Sokari and Karibo (1992) also established that the highest reduction in the bound cyanide of >99% (from 89.0 to 0.6 ppm) occurred in grated cassava with 75% added water held at 50^{o}C.[31] There is also a report on the residual HCN in garri flour made from cassava. Odoemelam found that the principal factor is the length of fermentation. With 72 hours formation, the least HCN concentration of 3.8±1.6 µg/g dry matter was realized, while 24 h fermentation yielded as high as 24.8±1.2. Addition of palm oil, prior to fermentation and during roasting, was also found to reduce the HCN content to 0.62±0.13 µg/g, and 0.8±1.4 after 72 h fermentation respectively; after 24 h fermentation it was 14.2 ±0.3 and 14.7±0.9 respectively.[13]

CONCLUSION

The following conclusions can be drawn from the foregoing summary on toxicity challenges of cassava:

A. There is a need to increase public understanding of the true nature of cassava plant and its derivatives as they contain substances that are beneficial and others that are hazardous to health especially, as more people are attracted to the business following the presidential initiative on cassava.
B. Improper processing of cassava can lead to high residual cyanide level, which may cause acute cyanide intoxication, endemic goiter, or neurodegenerative disorders.
C. There is need to avoid channeling waste, drainages and affluent from factories to farm lands.
D. Effort should be geared towards developing new cassava varieties that are acyanogenic and/or have protein-rich roots via biotechnology.

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