Original Review Article

Food and Feed Potentials of Cassava: The Challenges of Prussic Acid in the Tubers

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Abstract

Cassava is one of the most productive crops in the globe and it is relatively drought-tolerant. The crop provides some yields even in periods of harsh environmental conditions. Prussic acid content in cassava hampers its utilization as food for man and as feed for livestock. Some cassava varieties have excellent qualities for consumers' acceptance and little cyanide content. Sweet varieties are pounded and eaten by man; *garri*, a product of cassava, is a staple for most tropical African countries such as Nigeria and Ghana. Cassava flour is utilized in making bread and cassava based infant food formulations. Terminal shoots of the crop are used as vegetable in soup. Starch which is an important industrial product derived from cassava is a major raw material for the production of glucose syrup. Adhesives, flour and ethanol are derived from cassava; chips and pellets which are obtained from cassava are valuable for livestock feeding. A significant contribution towards cassava utilization would be the provision of high yielding cassava varieties with low cyanide content made readily and cheaply available to farmers.

Keywords: Cassava starch, Cyanide in foods, Hydrocyanic acid, Prussic acid, Utilization challenges

Introduction

Cassava, which is one of the most productive crops in the world, is relatively drought- tolerant and grown mainly in Brazil, Indonesia, Congo, Nigeria and Uganda. Africa produces more cassava than any other continent of the world, and it is one of the staple foods of the people in tropical African countries such as Nigerian and Ghana. Cassava plays a vital role in toning down famine conditions in Africa by providing sustained food supply when other crops fail. However, the tubers, especially of unimproved varieties of the crop, are known to be high in hydrogen cyanide (also known as hydrocyanic acid or prussic acid), which is toxic to man and livestock in large dosed (Piero *et al.*, 2015). Notwithstanding the presence of hydrocyanic acid in cassava tubers coupled with its effects on cassava utilization, the crop still remains the single most important staple for most tropical African countries.

Traditionally, there are established methods of processing cassava which reduce the hydrogen cyanide content to a safe level. Piero *et al.* (2015) reported that cyanogenic glycosides are contained in all parts of cassava; the glycosides have to be removed through backbreaking processing before cassava can be safely consumed. Similarly, Tawanda *et al*. (2017) noted that cassava contains high levels of cyanogenic glycosides which protect it against being consumed by herbivorous animals. The objectives of this paper are to look at prussic acid, consider the implications of prussic acid in cassava and submit some potential approaches that could trim down the challenges of the presence of prussic acid in cassava and highlight the contemporary and potential utilization aspects of cassava.

Relationship Between Prussic Acid and Cyanogenic Glucosides

Prussic acid (HCN) is normally not present in plants. However, several common plants can accumulate large quantities of cyanogenic glycosides. When plant cells are damaged by wilting, frosting or stunting, the glycosides degrade to form free HCN. Conditions in the rumen of livestock also favour degradation of the glycosides to free HCN. Thus plants that contain the glycosides have the potential to cause HCN toxicity when consumed by ruminants (Whittier, 2014). Sudangrass and sorghum are two of a group of plants that produce cyanide, which can poison livestock under certain conditions. These plants, called cyanogenetic plants, produce cyanogenic glucosides during their growing stages. Glucosides are compounds that break down or decompose into glucose sugars by hydrolysis - addition of water. In cyanogenetic plants this decomposition process frees the cyanide from its chemical bond, and it becomes hydrocyanic acid, frequently called prussic acid. The intact, still-bonded cyanide and glucosides are not in themselves poisonous, but when certain enzymes are present, they are released, and become highly toxic to both man and animal (Vough, 1978).

The cassava tuber contains small but significant amount of the cynogenic glucosides, *limarin* and *lotaustralin*. Under the influence of the enzyme *linamarase* present in cassava plants, both glucosides are hydrolysed to produce hydrocyanic acid which is highly poisonous to humans and animals (Onwueme, 1978). Young plants and leaves of sudangrass and sorghum also contain the cyanogenic glucoside *dhurrin* (or *durrin*). Also present in these young plants and leaves is an enzyme called *emulsin*, which breaks down some of the harmless glucoside *dhurrin* to release the poison known as "prussic acid" or "hydrocyanic acid" (HCN). If plants are damaged by freezing, chewing or trampling, then *emulsin* easily frees larger quantities of the poison, hence the hazard (Vough, 1978).

Classification of Cassava Varieties Based on Glucoside Partitioning in the Plant

Cassava is a single species, *Manihot esculenta* Crantz, synonymous with *Manihot utilisima* Pohh. Erhabor and Emekaro (2007) noted that the two main varieties grown in Nigeria are *Manihot* *utilisima* and *Manihot palmata*. The species could be differentiated into bitter and sweet varieties depending on their cyanogenic acid content. Purseglove (1968) had earlier observed that the content of cyanogenic glucoside has been used to place cassava cultivars into two major groups: the bitter varieties, in which the glucoside is distributed all over the tuber and is at high concentration, and the sweet varieties, in which the glucoside is confined mainly to the peel and is low in concentration. The flesh of the sweet one is therefore relatively free of glucoside, although it still contains some.

Figure 1 shows two types of cassava cultivars: one with green petioles (A), another with red petioles (B) and one with green petiole growing side by side with red petiole type of cassava (C) as well as a ruminant found on the same farmland (D). All the leaf blades in the green petiole cassava cultivars were intact (Figures 1 (A) as well as the plant on the left hand side in Figure 1 (C), while some of the leaf blades in the reddish petiole cassava cultivar in Figure 1 (B) and the plant on the right hand side in Figure 1 (C) have no leaf blades. With prolonged stay in the farm, small ruminants such as the goat seen in the Figure selectively eat up the leaves of cassava cultivars with reddish leaf petioles leaving out the leaves with green petioles most probably because of higher levels of prussic acid in the green-petioled variety. Some cassava cultivars have green petioles while others have reddish-coloured petioles (Onwueme and Sinha (1991). In situations where green and red petiole cassava cultivars are growing side by side, the leaves of the red petiole cassava cultivars are selectively eaten-up leaving out the green petiole cassava as seen in Figure 1 (C). Tawanda *et al*. (2017) asserted that high concentration of cyanogenic glucosides in cassava act as protection against its being devoured by herbivorous animals.

Factors that Influence the Concentration of Prussic Acid in Cassava

Prussic acid content in cassava hampers its utilization. It is currently recognized that the high amount of hydrocyanic acid present in bitter cassava is poisonous to man and livestock mostly when used in the un-processed state. For instance plantain and yam can be eaten after simply frying, roasting or cooking, but this is not the case with cassava, especially with bitter cassava. Preparing cassava tubers as stated above for plantain or yam may lead to food poisoning. Soil characteristics, cassava variety, age of the crop at harvest as well as and length of storage and extent of processing affect the level of prussic acid in cassava.

Certain conditions involving climate, soil fertility, stage of growth, and anything that retards plant growth and development may increase cyanogenic glucosides content in the plant. A rapid re-growth following retardation favours the increase of glucosides. Wilting and frost injury may cause a rapid increase of hydrocyanic acid (prussic acid) in a plant that would otherwise have been non-toxic (Vough, 1978). Whittier (2014) equally noted in sorghums that many of the same factors that tend to cause nitrate accumulation – drought, reduced sunlight, excessive soil nitrogen, and young plants – also increase HCN potential. HCN potential is greater in leaves than in stems. Proper curing for hay or ensiling greatly reduces the potential for HCN poisoning. Lush re-growth in sorghums after cutting for hay, grazing or frost is often dangerous. Obiazi and Ojobor (2013) noted that cassava has high prussic acid content in the unprocessed state; and added that it is of great concern to nutritionists.

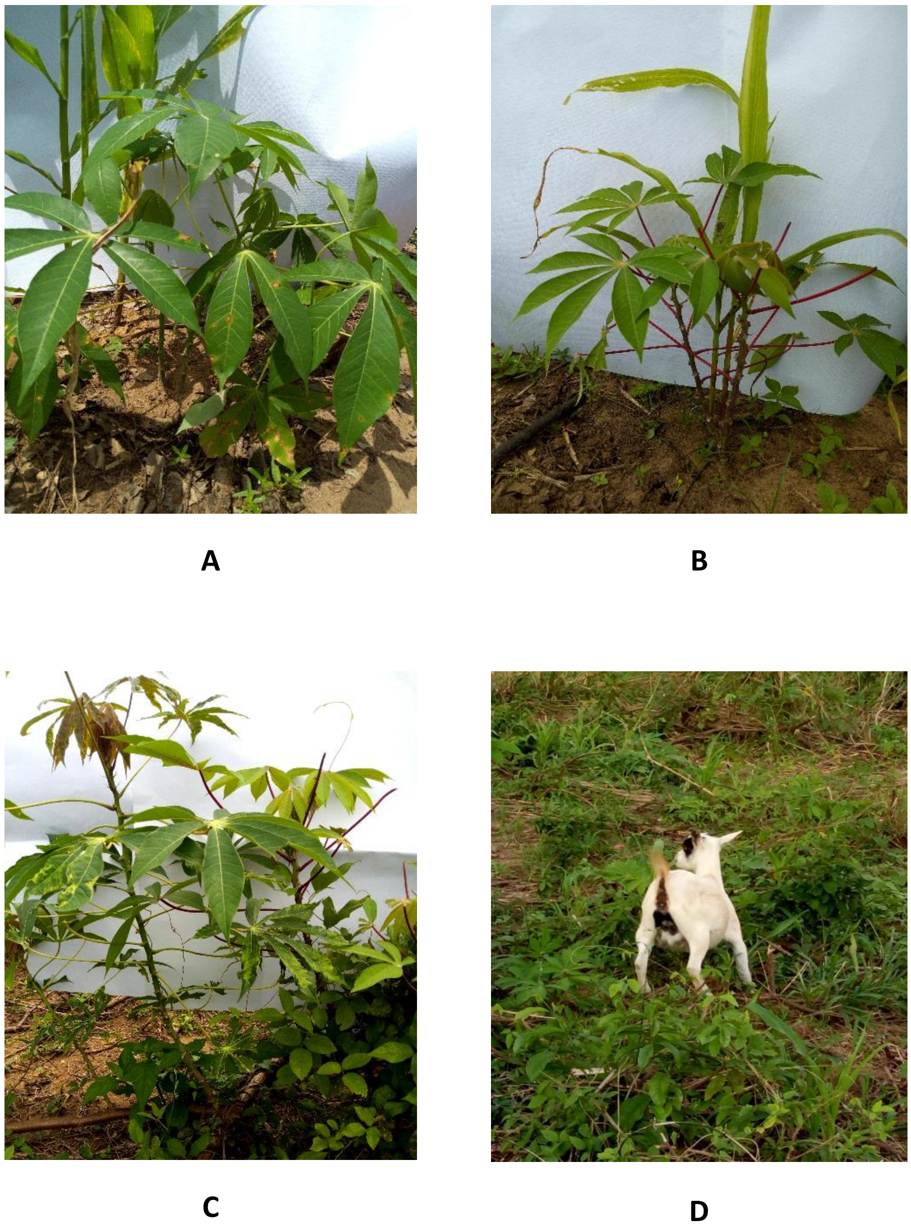

Figure 1. Cassava cultivars with green petioles (A); reddish petioles (B); green and reddish petioles near each other (C); herbivorous animal (goat) in the farm (D).

1. Soil characteristics

Cassava plant in a soil low in potassium or high in nitrogen has high prussic acid concentration in its tubers. In other words, plants tend to have more prussic acid if the soil is high in nitrogen and deficient in phosphorus and potash. An adequate supply of available phosphorus tends to decrease the prussic acid content (Vough, 1978). Cassava grown in wet regions has higher prussic acid content than that grown in drier regions (Sinha and Nair, 1968).

2. Cassava variety

Sweet cassava has less prussic acid than bitter cassava. Sweet cassava tends to have a short growing season, their tubers mature in 6 - 9 months, and deteriorates rapidly if not harvested soon after maturity. The bitter cassava on the other hand requires 12-18 months to mature, and will not deteriorate seriously if left un-harvested for several months thereafter (Onwueme, 1978). Sorghum is much higher than Sudan grass in prussic acid content, and, in general, it is unsafe for pasturing except after plants reach maturity and no new growth is present (Vough, 1978).

3. Age of the crop at harvest

When cassava is left un-harvested for more than about a year in the humid tropics, the tubers start to become woody, and starch content decreases (Williams *et al*., 1979). Leaf blades normally contain higher levels of prussic acid than leaf sheaths or stems. Tillers and branches have higher levels than older plants because they are mostly leaves with little stalk material present. Younger leaves contain more prussic acid than older leaves. The stalk content increases with age of sudangrass and sorghum, causing the prussic acid content in the total forage to decrease. It is to be noted that younger leaves have more prussic acid than older leaves (Vough, 1978).

4. Length of storage

Storage lessens cyanide concentration in *Garri*. *Garri* (also known as *Gari*) is a popular West African food made from cassava tubers. CIAT (1972) reported that fresh cassava roots can be stored for up to eight weeks in boxes containing moist sawdust. The storage is preceded by curing the tubers at 30 – 35^{0}C and 80 - 85% relative humidity. This is an expensive practice. Presently, cassava is stored as cassava floor and *Garri*; these two products stay for a long period of time before they deteriorate.

5. Extent of processing

As cassava gets older, the prussic acid content of the tuber increases, attains a peak, and then begins to decline (Sinha and Nair, 1968). But the exact age of the peak level of prussic acid concentration may vary with cultivar. The acid is lethal if more than 0.1g of it is contained in the food eaten by an individual at any one meal. Okafor (2004) noted that cyanide poisoning from cassava can only result when food preparation is carelessly done, or is almost non-existent and people begin to consume insufficiently processed foods.

Some residual glucosides remain in boiled tubers, and will release poisonous prussic acid after the tuber has been eaten. This is likely to be the reason why most people in some tropical countries hardly boil cassava, and eat it directly like is done in the case of plantain and yam. After undergoing some processing, the final cassava products still contain some prussic acid.

Despite the presence of hydrocyanic acid in cassava tuber, cassava still remains a staple food in some tropical countries in Africa like Nigeria.

Traditionally, there are established methods of processing cassava which reduce the hydrogen cyanide content to a safe level. Cassava tubers which have been processed into *fufu*, *elubo*, *opopogarri*, *bobozee* have minimal concentrations of hydrocyanic glucoside because the tuber has been processed to produce them. However, there still exist some utilization problems.

Garri is a product of cassava which is one of the staple of the people of Southern Nigeria (Uzomah *et al.* 2001). The cyanide content of *Garri* gives scientist some concern in terms of food safety for consumption. However, Uzomah *et al.* (2001) reported that all the samples taken from markets in a part of Nigeria for analysis complied with the regulatory standard of not more than 1% acidity as lactic acid.

Trimming Down the Challenges of Prussic Acid in Cassava Tubers

1. Soil characteristics

Since cassava growing in soils low in potassium or high in nitrogen has high prussic acid concentrations in their tubers according to Sinha and Nair (1968), enhancing the potassium level and minimising the level of nitrogen in the soil should reduce the level of prussic acid content in cassava. It is acknowledged that nitrogen is essential for appreciable growth and development of cassava, hence the need to ensure the availability of nitrogen. It is, however, advocated that soil nitrogen should be reduced close to the initiation of tuber formation in the crop.

The speculations just put forward find support in contemporary practice in pasture management. Whittier (2014) observed that sorghums fertilized heavily with nitrogen and stunted by drought or cool, cloudy weather should be suspected. Risk of poisoning from sorghums can be reduced by using a maximum of about 50 pounds of nitrogen per application.

Testing the prussic acid content in tubers before harvest is a good approach in the sense that the target will be the time when an appreciable yield level would have been attained without too much build-up of prussic acid in the tuber.

2. Cassava variety

By developing high-yielding cassava varieties, the International Institute of tropical Agriculture (IITA) and various national programmes have made it possible for cassava to be grown profitably by farmers in the tropics. IITA has also developed methods to utilize cassava in making bread with flour from cassava varieties which are particularly suitable for farming in Nigeria (Eggleston, 1991). Sorghums are generally much higher in prussic acid than sudangrass. As a group, sorghum-sudangrass hybrids also contain more prussic acid than sudangrasses. Some varieties, such as Piper and Trudan sudangrasses, tend to be lower in prussic acid than others. Growers should select varieties that tend to be lower in prussic acid potential (Vough, 1978).

An adequate supply of available phosphorus tends to decrease the prussic acid content in sudangrass according to Vough (1978), who also suggested that more detailed attention be given to phosphorus fertilizer application study in cassava which will ensure adequate phosphorus supply and detect if it significantly influences prussic acid content in cassava.

3. Age of cassava at harvest

In cassava, there is a relationship between the growth stage and the level of starch concentration in its tuber. Depending on the variety, the peak concentration is at a particular growth stage. Any period outside that point would record a lower level of starch concentration in the cassava tuber. There is need for elaborate research to establish the starch concentration curve both for starch and prussic acid in cassava tuber. As these two factors are being monitored in cassava tuber, that of the cassava yield should not be left out. Such findings will help farmers determine the right time to harvest cassava when it has appreciable yield as well as sufficiently low level of prussic acid for the safe use of the tubers for food and feeds.

4. Length of storage

Storage lessens cyanide concentration in *Garri*. Research is advocated for contemporary methods of storing cassava and cassava products which would be cost effective and ensure the retention of nutrition and safety qualities of the produce. It has earlier been stated that storage lessens cyanide concentration in *Garri*. It is therefore one of the ways of overcoming the challenges of cyanide in *Garri* so long as we are able to research on the least time duration when a significant cyanide concentration would have been removed due to storage, and recommend it for adoption.

5. Extent of processing

The hydrocyanic glucoside in bitter cassava varieties forms cyanide when the tubers are harvested or the tissues are damaged. It is only through processing that the cyanide content is reduced before the product becomes fit for human consumption.

Some cassava varieties combine low hydrocyanic acid content with high yield capacity in addition to early maturity. Such varieties include TMS 53101 for farmers in the western areas of Nigeria and 60 444 in the eastern areas of Nigeria, both of which are in the rainforest ecological zone. For the northern areas which are akin to the derived Guinea savannah and savannah ecological zones we have TMS 60 446 and 60506. TMS 30 555 and TMS 30 572 are high-yielding and have the ability to suppress weeds. The International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria has developed improved cassava varieties that are high yielding, resistant to diseases and insect pests, good in quality for customers' acceptance and low in hydrogen cyanide content. In Nigeria, the following have some of the above stated qualities: TMS 30 572, 30 555 30 339 and 30 001, and have been rapidly multiplied and distributed to many farmers through the National Accelerated Food Production Project (NAFPP), National Root Crops Research Institute, National Seed Service, State Ministries of Agriculture and private organizations. These improved varieties have been mass-adopted by farmers (IITA, 1983).

Some of the currently expensive and complicated processing phases in cassava utilization should be made cheaper and less expensive through sponsored researches and focused research inducements. Research findings from such undertakings need to be publicized for popular adoption, while the smallholder farmers or processors should be empowered through aids and encouragement to form cooperative associations.

Contemporary Uses of Cassava

Cassava is used as food for man, and feed for livestock and as a raw material for industries. Sweet varieties are cooked without processing and pounded and eaten by man; it takes deep knowledge and experience to be sure of the varieties that are known as sweet varieties because to erroneously use a bitter cassava variety for a sweet thereby cooking it and eating it without any level of processing may result in a bitter or a deadly experience. Instances abound where groups of people have been hospitalized after eating unprocessed cassava due to shortage of food. *Garri*, a product of cassava, is a staple for most tropical African countries, such as Nigeria and Ghana. Cassava flour is utilized in mixture with other materials in making bread and cassava-based infant food formulations. Chips and pellets are valuable for livestock feeding. Terminal shoots of the crop are employed in making vegetable soup. An important industrial product derived from cassava is starch which is a major raw material for the production of glucose syrup. Adhesives, flour, ethanol, chips and pellets are also derived from cassava. Adhesives are very handy in agricultural and domestic utilities. In agriculture, adhesives are used in joining irrigation pipes for the conveyance of water from water sources such as rivers, lakes or bore holes and for fixing irrigation pipes for water distribution on the farms.

One of the major constituents of cassava tuber is starch. It comprises about 20 - 30% of the wet tuber (Ihekoronye and Ngoddy, 1985). Starch is widely used in the food and pharmaceutical industries (Wallenstein, 1950).

Potential Uses of Cassava

Osuji and Anih (2011) recognised that cassava tuber can be used as raw material for the manufacture of various industrial products. Cassava based infant food formulations have been researched upon, Nwanekezi *et al*. (2001) discovered from their study that cassava based infant food formulations had the highest digestibility among the food formulations assessed and that rats fed with cassava based diets recorded the highest mean weight gain ($p < 0.05$) and concluded that high quality cheap infant weaning foods can be produced from the blends of either fermented yam (sprouted and un-sprouted) or cassava flours with soybeans flour. More nutritious quality cassava-soybeans infant food formulations can be produced by blending the soybeans flour with solid state fermented cassava flours rather than natural fermented cassava flours. Pandey (2003) noted that solid-state fermentation has emerged as a potential technology for the production of microbial products such as feed, fuel, food, industrial chemicals and pharmaceutical products. Its application in bioprocesses such as bioleaching, bio-beneficiation, bio-remediation, bio-pulping, etc. has offered several advantages.

Conclusion

Enhancing the potassium level and minimizing the level of nitrogen in the soil are likely to reduce the level of prussic acid content in cassava. A significant contribution towards cassava utilization would be the provisions of cassava varieties with low cyanide content which will be supplied to farmers readily and cheaply.

It is hoped that we shall be able to identify the appropriate growth stage for different varieties when an appreciable yield level would have been attained without significant buildup of prussic acid content in the tubers meant for food and feeds.

Governments in developing countries, especially in tropical Africa should start making research institutes and universities relevant in their bid to take off industrially. Whatever the setback in the baking of bread using cassava flour should be given as a research project to researchers. Cost of wheat is a challenge to bakers of bread mostly in the presence of the low exchange rate of the currencies of Africa countries. In the array of locally available materials, consideration could be made of a single crop produce such as cassava or a combination of materials derivable from local crops which can replace or supplement the use of wheat for bread making. Universities and research institutions have significant roles to play in addressing the challenges of cassava utilization so that humanity can tap into the vast potential usage of cassava as food, feed and raw material for industries. For example, it should be useful in providing the bulk of the raw material as flour required to bake bread which is cherished by most tropical country dwellers. Breeding of crop varieties with low cyanide content should be either initiated where such programmes have not commenced or invigorated where such activities have commenced in cassava and other crops such as maize (*Zea mays*) and Sorghum spp which have been found to contain significant levels of cyanogenic glucosides.

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