CODEX ALIMENTARIUS COMMISSION

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CODEX COMMITTEE ON CONTAMINANTS IN FOODS

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DISCUSSION PAPER ON LEVELS OF HYDROCYANIC ACID AND MYCOTOXIN CONTAMINATION IN CASSAVA AND CASSAVA PRODUCTS

(Prepared by the Electronic Working Group chaired by Nigeria and co-chaired by Ghana)

BACKGROUND

CCCF11 (2017)

1. CCCF11 considered a request from the FAO/WHO Coordinating Committee for Africa (CCAFRICA) on whether it was appropriate to extend the existing maximum level (ML) for hydrocyanic acid (HCN) of 2 mg/kg in gari to fermented cassava products, and whether mycotoxins were of public health concern in these products.

2. Based on the request of CCAFRICA22 (2017), CCCF11 recommended[1] that an Electronic Working Group (EWG) chaired by Nigeria be established to prepare a discussion paper to address the following:

    a. The need and feasibility to establish ML(s) for HCN in cassava and cassava products and address the issue of harmonizing the expression of HCN levels, i.e. free or total HCN.

    b. Source for data on mycotoxins occurrence in these products that would allow CCCF to determine whether mycotoxin contamination is a public health issue in these products.

CCCF12 (2018)

3. The EWG carried out its mandate and submitted a discussion paper[2] for consideration by CCCF12 (2018) which could not be discussed due to the inadvertent absence of Nigeria, the EWG Chair. The discussion paper was defered for presentation at CCC13 (2019) while Codex members and observers were encouraged to continue submitting new data on the GEMS/Food platform.[3]

4. The discussion paper[4] was updated by Nigeria and the conclusions and recommendations submitted to CCCF13 for consideration.

CCCF13 (2019)

5. CCCF considered the conclusions and recommendations in relation to the opportunity and feasibility to establish MLs for HCN and the development of risk management guidance to prevent and/or reduce mycotoxin contamination in cassava and cassava products and agreed[5] to:

    (a) establish an EWG, chaired by Nigeria and co-chaired by Ghana to prepare a discussion paper for consideration at CCCF14 (2020) as follows:

        (i) information on the global picture of fermented cassava products taking into account the issues raised in written comments and the points raised at CCCF13; and

        (ii) identification of mitigation measures to support development of a code of practice for the prevention and reduction of mycotoxin contamination in cassava and cassava products taking into account the points raised in this session.

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[1] REP17/CF, paras. 14-15
[2] CX/CF 18/12/13
[3] REP18/CF, para. 125
[4] CX/CF 19/13/14
[5] REP19/CF, paras. 128-145

(b) inform CCAFRICA of the discussions on MLs of HCN in fermented cassava products and the possible development of a COP for the prevention and reduction of mycotoxin contamination in cassava and cassava products

6. The EWG revised the discussion paper[4] presented at CCCF13 based on the considerations given in the plenary session, information submitted in reply to circular letter CL 2019/74-CF requesting information on mitigation measures for mycotoxin contamination in cassava and cassava products as well as the information provided and discussion held by members of the EWG. The participants list is contained Appendix III.

CONCLUSIONS

7. The EWG reached the following conclusions:

MYCOTOXIN CONTAMINATION IN CASSAVA AND CASSAVA PRODUCTS

8. There are sufficient materials from which to source information for development of a code of practice for the prevention and reduction of mycotoxin contamination in cassava and cassava products. This is not surprising because the conditions that make fungi the precusors of mycotoxins thrive is the same irrespective of the matrix and their food sources. Codex has such in abundance. The outcomes of some of the ongoing studies on cassava and cassava products might address the effect of unit process steps on the reduction or otherwise of mycotoxins in cassava and cassava products.

9. Since cassava and cassava products continue to see an increase in regional and international trade, the development of such a code of practice may help to contain mycotoxin contamination.

10. The COP should use the format and content in the existing *Code of practice for the reduction of HCN in cassava and cassava products* (CXC 73-2013) and should also consider the application of hazard analysis and critical control points (HACCP) in the processing of cassava roots to identify critical control points in preventing fungal contamination and subsequent mycotoxin development.

11. Further information in support of the above recommendation is contained in Appendix I.

LEVELS OF HCN IN CASSAVA AND CASSAVA PRODUCTS

12. Cassava and cassava products have gained attention of Codex committees over the years and there are Codex texts supporting their safety, quality and trade. These include Codex *Standards for Gari* (CXS 151-1985), *Edible Cassava Flour* (CXS 176-1989), *Sweet Cassava* (CXS 238-2003) and *Bitter Cassava* (CXS 300-2010) and the *Code of practice for the reduction of HCN in cassava and cassava products* (CX/C 73-2013). They have provided guidance on end-product characteristics including labelling, cultivation, pre- and post-harvest operations, processing, packaging and distribution of cassava and cassava products, especially in the prevention and reduction of hydrocyanic acid.

13. While Codex recommended processing steps, when adopted, have proven to be effective in cyanide content reduction; deliberate promotion and massive replacement of bitter cassava *Manihot utilissima Pohl* cultivars with the sweet cassava *Manihot esculenta Crantz* cultivars might prove to be the long lasting solution to the likelihood of the occurence of cyanide toxicity.

14. While global trading in cassava pellets for feed mill and other industrial usage have been around for years, the international and regional trading in treated fresh cassava tubers and cassava-derived food products are gaining traction and might be proven to be of immense economic benefit to peasant farmers in the developing countries who are the largest producers of cassava.

15. Analytical testing is the best way of determining HCN levels at each value chain stage. Testing for HCN appears more promising employing the combination of corrin-based chemosensor (for instantenous detection of bound HCN) coupled with spectrophotometric method for rapid quantification of total HCN because it allows for the determination of different forms of HCN - total, bound and free in both agricultural, food and industrial cassava products.

16. It is pertinent to note that since the advent of Codex guidance documents, the incidences of cassava toxicity has gradually become rare worldwide. However, there are a number of on-going studies in some member countries (Brazil, Nigeria and possibly others too) on effects of processing units and conditions on the residual HCN in cassava product during various value addition steps and in the final products including ready-to-eat.

17. It is recommended to wait for the outcomes of these studies for guidance on whether to set separate HCN maximum level for each of the cassava product or otherwise.

18. Further information in support of the above recommendation is contained in Appendix II.

RECOMMENDATIONS

19. CCCF is invited to focus its discussion on the recommendations below, taking into consideration the conclusions reached by the EWG and the supporting information provided in Appendices I and II.

Mycotoxin contamination in cassava and cassava products

20. To develop a Code of practice for the prevention and reduction of mycotoxin contamination in cassava and cassava products.

Levels of HCN in cassava and cassava products

21. To await availability of further data and information to re-assess the need and feasibility to establish MLs for cassava and cassava products.

APPENDIX I

MEASURES TO PREVENT AND REDUCE MYCOTOXIN CONTAMINATION OF CASSAVA AND CASSAVA PRODUCTS
(For information)

1.0 Preamble

1. After sugar cane, maize, wheat, rice, potatoes, soybeans, oil palm fruit, and sugar beet, cassava is the 9th most produced crop in the world. It is produced in 102 countries covering 26,342,326 hectares of the world food production land and up to 296,855,459 tonnes was produced (FAO, 2017). The world leading producers of cassava in 2017 were Nigeria, Democratic Republic of Congo, Thailand, Indonesia, Brazil, Ghana, Angola, Cambodia, Viet Nam, Mozambique, Cameroon, Cote d'Ivoire and the United Republic of Tanzania with over 5 million tonnes contribution each. According to FAO (2014), the world net production value of cassava in 2014 was $26.1 billion US dollars. There are many cultivars and species of cassava however, they fall under one or two categories, bitter and sweet varieties depending on the cyanogenic glucoside levels. The bitter and sweet varieties have high (≥ 100/mg/kg) and low (≤ 50 mg/kg) HCN content respectively. Cassava is usually processed and consumed in various forms which may differ across countries. Generally, one target of cassava processing is to reduce its cyanogenic glucoside content to the lowest level possible.

Some Background Notes On Mycotoxins:

i. The presence of fungi toxins in cassava products are reviewed in the discussion paper presented at CCCF13 (2019) (CX/CF 19/13/14). These mycotoxins pose health and economic consequences. Among the group of mycotoxins reported, aflatoxins and ochratoxins were the most occurring.

ii. Aflatoxins (AFs) are highly potent toxins that are reported in a wide variety of agricultural products. They are mainly produced by *Aspergillus flavus*, *Aspergillus parasiticus* and *Aspergillus nomius*. Aflatoxins are among the most potent carcinogenic, teratogenic, and mutagenic compounds known. The major aflatoxins commonly found in agricultural commodities are aflatoxin B1, B2, G1, and G2, of which aflatoxin B1 is the most potent and it has been listed as a group 1 carcinogen by the International Agency for Research on Cancer (IARC, 2002). The quantity of aflatoxins in food and feed is strictly monitored and regulated in most countries.

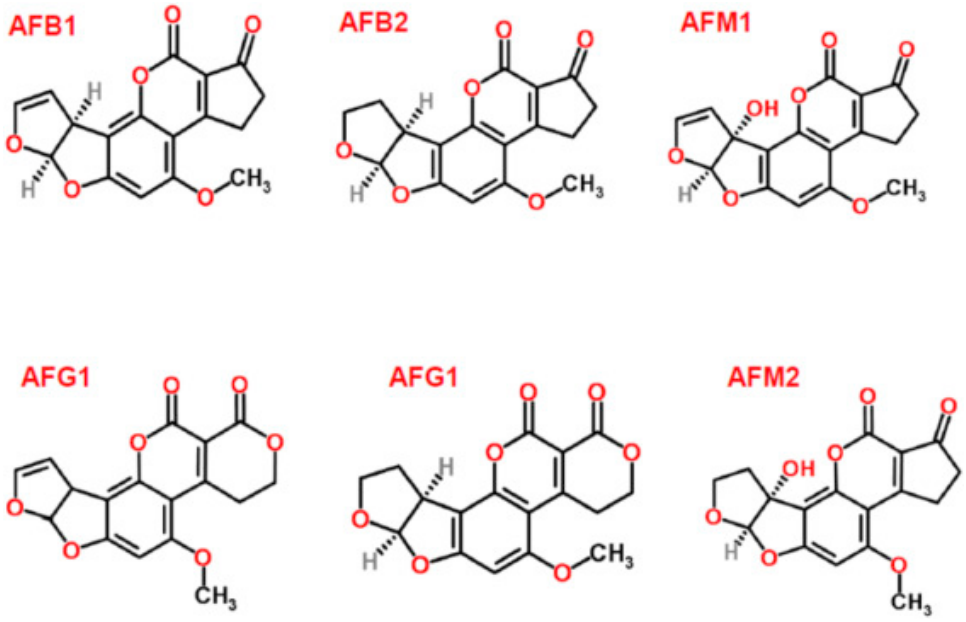
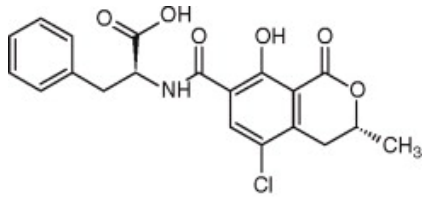
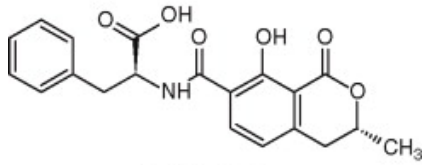


Figure 1. Chemical structures of aflatoxins.

iii. Ochratoxins are a group of toxins produced by *Aspergillus ochraceus*, *Aspergillus carbonarius* and *Penicillium verrucosum*, the three most important being ochratoxins A, B, and C. Out of these three, ochratoxin A is the most toxigenically potent. Ochratoxins are found as natural contaminants on peanuts, corn, stored grains, grapes and coffee among others, and are toxic to humans and livestock. Depending on the host species, these mycotoxins can act as nephrotoxins, hepatotoxins, immunotoxins, neurotoxins, teratogens, or carcinogens (O'Brien and Dietrich, 2005), however, the kidney is the primary target for toxicity.



Ochratoxin A



Ochratoxin B

Figure 2. Chemical structures of ochratoxins

iv. Mould presence is associated with regions having climate and soil conditions that permit both small or large scale the of cassava cultivation. The prevalence of several species of fungi that are implicated in mycotoxin production usually differs from one region to another. The fungi which can be found in soil and dust, residues of cultivated crops, stored cassava and cassava products at processing or storage facilities are usually associated with pre-harvest and/or post-harvest contamination of cassava and cassava products.

v. The severity of pre-harvest fungi infection and propagation largely depends on the prevailing environmental and climatic factors which may differ from year to year and from region to region. It also depends on the presence of inoculums, and the farming practice. The degree of damage of the crop by rodents, insects and other organisms also influences the contamination severity (*Code of practice for the prevention and reduction of mycotoxin contamination in cereals* (CXC 51-2003)). Good agricultural practices (GAP) and good manufacturing practices (GMP) could play a major role in the reduction of severity. Risk of post harvest fungal infection and productiion of mycotoxins in stored grain increases with the duration of storage (CXC 51-2003).

vi. Like the case with other crops, the complete prevention of dissemination by pre-harvest and post-harvest toxigenic fungal species is not practically achievable, even when GAP and GMP are followed. Therefore, the intermittent presence of certain mycotoxins in cassava and cassava products destined for human food and animal feed use is to be expected. Consequently, it is important to diligently monitor products for indications of the various conditions that promote fungal contamination and mycotoxin accumulation (CXC 51-2003).

vii. This information note is based on the current knowledge available about cassava production and processing. It is important to continue information review for increased knowledge and to improve practices along the value chain of cassava from farm-to-consumption.

2.0 Recommended practices applicable to pre-planting stage

Farm land selection

2. This is very critical. A fertile soil should be selected. Most preferred is a loamy soil with good drainage. The farmer should avoid planting in valleys, to avoid flooding. Flood water could transport fungi inoculum from an infected farm (Edia, 2018).

Farm land clearing and preparation

3. After the land is selected, it should be cleared and debris properly disposed. The soil should be loosened by **tilling**, to reduce stress to cassava roots particularly during enlarging period and also encourage healthy root development.

Organic fertilizers

4. They could be added during tilling to increase soil fertility or to address specific soil nutrient deficiencies. **Ridges or mounds** should be up to 0.75 m - 1 m apart. This will also be determined by the farming practice either with cassava alone or planted along with other crops (Edia, 2018).

Cassava variety (cultivar) selection

5. The following should be considered when selecting cassava variety: ability to germinate, ability to store well in the soil, ability to resist fungi and other plant pathogens, resistance to pests and diseases, longer shelf life and high starch content. When possible, cassava cuttings that are free of toxigenic fungi should be planted.

6. As an example, the International Institute of Tropical Agriculture (IITA) and the Nigerian Root Crops Research Institute (NRCRI), both developed the UMUCASS 42 and UMUCASS 43 varieties of cassava respectively. Both of which performed well with high yield and high dry matter. The varieties are also resistant to major pests and diseases that affect cassava in the country including cassava mosaic disease, cassava bacterial blight, cassava anthracnose, cassava mealybug, and cassava green mite (www.iita.org).

3.0 Recommended practices applicable to planting and pre-harvest stage

Planting

7. To achieve maximum yield, the stem cuttings of 25 cm length is recommended for planting at space of 1m x 1m; no dead stem should be planted. However, different producers may adopt slightly modified practices depending on cassava variety and the region. When cassava cuttings are to be planted, the method used depends on the climatic and rainfall conditions.

- **Horizontal Planting involves placing the plants** 5 – 10 cm deep into the soil in *dry climates*,
- **Vertical Planting** involves placing the cuttings vertically to avoid rot, especially *during the rainy season*, while
- **Inclined Planting** involves placing the cuttings at 45 degrees and leaving 2 - 3 nodes above the ground. This is recommended in areas with the *least rainfall*. Planting should be done when the sun heat is minimal or absent such as early morning or in the evening.

8. Avoid planting cassava on land where groundnut, maize, sugarcane or other highly susceptible crops were cultivated the previous year because such soils are likely contaminated with *Aspergillus flavus, Aspergillus parasiticus* and related species. The farmers should plant during the right month, based on geographical location.

Weed control

9. The use of post emergence herbicide is recommended immediately weeds are spotted on the field. In some cases, pre-emergence herbicides could be used before planting to minimize weed growth. Small scale farms could use hoes and cutlasses to remove weeds but care should be taken not to induce mechanical injury on the plant. While mechanised equipment could be used in large scale farms. Note that, land preparation needs to be done properly to control the weeds at least for the first 3 months to achieve optimum yield.

10. Certain weeds can harbour toxigenic fungi. The weeds can also increase plant stress when they are in competition for nutrients during the plant development. Either manual or mechanical approaches can be used for weed control; approved herbicides could also be used.

Fertilizer Application

11. The type and quantity of fertilizer to use are based on the cassava variety and nature of the soil. Fertilizers could be applied around 4 - 8 weeks after planting and 16 weeks after planting, and be applied 6 cm in width and 10 cm from the stems or leaves of the cassava plant. Also, it is advisable to conduct a soil test to determine the type of fertilizer to apply.

Pesticide use

12. Approved pesticides could be used to minimise insect damage and fungal infection around the crop. Predictive weather models could be used to plan the best application timing and mode of pesticide application.

Irrigation

13. If irrigation is used, ensure that it is applied evenly and that all plants in the field have an adequate supply of water. Irrigation is a valuable method of reducing plant stress in some growing situations. Excess precipitation during anthesis (flowering) makes conditions favourable for dissemination and infection by *Fusarium spp*.; thus irrigation during anthesis and during the ripening of the crops should be avoided.

4.0 Recommended practices applicable to harvest stage

Mechanical / Manual Harvesting

14. If mechanized processing materials are available, it is advisable to harvest cassava immediately the roots mature. Harvesting manually by hand is done by raising the lower portion of the cassava plant stem and cutting off a part leaving a small portion at the base of the plant to serve as a handle to pull the cassava root out of the ground. Here, the stems are kept for reuse in the next planting season or sold to other cassava farmers. The leaves can also serve as animal feed.

Conveyance Tools

15. Containers and conveyances (e.g. trucks) to be used for collecting and transporting the harvested roots from the field to the further processing facilities, and to storage facilities, should be clean, dry and free of crop residues, insects and visible fungal growth before use and re-use.

Holding Conditions

16. Prior to the processing step, cassava roots should not be exposed to the sun, high temperatures, mechanical damage, etc., since the roots still have high water activity suitable for microbial development. The water activity at this stage varies from 0.922 to 0,996 (Ono, 2020). A continuous flow from harvest to final product should be planned, in order that the roots will not be stored for a long period. The ideal time is 2 to 3 days and the excess should be taken to a suitable raw material storage room (Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA), 2006).

5.0 Recommended practices applicable to post-harvest stages

Cassava Based Products

17. Cassava roots can be processed into fermented or unfermented cassa-based products. These products, which depend on the region, have a wide range of applications including food for humans, animal feed, industrial uses such as fillers, and cloth starch among others. The processing steps by which these various products are arrived at differs and can be found in the *Code of practice for the reduction of HCN in cassava and cassava products* (CXC 73-2013). The approach here is to discuss the various steps individually but not under any specific product name.

Washing

18. After harvest, if cassava root is to be processed immediately, it should be washed to remove the surface dirt and soil acquired microbes. The source of water is an important factor not to be ignored.

Peeling

19. Peeled cassava roots should be processed immediately and should not be stored unprocessed. Peeling is either done manually using a knife or is done mechanically. It is done to remove the outer inedible portion of the cassava roots. Peeling should be carried out in a clean environment, and not in one where other crops have been stored otherwise, they will serve as sources of spores for the cassava.

Boiling

20. For sweet varieties cassava roots that can be consumed after peeling or boiling, it is recommended to boil roots immediately after peeling. This will expose any fungus to temperatures they cannot survive.

Grating and pulping

21. Depending on the size of the roots to be processed as well as available equipment, grating of cassava roots can be done manually or using a grater. In many parts of Africa, a perforated metal sheet is used for manual grating. During grating, the cyanogenic glycosides are hydrolyzed by the enzyme, linamarase. Unhygienic practices at this stage could serve as a source of inoculation. The environment should be kept clean, and the grater washed after each use and stored dry.

Fermentation

22. The purpose of fermentation in cassava processing is for further cyanide elimination, flavor development and product stability. Fermentation of cassava for traditional food processing is usually allowed to take a natural course, some optimization research has been carried out to the effect of using selected starter cultures, however this method is not widely used. The sack in which the grated pulp or the container in which the peeled root will be kept, allowing for 2-5 days fermentation must be kept clean at all times and especially well cleaned before use, to avoid it being a natural source of inoculum.

Dewatering

23. This process involves removing water from grated cassava roots and it is usually done by pressing. The dewatering process could last up to two days. Dewatering could be done before or after fermentation. Water removal should be optimal and care should be taken not to use contaminated processing materials as they may become sources of fungi inoculation.

Drying

24. This is a very important stage, fermented cassava pulp is usually spread in the open air to be dried under non-aseptic conditions, thus exposing them to insects and rodents as well as impurities carried in the air. Any of these could be sources of fungi inoculation. Drying should thereby be done in a controlled environment. Drying should be properly done to avoid moisture.

Sieving

25. The sieve to be used in further processing steps should be stored properly and cleaned before use.

Frying

26. Frying of garri among other fermented cassava products contributes dryness to the end-product, thus further discouraging fungi proliferation.

Storage

27. Storage facilities should be cleaned before materials are brought in, to remove dust, fungal spores, crop residues, animal and insect excreta, soil, insects, foreign material such as stones, metal and broken glass, and other sources of contamination. Sheds, silos, bins and other building materials intended for cassava and cassava products storage should be dried and well ventilated. They should provide protection from ground water, moisture condensation, rain, entry of rodents, and insects whose activity makes the commodities more susceptible to mould infection. Ideally, it should be able to prevent wide temperature fluctuations.

28. For bagged commodities, ensure that bags are clean, dry and stacked on pallets or incorporate a water impermeable layer between the bags and the floor. The bags should facilitate aeration and be made of non-toxic food-grade materials that do not attract insects or rodents and are sufficiently strong to resist storage for longer periods (CXC 51-2003).

29. Determine moisture content of the lot, and if necessary, dry the crop to the moisture content recommended for storage. Fungal growth is closely related with water activity (a_w), commonly defined in foods as the water that is not bound to food molecules that can support the growth of bacteria, yeasts, and fungi. Although the appropriate moisture content for fungal growth on various crops is different, the maximum a_w to avoid fungal growth is basically the same. It is recognized that fungal growth is inhibited at a_w of less than 0.70. In addition, safe storage guidance may be provided to reflect the environmental situation in each region.

Packaging

30. In some parts of the world, cassava products mainly in form of flour or granules are stored in sacks and then openly displayed in the market.

Transportation

31. Transport containers, vehicles such as trucks and railway cars and vessels (boats and ships) should be dry and free of old crop dust, visible fungal growth, musty odour, insects and any contaminated material that could contribute to mycotoxin levels in lots and cargoes of cassava and cassava products. As necessary, transport containers should be cleaned and disinfected with appropriate substances (which should not cause off-odours, flavour or contaminate the cassava and cassava products) before use and re-use and be suitable for the intended cargo. The use of registered fumigants or insecticides may be useful. At unloading, the transport container should be emptied of all cargo and cleaned as appropriate.

32. Shipments of cassava and cassava products should be protected from additional moisture by using covered or airtight containers or tarpaulins. Minimise temperature fluctuations and measures that may cause condensation to form on the cassava and cassava products, which could lead to local moisture build-up and consequent fungal growth and mycotoxin formation.

33. Avoid insect, bird and rodent infestation during transport by the use of insect-and rodent proof containers or insect and rodent repellent chemical treatments if they are approved for the intended end use of the cassava and cassava products.

6.0 Conclusion and Recommendations

34. See conclusions and recommendations above.

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APPENDIX II

DISCUSSION PAPER ON
LEVELS OF HYDROCYANIC ACID IN CASSAVA AND CASSAVA PRODUCTS
(For information)

Introduction

1. Cassava (*Manihot esculenta Crantz*), is a crop that is very tolerant to drought, heat stress and can thrives well on marginal soils (Alves, 2002; Calle *et al*., 2005; Dixon *et al*., 2008). It serves as a staple food crop in various parts of the world including Africa - Nigeria, Ghana, Kenya, Cameroon, Cote d'Voire, Tanzania; the Americas – Brazil, Colombia, Paraguay, Costa Rica, and Asia – Indonesia, Thailand, India Cambodia, Philippines, Vietnam, Malaysia and China.

2. Major producers of cassava and cassava products are Nigeria, Thailand, Indonesia, Ghana, Kenya and Brazil. Apart from Thailand, these major producers are not major exporters due to the high domestic consumption of the product especially in Nigeria, the leading producer of cassava. The inconsistency and lack of political will to implement policies in cassava production and value addition; inadequate conversion of raw cassava to industrial product and finished consumer goods with longer shelf life, are some of the factors responsible.

3. The global trade of cassava took off in the 1980s with the introduction of pellets form for animal feed from Asia into the European markets. It started declining with the intoduction of reforms of the European Union (EU) grain markets. This decline has led to the development of intra-South East Asian trading and to China. While evidences of non-interregional trading in cassava is overwhemling in Africa, there are however emerging evidences of intra-regional trade in cassava and cassava products. In some other regions of the world where cassava is not cultivated, cassava products e.g. cassava chips and tapioca starch or flour, unmodified and modified starches, ethanol, glucose syrup used as food ingredients are imported for retail sale and/or further processing.

4. Cassava products are are many and because of their local consumption there are different names for same or similar products and there are variants that are peculiar to particular localities. Table 1 depicts some of these local products and some globally well known cassava product forms.

Table 1: Names and Classification of Various Types of Cassava Products Worldwide

S/N	Region	Local Name(s)	Product Description	Countries Located	Trading Zones
1.		Gari	Dried fermented cassava flakes	Nigeria Ghana Cameroon Cote D'Voire	Domestic Regional International
2.		Lafun	Unfermented Sun dried Cassava flour	Nigeria	Domestic Regional International
3.		Fufu	Fermented Cassava Paste or can be dried and milled to Powder	Nigeria	Domestic
	Africa	Variants of Fufu		Ghana	
4.		Makopa	Dried cassava	Tanzania	Domestic
5		Attieke	Steamed Cassava fermented granules	Cote d'Voire	Domestic
6		Kirinde / Kondowole			Domestic
7.		Chikwangue	Fermented cooked cassava	Kenya	Domestic
8		Ebobolo	Fermented cooked cassava	Cameroon	Domestic Regional

S/N	Region	Local Name(s)	Product Description	Countries Located	Trading Zones
9		Mangbere	Fermented cooked cassava	DRC Rep of Congo	Domestic Regional
10		Miondo sawa	Fermented cooked cassava		Domestic Regional
11		Meedo	Fermented cooked cassava		Domestic Regional
12		Nyange			Domestic
13		Bada			Domestic
14		Ntobambodi	Semi solid fermented cassava leave soup	Congo	Domestic
15		HQCF High Quality Cassava Flour		Nigeria Cote d'Voire	Domestic
16		Chips Pellets		Nigeria	International
17	Latin America / Carribeans	Sour Pan deynca Pan de bono	Cassava flour Cassava chips Dry chips	Colombia	Domestic
18		Bammy Casabe	Bake cassava cake Cassava bread	Jamaica Countries of Carribean Basin	Domestic
19		Farinha de mesa		Brazil	Domestic International
20		Polvilho azedo		Brazil	Domestic
21		Pao de gneijo		Brazil	Domestic
22		Chipa	Cassava bread	Paraguay	
23		Casareep	Processed juice of bitter cassava	Guyana	Domestic Regional
24		HQCF			
25	Asia	Cassava Sago		India	Domestic
26		Cassava starch			Domestic
27		Baked Roots			Domestic
28		Roasted starch			Domestic
29		Gaplek		Indonesia	Domestic
30		Starch			Domestic
31		Starch		Malaysia	Domestic
32		Cassava based noodles, Cakes and Pasteries		Thailand	Domestic
33		Pellets			International
34		Noodles		China Vietnam	Domestic

S/N	Region	Local Name(s)	Product Description	Countries Located	Trading Zones
35		MSG			Domestic Regional International
36		Medical Glucose			Domestic Regional International
37		Glocose syrup			Domestic Regional International
38		Kanoleng kahoy		Philippines	

Types of Cassava

5. Cultivars of cassava are generally classified as bitter (high cynide) or sweet (low cyanide) depending on the level of the two cynogenic glucosides (CG) (linamarin, which accounts for 80% of CG and lotaustralin) present in the plant parts (Siritunga and Sayre, 2003); these compound upon enzymatic hydrolysis release cyanohydrin and free-hydrocyanic acid (HCN) (Cardoso *et al*., 2005; Njoku and Ano, 2018). The value of cassava as food is greatly compromised by the level of toxic HCN in it (Akely *et al*., 2007; Adepoju *et al*., 2010). According to World Health Organization (WHO), the safe level for cyanide in cassava flour is 10 ppm or 10 mg HCN kg^{-1} (FAO/WHO, 1991; Cardoso *et al*., 2005).

6. Farmers in Africa grow several cassava varieties. For example, the researchers of the Collaborative Study of Cassava in Africa (COSCA) identified over 1000 local cassava varieties in six counties of the study, namely the Congo, Côte d'Ivoire, Ghana, Nigeria, Tanzania and Uganda. The farmers group the local cassava varieties into the bitter and the sweet varieties.

Sweet cassava

7. The sweet varieties are more popular in Côte d'Ivoire, Ghana and Uganda. Farmers, however, plant sweet varieties in the forest zone more than in the transition and the savannah zones because limited sunshine in the forest zone makes it difficult to sun-dry the roots after they have been soaked to eliminate cyanogens. Tree crop farmers also plant sweet varieties which they eat without the soaking and sun-drying (and not fearing cyanide poisoning). Sweet (low-cyanide) cassava roots are processed simply by peeling and boiling or roasting and contains low cyanide contents, approximately 15–50 mg HCN per kilogram of fresh weight of roots (Irtwange and Achimba, 2009; Njoku and Ano, 2018).

Bitter Cassava

8. The bitter varieties of cassava are more common in Congo, Nigeria and Tanzania than the sweet varieties. The COSCA farmers reported that the bitter varieties are more resistant to pests, higher yielding and store better in the ground unharvested than the sweet varieties. Bitter (high cyanide) cassava roots demand a more extensive processing method that goes in sequential order as follows: peeling, washing, grating, fermenting, drying or frying, among others to reduce the HCN content to acceptable level for human consumption. Among the two main cassava groups, bitter cassava is characterised by its high contents of CG (15–400 mg of HCN per kilogram of fresh weight of roots) (Irtwange and Achimba, 2009; Njoku and Ano, 2018).

9. There is therefore need to implement practices and processes that will eliminate HCN from cassava and cassava products destined for human and animal consumption because of its toxicity and some resultant health effects which include but not limited to tropical ataxic neuropathy and epidemic stastic paraparesis.

Practices and Processes Used for Prevention and Reduction of Contamination

10. There are existing Codex texts addressing practices and processes for prevention and reduction of the occurrences of HCN in cassava and cassava products. Some of the texts include Code of practice for the reduction of hydrocyanic acid in cassava and cassava products (CX/C 73-2013).

11. *Codex Standards for Gari* (CXS 151-1985); *Edible Cassava Flour* (CXS 176-1989); *Sweet Cassava* (CXS 238-2003) and *Bitter Cassava* (CXS 300-2010). The texts variously address steps before cultivation land preparation, climatic conditions during cultivation, harvesting and post harvesting processes that will ensure the production of safe cassava products.

Main Processing Methods Used Worldwide

Boiling

12. Boiling is not an effective method for cyanide removal (50%). The inefficiency of this processing method is due to the high temperatures. At 100°C, linamarase, a heat-labile *β*-glucosidase, is denatured and linamarin cannot then be hydrolyzed into cyanohydrin. Cooke and Maduagwu (1978) reported that bound glucosides were reduced to 45% to 50% after 25 min of boiling. Free cyanide and cyanohydrin in boiled cassava roots are found at very low concentrations. Nambisan (1994) reported a cyanohydrin and free cyanide content of 6% of the total cyanogens content in 50 g of boiled cassava roots, and only 3% in small pieces (2 g).

13. Furthermore, Oke (1994) reported that cyanohydrin and free cyanide were volatilized during boiling, which reduced the content in boiled cassava roots. However, using small-sized cassava pieces or increasing the volume of water in which cassava roots are boiled can increase the efficiency of the boiling method (Table 2). For example, by reducing cassava chip size, Nambisan and Sundaresan (1985) demonstrated that boiling 2g and 50g pieces of cassava root for 30 min resulted in a 75% and 25% reduction in cyanide content, respectively.

14. Similarly, by increasing the volume of water from 1- to 5-fold, cyanogen retention was reduced from 70% to 24%. Oke (1994) reported that the solubilization of cyanogenic glucosides from the small cassava chips into the large volume of water seemed to better explain the cyanogen removal than enzymatic degradation.

Table 2: Effects of different processing methods and boiling technique variations on cyanogen glucoside content of cassava roots.[a]

Process	Retention%	Cyanogen glucoside mg HCN/kg
Fresh root	100	140
Boiling	55.5	77.6
Baking	87.1	122
Steaming	86.5	121
Changing size boiling (30 min)		
Fresh root	100	160
2g piece	25.6	41
5g piece	50	80
50g piece	75	120
Changing water ratio boiling (30 min)[b]		
Fresh root	100	165
Root: water (1:1)	69.6	115
Root: water (1:2)	36.7	60.5
Root: water (1:5)	24.2	40.1
Root: water (1:10)	22.3	36.8

[a]Adapted from Nambisan and Sundaresan (1985).

Expressed as µg cyanide/g fresh weight in reference.

[b]2g piece were used during the trial.

Steaming, baking, and frying

15. The loss of cyanide resulting from steaming, baking, or frying is small (Table 2) due to processing temperatures of over 100°C and to the stability of linamarin in neutral or weak acid conditions (Nambisan and Sundaresan 1985; Bradbury and others 1991). These methods are only suitable for sweet cassava, common in the South Pacific, because they contain low cyanide content (Bradbury and Holloway 1988).

Drying methods

16. Two kinds of drying are used for cassava: mechanical drying, such as in an oven, and natural drying by the sun (Table 3). In the drying process, endogeneous linamarase controls the cyanogenic glucoside removal, and thus is responsible for cyanohydrin and free cyanide accumulation in dried cassava. During oven-drying, an increase in drying temperature is accompanied by an increase in cyanide retention.

17. Indeed, Cooke and Maduagwu (1978) observed a cyanide reduction of 29% at 46°C and of 10% at 80°C. In 10-mm-thick chips, Nambisan (1994) observed similar cyanide reductions of 45% to 50% and 53% to 60% at 50 and 70°C, respectively. At drying temperatures above 55°C , linamarase activity is inhibited and, therefore, linamarin starts to accumulate in dried cassava. Nambisan (1994) showed that at equal temperatures, a decrease in cassava size was associated with an increase in cyanide retention in the oven-drying processes. Indeed, at 50°C , 10mm thick chips retained 45% to 50% of the cyanogenic glucosides, and 3-mm-thick chips retained 60% to 65%. Thin chips dry faster allowing less time for linamarase to act on the glucosides. At 70°C, the effect of chip size on the removal of cyanogenic glucosides was minimal, but cyanogen retention was greater due to a higher drying temperature. Cyanide retention during sun-drying is lower than in ovendrying because the temperatures remain well below 55°C .

18. These temperatures are optimal for linamarase activity resulting in better cyanogen degradation. Free cyanide contents of 30% total cyanogens in oven-dried and 60% in sun-dried cassava have been reported (Gomez *et* al., 1984; Gomez and Valdivieso 1984). Because linamarase activity is higher in the sun-drying process, more linamarin is deglycosylated into cyanohydrin and, therefore, cyanohydrin and free cyanide accumulate. However, chip thickness may still be an important factor in cyanogen removal during sun-drying because thin chips dry faster. Nambisan and Sundaresan (1985) reported a 52% to 58% cyanogen glucoside retention in 3mm thick chips, and 27% to 33% cyanogen glucoside retention in 10mm thick chips.

19. Generally, drying is not an efficient means of detoxification, especially for cassava varieties with high initial cyanogen glucoside content. In Tanzania, sun-drying whole roots into *makopa* reduced cyanide levels from 751 to 254 mg HCN equivalents/kg DW, that is, 66% of total cyanogens were removed (Mlingi and Bainbridge 1994). Cyanogenic glucoside breakdown during sundrying depends on enzymatic hydrolysis and on gradual root cell disintegration. Thinner cassava pieces dry faster, and at low moisture content levels (13%) linamarase is inactivated, and cyanogen glucoside break down ceases (Mlingi and Bainbridge 1994). Cyanohydrin removal is increased with complete sun-drying. A possible explanation would be that dehydration of the roots and moisture losses result in pH changes, which affects cyanohydrin stability (Mlingi and Bainbridge 1994).

20. Because drying temperatures are above the boiling point of HCN (26°C) and free cyanide is easily released into the atmosphere, free cyanide can readily be removed (Mlingi and Bainbridge 1994). Meuser and Smolnick (1980) reported that freeze-drying pulp and flash-drying cassava slices removed 51% to 52% of cyanogens, and that these 2 kinds of drying tended to remove only the free cyanide, which was most likely produced during the short processing time. Oke (1994) concluded that free cyanide represents only a small fraction of total cyanogens and, therefore, freeze- and flash-drying must be considered inefficient.

Table 3: Effects of drying processes on cyanogen content of cassava roots

Processing methods	Cyanide retention (%)	Total HCN (mg HCN/kg)
Oven drying[a]		
Fresh root	100	140
50°C , 10mm chips	46.4	65
50°C , 3mm chips	64.2	89.5
70°C, 10mm chips	60	84.5
70°C, 3mm chips	74.2	104
Sun drying[a]		
Fresh root	100	140
10mm chips	27.8	39
3mm chips	53.1	75
Crushing and sun drying[a]		
Fresh root	100	165
	2.1	3.5
Sun drying by time[b]		
Fresh root	100	1090
8 d sun drying	54.2	591
17 d sun drying	36.8	401
Repeated pounding + sun drying[b]		
Fresh root	100	513
	14.6	75

[a]Adapted from Nambisan and Sundaresan (1985).
Expressed as µg cyanide/g fresh weight in reference and referred to as cyanide glucoside.
[b]Adapted from Mlingi and Bainbridge (1994)

Fermentation

21. Fermentation by lactic acid bacteria is a processing method commonly used in Africa. Fermentation is initiated with grated or soaked cassava roots (Table 4) and results in a decrease in pH value. The efficiency of the 2 kinds of fermentation differs due to the mechanisms of cyanogen removal. The microorganisms in the traditional fermentation process of grated roots have been characterized (Coulin *et al*., 2006).

22. The fermentation of grated cassava roots is efficient at removing cyanogen glucosides. Westby and Choo (1994) reported that 95% of linamarin was removed within 3 h of grating. Vasconcelos *et al*., (1990) showed that microorganisms played only a minor role in cyanogen reduction and that grating was mainly responsible for linamarin hydrolysis. Although linamarin is rapidly removed by grating, cyanide retention stays high in products of grated and fermented cassava roots. Indeed, after 3 and 80 h of grated cassava fermentation, 74% and 40.3% of total cyanogens, respectively, were retained. Vasconcelos *et al*., (1990) reported that high concentrations of cyanohydrin and free cyanide were left in the fermented paste. This might be explained by the stability of cyanohydrins at acidic pH (Cooke, 1978). Thus, post fermentation operations are important and need to be effective for reducing cyanohydrin and free cyanide levels in such final products as lafun, fufu, gari and pupuru

23. The process of roasting after fermentation of grated cassava, which is used for *gari*, is relatively efficient as free HCN and cyanohydrin are steadily removed into the atmosphere leaving little free HCN (3.4 mg/kg DW) and cyanohydrin (2.2 mg/kg DW) (Vasconcelos *et al*., 1990) in the finished products. Cyanide content of *gari* further decreases during storage. Indeed, Mahungu *et al*., (1987) showed that a 4-mo-old *gari* (2.9 mg HCN equivalents/kg) had a cyanogen content 9 times less than its initial content (26.6 mg HCN equivalents/kg), and after 2 y of storage, *gari* seemed to be a cyanogen-free product, that is, in 57 samples analyzed, no cyanogen could be detected.

24. The fermentation of soaked roots in water is much more effective than that of grated roots in terms of cyanogen reduction. Indeed, more than 90% of total cyanogens were removed after 3 d of fermentation and about one-third of initial linamarin was found in the water. No significant accumulation of cyanohydrin or free cyanide was noted (Westby and Choo, 1994). In this case, microbial growth is essential for removing cyanogens. The cyanogen removal process can be improved by increasing the soaking and fermentation times (Oke, 1994) and by peeling and grating cassava roots between the soaking and fermentation stages. Dufour (1994) showed that soaking cassava roots for 6 d, grating them on the 6th day, and fermenting the mash obtained for 4 d into *farina* allowed a cyanide removal of 98%. Soaking for long periods can introduce fungi (Thambirajah, 1989), mold spores, and undesirable bacteria into the final products (Hakimjee and Lindgren 1988). The mold is typically nontoxic and contributes to reduced viscosity in weaning foods. The undesirable bacteria are thought to be destroyed during the cooking process (Hakimjee and Lindgren 1988).

25. Dry fermentation can also be used to remove cyanogens. Gidamis *et al*., (1993) showed that 89.6% of total cyanogens were lost in *ugali* after a dry fermentation (solid state fermentation) of cassava roots. Similarly, a cyanide retention ranging from 12.5% to 16.5% in cassava roots that have undergone heap fermentation has been reported (Essers *et al*., 1995; Cardoso *et al*., 1998; Ernesto *et al*., 2000, 2002a, b).

Table 4: Effects of fermentation on cyanide content of cassava roots.[a]

	Cyanide retention %	Total HCN mg HCN/kg
Fermentation		
Grated roots		
0 d	100	170
1 d	53	90
3 d	42	70
Soaked roots		
0 d	100	850
1 d	110	950
3 d	6	50

[a] Adapted from Westby and Choo (1994).

Table 4: Classification and Attributes of cassava processors

Individual/household processors	Medium scale processors (SMEs)	Industrial processors
• Artisanal. Manual techniques and rudimentary technologies	Semi-automated techniques. New technologies	Automated techniques and new technologies
• Often purchase cassava from smallholder farmers	Mostly cooperatives which process cassava into gari or individuals that source cassava food products from community-based processors	Predominantly integrated operations, with commercial cassava farms and automated processing equipment
• Process into food products for household consumption and few sales in open markets		Process cassava into industrial starch, HQCF, ethanol, chips, and syrups
• 95% of the processors' population		

Source: Sahel capital agribusiness managers limited 2016

Testing Method for HCN (Total HCN)

26. There are available analytical methods for monitoring and checking whether a cassava and cassava product is in compliance with the maximum level of HCN. Some of these methods are screening tests without laboratory equipment such as chemosensor, other methods include picrate method, spectophotometry/ colorimetic techniques, enzymatic hydrolysis method using linamarase, acid hydrolysis method, electrochemical method using cyanide electrode, alkaline titration method and bench methods.

Determination of cyanide content in cassava products

Sample extraction:

- Weigh 5g of the sample into a 250ml flask
- Add 50ml of distilled water and allow to stay overnight
- Filter to collect the FILTRATE

Preparation of alkaline picrate solution:

- Weigh 25g of anhydrous sodium carbonate in a beaker and 5g of anhydrous picric acid in another beaker
- Dissolve in minimal amount of warm distilled water separately
- Transfer them into a 1000ml volumetric flask
- Make up to the 1000ml mark

Construction of a standard curve for cyanide using alkaline picrate solution:

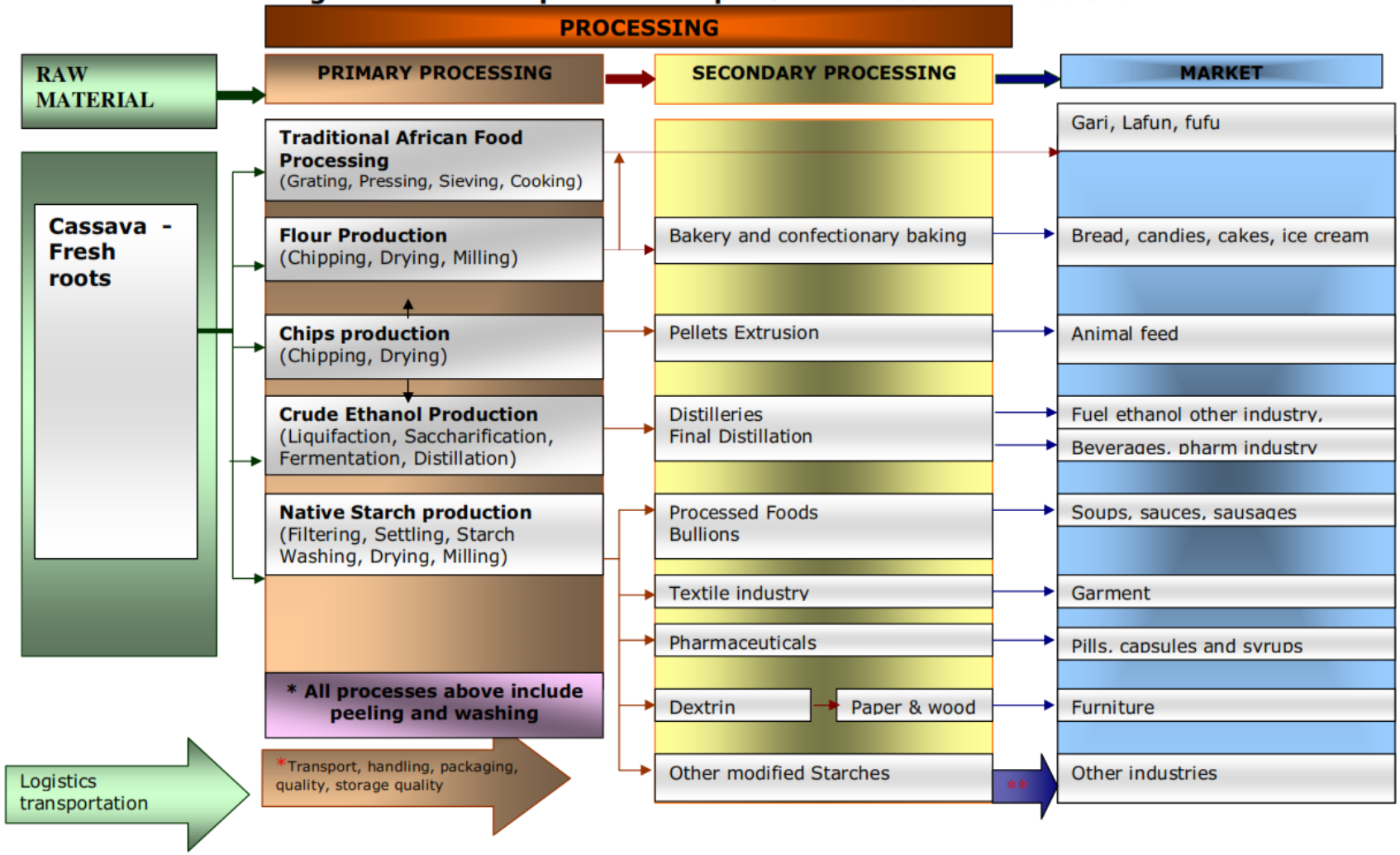
- Weigh 200mg of potassium cyanide (KCN) into a beaker
- Dissolve with distilled water
- Transfer into a 1000ml volumetric flask Make up to the 1000ml mark with distilled water
- This gives a concentration of 200mg/L (200PM) KCN STOCK SOLUTION
- Prepare 1ppm, 5ppm, 10ppm, 15ppm 20ppm and 25ppm

Quantitative analysis:

- Measure 20ml of the sample extract (filtrate) into a 100ml volumetric flask
- Add 40ml of alkaline picrate solution
- Incubate in a water bath at 95^0C for 5 minutes
- Allow to cool to room temperature
- Set the UV-Spectrophotometer at 490nm
- Run the Standards (1ppm, 5ppm, 10ppm, 15ppm, 20ppm and 25ppm) and the samples to obtain absorbances
- The concentration of cyanide is extrapolated from the calibration curve of Absorbance Vs Concentration

Ref: Babalola Olabukola Omolara. Cyanide Content of Commercial Gari from different areas of Ekiti State, Nigeria. World Journal of Nutrition and Health, Vol. 2, No 4 (2014): 58 - 60

Diagram 1: A Simplified Example of the Casssava Value Chain



Conclusion and Recommendations

27. See conclusions and recommendations above.

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