CODEX ALIMENTARIUS
INTERNATIONAL FOOD STANDARDS

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CODE OF PRACTICE FOR THE PREVENTION AND REDUCTION OF MYCOTOXINS CONTAMINATION IN CASSAVA AND CASSAVA-BASED PRODUCTS

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1. INTRODUCTION

Mycotoxins are fungal toxins that have been reported in a wide variety of agricultural products. They can pose health and economic consequences. The most frequently occurring mycotoxins in cassava and cassava-based products are aflatoxins and ochratoxin A. The aflatoxins are mainly produced by *Aspergillus flavus*, *A. parasiticus* and *A. minisclerotigenes*; while ochratoxin A is mainly produced by *Penicillium verrucosum* and *Aspergillus ochraceus* as well as *A. carbonarius* and *A. niger*. Aflatoxins are among the most potent carcinogenic, teratogenic, and mutagenic compounds known. Depending on the affected species, these mycotoxins can act as nephrotoxins, hepatotoxins, immunotoxins, neurotoxins, teratogens, or carcinogens, however, the liver is the primary target for toxicity. The major aflatoxins commonly found in agricultural commodities are aflatoxin B1, B2, G1, and G2, of which aflatoxin B1 is the most potent. Ochratoxin A may cause nephrotoxic, teratogenic, immunosuppressive, and carcinogenic effects, depending on the affected species. Ochratoxin A is one of the most potent renal carcinogens, inducing cancer in rats at very low doses. The International Agency for Research on Cancer (IARC) has classified aflatoxins as carcinogenic to humans (Group 1) and ochratoxin A as *possibly* carcinogenic to humans (Group 2B).

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

The severity of pre-harvest fungal 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 inocula, and the farming practices that are employed. The degree of damage to the roots made during harvest or by rodents, insects and other organisms also influences the severity of contamination. Good agricultural practices (GAP) and good manufacturing practices (GMP) could play a major role in reducing the severity of contamination. Storage duration may also play a role in mycotoxin production, as it is known that the risk of post-harvest fungal infection and production of mycotoxins in stored grain increases with the storage duration as indicated in the *Code of Practice for the Prevention and Reduction of Mycotoxin Contamination in Cereals* (CXC 51-2003).[1]

There are many species and cultivars of cassava. Edible types are classified into one of two categories: bitter and sweet, depending on the cyanogenic glycoside levels. The bitter and sweet varieties have high (≥ 100 mg/kg) and low (≤ 50 mg/kg) hydrocyanic acid (HCN) content respectively, as indicated in the *Code of Practice for the Reduction of Hydrocyanic Acid in Cassava and Cassava Products* (CXC 73-2013).[2] Cassava roots are usually processed and consumed in various forms, which may differ across countries. However, the primary reason for processing cassava root is to reduce the cyanogenic glycoside content. The presence of certain mycotoxins in cassava and cassava-based products destined for human food and animal feed use is not unexpected. Therefore, it is important to diligently monitor products and processes for indications of the various conditions that promote fungal contamination and mycotoxin accumulation.

This code of practice provides science-based information for all countries to consider in their efforts to prevent and reduce mycotoxin contamination in cassava and cassava-based products.

The effectiveness of this code of practice will be determined by regulatory authorities, extension educators, farmers, producers, processors, distributors, and food business owners in each country by considering the general principles and examples of GAP and GMP provided in the code. Additionally, other local crops, climate, and agronomic practices should be examined to facilitate implementation of these practices where applicable. This code of practice is expected to apply to all cassava and cassava-based products relevant to human dietary intake and health, as well as international trade.

This code of practice provides information on general principles for the reduction of various mycotoxins in cassava and cassava-based products. In addition, it provides a basis for training and education of farmers, agricultural workers, processors, manufacturers, and distributors.

2. SCOPE

This code of practice covers cassava and cassava-based products meant for human consumption and intends to provide national and local authorities, farmers, producers, manufacturers, distributors and other relevant bodies with information and guidance to aid in the prevention and reduction of mycotoxin contamination in cassava and cassava-based products. This guidance covers: GAP, GMP, good storage practices (GSP) and good distribution practices (GDP).

3. RECOMMENDED PRACTICES APPLICABLE TO PRE-PLANTING STAGE

Site selection

Farmers should avoid planting in valleys to avoid pooling water and flooding. Water can transport fungal inocula. Where possible, ensure proper planning for crop rotation in successive seasons. This will help in reducing inocula on the farm which may be present from post-harvest waste that harbour toxigenic fungal spores. Particular crops (e.g. groundnuts, maize and sugarcane) have been found to be susceptible to certain species of toxigenic fungi and rotating planting with these crops should be monitored and evaluated. Crops that are said to be of low susceptibility to toxigenic fungi should be used in rotation to reduce the cross contamination from inocula.

Farmland clearing and preparation

After selecting appropriate sites for planting, the land should be cleared, and waste properly disposed of to avoid contamination of the cassava roots with inocula from infected weed or other crops. The soil should be loosened by tilling using clean (sanitized) and suitable farm tools and equipment to reduce stress to cassava roots. This is particularly critical during the root growth and maturation period and also to promote healthy root development. Farmers are encouraged to adopt GAPs.

Cassava variety (cultivar) and seed selection

Selection and use of healthy, pest- and disease-free cassava stems are important for good planting. The ability to resist fungi and other plant pathogens should be considered when selecting cassava varieties. Cassava cuttings that are free of fungi should be planted.

4. RECOMMENDED PRACTICES APPLICABLE TO PLANTING AND PRE-HARVEST STAGE

4.1 Planting

To prevent fungal growth, no infected (having rotting spots) stems should be planted. Planting practices that have been reported to prevent rot could be adopted including *vertical planting* which involves placing the cassava cuttings vertically to avoid rot, especially during the rainy season.

In addition, planting material may be dipped in a fungicide/insecticide/nutrient solution in an attempt to reduce soil-borne pathogens and are recommended for pre-planting treatment. Planting stakes should be dipped for five minutes in prophylactic fungicide/insecticides/nutrient solutions as guided by label instructions. The dipped stake should then be allowed to dry, and be placed in a shaded, well-ventilated area before field planting.

Where possible, planting cassava on any land where groundnut, maize, sugarcane, or other highly susceptible crops were cultivated the previous year is not recommended or would need to ensure the soil has not been contaminated with *A. flavus*, *A. parasiticus* and other related species.

4.2 Weed control

Certain weeds can harbour toxigenic fungi and compete for moisture, light and nutrients thereby stifling cassava plant development. Either manual or mechanical approaches can be used for weed control; approved herbicides could also be used.

The use of post-emergence herbicide could be recommended immediately once weeds are spotted in 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, however, care should be taken to prevent mechanical injury of the cassava plants. Note that land preparation needs to be done properly to control the weeds, at least for the first 3 months.

4.3 Pesticide use

Approved pesticides can be used to minimize insect damage and fungal infection in the soil or around the crop. Weather models can be used to plan the best pesticide type and application timing. When applying pesticides, users should follow all label instructions to ensure the safe and proper use of the pesticide product. Where needed, ensure access to agrochemicals authorized for use.

4.4 Irrigation

Where 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 root maturation provides favourable condition for fungal infections, thus, sprinkle irrigation during anthesis and the maturation of the roots should be avoided.

5. RECOMMENDED PRACTICES APPLICABLE TO HARVEST STAGE

5.1 Harvesting

Harvesting should involve adequate planning in order to maintain quality and prevent crop wastage and possible rot. The amount of roots to be harvested should be determined based on market needs and demand.

Cassava should be harvested when the soil is slightly soft and not overly saturated, in order to easily remove soil from the roots and avoid fungal contamination during peeling.

However, to meet market demand, cassava roots may be harvested through the different climatic seasons. As such, it is necessary that measures be taken to prevent or reduce damages to harvested cassava roots, especially for hard soils, to prevent fungal growth after damage.

5.2 Conveyance tools

Containers and conveyances (e.g. trucks) used for collecting and transporting the harvested roots from the field to processing and storage facilities, should prevent mechanical damage to cassava roots and be cleaned, sanitized, and dried.

5.3 Holding conditions

Prior to the processing step and while being held for use, cassava roots should not be exposed to the sun, high temperatures, mechanical damage, or other conditions that could promote fungal contamination, since the roots still have high-water activity suitable for microbial development. Water activity (a_w) is commonly defined in foods as the water that is not bound to food molecules and that can support the growth of bacteria, yeasts, and fungi. A continuous progression from harvest to final product should be planned, so that the roots will not be stored for a long period. The ideal time is 2 to 3 days without enhanced storage methods.

Cassava roots should be stored in a suitable storage room. Enhanced storage methods of fresh cassava roots, such as storing in low temperatures in combination with fungicide treatment or waxing, can help extend shelf life of fresh roots by 2 to 6 weeks. This practice is suitable for storing or exporting large amounts of roots. Food handlers that can afford specialized equipment with the necessary technical skills may use improved storage methods to store fresh roots for preservation.

6. RECOMMENDED PRACTICES APPLICABLE TO POST-HARVEST STAGES

6.1 Cassava-based products

Cassava roots can be processed into various fermented or non-fermented cassava-based products. These products, which may be specific to certain regions, have a wide range of applications including food for humans. The processing steps by which these various products are obtained differ and can be found in the *Code of Practice for the Reduction of Hydrocyanic Acid in Cassava and Cassava Products* (CXC 73-2013).[2] The approach here is to mention some of the various steps that may potentially influence fungal contamination but not for any specific product type (for some product types see Figure 1). Processing of cassava should be initiated within 8–12 hours of receiving cassava roots as a raw material to avoid spoilage.

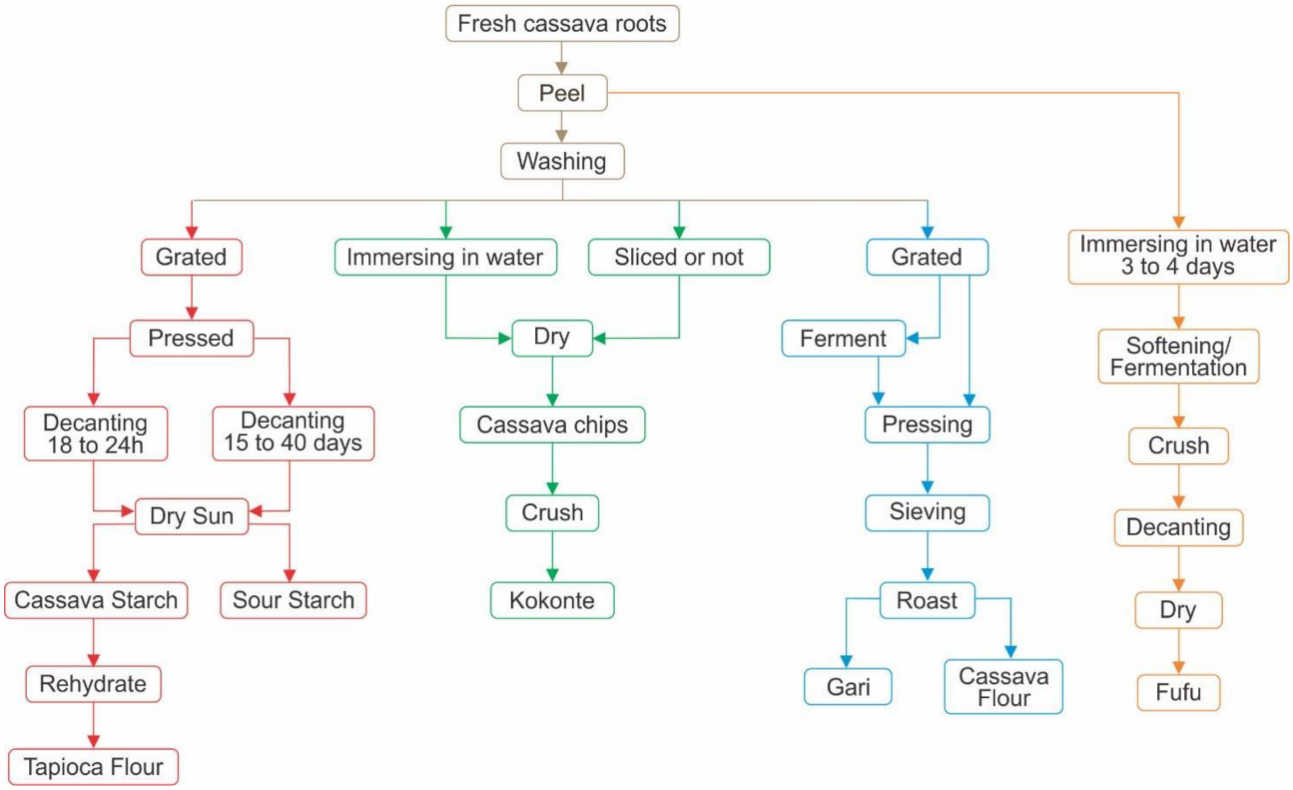

Figure 1. Flowchart of cassava products.

6.1.1 *Washing*

After harvest, if cassava root is to be processed immediately it should be washed to remove the surface dirt and soil thus reducing inocula of toxigenic fungal species. The source of water is an important factor to be considered, also. Either potable water or water treated such in a way that it makes it fit for its intended purpose should be used for washing to avoid potential contamination. Proper washing is vital to ensure sand or mud is removed from all parts of the root, especially the contours.

6.1.2 *Peeling*

Immediately after washing, peeled cassava roots should be processed 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 where other crops have been stored, otherwise, it may serve as a source of contamination for the cassava.

6.1.3 *Boiling/steaming*

For the processing of roots of sweet cassava varieties, it is recommended to boil or steam the roots immediately after peeling and washing. This will expose any fungus to temperatures they cannot survive. If not used, immediately, adequate care should be taken to prevent fungal re-contamination.

6.2 Size reduction: Grating, pulping and slicing or chipping

Where further processing of washed cassava roots includes size-reduction activities, regardless of the size of the roots to be further processed, cassava variety, or type of available equipment, adequate care must be taken to ensure such unit processing does not lead to fungal contamination.

Where cassava chips or slices are dried at farm level or in a processing facility, the chips or slices should be dried on cleaned, dry, raised platforms and at appropriate distance from probable sources of contamination, such as refuse dumps. When sun-drying is carried out, it should be done on raised platforms that would ensure good hygienic practice.

If chips or slices are dried artificially, the dryer thermostat should be optimally maintained to achieve the acceptable moisture content of the cassava and cassava-based products at the right time to prevent mould growth.

Unhygienic practices at this stage could serve as potential sources of fungal inocula. Therefore, the environment and all tools used should be kept clean in all steps of processing.

6.2.1 *Fermentation*

The fermentation of cassava roots is primarily used for further cyanide elimination, flavour development and product stability. All containers and equipment used in fermentation should remain clean at all times to ensure they do not become a natural source of inoculum. Fermentation typically takes place over 2 to 5 days.

6.2.2 *Dewatering*

This process involves removing water from grated cassava roots and is usually done by pressing. The dewatering process can last up to 2 days. Dewatering can be done before or after fermentation. Water removal should be optimal, and care should be taken not to use contaminated processing materials such as contaminated sacks, as they may become sources of fungi inocula. Food-grade sacks should be used. Adequate cleaning and sterilization of the sacks should be done frequently.

6.3 Cake breaking/granulating

The process involves feeding the cassava cake into a cassava grater that will break it into granules. Wet cakes can be sifted to remove lumps. Where a cassava grater is not available, a manual sifter is most often used to break the cake and sift the granules at the same time. The grater should be clean and the sacks containing cake or granules should not be placed on dirty surfaces (such as floors). Clean containers should be used to hold the wet granules to ensure product is not contaminated. Clean pans, bowls or sacks should be used in emptying the cakes.

6.4 Drying

Cassava should be dried to acceptable moisture content to prevent fungal growth and subsequent mycotoxin production. High microbial loads may be caused by the use of unclean drying surfaces and materials, so care must be taken to clean surfaces. Granules or chips should be properly spread per square meter of drying surface and should not be overloaded to allow for air circulation. Platforms for drying should be raised to prevent contamination such as dust, animals, and pests. Batches of granules not adequately dried should be spread out in a ventilated room until the products are dried. Drying surfaces and materials should be clean.

6.5 Milling

The environment should be monitored to prevent cross contamination from dust. The dried flour should be stored in a clean moisture-proof container. The milling machine should be cleaned and dried after use.

6.6 Sieving

The sieve to be used in further processing steps should be stored properly and cleaned with potable water and completely dried before use.

6.7 Frying

Frying of gari, among other fermented cassava products, should be done at high temperatures and monitored in order to discourage fungal proliferation.

7. STORAGE

Storage facilities should be cleaned and can be disinfected with approved fumigants and pesticides before materials are brought in, to remove dust, fungal spores, crop residues, animal and insect droppings, soil, insects and foreign materials (e.g. stones, metal and broken glass, and other sources of contamination). Sheds, silos, bins, and other building materials intended for cassava and cassava-based product storage should be dried and well ventilated. Contamination from the ground water, moisture condensation, rain, entry of rodents, and insect activities can make the commodities more susceptible to fungal infection. Ideally, storage areas should be able to prevent wide temperature fluctuations. Temperature and humidity can be monitored and controlled where possible.

Packaged cassava and cassava-based products should be stored in dry and cool conditions. Avoid direct contact with the floor or walls.

Determine moisture content of the lot, and if necessary, dry the product to the recommended suitable moisture content prior to storage. Fungal growth is closely related with a_w, and it is recognized that fungal growth is inhibited at a_w of less than 0.60. In addition, safe storage guidance may be provided to reflect the environmental situation in each region.

8. PACKAGING

Moisture content of cassava-based products mainly in the form of flour and granules shall be monitored before packaging to avoid packing a product that will favour the growth of microorganisms. Cassava and cassava-based products should be packaged in food-grade materials. Packaging materials should be made of materials, which should not absorb moisture when packed and sealed. Where necessary, packaging technologies such as vacuum and modified atmosphere packaging can be applied.

9. TRANSPORTATION

Transport containers, including vehicles such as trucks, railway 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-based products. As necessary, transport containers should be cleaned and disinfected with appropriate substances (which should not cause off-odours, off-flavour or contaminate the cassava and cassava-based products) before use and re-use and be suitable for the intended cargo. At unloading, the transport container should be emptied of all cargo and cleaned as appropriate.

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

Avoid pest infestation during transport by the use of pest-proof containers.

10. PRODUCT INFORMATION AND CONSUMER AWARENESS

Specific storage instructions for cassava and cassava-based products should be provided on the packaging to ensure protection from unfavourable conditions, which may promote fungi growth and contamination. The instructions for storage before (e.g. store in a cool, dry, well-ventilated area) and after the product is opened, should be legible and in clear language, in order to maintain product quality.

NOTES

[1] FAO and WHO. 2003. *Code of Practice for the Prevention and Reduction of Mycotoxin Contamination in Cereals.* Codex Alimentarius Code of Practice, No. CXC 51-2003. Codex Alimentarius Commission. Rome.

[2] FAO and WHO. 2013. *Code of Practice for the Reduction of Hydrocyanic Acid in Cassava and Cassava Products.* Codex Alimentarius Code of Practice, No. CXC 73-2013. Codex Alimentarius Commission. Rome.