Cassava Processing Technology Toolkit Catalogue

TAAT Clearinghouse

Clearinghouse Technical Report Series 013

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The Technologies for African Agricultural Transformation (TAAT) is funded through a grant from the African Development Bank and is implemented by the International Institute of Tropical Agriculture (IITA) in close collaboration with other centers of the Consultative Group for International Agricultural Research (CGIAR) and specialized institutions such as the African Agricultural Technology Foundation (AATF), the Forum for Agricultural Research in Africa (FARA), the International Fertilizer Development Center (IFDC) and others. For more information, email *I.Musabyimana@cgiar.org* or *plwoomer@gmail.com*.

Front cover photographs: Cut cassava roots and processed flour (upper left), a variety of baked goods containing cassava flour (upper right); noodles prepared from cassava flour (lower left), processed cassava peels packaged for sale as animal feed (lower right).

Correct Citation: TAAT Clearinghouse. 2022. Cassava Processing Technology Toolkit Catalogue. Clearinghouse Technical Report Series 013, Technologies for African Agricultural Transformation, Clearinghouse Office, IITA, Cotonou, Benin. 28 pp.

Cassava Processing Technology Catalogue

A Report by the Technologies for African Agricultural Transformation Clearinghouse

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Purpose and Introduction

The purpose of this technology catalogue is to advance high quality cassava flour (HQCF) as a substitute for wheat in Africa. While Africa has potential to increase its wheat production, it appears to be small in proportion to the massive demand for imported wheat. For example, Africa imported US $11 billion from eight European and North American countries in 2020, a massive expenditure of foreign reserves that could be better directed toward longer-term development goals. At the same time, cassava is well suited to African agricultural conditions and may be processed into flour that can be substituted for wheat as documented in this catalogue. In the past, cassava was too widely viewed as a subsistence crop and food for the poor, when in reality it has enormous agro-industrial application and potential. One of these applications is processing into a flour useful in baking and other food manufacturing purposes. The most immediate application of cassava flour is its partial substitution in bread and other baked products, but due to its different chemical properties, industrial-scale producers must make procedural adjustments. This catalogue draws an important distinction netween fermented and unfermented cassava flours, offers eight key technologies that promote the production and use of unfermented cassava flour and the better use of cassava by-products.

About TAAT. Weaknesses in the production and supply of commodities are viewed as responsible for Africa's food insecurity, need for excessive importation of food, and unrealized expansion of Africa's food exports. The TAAT Program led by the International

Institute of Tropical Agriculture (IITA) pioneers new approaches to the deployment of proven technologies to African farmers. TAAT arose as a common effort of IITA and the African Development Bank (AfDB) and is an important component of the latter's Feed Africa Strategy. Currently, TAAT is advancing 100 carefully selected technologies through 88 interventions in 31 countries organized around 15 "Compacts" that represent priorities in terms of achieving Africa's potential in achieving food security and advancing its role in global agricultural trade. Nine of these Compacts relate to specific priority value chains of cassava, maize, rice, fish, common bean, wheat, sweet potato, sorghum and millet and small livestock. Together these Compacts design interventions in collaboration with national programs to introduce technologies and innovations that are designed to meet ambitious targets for agricultural development. In many cases, these targets are addressed through the implementation of projects resulting from sovereign country loans awarded by development banks, where TAAT's role in the design, planning and execution of these loan projects is a vital element of their success and uptake.

About the DR Congo Agricultural Transformation Agenda. DRC-ATA is a collaborative effort of the Government of the Democratic Republic of Congo, the African Development Bank, and the International Institute of Tropical Agriculture that is designed to modernize that country's agricultural sector. It operates nationwide and focuses upon cassava, rice, maize, soybeans, beans and aquaculture as key commodities and value chains. It serves to double agricultural yields through greater use of improved crop varieties, fish breeds and production inputs. Its goal is to create wealth and jobs through modernized agriculture by consolidating and building upon several ongoing projects. It also seeks to better structure new projects being developed and financed by donors and development banks. It works closely with Bio Agronomic Business on behalf of the Ministry of Agriculture, welcomes a wide assortment of private sector actors and is intended to reach all 145 territories of the country. Its immediate activities include reduced dependency upon imported wheat through the production of cassava flour and its use in the bakery industry.

About the African Agricultural Leadership Institute. AALI is an independent, non-profit international entity that provides an African perspective and voice to the diverse services required to accelerate Africa's agricultural transformation, particularly among its political leadership, and for its women and youth beneficiaries. African agricultural development is too often defined by constantly adjusting paradigms in response to less than expected progress. The vision of AALI involves *"Advancing Leadership in African Agricultural Transformation".* It envisions a vibrant and bold African leadership, supported by experienced African agricultural professionals, to catalyze public and private investments and accelerate and sustain Africa's needed agricultural transformation, particularly among its poorest households, and women and youth. This vision demands that agriculture be viewed as a business that attracts the private sector and investment from governments and development banks to stimulate and modernize its advancement. This approach contrasts with the existing view that agriculture is a neglected sector with insufficient budget allocation from governments and largely dependent on the donor community priorities and funding. For this transformation to occur, the mindset of the current SSA leadership at all levels must change to acknowledge that modernized and more resilient agriculture drives Africa's future economic growth. AALI is a co-leader of the DR Congo Agricultural Transformation Agenda.

Technology 1. Cassava as a Traditional and Fermented Food

Summary. Cassava is one of the world's most important food crops and is particularly important in the tropics. Much of the cassava grown before the advent of modern agriculture was high in cyanide and its traditional preparations were designed to detoxify the starchy roots. Detoxification results from cutting, soaking, fermenting, and cooking in different ways. Gari is granular powder produced from shredding, pressing, fermenting, drying and sieving cassava root that resembles a flour and is often consumed as a paste, but should not be confused with High Quality Cassava Flour used in baking and for wheat substitution. Nonetheless, this material is extremely important as a food in West Africa and its processing is being increasingly industrialized and widely marketed. For more information on this topic contact Adebayo Abass of IITA by email at a.abass@cgiar.org.

Technical Description. Traditional methods of processing cassava roots result in products that often contain unacceptable levels of cyanide, foreign matter, and harmful microorganisms. Proper processing of traditional foods using modern methods improves both their safety and marketability by reducing cyanide levels to regulated levels, avoiding contamination from other materials and prolonging shelf life.

Uses. Gari is the gritty granular flour obtained by fermenting and de-watering the starchy roots of freshly harvested cassava. It is most often consumed as a stiff dough made by soaking gari in hot water and kneading it by hand, and then shaping it into a flattened ball. It is served as part of a meal with various soups and sauces. Gari is used as a main ingredient of fufu, a popular dish in Central and West Africa. Fufu consists of starchy foods of cassava, yams or plantains that are boiled, pounded, and rounded into flattened balls. The pounding process is quite laborious. Fufu is often dipped into sauces or eaten with stews of meat, fish, or vegetables. Fufu is a healthy food, low in cholesterol, rich in fiber and potassium, and promotes digestive health.

A commercial gari from Ghana (left) and a ball of gari dough ready for consumption (right)

Composition. Gari is a nutritious food. An analysis of gari reveals 86% carbohydrates, 7% moisture, and less than 2% protein, fat, ash and crude fiber. Thus, the majority of its content is carbohydrates and it contains very little fat and no saturated fats or cholesterol. It is low in protein content and that is why it is best consumed with other foods, but it can also serve as a quick snack.

Preparation. Gari is one of many kinds of food products that can be produced from fresh cassava. It is made from cassava roots that have been crushed into a mash, fermented, and sieved into small pieces that are then roasted or fried to form a crispy product. First, freshly harvested cassava roots are washed with clean water, peeled to remove the outer brown skin, and washed again. Next the clean, whole roots are grated by hand or machine into a mash or pulp. The mash is then placed into porous bags and stacked into a rack for draining and fermentation for one or two days. The time spent in fermentation determines the degree of the product's sour taste. The mash is further dewatered by a hydraulic or screw press. Pressing is repeated until no more water drains, resulting in a firm wet cake. Sufficient water must be removed, otherwise the gari will form into lumps during roasting. The wet cake is sieved into "grits", roasted on a hot tray to form the final dry, crispy product and then dry sieved. Gari is classified by its particle size as extra-fine (0.5 mm), fine (0.5 mm to 1 mm), coarse (1 mm to 1.25 mm) and extra-coarse (1.25 mm to 2.0 mm). Often, a grinder is required to break the larger granules into smaller ones. The gari is packed into airtight, labelled bags for marketing and stored under cool, dry conditions. Gari will keep for up to a year. If packaging is not airtight, the gari will absorb moisture and lose its crisp texture, reducing its quality and shelf life.

A fabricated gari screw press in operation (left) and a hydraulic press suitable for commercial production (right)

Commercialization. Local food processors produce gari as a viable business. This strengthens local demand for cassava as a commercial crop through the establishment of small- to medium-scale processing factories and requires that investors select the best sites and most appropriate machines to match production targets and meet quality standards. In general, gari processing is conducted in two separate working areas. The wet area is where fresh cassava roots are transformed into wet cake or chips. The equipment and machines used for peeling, washing, grating roots into a mash, and removing excess water are installed here. The dry area is where the finished cassava product is prepared. The dry area houses machines used for breaking and sieving wet cakes, roasting wet cake particles, drying and milling. A wide range of modern equipment is available for making gari including washers, peelers, shredders, presses and dryers are available for more automated processing.

Customer Segmentation. Gari is acceptable to a wide range of consumers as it is popularly served alongside a wide variety of traditional stews and soups. As it is also an ingredient of other foods, strong demand is expressed by both homemakers and restaurants, and it tends to be sold in a range of packaged sizes from 2 to 25 kg depending on intended use.

Legal and Regulatory Requirements. As a commercially available food, gari is subject to a suite of quality control standards similar to other flours. The cyanide content must be very low (e.g., <10 ppm) and it must not contain foreign material or harmful organisms. Ill-informed processors may assume that flour from fermented cassava is interchangeable with High Quality Cassava Flour used in baking and other forms of wheat flour substitution (see Technology 3). This is not the case and this misunderstanding has caused consumer distrust and economic hardship in the past.

Technology 2. Mechanized Cassava Chip Production

Summary. Dried chips of peeled cassava are a major international trade commodity but Africa, despite being the world's largest cassava producer, is mostly bypassed from this trade. Drying cassava roots allows it to be transported for processing elsewhere as an agro-industrial substrate. Reducing the weight and volume of chips while improving their storage allows massive international trade of this commodity, currently valued at US $2.7 billion annually. Producing these chips is relatively simple; after cassava roots are washed and peeled, they are chopped, dried, and packaged in bulk, a process that is fully automated in several Asian countries. These chips are then processed into starch and animal feed or used as a substrate in the production of biofuels. While potential exists for Africa to join in export of this commodity, it is likely less advantageous than using cassava harvests to improve food security and boost agro-industrial capacities domestically and within the region. For more information on this topic contact Adebayo Abass of IITA by email at a.abass@cgiar.org.

Technical Description. Cassava chips are the dried interiors of starchy cassava roots usually cut at a diagonal to facilitate drying and packed in bulk for transport and subsequent industrial processing. The international demand for cassava chips is expanding at a rate of 18% per year. Modern processing techniques allow for safe storage of cassava chips over a long period without loss of nutritional value and buildup of aflatoxins. Reducing the weight and volume of chips optimizes the costs of packaging, storage, and transportation, which allows massive export trade of this agro-industrial commodity. Note that cassava chips should not be confused with the snack food cassava crisps resulting from thinly sliced, deep fried roots.

Diagonally sliced and dried cassava chips of export quality

Production. The first step in cassava chip production is washing of freshly harvested roots to remove soil, following by peeling to separate its brown skin from flesh. Various types and sizes

Steps of large-scale cassava chip production process.

of chipping machines are available from international manufacturers that determine shape and thickness according to market requirements. Combined peeler and chipper units with a capacity to process 5-10 ton of fresh roots per hour that are suitable for industrial producers cost about US $8,000. Smaller units that can process 2-4 ton of fresh roots per hour are suitable for community-based producers and cost as little as US $750. The shape of cassava chips and drying temperatures have a major influence on energy used for processing and the quality of the final product. Oval and semi-rectangular chips have a shorter drying time compared to cylindrical ones. Cassava chips are dried in hot-air convection ovens at 45° to 165° C, and throughput rates depend on loading density, and initial and final moisture content. Chips can be stored for up to 6 months in high-density polyethylene bags of 50 kg or in bulk sacks that can hold up to 500 kg, but these goods may require addition of an insecticide to avoid damage.

A mechanized cassava peeler and chipper

Uses. Chips are processed into starch allowing production of tapioca and a variety of other food industry applications (e.g., thickener). As an animal feed, cassava is a high-carbohydrate energy source able to partially substitute for maize or wheat. Mold infection is rare in dried cassava chips, offering advantages for animal health. These chips are usually pulverized and pelleted for use in mixed feeds. Pulverized chips are also fermented to produce bioethanol for use as an environmentally friendly fuel or in cosmetics and pharmaceuticals.

Composition. Dried cassava chips must meet the following criteria to be marketable and attract price premiums: a minimum starch content of 68% to 70%, a final moisture content of 14% to 17%, a maximum fiber content of 5%, and a maximum sand content of 3%. Oval shaped cassava chips dried at a temperature of 100°C are preferred on the market because of their pliability and white color.

Trade Opportunities. In 2020, the trade in dried cassava chips was $2.6 billion. The top exporters of cassava chips in 2020 were Thailand (US $697 million), Cambodia ($424 million), Vietnam ($207 million), and Laos ($195 million). Cassava has one of the lowest taxation rates of edible commodities, at an average of 18%. Top importers were China ($875 million), Thailand ($439 million), Vietnam ($175 million), Netherlands ($144 million) and United States ($127 million). Currently the total value of cassava chips produced in Sub-Saharan Africa is only US $40 million. These trade statistics suggest that Africa is largely bypassed from world trade, but this may not be disadvantageous as its cassava is better put to domestic and regional applications. For example, 450,000 tons of dry chips are required per annum if 25% of Nigeria's poultry feeds contained cassava pellets. Otherwise feed materials must be imported. A market study in Uganda showed that cassava processors pay US only $113 per ton for dried chips that are produced through traditional techniques, but the price for high-quality chips from mechanical processing is three times greater. Let African countries target international trade in cassava chips after it first meets its regional needs for food security and agro-industrial growth!

Technology 3. Processing High Quality Flour from Cassava

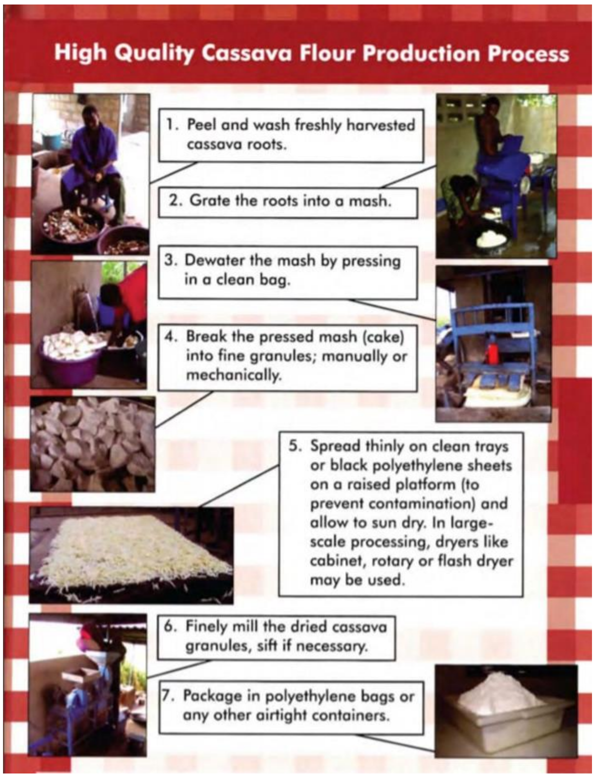
Summary. Fresh cassava roots are very quick to perish because of their high water content, thereby posing a challenge for farmers to store them as food or sell them in markets. African communities growing cassava often process roots to extend the shelf life and reduce toxic compounds, usually by a combination of peeling, chopping, washing, fermenting, drying, and other processing steps. The techniques that are traditionally used for producing cassava flour do not provide significant market opportunities to cassava farmers operating at commercial scales. High Quality Cassava Flour (HQCF) provides an alternative as an odourless, white product. This processing must be completed within 24 hours of harvest. The main advantages of processing fresh roots into HQCF is its extended shelf life. HQCF and cassava derived starches are suitable for manufacturing into a wide range of foods and goods, and to partially substitute for massive imports of wheat and other commodities. Building capacity for processing cassava flour results in greater competitiveness along the entire cassava value chain, and thus strengthens the advantages of modernized cassava production. For more information on this topic, contact Adebayo Abass of IITA by email at a.abass@cgiar.org.

Technical Description. Manufacturing HQCF is done using fresh roots with high starch content and needs to take place shortly after harvest. The key steps in producing HQCF are raw material selection, peeling, washing, grating, pressing and dewatering, drying, milling, screening, packaging, and storage. Detoxification of cassava roots in this process happens through grating, dewatering, and drying, and avoids a bitter taste and odour. Chipping of roots can be performed prior to drying and milling. Only varieties with low levels of cyanide should be used with the chipping method. Extraction of starch from cassava follows a process similar to the grating method, however, it requires wet milling of cassava roots followed by physical separation of fibers. HQCF is a gluten-free product, making it ideally suited for manufacturing of non-allergenic foods, a property that attracts a growing market.

The conversion of fresh cassava root to high quality cassava flour

Uses. HQCF is suitable for manufacturing a large range of food products including those that substiture for imported wheat. The proportion of HQCF acceptable within wheat-based bakery products ranges between 10% to 35%, and many consumers prefer the heavy “cake structure” that cassava produces at higher concentrations. Through the use of commercially available enzymes, it is possible to convert of HQCF into sugar syrups that are similar to common dextrose products and meet different sweetener requirements. In further steps, the sweet syrup derived from cassava can be industrially fermented into alcohol for potable and industrial use. When blending HQCF with salt and caustic soda it can be used as adhesive for paper board and plywood glues, and extracted starches as filler for cosmetic, pharmaceutical and regular products, or as textile stiffener. These applications are important to Africa’s industrial growth as a replacement to imported materials.

Composition. The nutritional and chemical properties of HQCF or derived starches are dependent on the cassava variety, freshness of roots, and processing steps; all of which must be harmonized within product and customer requirements. The typical quality requirements of HQCF are: moisture content ≤12%, crude fibre ≤2%, crude ash ≤ 3%, fineness ≥90% (pass through 0.6 mm sieve), starch content ≥60%, protein content 1.3-2.0%, crude fat content 0.3-0.5%, and pH >5.8. The safety requirements include total cyanogens ≤10 mg/kg, aflatoxins ≤ 10 µg/kg and yeast and mold ≤ 1000 CFU/g, max (see Technology 3). Pro-vitamin A or beta-carotenoids levels measure 0.06 µg/g for HQCF that is made from white fleshed cassava and increases to 11 µg/g when biofortified yellow fleshed cassava is used. Reduced moisture content improves its storage capacity. The cyanide content for HQCF prepared using sweet varieties and recommended methods is very low and falls within a safe level for human consumption. Foaming and emulsion capacity of HQCF is low while its bulk density, and water and oil absorption capacities are high.



The seven-step process to converting fresh cassava roots into cassava flour

Application. Manufacturing HQCF can be performed using simple cottage style equipment that are manually operated, similar to that already used for gari processing (see Technology 1). Large automated systems are also available for industrial-scale processing into unfermented cassava flour. The minimal infrastructure required for manufacturing HQCF includes a grater for size reduction, a press for dewatering, a mechanical dryer, a mill and a sealer for packaging. For production of starch, there is need to remove cellulose fibres that are released during wet milling, and this is performed by a starch extrcator. The extracted wet starch is then dried and sieved. Reliable supply of electricity must be in place because this process requires uninterrupted power supply.

Commercialization and Start-up Requirements. Cassava flour and starch production technologies are commercially available in several African countries although some equipment must be imported. Industrial-scale operations require considerable investment but may be modified around other existing food processing approaches. In order to enter into cassava flour and starch production, the following general steps must be followed: 1) Raise awareness with cassava farmers, agri-food companies and investors concerning economic opportunities related to HQCF and starch; 2) Identify profitable, durable and equitable integration of HQCF and starch into domestic and export markets; 3) Organize reliable supply of cassava roots with high dry matter and starch content close to processing plants; 4) Set up processing methods and simple energy-efficient and labour-saving equipment; and 5) Train machine operators and workers on maintenance, safety and quality adherence.

Production Cost. The cost of cassava fresh roots at the factory gate, including transportation, is a major determinant of the economic viability of manufacturing HQCF. Producing 1 ton of HQCF requires on average 3.5-4.0 ton of fresh cassava roots. About 60% of the capital investment that is required to set up a processing plant is directed to machinery and tools, while the rest to construction. A pilot factory in Madagascar showed that processing 288 MT of fresh cassava roots into HQCF over a year costed US $17,238, which corresponds to a production cost of US $60 per ton fresh root product. Production of starch is more capital intensive and requires higher levels of inputs compared to HQCF, thus larger investments are needed to enter that market.

Client Segmentation. This technology is applicable to small-scale flour processors and larger food manufacturers, and may be modified to suit the needs of more localized processors and community-based activities. It also requires that consumers accept the products resulting from blended flours.

Potential Profitability. HQCF is currently sold at US $550 to $650/ton. Partial substitution with cassava flour offers a potential 25% reduction in raw material costs for bakeries that now use imported wheat flour. For example, if a producer of biscuits processes 200 MT flour per month, the substitution of wheat flour by HQCF can lead to an annual saving of US $130,560 per year. The higher value of HQCF and starch offers incentive to agro-processing, particularly in conjunction with higher dry matter varieties. A study in Uganda found that a net margin of US $79/ton can be achieved when starting from dried chips (see Technology 2), which suggests a real potential for enterprise development in rural communities.

Licensing Requirements. Producers of HQCF and starch must comply with food safety regulations. Most of the simple cottage style machinery and equipment can be fabricated free of license, while industrial systems fall under intellectual property protection. Technologies for production of HQCF and starch are a public good, and the International Institute of Tropical Agriculture is actively involved in disseminating this information across Sub-Saharan Africa.

Ten workstations in a labor-intensive cassava flour factory: 1) receiving fresh roots, 2) peeling and cleaning roots, 3), grating or chipping cleaned roots, 4) dewatering the cassava mash or chips, 5) disintegrating the pressed cassava, 6) drying wet grits, 7) milling dried grits, 8) packaging the flour, 9) boxing packaged flour and 10) dispatching boxed product.

A modern industrial cassava flour processing approach where all operations are mechanized (from: cassavaprocessing.com)

Technology 4. Quality Assurance of Unfermented Cassava Flour

Summary. Quality assurance is critical to the widespread acceptance of unfermented cassava flour by the food industry. The main safety threats to the flour are hydrogen cyanide, microbial and aflatoxin contamination; three major health risks for consumers. The first risk is addressed by reliance upon improved "sweet varieties" of cassava having low or safe levels of this toxic substance, and the second met through proper handling and rigorous monitoring. Other criteria include the absence of foreign matter and harmful microorganisms. Adherence to safety standards requires implementation of well-designed management systems practiced along all processing steps. Central is the use of good manufacturing practices involving personal hygiene, safe handling, preventing contamination, and safe storage. Sanitation is another key aspect of risk prevention, including upkeep of the building, ventilation, vermin control, and waste management. More information can be obtained from Adebayo Abass of IITA by email at a.abass@cgiar.org.

Technical Description. Preventing health risks and matching consumer preferences are the key objectives of any food producer and must be closely safeguarded. The Hazard Analysis and Critical Control Point (HACCP) system deals with ensuring the safety of food products. It is a scientific and systematic approach to identifying hazards and providing measures for their control to guarantee food safety. A quality assurance system monitors product characteristics such as color, taste, smell, and nutritional value as a mechanism toward both consumer and regulatory acceptance.

Principles of a food safety system

Uses and Composition. Hazard and quality control touch on all segments of the cassava flour value chain from growing, harvesting, purchasing, processing, distributing, and merchandising. Systems for quality control are based on an inventory of hazards and defects that are likely to occur and cause serious injury, illness, or customer dissatisfaction. Critical control points are located along the processing chain where hazards and defects can be reduced and the maximum acceptable limits of contamination satisified. Monitoring procedures with a sequence of observations and measurements assess whether quality standards are met. Plans for corrective action specify what is done when a deviation occurs, who is responsible for what action and how remediation is documented. Verification procedures determine if the quality control plan is valid and if the facility operates to expectation. Recordkeeping and documentation procedures outline how observations and tests must be logged and tracked in an accessible and transparent manner.

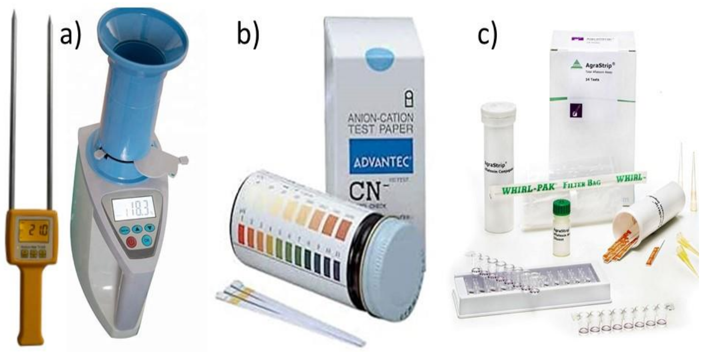
Application. Ensuring that cassava flour meets chemical safety standards starts from the selection of a variety that has a low cyanide content. The necessary analyses for safety and quality control include those for cellulose, ash, viscosity, acidity, water quality, content of cyanogens and microbiological loads. Routine tests may be performed in-house and others contracted to reputable laboratories. The critical limits and criteria for food safety are embodied into regulatory standards and guidelines. For reliable results, instruments for quality analyses should be regularly inspected, properly maintained and accurately calibrated.

Recommended physical, chemical, and biological quality limits for cassava flour

Parameter	Acceptance level
Moisture content	≤12%
Starch content	≥60%
Total cyanogens	≤ 10 mg/kg HCN equivalent
Total aflatoxins	<10 µg/kg
Particle size	250-500 µm
Yeast and Mold	<100 colony forming units/g
Harmful organisms (e.g. Salmonella, Staphylococcus)	Nil
Acidity (pH)	>5.8

Commercialization and Start-up Requirements. Services for developing, implementing, and monitoring food safety and quality plans are offered by consultancy firms. These hold accreditation from national regulatory agencies and can award certificates for product compliance. Various steps must be taken to set up a food safety and quality control system in cassava flour enterprises: 1) Developing plans for hazard and quality analysis, and critical control points along the processing steps, 2) Educating personnel, suppliers, and buyers about the rationale behind the system, its operational procedures, and its benefit for marketing, and 3) Building the infrastructure needed to test for health hazards and quality norms.

Production Cost. Implementing a quality assurance system requires skilled personnel and laboratory testing which bear an additional cost for producers. Generally, the cost to develop food safety plans and sampling procedures starts at about US $3,000 for a small food processing enterprise. Training on food safety standards and quality testing costs about US $1,200 per employee.



Examples of a) flour moisture meters and b) cyanide and c) aflatoxin qualitative test kits

Customer Segmentation and Potential Profitability. Quality control is applicable to industrial flour processors and food manufacturers, as well as small-scale and community-based activities. Having quality control systems in place largely determines the success of a cassava flour enterprise in a competitive environment. When food safety and quality standards are met, the market value of cassava flour is ensured, protecting both profitability for processors and farmer livelihood. Implementing rigorous hazard prevention reduces product loss resulting from spoilage and promotes consumer confidence.

Legal and Regulatory Requirements. National laws provide clear guidelines and regulations which food processors must abide by when selling on domestic markets. Implementing a quality assurance system is a priority to ensure that cassava flour is compliant with these food regulations and standards.

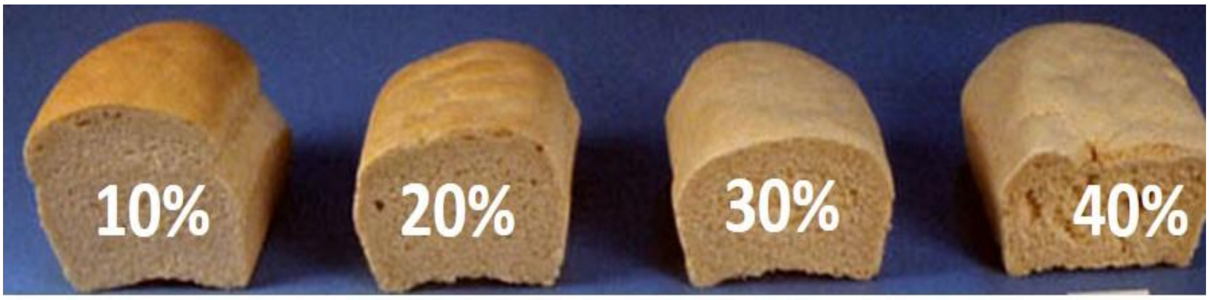
Technology 5. Cassava Flour as a Major Bakery Ingredient

Summary. Demand for bread and other baked goods in Africa results in massive importation of wheat flour. Much of this wheat is imported from Europe, in particular Russia, France and Ukraine, with prices surging by 50% over the past few years. At the same time, it is possible to use cassava flour as a blended ingredient in baked products. It can readily substitute for 10% to 20% of the wheat flour in bread without noticeable affects in taste and texture, but adjustments are required in the baking process to account for its different chemical composition, particularly the lack of gluten that binds bread together, and its resistance to rapid yeast fermentation. The importance of reducing wheat imports into Africa is critical, so that its limited foreign reserves may be better directed toward development, and widespread partial substitution of cassava flour for wheat in bakery products is an important component of that goal. More information on cassava flour as an ingredient for baked products in Africa may be obtained from Adebayo Abass of IITA by email at a.abass@cgiar.org.

Technical Description. To produce cassava flour suitable for baking, roots are peeled, washed and grated, dewatered by pressing, dried and milled (see Technology 3). Within airtight plastic bags, the flour can be stored for at least eight months. Cassava flour is gluten-free and in many ways is the most similar gluten-free alternative to wheat flour in terms of taste, texture and baking substitution. This includes the production of bread, muffins, cookies, cakes and pasta (see Technologies 6 and 7). Because cassava flour does not contain gluten, its replacement of wheat causes the characteristics of baked products to differ, and ratios for replacing wheat flour that consumers find acceptable varies among baked products. Cassava flour can replace 75% of wheat flour in sponge cakes, 50% in butter cookies, 25% in doughnuts, and 10% to 20% in bread. Cassava flour can replace 25-50% of the rice starch in oriental noodles, making them softer and more elastic (see Technology 7).

A variety of baked goods prepared with cassava flour

Uses. Bread requires High Quality Cassava Flour (HQCF) produced within a day of harvesting the root. It is pure white, has a low fat content, and can be mixed with wheat flour to produce a variety of baked products. HQCF is different from traditionally fermented cassava flour (see Technology 1), as it does not have the same smell or taste, and has a very uniform consistency. It has a very fine, slightly gritty texture useful for baking, pasta dough and as a thickener of stews. Cassava flour is increasingly mixed with wheat flour to make bread. Cassava bread has a nutty taste and a somewhat chewy texture. Cassava flour is lighter than all-purpose flour (130 g per cup versus 150 g), and it absorbs slightly more liquid. The counteracting characteristics allow for partial substitution of cassava flour for wheat flour and all-purpose flour using a substitution 1:1 ratio. Cassava flour is lower in calories, higher in fiber and contains some vitamin C and antioxidant. It is a grain-free and gluten-free for those on restricted diets. At the same time, cassava flour does not rise well when mixed with yeast because of its lack of gluten, so it must be used in limited proportions within yeasted



The volume of baked bread decreases with increased substitution of cassava flour for wheat flour and is generally acceptable to consumers up to 30%

baked goods. Inclusion of cassava flour in bread production does not pose a threat to blood glucose, it has anti-inflammatory properties, and nourishes beneficial bacteria in the digestive system. In this way, intake of cassava assists in the prevention of cardiovascular diseases, reduced obesity and treatment of Type-2 diabetes.

Composition. Cassava flour contains about 10% moisture, 65% to 70% starch, 3% ash, and 2% crude fiber. Its particle size is between 250 and 500 microns. Total cyanogens must not exceed 10 ppm. It must be free of any foreign matter, both mineral and organic and must not contain insect parts or mold. The finished product must be white (or yellow when produced from vitamin-A cassava varieties) and be free of off-flavors and odors.

Application. Cassava flour is not as useful as wheat flour for bread production because it contains more starch and less protein, including gluten, and absorbs more water. Nonetheless, a simple bread may be prepared from it in the following manner.

Cassava Bread. A simple bread prepared from unblended cassava flour takes only 10 minutes of preparation and 40 minutes baking. It requires 2 cups of cassava flour, 6 eggs, 1 teaspoon baking powder, 1 teaspoon salt, 1 tablespoon vinegar, 1 tablespoon honey, ½ cup oil and ½ cup water. These ingredients are mixed in a large bowl, placed into an oiled bread pan and baked at 180^{o} C (= 350^{o} F) F. Beforehand, grease the loaf pan. After removing from the oven, the cool the bread for 60 minutes before slicing. The resulting bread tastes slightly nutty and earthy, and is a gluten-free product. Partial substitution with cassava flour must take into consideration the texture, aroma, flavor and color in comparison with bread made only with wheat flour. In general, cassava flour may replace between 10% and 20% of the wheat flour typically used to make bread without significantly altering its leavening, baking and sensory characteristics. Above the 20% limit, the appearance, texture and taste of bread made with a mixture of wheat and cassava flour start to display different characteristics compared with bread made with wheat flour alone. These differences result from reduced gluten, differences in the composition of starch, limited activity of the enzyme amylase, and restricted yeasted leavening. The addition of xanthan gum lends many favorable properties to blended cassava-wheat breads. Its inclusion at 1% results in greater bread volume, stronger crumb structure and better sensory acceptability at increased levels of cassava flour. It locks in moisture to the dough and provides structure to the loaf. To achieve these effects, add ½ to 1 teaspoon per 1 cup of cassava flour.

Cassava-Wheat Bread. A simple recipe for cassava-wheat bread follows. Combine 1 cup of cassava flour, 4 cups of wheat flour, 40 g (4 tablespoons) sugar, 35 g (1.5 tablespoon) margarine or butter, 20 g (6 teaspoons) instant yeast and 3 g (1/2 teaspoon) salt. Combine these ingredients in a mixing bowl, and add water to produce a soft dough. Allow to rise to three times its initial volume (30 to 60 minutes), then kneed until smooth, and divide into four equal parts, placing each into a greased bread pan. Allow to rise again then bake at 200º C (400º F) for 15 to 20 minutes. Remove from bread pan and allow to cool before slicing or wrapping. This recipe uses 20% cassava flour (1 to 4 parts) and can be increased to up to 30% cassava flour (1 to 3 parts) without considerable change in its characteristics.

Bread loaf prepared using 20% cassava flour, note the substantial rising and color

Start-up Production Cost and Profitability. Breadmaking at commercial scales require baking ovens that are available in a range of sizes. A smaller, portable three-tray oven that operates from either electricity or cooking gas costs between US $2,000 and $3,000 and is suitable for a local bakery or larger restaurant. A larger stationary commercial oven with 32 to 64 baking trays costs between US $7,000 and $12,000, with the higher quality ovens offering rotary features. The most rapid approach to substitution of wheat flour with cassava flour is for current breadmakers to modify their ingredients accordingly. The cost of this substitution depends upon the comparative price of wheat and cassava flours, respectively. Wheat prices have risen sharply over the past decade but nonetheless a ton of wheat flour costs about US $250 from the factories located near to its production and over US $450 when it is imported to Africa. Cassava flour produced in Africa is similar in price, costing around US $450 per ton. One of the disadvantages of bread, its perishability and rapid loss of quality, is also an opportunity allowing competitive advantage to local bakeries and brands. Even large bread manufacturers often operate using decentralized production models.

Two commercial oven options, a mobile three tray batch oven (left) and, a 32-tray fixed convention oven (right)

Client Segmentation. Segmentation exists among both producers and consumers. Bread production occurs within both large industrial bakeries and smaller localized operations. Before large bakeries commit to blended flours, they must be assured both reliable supply of the substitute flour and consumer acceptance of the adjusted ingredients. Assuming that producers are able to maintain desired texture and consumers are willing to accept a moister bread with less hint of yeast, the potential for widespread manufacture and sale of baked goods made mostly or entirely from cassava flour is enormous.

Regulatory Requirements. Breadmaking is subject to many necessary quality control conditions. The issue of mandatory substitution of cassava for wheat flour must be handled carefully to ensure that bread supply is not constrained by insufficient availability of cassava flour. Bakeries can be offered incentives to include cassava flour as an ingredient, and later inclusion can be required in a way that reduces crippling national dependency upon wheat importation. These regulations also interact with national efforts to increase domestic wheat production.

Technology 6. Cassava-based Pastries and other Recipes

Summary. Many other tasty and nutritious foods beside bread may be prepared from cassava in ways that substitute for wheat flour. These preparations include snacks and pastries such as cookies, cupcakes and donuts whose recipes are featured in this section.

Cassava Pancakes. *Ingredients:* 2 cups cassava roots, grated, de-watered; 1/2 teaspoon chopped ginger; 2 medium eggs, ¼ cup sugar; 1 tablespoon vegetable oil. *Instructions:* Place 2 cups of grated, dewatered cassava mash into a mixing bowl. Add ginger, eggs, and sugar and mix thoroughly. Spread a little vegetable oil onto the surface of a frying pan and set to low heat. Spoon and spread the mixture into the heated pan and allow it to brown, turning each side until evenly cooked. Repeat until all the batter is cooked. Makes about 6 large pancakes. Serve with syrup or fruit jam as breakfast food.

Cassava Cookies. *Ingredients:* 2 cups cassava flour; ½ cup margarine; ½ cup sugar; 2 teaspoons baking powder; pinch of salt; ¼ teaspoon of nutmeg or cinnamon; water. *Instructions:* Add the dry ingredients into a bowl and mix thoroughly. Add margarine and mix again. Gradually add sufficient water to form a stiff dough that no longer sticks to the sides of the bowl. Lightly flour a rolling surface, and roll the dough to a thin layer. Cut the rolled dough into desired shapes and size using a biscuit cutter. Place into a baking pan and prick the surface of these raw cookies with a fork to reduce rising while baking. Bake in a pre-heated oven at 175° C (= 350° F) for 15 minutes or until golden brown.

Cassava Queen Cakes. *Ingredients:* 4 cups sifted cassava flour; 1 cup sugar; 1 cup margarine; 4 teaspoons baking powder; 1 teaspoon vanilla essence; 2 eggs; 1 cup milk.*Instructions:* Mix together sugar and margarine until fluffy. Beat eggs and add to the sugar/margarine mixture, add vanilla essence and mix again. Add baking powder to the dry cassava flour and mix. Fold the cassava flour into the first mixture and gradually add milk as it becomes stiff. Add other ingredients as desired such a fruit or nuts to the batter. Grease queen cake pans with oil or margarine, dust the greased pan with some flour and scoop batter to fill ½ full. Bake in a pre-heated oven at 175° C (350° F) for 20-25 minutes or until evenly brown.

Cassava Donuts. *Ingredients:* 2 cups cassava flour; ¼ cup sugar; 1 rounded tablespoon margarine; 1 egg; 2 teaspoons baking powder; ½ teaspoon nutmeg or cinnamon; 3 cups of vegetable oil. *Instructions:* Mix 1½ cups of cassava flour with sugar, margarine, baking powder and nutmeg. Boil ½ cup of water and add the remaining 1/2 cup flour, mixing shortly under heat. Combine the dry mixture and the boiled cassava flour, mixing by hand until it resembles breadcrumbs. Whisk the egg until light and add to the mixture, again mixing by hand until a smooth dough results. Note that this dough should not stick to the edges of the mixing bowl.

Do not knead the dough as this will make the final product too dense. Mold the dough into doughnut shapes, forming balls, flattening each and putting a hole in the center. Deep-fry in hot oil until golden. Note that donuts may also be baked instead in a pre-heated oven at 175° C (350° F) for 20-25 minutes, after brushing with beaten egg to ensure a crispy crust.

Cassava Chinchin. Chinchin is a fried, crispy snack food. *Ingredients:* 4 cups cassava flour; ½ cup sugar; 2 heaping tablespoons margarine; 2 level teaspoons baking powder; 2 medium sized eggs; 1 teaspoon nutmeg or cinnamon; 1 cup water; 3 cups vegetable oil for deep frying. *Instructions:* Mix 3 cups of the cassava flour with sugar, margarine, baking powder and nutmeg. Boil I cup of water, once boiling add one cup of cassava flour and remove from heat, folding cassava flour into the water. Add the cooked cassava flour and mix together by hand until the mixture resembles breadcrumbs. Whisk eggs until light, and add to the mixture. Again mix by hand into a smooth dough that does not stick to the side of the bowl which leaves the sides of the bowl clean. Do not knead! Roll evenly on a floured board and cut into desired shapes and sizes. Deep-fry in oil until attractively brown. Drain away excess oil.

Cassava Banana Bread. *Ingredients:* 1½ cups cassava flour; 1 teaspoon baking soda; 1/2 teaspoon salt; 1/4 teaspoon cinnamon; 3 extra ripe bananas (1½ cups mashed); 1/3 cup vegetable oil; 1/3 cup sugar; 3 eggs, 2 teaspoons vanilla extract; 3 tablespoons milk. *Instructions:* Preheat oven to 175° C (375° F). Grease a medium-sized pan (e.g. 25 cm x 10 cm) and set aside. Mix cassava flour, baking soda, salt and cinnamon in a medium bowl. Mash bananas in a large bowl and whisk in oil, sugar, vanilla extract and milk until combined. Add eggs and whisk until smooth. Carefully add and mix the dry ingredients (cassava flour, baking soda, salt and cinnamon) to the large bowl of wet ingredients (bananas, oil, sugar, vanilla extract and milk). Do not over-stir. Transfer batter to prepared pan and bake oven at 175° C (= 350° F) for 35-40 minutes or until brown, cover top with foil if browning is too rapid. Cool bread for about 15 minutes before slicing. Note that coconut, dates, and nuts can be added to the wet ingredients to provide more texture, and that overripe bananas still produce a tasty bread.

Cassava Flour Flatbread. *Ingredients:* 1 cup cassava flour, 2 teaspoons honey; 2 teaspoon salt; 1½ teaspoon baking powder; 4 teaspoons vegetable oil; 1 cup coconut milk; 1 egg. *Instructions:* Combine cassava flour, salt and baking powder in a large bowl, and mix together. Create a well in the middle of these dry ingredients and add the honey, olive oil, coconut milk, and egg. Mix and form a ball. Place the ball on the counter and knead for 5 minutes, adding more flour as needed. Rest the dough for 10 minutes. Divide into 16 equal pieces and roll each piece of dough until thin. Heat a pan over medium heat and cook the rolled dough one at a time for about 1½ minutes on each side until parts blacken. These flatbread are best eaten with stew.

Cassava Flour Brownies. *Ingredients:* 3 tablespoons unsweetened cocoa powder; 1/3 cup plus 1 tablespoon cassava flour; 1/2 teaspoon salt; 1/4 teaspoon baking soda; 1 cup chocolate pieces; 1/2 cup butter; 3/4 cup sugar; 2 eggs; 2 teaspoons vanilla extract. *Instructions:* Preheat oven to 175^o C (350^o F) and grease a 20 cm x 20 cm baking pan. Combine cassava flour, unsweetened cocoa powder, salt and baking soda in a medium bowl. Melt together chocolate pieces with butter over low heat, whisking until smooth, allow to cool slightly, then whisk in sugar until smooth. Add vanilla and eggs, whisk for 2 more minutes. Transfer chocolate mixture to large bowl and add dry ingredients, and mix a with spoon to form a thick and fudgy batter. Transfer to the baking pan and bake for 20 minutes or until edges of brownies rise slightly. Cool at room temperature for 45 minutes to 1 hour. Cut brownies into squares.

Many other foods. Note that many other foods may be prepared from cassava flour including its use as a short crust and wrapper in meat pies, sausage rolls and egg rolls. Many other types of pastry and cookies can be made with cassava flour than those simpler ones described above. Other recipes describe the use of cassava flour in scones and dry crackers. Fresh cassava root may be cut into slices or strips and fried into crisps (chips) and French fries. Shredded cassava root is used in fritters, and is delicious in combination with shredded coconut. Tapioca is a starch extracted from cassava root that is distinct from cassava flour, with a gummy texture useful in pudding. Also note that cassava leaves are also eaten after cooking and are widely incorporated into stews and soups.

Technology 7. Cassava Flour as a Pasta Ingredient

Summary. One of the challenges faced by the pasta industry is the rising cost and availability of its ingredients, and in the case of Africa this is primarily imported wheat flour. Wheat in pasta competes with other food sectors including baking, brewing and snack foods; so pressure on this commodity results in fluctuations in price and availability. At the same time cassava flour is a practical substitute for wheat flour and may be blended to reduce the quantity wheat needed to make pasta and noodles. Pasta made from wheat is usually produced without eggs or cooking, but inclusion of cassava requires different processing. Cassava flour does not contain gluten as a product adhesive, so eggs play that role. Cooking blended pasta and noodles before drying binds the flours, resulting in an improved product. More information on cassava flour as a pasta ingredient may be obtained from the TAAT Clearinghouse.

Technical Description. Pasta is an ancient food formed from dough extruded or stamped into various shapes for cooking. Dried pasta is economical, easy to prepare, has an extended shelf life, and consumed in many different ways. Pasta products are traditionally made from durum wheat milled into semolina flour and mixed with water, salt, and vegetable oil. More recently, pasta includes non-wheat ingredients including cassava.

A cooked cassava pasta ready for eating

Uses. Pasta dishes are served for lunches or dinner and with different sorts of sauce that vary in taste, color and texture. Italian pasta is generally made from wheat and described by its shape including spaghetti (long strands), penne (hollow cylinders), lasagna (sheets), and linguine (strips). Pasta may be made at home, immediately before eating, or more commonly purchased as a dry product prepared by boiling in salted water for a few minutes. Asian noodles are similar but made from a wider variety of ingredients including rice, yam, and mung bean in addition to wheat. These include egg noodles, ramen, glossy rice sticks and thicker udon; with different preparations in soups and stir fries. Cassava flour may be added as an ingredient to either of these products.

Application. It is possible to make ready-to-eat cassava pasta with the following recipe.

A hand operated pasta press suitable for restaurant use

Cassava Pasta. Add cassava flour to a large bowl and make a small well in the center of the bowl. Add three mixed eggs to the well. Using hands, swirl the flour into the egg mixture; being careful not to form flour dust. Begin boiling 3 cups of water with salt ¼ cup of salt. The salt from the water seasons the pasta. There is no need to knead the dough, if it seems dry add 1 or 2 tablespoons of water. Roll the pasta dough into a ball, roll the ball into additional cassava flour and then flatten the ball of dough with a roller. Cut the flattened dough into strands. Once your pasta is formed, toss the strands in extra cassava flour to ensure they don’t stick. Once your pasta water reaches a rolling boil, add the cassava pasta in small amounts, stirring to ensure the pasta does not stick together. The pasta cooks quickly, remove it from the pot after 1-2 minutes in the salted boiling water. The pasta is now ready to eat.

Cut strips of cassava pasta ready for cooking

Blended Wheat-Cassava Pasta. A similar, blended (25% cassava) flour wet noodle can be produced at a larger (e.g. restaurant) scale by combining 1 kg cassava flour, 3 kg wheat flour, 10 large eggs, and 3 tablespoons cooking oil. Mix the flours, knead the dough, flatten and cut to desired dimensions, cook in salted water with oil on surface to prevent clumping, cook for 3 minutes, strain and place under running water and accompany with sauce.

Paleo Cassava Pasta. A paleo diet emphasizes foods were first obtained by hunting and gathering, prior to agriculture. It discourages use of dairy products, legumes and grains. In this case, cassava is viewed as a total replacement for wheat. This recipe describes a small- to medium-scale cottage-industry preparation of cassava pasta that requires about five hours to prepare and does not rely upon a mechanized pasta roller and cutter. *Ingredients:* for each 1 cup of cassava flour; 3 eggs; ¼ teaspoon of salt and 3 tablespoons of vegetable oil are required. *Instructions:* Pile cassava flour on a clean, flat surface, form a crater in the center large enough to hold the liquid ingredients. Place the eggs, oil and salt into the crater and whisk the eggs in a way that mixes with some of the flour. Further mix and knead the dough by hand, forming it into a ball. The ball should be flexible but not sticky. Form the ball into a cylinder and add flour to the rolling surface. Press the cylinder into a flat rectangle and roll it as thin as possible with the shorter edge equal to the intended length of the pasta strips. Cut the pasta strips with a thin knife and remove the strips from the rolling surface. Bring a large pot of salted water to a boil and boil the pasta strips for 2 or 3 minutes. Drain the pasta in a strainer and rinse with cold water to remove excess starch. Spread the strips on a trays without them touching each other. Dehydrate strips at 60^{o} C (135°F) for 5 to 6 hours. Alternatively, pasta may be dried in an oven at 80^{o} C (175 F°) for 3 to 4 hours, testing for dryness. Package the dried pasts into an airtight bag and label with date and ingredients.

An industrial-scale pasta roller and cutter (left) and drying oven (right)

A wide variety of hand operated pasta presses are available for home and cottage industry use. These consist of adjustable rollers and cutters and are made of stainless steel. These devices roll sheets of dough to 0.6 to 5 mm thickness and about 15 cm width. Some models are upgraded with motorized and additional pasta cutting accessories. Hand pasta presses cost between US $30 and $80 from suppliers, and are available in some African countries.

Commercialization. Commercial blended pastas are produced in four steps: weighing and mixing dry ingredients, adding water, rolling out and cutting the dough, and drying. The dry ingredients are mixed by machine and then water added, followed by kneading to obtain homogeneous dough. The dough is rolled out in a pasta machine (or extruded to shape) to about a 0.4 cm thickness and then cut to desired dimensions depending upon the intended product. Pasta is then dried with forced air at temperatures ranging between 60^{o} to 70 °C and packaged.

Start-up Requirements. The consumption of dry pasta continues to grow, and investment into pasta production is timely. The pasta industry now responds to nutrition and health concerns, including the use of blended materials and gluten-free products. Production capacity depends upon commercial objectives, and the availability of ingredients and market. Pasta factories require reliable, clean water and electricity. A reasonable production objective is a pasta factory manufacturing 250 kg h^{-1} dry pasta, or 2 t of pasta in an 8-hour workday. The most important machine is the press where ingredients and water are mixed together and the dough transformed into pasta. Pasta presses are available for US $10,000 to $30,000, and fully automated factories sold for US $100,000 or more. The dough is pushed through a die that gives shape to the pasta and a blade cuts it according to desired length. All other operations must be scaled to the press, including drying. Drying is a thermal treatment where moisture is reduced from about 30% to 12%, preferably within 8-12 hours. Suitable forced air pasta drying ovens are available for US 4,000 to $10,000 depending upon their capacities. The final moisture content is checked and the product packaged. It is common that dried pasta be sold with a three-year expiration date.

Production Cost and Profitability. As with the bakery industry, the most rapid approach to substitution of wheat flour with cassava flour is for current domestic pasta manufacturers to modify their ingredients and process accordingly. The rise of domestically-produced quick cooking Asian noodles across Africa provides a promising entry point. The cost of this substitution depends upon the comparative price of wheat and cassava flours. Wheat prices have risen sharply over the past decade but nonetheless a ton of wheat flour costs about US $250 from the factories located near to its production and over US $450 when it is imported to Africa. Cassava flour produced in Africa is similar in price but represents savings in foreign reserves. To a large extent, the advantage rests with local supply conditions and national economic strategy.

Client Segmentation. Throughout much of Africa, pasta is considered a food of the rich but more widespread production of pasta and noodles based upon cassava as a main ingredient can change this perception. Basically two different products are offered; perishable fresh noodles and non-perishable dried pasta. Fresh noodles are used by restaurants and offered in upper-end retail outlets. Dried pasta is intended for home use and cooks quickly, and may be stored safely for up to three years. A key to the popularization of cassava-based noodles and pasta is the understanding of which sauces are served as an accompaniment. Tomato-based pasta sauces are widely recognized, other options include traditional stews, pumpkin or leafy green purees. Asian noodles are often served within soups.

A popular instant noodle product from Nigeria made with cassava

Regulatory Requirements. Inclusion of unfermented cassava flour within pasta manufacture is not subject to any additional regulatory scrutiny than other pastas. It is likely that as increased dependency upon imported wheat grows, African countries will respond by requiring that cassava flour be substituted for wheat within reasonable limits, and that proof of this compliance be documented.

Technology 8. Cassava Peels for Animal Feed Production

Summary. Processing cassava roots into food or starch products results in massive amounts of peels that were previously regarded as a waste product. Typically, 1 ton of fresh cassava roots results in 200 to 300 kg of peels, with a staggering total of 40 million metric ton peels being generated annually across Sub-Saharan Africa per year. In contrast, cassava peels can be used as a feed and fibre source for livestock and fish, but it is often unused because of difficulties in transport, drying, risk of aflatoxin contamination and poor storability of the resulting feed products. Simple equipment can be relied upon to mechanize the conversion of cassava peels into animal feed that not only result in a saleable product but also provides a source of employment. This opportunity literally creates a market for the fresh peels themselves, positioning cassava producers and food manufacturers as suppliers of nutritious animal feeds. Scaling mechanized processing of cassava peels into wet cakes and dry grits clearly presents many opportunities for business development across Africa wherever cassava is processed, and business models are available toward that end. For additional information about this topic, contact Dr. Iheanacho Okike of the International Livestock Research Institute by email at i.okike@cgiar.org.

Technical Description. Low-tech approaches for processing wet cassava peels into safe and hygienic animal feed sources have been developed that can be powered by small generators and carried out in small-scale farming communities with limited road connectivity and electrification. Using mechanized graters and presses, this processing makes it possible to remove five hundred litres of water from a ton of fresh peels in only 30 minutes, and reduce the drying time of peels to 6-8 hours instead of the 2-3 days for traditional methods. The major savings in labour and time achieved through these simple equipment allow for large volumes of cassava peels to be processed into animal feed in a cost-effective manner. With this technology, harmful substances like cyanides and aflatoxins do not accumulate in the final wet cake or dry mash product, thus safeguarding the health of animals and consumers along the food chain. Farmers and processors can organize timely and low-cost supply of cassava peels through data applications like 'Peel Tracker'; a virtual market place in which the location, quality and amount of resources can be shared. Animal feed production from cassava peels creates additional sources of income for farmers growing the crop, and brings down prices of feed ingredients for manufacturers and livestock owners.

Uses. Simple mechanized processing of cassava peels into animal feeds can be deployed in all cassava growing areas of Africa as it does not require large infrastructure and can be performed by persons with limited technical training. Animal feed ingredients from cassava peels can replace maize and wheat that are more expensive, and thus very suitable for areas in Africa that suffer from shortage of affordable, high-quality animal feed. Wet cakes, obtained after one round of grating and pressing cassava peels, have a shelf life of one week and can be fed in pure form to cattle, sheep, goats, and pigs. Mashes that undergo fuller processing and drying can be stored for 4 to 6 months, and are suitable for feeding all types of livestock, poultry and fish. These high-quality feeds can fulfil up to 40% of the dietary needs of pigs, 27% of brood hens and 15% of broiler chickens. Cassava peels are energy-rich but have relatively low levels of protein, which requires that diets are adequately supplemented with crude proteins, particularly those containing the amino acids methionine and lysine available from soybean and maize.

The process of preparing animal feed from fresh cassava peels

Composition. The crude protein content of cassava peel animal feeds is low, amounting to only 4% to 6% for wet meal, 3.1% for coarse mashes, and 2.6% for fine mashes. Crude fat contents of mashes are also low at 1.7% but the starch content is 78%. This results in an energy-rich feed that contains insufficient protein. Fine fractions of dry mashes are higher in energy content and lower in fibre content, whereas the coarse fractions have a lower energy content and higher fibre content. When cassava peel processing is done appropriately, the hydrogen cyanide concentrations of animal feed products fall below 10 parts per million (tolerable limit: 100 ppm), and aflatoxin presence is well under the permissible 18-20 parts per billion. Wet cakes made from cassava peels typically contain 38−42% of moisture after one round of grating and dewatering, while dry mashes should have 10-12% moisture before packaging to achieve safe storage.

Application. Before processing of cassava peels, all remnants of soil must be removed for protecting the grater from damage and avoiding spoilage of feed products. As a first step, the peels are grated up to three times to reduce the desired particle size, and then packed into sacks that are placed in a hydraulic press for dewatering (similar to Technology 1). The resultant wet cake is left in sacks overnight to ferment which causes hydrogen cyanides in the product to break down. As a next step, wet cakes are grated again to further reduce particle sizes, and then sieved to separate fine and coarse fractions. Mashes can be dried in direct sunlight by spreading the product thinly over clean plastic, metal sheeting or a cement slab; and turning the materials at hourly intervals. The mashes can also be oven dried, particulrly through heat tunnels. In more industrial settings, they may be flash dried. All machines and processing areas must be kept in hygienic condition after each run to restrict microbial contamination, particularly aflatoxin-producing fungi. Disposal of process waste water should be done through seepage tanks that avoid pollutants from entering surface waters.

Commercialization and Start-up Requirements. Hand and mechanical equipment to prepare animal feed from cassava peels are commercially available in all African countries, allowing for this technology to be adopted widely wherever cassava peels are plentiful.

Commercializing the processing of converting cassava peels into animal feeds requires several steps: 1) Raise awareness of cassava farmers and processors about the advantage of animal feed production from cassava peel wastes; 2) Identify processing equipment and facilities appropriate to the scale of intended cassava peel processing that match expected throughput volumes; 3) Tailor operational protocols and business plans for processing and marketing of cassava peel animal feed products; and 4) Adjust operations to the different forms of animal feeds and their required supplementary materials, and brand and market the resulting products.

Production Cost. The base equipment required for small-scale processing of cassava peels into animal feeds requires an investment of approximately US $3,400 including a motorized grater for US $1,000, a hydraulic or screw press for US $600, a motorized pulveriser for US $850, a mechanical sieve for US $400, and a supplemental dryer for US $550. In addition, a backup generator is needed in areas with unreliable power supply. Once this equipment is assembled, the approximate total cost of producing one ton of dry mash is about US $114 including production of wet cake at US $20, grating at US $18, dewatering by the hydraulic press at US $6, drying at US $40, fuel costs at US $17, and other miscellaneous costs.

Offering processed cassava peels for sale as animal feed

Customer Segmentation and Potential Profitability. This technology targets small- to medium-scale animal feed processors operating in areas where abundant wastes of cassava peels occur, and where strong potential demand for animal feeds exists, particularly where livestock feeds are currently unavailable or unaffordable. The market price for one ton of dry ffed mash in Nigeria is US $210 and if it costs US $114 to produce. then a potential profit margin of 84% exists. This is quite high for industrially produced bulk products, so it is likely that as more processors are attracted to the market the value of "peel meal" will be reduced. At the same time, feeding poultry a diet of 50% cassava peels instead of 100% maize-based blend reduces feed costs by over 20%. Substituting maize with cassava peels serves to overcome shortages of animal feeds in Africa, and at the same time increases profit margins for livestock, poultry and fish producers. In this way, the use of cassava peels is able to release millions of tons of maize meal toward human consumption that is otherwise used for animal feed; significantly increasing food security. When cassava peels are exploited to the fullest, it is possible to produce at least 4 million ton of high-quality animal feed ingredients per year across Africa, valued at around US $600 million.

Licensing Requirements. Phytosanitary certificates may be required to produce and sell animal feeds made from cassava peels in many African countries that are based in part upon regular testing for aflatoxins. Technologies for feed production from cassava peels are a readily available Regional Public Good and The International Livestock Research Institute disseminates this technology across Africa.

Youth-led Cassava Processing Enterprises

Youth entrepreneurship is a critical ingredient of Africa's agricultural transformation and their engagement with modernized agriculture reflects this opportunity. A widespread opportunity is through the establishment of small- to medium-scale cassava processing enterprises reliant upon several of the technologies presented in this catalogue. These enterprise opportunities include the processing of high quality cassava flour (Technology 3) and providing quality control services to other operations (Technology 4); establishing local bakeries that rely upon cassava flour and flour blends (Technologies 5 and 6); exploring pasta and noodle making as expanding food products (Technology 7); and preparing cassava peels as livestock feed (Technology 8). In some cases, these enterprises are most readily established through collective action within youth groups, while in others cases, entrepreneurial youth can be offered incentives to start food businesses. For example, enterprising youth may be offered opportunity by larger cassava flour producers in need of markets to operate bakeries or animal feed businesses based upon the increased availability of cassava flour and by-products. Also note that other enterprises are necessary along the cassava value chain to ensure reliable supply of raw cassava roots, such as the propagation of improved starchy varieties or the market collection of roots among small-scale producers.

As early innovators, youth groups are able to establish cassava processing facilities, develop skill sets around their management, and then replicate the enterprise within individual private businesses. Literacy and smart phone access contribute to this advantage as a wealth of free information is readily available on reliable cassava processing technologies. A youth group established a pioneering cassava flour factory in east DR Congo with the encouragement and partial support from IITA. The factory is designed to process one ton of cassava roots per hour, resulting in 60 ton of flour per month worth over US $24,000. Construction of the factory required $19,000 and equipping it cost $16,000. Another US $9,000 was required to meet miscellaneous start-up costs, bringing the total initial

A "low-tech" youth-led cassava flour factory in action: a) washing and shredding peeled cassava roots, b) air drying shredded roots, c) milling dried roots into flour, d) displaying the finished product investment to US $52,000. The factory employs 20 workers with 14 of them being casual workers that peel and wash the incoming fresh roots. Production and marketing costs are about US $240 per ton of flour and casuals paid an additional US $100. The youth serve as supervisors, equipment operators, administrators and marketers. This margin provides a modest income to the youth who invest their time in the factory. These operations are relatively "low-tech" and could greatly benefit from mechanized peeling, shredding and oven drying but still demonstrate the strength of collective action by committed youth.

Youth in DR Congo learning baking skills involving cassava flour

Another youth group in DR Congo established a successful collective baking venture. Starting with five initial products, a youth group developed a suite 35 bakery products reliant upon flour blends and pure cassava flour. Their approach included combining cassava flour into other popular baked goods and then assessing local demand for these modified products. As it was located in a relatively remote area, the group opened a sales outlet in the nearest city to market both its baked products and the cassava flour produced by another team (see above). It also relied upon online marketing and sales that in turn created wider awareness on the opportunities of cassava processing.

Youth operating a shop that sells cassava flour and the baked goods they produce from it

Another youth group in Ibadan, Nigeria explored opportunities in establishing business enterprise around cassava processing. It initially focused upon producing gari, a traditional fermented food, packaged into 5 kg quantities, and later into 25 kg and 50 kg packages as well. This activity serves as a learning enterprise that was replicated within a youth agribusiness park 60 km distant. The youth team renovated and equipped an abandoned facility to operate at a commercial scale at a cost of US $25,000. Its location is strategically located in proximity to smallholder cassava producers and it provides employment to six persons. While intended as a business, it also trains additional young people through internship. Meanwhile, the initial youth group in Ibadan expanded to the production of baked goods as well, producing cassava-based and blended bread, cakes, meat pies and other products. This effort employs two full-time staff who primarily produce goods for the IITA community and visitors using cassava flour from the institute's pilot factory, further popularizing this business opportunity but perhaps limiting its market growth.

The IITA Youth Agripreneurs are expected to establish their own businesses after several months' internship. One of these youth established a private business, F-STEP Cassava Enterprise, that produces gari and fufu, another traditional fermented crop prepared from cassava (see Technology 1). These two foods are widely appreciated in Nigeria, particularly with meat and fish stews. Through this effort, a new service opportunity arose, processing farmer's own cassava into gari and fufu for their home use. These products are less perishable than raw cassava roots and it improves the household food supply of smallholder producers that would otherwise just sell their roots seasonally to F-STEP as a commercial buyer.

Meat pies prepared with cassava flour by two entrepreneurial youth in Nigeria

Youth are also well positioned to provide commercial services to cassava processing including the establishment and operations of vegetative propagation nurseries and their distribution to smallholder out-grower networks, marketing of cassava processing equipment and supplies, and contract expertise in quality control services. Indeed, youth will adopt the technologies offered in this catalogue provided the opportunity to do so. In part, these technologies were selected based upon that attraction to them. In particular, educated youth that find themselves un- or under-employed are able to appreciate the complexities of cassava processing in ways that older, more conventional local businesspersons do not, and can move into the sector quickly once access to reliable, serviceable and properly-scaled equipment is established. These youth are also better connected to information flows via the internet and social media, and can use these media to advertise and market their products. One disadvantage youth suffer, however, is a shortage of collateral and creditworthiness that translate into loan opportunities. This shortcoming is recognized and incentives for youth participation within development programs based upon sovereign country loans is increasingly offered, particularly those promoting the cassava value chain. When it comes to engagement in cassava processing, give youth a chance! *Information courtesy of the ENABLE TAAT Compact.*

An IITA youth group in DR Congo displaying the range of food products they make and sell through local outlets

Make TAAT Your Technology Broker of Choice

TAAT offers its services toward the advancement of modernized agriculture. It brokers a wide range of needed technologies and bundles them through a process of co-design into winning solutions. It recognizes that modernized agriculture must serve as the main engine for economic growth in Africa and operates accordingly. Change is intended to achieve not only food and nutritional security but also to meet obligations under climate agreements allowing collaborative efforts to better combine global, national, and community-level interests. TAAT operates from this unique perspective to mobilize innovative solutions through better partnering that includes honest technology brokerage and effective, scalable skills development through five key mechanisms.

- ☑ **Unique understanding:** Expertise is offered in the areas of site characterization and problem identification.
- ☑ **Innovative solutions:** Leadership is provided in technology brokerage and solution bundling based upon a dynamic portfolio of candidate technologies.
- ☑ **Better partnering:** Assistance is offered in the better co-design and management of projects prompting agricultural transformation.
- ☑ **Honest brokerage:** An robust capacity for impact assessment and constructive learning is achieved through standardized monitoring and evaluation.

Conclusions

This catalogue produced by the Technologies for Technologies for African Agricultural Transformation Program documents the massive potential for agro-industrialization of cassava and its role in reduced food dependence upon imported wheat. Cassava is advancing from a subsistence food to a major agricultural commodity with many opportunities emerging along its entire value chain. Foremost among those opportunities is its processing into a flour for further manufacture into a wide range of foods (Technology 3). High Quality Cassava Flour differs considerably from the traditional processing involving fermentation (Technology 1) and guidelines exist for the quality assurance of cassava flour (Technology 4). Cassava flour is either a partial or complete substitute for wheat flour depending upon the product. This level of substitution is based upon the characteristics of cassava flour itself, particularly its lack of gluten, weak reaction to yeasting and greater retention of moisture. As a result, in the manufacture of conventional bread, cassava flour may only be substituted by 10% to 20% without changing its texture and taste beyond conventional consumer expectations (Technology 5). But these expectations can be strongly influenced by the variety of products on offer. Numerous food products can be prepared from all cassava flour including gluten-free bread, pastries and other products (Technology 6). Another opportunity is the use of cassava flour in the production of pasta, where it can be substituted in part or whole depending upon the type of pasta manufactured (Technology 7). The first step in agro-industrial processing of cassava involves peeling, and these peels have value as animal feeds, that also impacts upon dependency of imported feed ingredients (Technology 8). The production of dried cassava chips for export offers longer-term potential (Technology 2) but Africa is better positioned to process its own cassava rather than export it as a dried raw material. Youth are particularly attracted to localized opportunities for cassava processing and this assists in overcoming their widespread economic marginalization. If only 25% of imported wheat is substituted by African cassava, this becomes an annual US $2.75 billion industry, strengthening Africa's food security and driving economic growth. Indeed, the time of cassava agro-industrialization has arrived!

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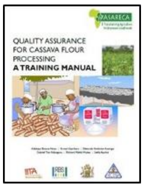

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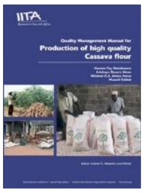

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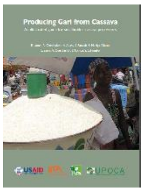

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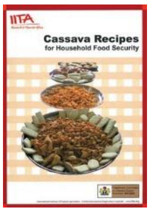

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Acknowledgements

This catalogue of cassava processing technologies results from a unique blend of two parallel efforts; the Technologies for African Agricultural Transformation Program (TAAT) and the DR Congo Agricultural Transformation Agenda. Paul L. Woomer, Dries Roobroeck, Adebayo Abass and Noel Mulinganya, operate in different capacities within IITA. P.L. Woomer and D. Roobroeck work with the TAAT Clearinghouse to characterize and validate technologies. A. Abass serves as the TAAT Cassava Compact Coordinator. N. Mulinganya works with the IITA Youth in Agribusiness Unit. Tola Adenmosun, Esperance Balezi and Jacob Mignouna, also with IITA, provided timely materials in support of this document. The TAAT Clearinghouse is funded through a project funded by the Bill and Melinda Gates Foundation. The larger TAAT Program, including its Cassava Compact, is supported through the African Development Fund of the African Development Bank. The DRC Agricultural Transformation Agenda is is a government program supported by a suite of grants and loans from the African Development Bank. For more information on the TAAT Program, visit its website at https://www.iita.org/technologies-for-african-agricultural-transformation-taat/.

Technologies for African Agricultural Transformation (TAAT) and its Clearinghouse Office

The development objective of TAAT is to rapidly expand access of smallholder farmers to high yielding agricultural technologies that improve their food production, assure food security, and raise rural incomes. This goal is achieved by delivering regional public goods for rapidly scaling up agricultural technologies across similar agro-ecological zones. This result is achieved through three principal mechanisms; 1) creating an enabling environment for technology adoption by farmers, 2) facilitating effective delivery of these technologies to farmers through a structured Regional Technology Delivery Infrastructure, and 3) raising agricultural production and productivity through strategic interventions that include improved crop varieties and animal breeds, accompanying good management practices and vigorous farmer outreach campaigns at the Regional Member Country level. The important roles of sound policies, empowering women, and youth, strengthening extension systems and engaging with the private sector is implicit within this strategy. The Clearinghouse is the body within TAAT that decides which technologies should be disseminated. Moreover, it is tasked with the responsibility to guide the deployment of proven agricultural technologies to scale in a commercially sustainable fashion through the establishment of partnerships that provide access to expertise required to design, implement, and monitor the progress of technology dissemination campaigns. In this way, the Clearinghouse is essentially an agricultural transformation incubation platform, aimed at facilitating partnerships and strengthening national agricultural development programs to reach millions of farmers with appropriate agricultural tools.

Dr. Innocent Musabyimana, Head of the TAAT Clearinghouse

Back cover credit: Different automated processing steps in the manufacture of cassava flour; root washing (upper left), wet shredding (upper right), milling and bagging (lower left) and stacking and storing (lower right).

Technologies for African Agricultural Transformation

Cassava Processing Technology Toolkit Catalogue

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