Meridian Institute
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Innovations for Agricultural Value Chains in Africa: Applying Science and Technology to Enhance Cassava, Dairy, and Maize Value Chains

Cassava Value Chain Overview

The Science and Innovation for African Agricultural Value Chains project will bring together leading scientists and innovators (Science Team) with key players in the maize, cassava and dairy value chains (Value Chain Partners and Participants) in Africa. The project goal is to identify out-of-the-box, innovative technology options that would add significant value for smallholder farmers (i.e., those farmers earning $1 - $2 per day) by reducing inefficiencies in these value chains in Africa, especially the harvest and post-harvest value chain elements. A value chain can be described as a series of sequential activities where at each step in the process, the product passing through this chain of activities gains some value. Generally, the chain of activities gives the products more added value than the sum of the added values of all activities.

The purpose of this paper is to highlight key constraints in the cassava value chain. To provide context for those constraints, the paper begins with an overview of cassava in Africa and highlights key issues such as gender and market dynamics. The paper concludes with a list of market inefficiencies and potential technological innovations that will be the focus for the Science Team. It should be noted that team members will be encouraged to consider potential cross-over technologies between value chains and with other processes outside of the value chains.

Cassava Value Chain Overview

Resembling a sweet potato, cassava is a starchy root crop that develops underground. The edible, tuberous root grows between 15 to 100 centimeters and ranges in mass between 0.5 and 2.0 kilograms. It holds the position as a primary food security crop in Africa due to its resistance to drought and disease, flexible planting and harvest cycle, and tolerance of low-quality soils. Cassava can remain in the ground for up to 18 months after reaching maturity (or more in the case of some varieties) and is well suited for a region that suffers both environmental and political hardships.

Total world cassava utilization is projected to reach 275 million tons by 2020 (IFPRI in Westby, 2008) with some researchers estimating the number closer to 291 million tons (Scott et al, 2000 in Westby, 2008). Africa claims 62 percent of the total world production. Africa is the largest producer of cassava, with Nigeria leading the world with nineteen percent of global market share (Hillocks, 2002). In sub-Saharan Africa, cassava is cultivated on small farms often in fields to be set aside as fallow and often cropped on marginal soils, replacing crops that require greater soil fertility and cultivation. Cassava also is associated with mixed cropping systems. Cassava roots can remain in the ground for 18 months or more without spoiling; however once unearthed has roughly a two-day shelf life without treatment. Over the past years, cassava production in sub-Saharan Africa has risen substantially, but most of the gains in overall production are attributed to an increase in the area of land cultivated rather than an increase in yield.

Cassava provides a reliable and inexpensive source of carbohydrates for people in sub-Saharan Africa, where consumption is the highest per capita in the world (Westby, 2008). Eighty-eight percent of cassava produced in Africa is consumed by humans, 50 percent of which is processed. In comparison, Thailand, where cassava processing is highly mechanized, exports a majority of its cassava to Europe and China as dried chips for animal feed. In addition to the root, the leaves of the cassava plant are edible and rich in protein. Cassava is vegetatively propagated. Each plant provides multiple cuttings and some areas of Africa have introduced the rapid multiplication method to increase plant productivity. Propagation rates are still however low in comparison with seed based propagation and vegetative propagation can be problematic in terms of spread of virus diseases.

Two of the major constraints to development of cassava post-harvest systems are (a) the perishability of the fresh roots and (b) the presence of cyanogenic compounds in cassava. Cassava is susceptible to physiological deterioration after the roots are harvested. This means that roots greater than 48 hours old have little market value and limits the range over which fresh roots can be marketed. Deterioration can be delayed by waxing or storage in plastic bags following a fungicidal treatment. Fresh cassava contains cyanogenic glucosides. If cassava is inadequately processed this creates a potential health hazard. Effective processing, essentially involving root disintegration and removal of the cyanogenic compounds with the water, ensures the safety of products. A "wetting technique" has been developed recently for food insecure areas where inadequately processed cassava could pose a problem (Nhassico et al, 2008).

Summary of Cassava Market Characteristics in sub-Saharan Africa

- Traditionally a food security staple, grown throughout Africa by small-scale farmers.
- Cassava can be grown in poor soils and is drought tolerant. Cassava is intercropped with other crops and inputs are rarely used.
- It can be stored in the ground for many months, but there are high opportunity costs to such storage.
- It is highly commercialized in parts of West Africa, but much less so in most of East Africa
- Fresh cassava has a very low value/bulk ratio and is perishable, so marketing is strictly local.
- After being dried, chipped, or converted to *gari* (toasted cassava flour) it has a longer shelf life, allowing longer-distance marketing.

Present and Potential Markets for Cassava

Consumption Habits in Africa

The form in which cassava is used and consumed varies across Africa. The majority of cassava is consumed either as fresh roots or as traditional processed products. Processing is important because of the perishability of the fresh roots, which limits marketing. Cassava consumption patterns vary between East and West Africa. For example, Ugandans consume 80 percent of their cassava crop largely in raw form (i.e., cooked fresh roots), while Nigeria uses most of its cassava in processed forms. Traditional uses of cassava fall into nine categories as identified by Ugwu and Ay (1992):

1. Cooked fresh roots (that include pounded fresh cassava, locally know as fufu in Ghana)
2. Cassava flours: fermented and unfermented
3. Granulated roasted cassava (gari)
4. Granulated cooked cassava (attieke, kwosai)
5. Fermented pastes (agbelima, fufu in Nigeria)
6. Sedimented starches
7. Drinks (with cassava components)
8. Leaves (cooked as vegetables)
9. Medicines

The enhanced production of processed cassava products throughout sub-Saharan Africa is of significant interest because of the potential for increasing smallholder farmers' income (given cassava production patterns in Africa, which is concentrated among smallholders).

One of the major challenges for cassava producers and processors is access to markets and creating interest in new market opportunities. These include, for example: high quality cassava flour (HQCF); improved and more convenient versions of traditional processed products; starch, sugar syrups; use in livestock feed rations; use for bio-ethanol production; and energy drinks (e.g., cassava-based version of maheus).

High quality cassava flour (HQCF) is of particular interest because it can be used as a substitute for 10 percent or potentially more wheat flour in pies, pastries, cakes, biscuits, and doughnuts and has some industrial applications (Ndossi quoted in Gwera, M., 31 March 2009). In Tanzania small milling companies report sales to supermarkets of a ton of HQCF daily (Abass, 2008, 8). The industrial "cross-over" potential of HQCF is significant, HQCF, for example, is the basis for extenders in urea and phenol formaldehyde resin plywood adhesives, and serves as a primary ingredient in Bauer type paperboard adhesives when combined with borax and caustic soda. Cassava flour is also commonly converted into sugar syrups used to produce ethyl alcohol. HQCF has the potential to completely replace imported, starch-based adhesives (Graffham, Natural Resources Institute). A distributor in Tanzania estimates that the demand for animal feed comprised of 70 percent cassava chips reaches 5MT/day and likewise the demand for animal feed with 60 percent cassava pellets is 20 MT/day (Abass, 2008, 8).

Beyond these industrial uses of cassava, which utilize HQCF, processed cassava holds other potential uses including sweeteners, mosquito coils, livestock feed, and brewing ingredients. Sweeteners derived from cassava compete with beet and cane sweeteners. Livestock feeds rely primarily on dried cassava pellets and can be used domestically or exported. Use of processed cassava in these products, however, is highly dependent on quality and price, which relates significantly to processing efficiency and on farm yields. For example, feeding trials conducted by the Livestock Development Trust found that, in order for farmer to substitute maize in animal feed, the price of cassava must be 60 percent the price of maize (Simbaya 2007 in Haggblade & Nyembe, 2008, 24). To serve as a substitute for wheat and maize in composite flour, the price of cassava must also be significantly lower than other inputs (Haggblade & Nyembe, 2008, 24).

If cassava can be processed in a more efficient manner, it stands to gain in domestic demand as well as a potential export. However, the lack of appropriate and affordable technologies (especially for use by farmers and farmer processors), a weak private sector (especially intermediary processors and bulking agents that link small-scale producers and processors with end-use industries), trade policies, consumer preferences, and price volatility threaten this transition.

Several initiatives are underway to support the development of processed cassava products, including HQCF. These initiatives are focusing on a wide array of activities across the cassava value chain that affect production and adoption of processed cassava products including but not limited to: supporting farmer organizations; deploying village-level processing units and other technologies; ensuring consistent quality; providing financial, business and technical support services; and, increasing adoption of processed cassava products.

Gender

The cassava value chain reflects different gender roles for men and women in production and processing activities. Due to their position in the labor market, women are typically found in low-status work and at the bottom of the value chain. This was exemplified in a presentation by Martin, Forsythe, and Butterworth, showing the gender division of labor in cassava activities, based on COSCA research on six African countries[1]. Their findings are summarized in the following table.

Table 1: Percentage Share of Labor by Gender[2]

	Men and Women	**Men**	**Women**
Clear	5	86	9
Plough	17	60	23
Plant	19	45	36
Weed	23	34	43
Harvest	13	36	51
Transport	13	19	68
Process	20	4	75

[1] Nigeria, Tanzania, Uganda, Ghana, Congo, Côte d'lvoire

[2] Martin, Forsythe, and Butterworth. "Gender implications of developing cassava post-harvest systems" presented at Expert Consultation on Cassava Processing, Utilization, and Marketing, December 11-12, 2008, in Anselm Enete, Felix Nweke and Eric Tollens, "Contributions of men and women to food crop production labour in Africa: information from COSCA", Outlook on Agriculture Vol. 31, No 4, 2002, pp 259–265.

As seen in the table above, women are responsible for the majority of the cassava processing, transportation, and harvesting tasks, while men are often associated with the farming tasks. Women's role in cassava processing is highly labor-intensive and is largely non-mechanized. However, men's involvement increases as processing becomes more mechanized and commercialized, as was noted by Martin, Forsythe and Butterworth (2008). Other researchers have corroborated this finding and noted the trend of men operating processing plants and becoming managers of such enterprises as processing became increasingly commercialized and mechanized (Adebayo, Lamboll and Westby, 2008).

Opportunities for women to improve their status along the value chain are limited. At the local level, women are unable to access the necessary capital to make investments. At the intermediary level, very few women hold permanent or management-level positions and stereotypes of women often hinder female attainment within the workplace. Subsequently, it is important to address gender issues along the value chain in order to have an equitable and positive impact on the livelihoods of men and women. Although this project is unable to work on some of these activities, it is important to be aware of the potential difference in the impact that certain technologies will have along gender lines.

Market Inefficiencies and Potential Technologies and Approaches

In some countries there is a tendency for production to be cyclic following increases and decreases in price—related to supply and demand. In addition to processing efficiency and price combined with the perishability of fresh roots, aggregation of raw materials for processing can be unreliable and unpredictable, thus processors cannot consistently guarantee output. Processing operations therefore tend to be smaller (household/village level) rather than larger to enable integration with production. In developing cassava-based enterprises there are a number of issues that repeatedly have been found to be important. These include: regular and consistent supply of product, quality, and price, especially when substituting for other products.

Value Chain Constraints

Key impediments to cassava production amongst smallholder farmers

Production

- Cassava production remains traditional with virtually no use of purchased inputs. This is because of its reputation as a food security crop—it is considered resilient and therefore planted in poor soils with little fertilizer.

Fresh cassava value chain

- Inefficiencies in the marketing chain (such as transport bottlenecks and repeated transactions) are very costly given fresh cassava is highly perishable.
- The bulkiness and low value of fresh cassava can cause transportation costs to be a large share of the final price.

Dry cassava value chain

- Requires the development of processing service providers.
- The perishability and bulkiness of fresh cassava requires that they be located close to production centers or in villages.
- The reliance on sun-drying for processing of chips and flour creates serious scale issues, although perhaps less important for *gari* which can be toasted.

- Labor intensity of processing is high creating demand for increased availability of small and medium scale processing equipment.

Demand constraints

- Other commercialized ventures have not been able to offer a high enough price to farmers to be sustainable (starch and beer in Benin, animal feed in Uganda).
    - This poses serious demand constraints on processed cassava in countries where there is little consumption of processed cassava.

General marketing constraints also affect cassava

- Poor coordination among actors in value chain,
- Lack of grades and standards (there is potentially a high return to well-graded processed cassava), need for market information, first-stage collection inefficiencies.

Given the focus of this project on the harvest and post-harvest elements of the value chain and income generation for smallholder farmers, the constraints analysis highlights, in particular, innovations that support processed cassava products in these key elements of the value chain.

- Harvest
- Storage and aggregation
- Processing

Processing is associated with some, and at times all, of these steps:

1. Root preparation (peeling and slicing)
2. Size reduction (grating)
3. Drying and/or dewatering
4. Fermentation
5. Sieving

In addition to these elements of the value chain, this project will also focus on issues related to:

- Quality indicators
- Cyanogenic compounds

It should also be noted that the suggested technology considerations in this paper not only suggest means to innovate the value chain with new technologies, but also improvement of existing technologies. This project and, therefore, this paper exclude other critically important value chain constraints that are being addressed in other projects funded by the Bill and Melinda Gates Foundation and other donors including but not limited to:

- Lack of communication and coordination of the market
- Poor infrastructure, geographic dispersal of farms and processors
- Access to capital for processors
- Consumer (baker) preferences for maize/wheat flour

Harvest

Harvesting cassava is labor-intensive and almost exclusively non-mechanized in Africa. Since cassava will perish within two days after being pulled from the ground, farmers sometimes choose to delay or stagger the harvest until they have buyers for the cassava. Due to these constraints, the high-yield varieties do not bring as much benefit to the smallholder farmers as the genetic innovations could allow. Nweke concludes "Without question, a mechanical revolution is now needed to break the labor bottleneck in cassava harvesting among farmers in Nigeria who are planting the TMS varieties" (2008, 7). Nweke goes on to explain that farmers who produce cassava for subsistence/famine reserve are not encumbered by the high labor costs of harvest because they do so in a piecemeal fashion. Although harvesting cassava is labor-intensive, the labor supply in sub-Saharan Africa is steady with many available to work. Cassava processing by some institutions has achieved successes on fabrication of hand lifter to small holder farmers in Africa (Sanni et al, 2006, 4).

- Technology Consideration: Mechanization of harvest through tools and equipment

Raw Cassava Storage

Although cassava roots survive well underground, this method of storage is inefficient and requires land to remain unproductive. In addition, the roots can turn woody, losing ideal flavor and in some cases can become infected with pathogens. Some experimentation has been done with storage methods that mimic underground conditions, for example piling roots in mud and straw or placing roots in plastic lined wooden crates with damp sawdust. However, in the first instance this method requires a great deal of space and in the second, crates can be hard to procure. In Colombia, there has been some success with placing roots sprayed with fungicide in plastic bags and using these at the retail level through supermarkets. Roots treated in this way remained fresh for 2-3 weeks. This technology has been adapted for use in Ghana and Tanzania where cocoa and rice replaced the plastic bags and, on the basis of cost, the fungicide was omitted (Westby, 2008, 286). Good quality roots were still obtainable after seven to ten days. Refrigeration, freezing and wax application are also used to store fresh cassava. These techniques are useful for export markets, such as the sale of waxed cassava from Central American markets, but they are not suited for use in traditional African markets.

- Technology Consideration: Storage and packaging technologies
- Technology Consideration: Low cost waxing methods

Processing

Cassava's bulk is substantially reduced when processed into flour or gari and thus more suitable for transport. Shelf life is also increased. The cassava roots must be peeled, chipped, soaked/fermented, dried, and sometimes grated. Peeling represents the most labor-intensive unit operation of the cassava value chain, non-mechanized and traditionally done by women and sometimes children. Moreover, peeling represents a critical stage in terms of food safety as the process removes the outer periderm of the root, where the highest concentrations of cyanogenic compounds lie. When farmers are able to efficiently and effectively chip, grind, and dry cassava, they are better able to trade with bulk purchasers in local markets. Farmer incomes will rise when they are able to guarantee processed cassava for products that are high-quality inputs and have a long shelf-life (Hillocks, 2002). Key processing steps are described below, along with potential technology considerations.

Root Preparation (Peeling and Slicing)

Peeling of cassava roots, for both domestic and industrial purposes in Africa is still being carried out manually. The process is labor intensive, arduous in nature, time consuming and unsuitable for large scale industrial processing. Peeling the cassava root is the best practice currently for removal of the outer skin, however, abrasion technology could allow for a minimal loss of viable cassava product (Haggblade, personal communication). Traditional methods of peeling cassava resulted in an average 6.1 percent loss of viable cassava (Akosua & Bani, 2007).

In Nigeria some institutes and private fabricators have produced prototype peelers that require further development (Sanni et al., 2007, 89).

- Technology Consideration: Mechanization of peel removal with special attention to root shape
- Technology Consideration: Mechanization of slicing where needed for a specific product
- Technology Consideration: Develop abrasion technologies further to reduce product loss and reduce cost

Size Reduction (Grating)
Grating is often mechanized in West Africa. This step is responsible for increasing surface area for drying and extracting the starch from the root. It is also an important step in ensuring the safety of processed products. In places where grating is not mechanized, the step represents an extremely labor-intensive component of the value chain. Graters have been successfully introduced in Nigeria and are now widespread.

- Technology Consideration: Improve efficiency of existing grating technologies
- Technology Consideration: Develop appropriate-scale (hand-held or mechanized) graters, chippers, pelletizers, and peelers

Drying and Dewatering
Cassava roots are 70 percent water by volume. Thus, drying is a critical step for many processed cassava products (e.g. flours, fufu, lafun and non-traditional products such as HQCF) and is accomplished through main through sun drying, although solar dryers and bin-type artificial dryers are also used. More efficient flash and rotary dryers with appropriate capacity for African scale of cassava production have been recently developed in Nigeria (Sanni, 2007, 89).

For some processed products (e.g., gari processing in West Africa and in the processing of HQCF), grated cassava (fermented cassava for gari) is dewatered by pressing prior to drying. Dewatering through pressing the cassava has problems associated with waste products. This is a challenge to reducing pollution in sub-Saharan Africa and recycling of water could benefit a region known for low soil nutrients, degradation, and drought.

Currently, farmers rely primarily on the sun for drying. While the sun presents a free input, drying is time-consuming and there is a greater risk of spoilage. Solar drying removes some seasonality from the process, as it is difficult to dry cassava during the rainy season. Solar dryers, however, generally add expense and can cope with relatively small volumes. Solar dryers have been used for some high value crops, such as fruits. As an indication of the impact of seasonability, in Zambia between August and October (dry season) the amount of dried cassava sold at market reaches 150 tons while in January it can be as low as 20 tons (Haggblade & Nyembe, 2008). Consequently cassava harvested during this time must be consumed without processing. In Ghana drying of kokonte (sun dried cassava pieces) takes seven to ten days during the dry season and requires an additional two to three days during the rainy season. These long drying times mean that the product is frequently moldy and hence potentially a source of mycotoxins, especially in the rainy season.

Dried cassava prices peak during the rainy season and bottom out during the dry climate periods. Fresh cassava, however, does not mimic the opposite pattern as might be expected; fresh cassava prices remain high during the rainy season because there are few staple crop substitutes (Haggblade & Nyembe, 2008). Nonetheless, the fact that cassava can be harvested at the beginning of the rainy season bolsters its position as a food security crop as the rainy season is often when hunger is most acute (www.un.ord/ecosocdev/geninfo/afrec/vol20no2/202-cassava.html). As compared to the sun, batch and bin dryers save time, ensure a consistently high quality product, but pose a significant increase in cost due to the need for fuel to power the dryers. Flash drying as developed and adopted in Nigeria holds some promise, but needs further development and price reduction.

To avoid costs associated with drying, the Dutch Agricultural Development and Trading Company (DADTCO) is working on a slurry process that peels and processes fresh roots and converts them into a paste. The paste can be economically transported and used in other manufacturing processes (glues, syrups and the like). Syrups, for example, may never need completely dried cassava. (Haggblade, personal communication)

- Technology Consideration: Improved mechanized (flash, rotary and bin) dryers
- Technology Consideration: New approaches to cost effective and efficient drying
- Technology Consideration: New energy sources for flash, rotary, bin, or other dryers
- Technology Consideration: Improvements to sun drying
- Technology Consideration: Waste reduction and water treatment/recycling from dewatering

Fermentation

Grated root fermentation, underwater/soaking fermentation, and mold fermentation represent the three major forms of cassava fermentation in sub-Saharan Africa.

The fermentation of grated roots from 1-5 days is common in West Africa and forms a unit operation in products such as gari, agbelima, placali and attieke. This is a fermentation dominated by lactic acid bacteria. The products differ in their final processing steps. Gari is sieved and roasted, while attieke is granulated then steamed.

Soaking roots in water is a lactic fermentation that is common across West and Central Africa and also found in some parts of East and Southern Africa. Fermentation softens the roots so that they can be easily broken up by hand into smaller pieces for sun drying or passed through a sieve to remove excess fibers. Fermentation also allows the leaching of cyanogenic compounds from cassava. Underwater fermentation is associated with products that require a wet paste like fufu and dried flours like lafun.

In a third type of fermentation, cassava root pieces are deliberately allowed to go moldy. This mold growth softens the roots contributing to a reduction of cyanogenic compounds. Mold growth is scraped away before the final stage of sun-drying. These products include, for example, udaga in Tanzania.

Significant research has been conducted to understand the microbiology of the fermentation process and the mechanisms by which cyanogenic compounds are reduced (Westby, 2008, 291-292). Common research approaches have included isolation and characterization of microorganisms that could be used as starter culture, modification to fermentation regimes, but to date little of this research has been put to use.

- Technology Consideration: Improvements to fermented products with identification of pure cultures, optimal temperatures, pH, and enzymes
- Technology consideration: Use of isolated starter cultures in product quality

Quality

Quality is critically important for cassava products. In traditional processing, quality of products can be variable and will be product specific. Variations in drying, processing and storage can have major impacts on product quality.

The recognition that there is demand for higher quality product has fostered research on improved versions of traditionally processed products—where quality and convenience can be provided in packaged food products. Instant fufu has been developed and commercialized in Ghana. This saves consumers the need to pound fresh, boiled cassava to make fufu. In Nigeria instant fermented fufu has been prepared using the rotary and flash drying technology to produce a high quality product that also saves on household processing.

- Technology Consideration: Techniques that would ensure consistent quality in the value chain for fresh roots, traditional processed products and new commercialization opportunities.
- Technology Consideration: Review of grades and standards for cassava products in Africa.

Cyanogens

Although many millions of people safely eat cassava every day of the week, cyanogenic compounds are a potential health risk associated with the crop.

Cassava contains cyanogenic glucosides, which can hydrolyze by linamarase during processing to form cyanohydrins. These cyanohydrins breakdown at a rate dependent on pH and temperature to release free HCN. If ingested in sufficient quantities, these cyanogenic compounds can lead acute intoxication resulting in nausea, dizziness, vomiting, and in some cases death. Additionally they can cause complications known as goiter or cretinism in individuals with iodine deficiencies. In some rare cases these cyanogenic compounds have been linked to konzo, a disease causing permanent lower leg paralysis.

Acute cyanide intoxication and konzo are rare and occur only under specific circumstances. Safety of cassava products can be ensured through effective processing involving cellular disruption (such as grating or certain types of fermentation) combined with effective drying. Konzo, for example, often occurs when food is in short supply or when the region is plagued by social instability, because typically households/processors seek shortcuts to enable to eat the cassava the same day.

Some varieties of cassava have higher levels of cyanogens than others and these are commonly referred to as "bitter varieties." These varieties should not be used in areas where processing methods are not conducted correctly, unless there is education as to what constitutes effective processing. Low cyanogens (or "sweet") varieties can be consumed without processing.

A promising prevention tactic of wetting the roots has reduced cyanide content by a factor of three to six (Nhassico, *et al*, 2008). A recent innovation has been the development of a wetting method that reduces the cyanogen content of high cyanogen cassava flour by wetting for 5 hours prior to consumption. This reduces the cyanogens content by a factor of 3-5.

Techniques exist for measurement of cyanogens in cassava in the laboratory, but there are more limited field methods available. The picrate test, which measures cyanide levels in cassava and urinary thiocyanate and can be done outside of a laboratory, has been deployed in kits to some communities in developing countries (Nhassico et al, 2008).

- Technology Consideration: Low-cost cyanogens detection tools.
- Technology Consideration: Ensuring that innovations in processing suggested above deliver a safe product.
- Technology Consideration: Rapid processing technique for bitter varieties that deliver a safe product.

Value Chain Partner

Ghana Food Research Institute (Field Trip Coordination and Expert Resource)

The Ghana Food Research Institute is one of thirteen affiliated centers of the Council for Scientific and Industrial Research (CSIR). It is tasked with conducting applied research on problems associated with food processing and preservation, storage, marketing, distribution and utilization, in support of the food industry and also to advise government on its food policy.

"The Institute's mission focuses on providing scientific and technological support to the growth of the food and agricultural sectors of the national economy in line with corporate prioritization and national objectives. Primarily, the FRI's mission is to conduct market-oriented applied research and provide technical services and products profitably to the private sector and other stakeholders."

The Institute aims to alleviate poverty by engendering opportunities to propagate and increase incomes within multiple levels of the food industry. In addition, its members seek to address food security and elevate the utilization of innovative and efficient food processing technologies that are environmentally sound.

The Institute outlines its objectives as follows:

- To develop and provide technical information, training and services to the private sector and other stakeholders in the food industry
- To provide appropriate technology packages for processing and storage of raw agricultural produce to facilitate curtailment of post-harvest losses and promote value addition for local ad export markets
- To strengthen the Institute's capability and linkages with industry through human resource and infrastructural development, restructuring and reorganization for effective commercialization of operations

Value Chain Experts

International Institute of Tropical Agriculture (IITA)

The International Institute of Tropical Agriculture (IITA) teams with partners in Africa and other international entities to reduce the risks to producers and consumers, improve crop quality and productivity, and improve livelihoods through agriculture. Founded in 1967 as an international non-profit, IITA is supported primarily by the CGIAR. The organization works throughout Africa at stations in Benin, Cameroon, the Democratic Republic of Congo, Ghana, Malawi, Mozambique, Nigeria, Tanzania, and Uganda.

The IITA articulates its Research for Development (R4D) model as:

1. *Development needs:* Identifies societal, producer and consumer needs that require addressing. Guarantees research relevance.

2. *Research:* Specifies research problems that can be addressed by IITA with advanced research institutes and national partners. The design demands envisioning the potential impact.
3. *Research impact:* Defines scalable research outcomes and any advocacy activities required. A successful outcome entices partners to adoption.
4. *EXIT:* Once the outcome is embraced by national/regional partners IITA exits implementation and changes role to monitoring the IITA research outcomes in the subsequent stages of development outputs and outcomes.
5. *Success/Development impact:* Ex-post evaluations are carried and compared to baseline information to measure the impact on the ultimate beneficiaries.
6. *Further work:* Development impact creates new challenges which are referred back to development needs.

IITA and national institutes in sub-Saharan Africa have invested in the development of high-yielding cassava germplasm, improved crop management technologies, processing technologies, and capacity development and dissemination in Africa. Processing technologies have been developed for: 1) machinery (chippers, graters, peelers, dryers, etc.); 2) new intermediate shelf-stable cassava-based raw materials (HCQF, chips, etc.); and 3) new food products from cassava (e.g., 20/80% cassava-wheat bread; 100% cassava cake; chinchin; dough-nuts; salad creams, etc.). IITA is currently implementing or participating in (as is the case with the C:AVAproject led by NRI) several cassava development projects in Africa. (personal communication, Adebayo Abass)

Natural Resources Institute (NRI)

Based in the United Kingdom at the University of Greenwich, the Natural Resource Institute (NRI) addresses and supports sustainable development, economic growth, and poverty reduction through research, advice, consulting, and learning. NRI became part of the University of Greenwich in May 1996 and was previously a part of the Imperial Institute when NRI was founded in 1894. NRI partners with development agencies providing research and technical evaluations to inform decisions on policy, economic investment, and planning. In addition to building relationships with the public sector, NRI harnesses the power of the private sector and other stakeholders in encouraging policies and investment that will benefit those living in poverty.

NRI divides its research portfolio into four program areas:

- Making agriculture work for the poor
- Food and trade
- Change and vulnerability
- Capacity strengthening

In terms of cassava value chain research, NRI's Post-Harvest and Value Addition Group address the issues concerning durable and perishable crops after harvest to reduce losses, enhance financial or nutritional crop-value, and assure food safety. Within this group, the research projects span a number of topic areas, including: the fundamentals of storage and preservation of quality throughout the marketing chain, food-science aspects of agroprocessing, and responses of consumers to new food products.

NRI is the lead investigator in a multinational research and development project, Cassava: Adding Value for Africa (C:AVA). Partnering with University of Agriculture in Abeokuta, Nigeria, the Ghana Food Research Institute, the Tanzania Food and Nutrition Centre, the Africa Innovations Institute in Uganda, and Chancellor College at the University of Malawi, NRI will address the cassava value chain and the production of High Quality Cassava Flour (HQCF) in the partner institutions' countries. The project aims to improve the livelihoods and increase incomes of smallholder farmers, focusing particularly on women and other historically disadvantaged groups.

C:AVA will address three intervention points in the value chain:

1. Ensuring a consistent supply of raw materials;
2. developing viable intermediaries acting as secondary processors or bulking agents in value chains; and
3. driving market demand and building market share (in, for example, bakery industry, components of traditional foods or plywood/paperboard applications).

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