Science and Innovation for African Agricultural Value Chains

*Lessons learned in transfer of technologies to smallholder farmers in sub-Saharan Africa*

A report prepared for Meridian Institute

by

New Growth International

DRAFT

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# Table of Contents

TABLE OF CONTENTS .................................................................................................................. II

1. BACKGROUND INFORMATION .............................................................................................. 1

2. ANALYTICAL FRAMEWORK .................................................................................................. 1
   
   2.1 ORGANIZATIONS, INSTITUTIONS, AND POLICIES IN AGRICULTURAL INNOVATION SYSTEMS ........................................... 2
   2.2 VALUE CREATION (AND DESTRUCTION) IN AGRICULTURAL COMMODITY TRANSFORMATION ........................................... 3

3. IDENTIFYING SUCCESSFUL INNOVATIONS ......................................................................... 3

4. TYPES OF AGRICULTURAL INNOVATIONS .......................................................................... 4

5. POLICY AND INSTITUTIONAL REQUIREMENTS ..................................................................... 5

6. INCENTIVES, PERFORMANCE, AND SCALABILITY ............................................................... 7
   
   6.1 RATES OF RETURN ............................................................................................................. 7
   6.2 SCALABILITY ....................................................................................................................... 7

7. SUMMARY GUIDELINES ON THE DO’S AND DON'TS OF AGRICULTURAL TECHNOLOGY DEVELOPMENT AND DEPLOYMENT ................................................................. 9

8. READING LIST FOR FURTHER INFORMATION ................................................................... 11

9. CASE STUDIES ..................................................................................................................... 15
   
   9.1 A SUCCESSFUL POST HARVEST CASSAVA PROCESSING TECHNOLOGY – THE MECHANIZED GRATER .......... 15
   9.2 A FAILED CASSAVA PROCESSING TECHNOLOGY – MECHANIZED CASSAVA PEELER ......................................................... 18
   9.3 A SUCCESSFUL TECHNOLOGY IN BANANA PRODUCTION IN KENYA – TISSUE-CULTURE .................................................. 20
   9.4 SUCCESSFUL OIL PROCESSING TECHNOLOGIES – KICKSTART’S MAFUTA MALI (OIL FOR WEALTH) PROGRAM ........... 23
   9.5 AN UNSUCCESSFUL TECHNOLOGY – LOW-COST FOOD-GRADE MILK HANDLING CANS BY INFORMAL TRADERS IN KENYA ............................................................................................................... 26
   9.6 A POTENTIALLY SUCCESSFUL TECHNOLOGY – THE HERMETIC GRAIN STORAGE BAG ................................................. 29
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1. BACKGROUND INFORMATION

This report has been prepared by New Growth International (NGI) for the Meridian Institute under an initiative that aims to identify out-of-the-box innovative technology options that will add significant value for smallholder farmers by reducing inefficiencies in the cassava, dairy and maize value chains in sub-Saharan Africa (SSA). The report reviews lessons learned from historical attempts (successful and unsuccessful) to implement technologies in selected commodity value chains in African agriculture. These lessons are framed within the larger context of constraints facing African agriculture.

The report provides practical guidance and direction for the Meridian Institute’s Science Team members about the potential pitfalls and success factors that could contribute to successful uptake of technologies by smallholder farmers and others in agricultural value chains in SSA. The Science Team will be generating innovation ideas and possible technological investments on harvest and post-harvest elements of the maize, cassava and dairy value chains that would have highest benefits to smallholder farmers in African agriculture.

The report synthesizes findings, insights, and lessons from a range of relevant reports and studies focusing on technology introduction in Africa, and draws on the expertise of NGI. The intent of this report is to create an overview of the many issues that affect (the impact of) technology innovations in sub-Saharan Africa; more in-depth detailed information about these issues is available in the resources listed in the reading list.

This report comprises two broad segments:

1. A summary analysis on “do’s and don’ts” of technology development and deployment for smallholder farmers. The analytical framework guiding the analysis is presented in the next section. Features of successful innovations and a typology of such innovations are described in the next two sections, respectively. Key lessons related to policy, institutional, incentive, and scalability dimensions of agricultural innovation are then set out. A summary of the “do’s and don’ts” rounds out the analysis.

2. Six specific case studies of “successful” and “unsuccessful” technology introductions to illustrate key lessons learned in more detail. These case studies are not intended to be representative of innovations in Africa’s agricultural value chains. Rather, they are selected and developed aiming to expand on, highlight, and complement the findings in the summary analysis, given the guiding framework.

2. ANALYTICAL FRAMEWORK

Sustained innovation in agricultural value chains depends on development of appropriate technologies by the research system, establishment of cost effective systems for farmer and trader access to these technologies, and correct incentives for farmers and traders to
integrate these new technologies and practices into their activities and investment plans. Two complementary analytical building blocks thus underpin the analysis:

1. Agricultural innovation systems; and
2. Agricultural commodity transformation.

2.1 Organizations, Institutions, and Policies in Agricultural Innovation Systems

According to the theory of induced innovation, agricultural production and trading decisions generally reflect technical choices that facilitate or catalyze the substitution of relatively abundant (hence cheap) factors of production and trade for relatively scarce (hence expensive) ones. Technological adjustments that ease these factor substitutions release constraints imposed by resource scarcity. Technical choices are thus behavioral responses to particular constraints that both determine and reflect resource intensities and specializations. Shifts in production and trading patterns are driven by changes in evaluations of the relative returns to resources employed in different pursuits, and on assessments of the range of feasible resource substitutions.

In addition to relative factor prices, agricultural decisions are determined by other phenomena such as market access, technical and economic risk, the irreversibility of decisions, the lumpiness of most investments, and how different (better) the new technologies are from those currently in operation. These several interacting elements define potential demand for innovation. Such potential demand is necessary for the emergence of new innovations, but it is not sufficient.

The emergence of innovations requires technical feasibility and new scientific knowledge that undergird exploration, giving rise to new technologies. Potential demand and the appropriate knowledge base thus must be integrated with the right institutional framework to provide the background for innovation activities. Government policies and regulations affect conditions of supply and demand for new knowledge; they also shape the institutions within which that supply and demand are accommodated. Together with the technology employed, these policies and institutions determine the costs of production and transactions and, thus, total costs.

This view of agricultural innovation is grounded in the increasingly influential “innovation systems” approach. In this schema, innovation—i.e., an idea, practice, or object perceived as new by an individual or other unit of adoption—is viewed as strongly embedded in prevailing social, political, and economic systems, which therefore determine what is learned, where, and by whom. Farmers, households, firms, and organizations are viewed to innovate not in isolation but rather in interaction with one another, within the context of institutions that span public and private spheres.

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1 “Traders” are taken here to represent all post-farm actors—e.g., assemblers, transporters, processors, etc.
Thus, even though specific agricultural innovations are adopted by individuals and firms in response to the incentives and constraints that they face, sustained innovation processes—i.e., ones that lead to broad-based productivity growth and income expansion—should be viewed as collective outcomes of sustained interactions among different actors, including individual farmers, NGOs, multinational firms, traders and input suppliers. The question is how the individual incentives and collective processes of learning, searching, and exploring lead to new products, new techniques, new forms of organization, and, where relevant, new markets. One of the fundamental analytical challenges for this paper was therefore to ascertain how extant policies, institutions, and organizational arrangements have contributed to successes and failures of innovations in agricultural value chains in SSA.

2.2 Value Creation (and Destruction) in Agricultural Commodity Transformation

By generating new sources of demand for innovation, market-based investments by the private sector can be major drivers of technical change in agricultural sub-sectors. Costs of commodity transformation over space (transport costs), time (storage costs), form (processing costs), and expectations (credit and insurance costs) define the scope for such investment.\(^7\) Farmers are concerned not only with availability of improved inputs and practices, but also with physical access to markets, with the riskiness of trade, and with scope for increasing their shares of final prices.\(^8\) Product transformation agents are concerned with costs of operation, and with accessing key trade-facilitating services, especially transport and finance. Consumers are concerned with price, quality, and convenience of purchased goods.

Commodity value chains thus comprise sets of technical activities in production, assembly, storage, handling, processing, and consumption, lubricated at all points by transport and finance. The more (less) efficient are these activities, the greater (lesser) is the potential for demand-led technical change in value chains. Another challenge for this paper thus was to evaluate the role played by commodity transformation costs in success/failure of innovations in agriculture in SSA.

3. IDENTIFYING SUCCESSFUL INNOVATIONS

An innovation may be an idea, object or practice that is perceived new by a social system in which actors invest cash, labor or learning.\(^9\) However, a clear cut definition of what comprises “innovation success” is difficult to locate in literature. This study did not attempt to define success per se, but rather followed IFPRI in demarcating successful innovations as those meeting four criteria.\(^10\)

1. They have contributed to productivity growth;

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2. They have resulted in enhanced efficiency and increased farmer incomes;
3. They have addressed equity concerns; and
4. They are sustainable.

Added to this list was the criterion of scalability.

Using these criteria of “success”, and drawing purposively and selectively from a vast published literature, the study sought to identify the factors that have contributed to episodes of “success” as well as those that may have provoked periods of uncertainty and decline, aiming to draw lessons that will guide successful introductions of new innovations. Further detail is provided below.

4. TYPES OF AGRICULTURAL INNOVATIONS

A clear-cut categorization of innovations in African agriculture does not exist in the literature. The study thus adopted the IFPRI taxonomy in which agricultural innovations are broadly classified as follows:11

1. Commodity-based innovations: These are innovations developed primarily to increase production in a specific commodity value chain. Examples include the biological control of cassava mealy bug in West Africa, varietal improvements in cassava, maize, cotton and rice across Africa, Rinderpest vaccine, among others.
2. Activity-based innovations: These are innovations that have been developed to enhance the efficiency of undertaking specific tasks within the value chains, with potential cross-over between commodity chains.

Four categories of these innovations can be identified:

a. Process innovations (like digging fallows for improving soil fertility; planting nitrogen fixing trees, application of locally available phosphate to boost fertility, among others);

b. Object innovations (like the cassava processing grater, the grain hammer mill, tissue culture propagation method, pasteurization process, or the UV treatment among others);

c. Institutional innovations (like receipt warehousing); and

d. Policy innovations (like currency devaluation, tax rebates, etc).

Lessons derived from innovation types:

- The most successful innovations (in terms of scale and longevity of technology uptake and utilization, and corresponding welfare enhancement) have been commodity-based object innovations targeted for relatively simple application, supported by relevant and timely institutional and policy innovations. Examples include the Tropical Manioc Selection (TMS) cassava in West Africa, the cassava grater in West Africa, tissue culture banana in East Africa, the hammer mill in East Africa, and milk pasteurization across the continent. Holding other factors constant (like relative advantage or cost)

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11 Ibid.
such technologies are less complex and easily observable, increasing their rate of diffusion.\(^\text{12}\)

- The least successful innovations (again, in terms of scale and longevity of technology uptake and utilization, and corresponding welfare enhancement) have been activity-based process innovations that are knowledge-intensive and require group action to overcome high transaction costs linked to major institutional gaps. Examples include soil fertility enhancement practices, integrated pest management, and watershed conservation.

5. POLICY AND INSTITUTIONAL REQUIREMENTS

As noted above, agricultural innovation does not take place in a vacuum. Historical evidence indicates that agricultural innovation is strongest in countries and regions with highly integrated technical and economic systems able to diffuse and apply the results of new research.

African agriculture is no different from agriculture elsewhere in the world in that knowledge, science, technology, and innovation have strong public good characteristics. Their provision is neither excludable nor rivalrous. Because private firms are unable to fully recover investment costs or make profits from such goods, they under-invest, leading to under-provision of goods and services with potentially high social returns. Unless appropriate private incentives exist (for example, conducive intellectual property rights regimes), markets for agricultural R&D products and services fail. Public roles in agricultural innovation systems therefore rest on providing such incentives for welfare-enhancing private investment, and, where necessary, public provision to fill key gaps left by market failure.

Most of Africa’s agricultural areas (especially those dominated by smallholders) are marked by highly diversified farming systems, limited market development, poor access to key services (for example, credit and financial services), and structural constraints on the spread of information. These conditions render agricultural production and trade in Africa risky and costly, directly militating against purely market-driven adoption and diffusion of improved technologies. Moreover, different agro ecological and market conditions require not only different technologies but also differentiation in technology providers. Justification is strong for policy intervention and targeted institutional reform.

Traditional approaches to agricultural technology development and diffusion in Africa were based on one-way flows of information (knowledge) from the public sector to farmers and traders. Private (market-based) and localized collective initiatives were either ignored altogether or viewed as passive recipients of publicly-generated and disseminated knowledge. Critics of this approach stressed the importance of both individual and collective innovation by farmers and by the groups within which they are members. The private sector has rightly come to be considered a major source of innovation and communication in agricultural sectors. Interactions among public, private, and collective initiatives are now viewed as crucial to sustainable processes of agricultural innovation and diffusion. These ideas appear to lie at the heart of several experiments in policy and institutional innovation in Africa’s agricultural innovation systems.

Take eastern Africa. In Uganda, there is complete restructuring and radical redesign of the public research and extension system, with contracting at the district level the core concept in the new National Agricultural Advisory Service (NAADS). In Kenya, the process has been more evolutionary, building on a period of significant experimentation in a pilot mode of various extension-type programs. A large part of that experimentation has occurred outside the cash-strapped public extension system. Developments in Tanzania lie somewhere in between those in Uganda and Kenya. Responsibility for providing key services has been assigned to the Ministry of Local Government, and further decentralized to the districts. But there is no national planning and financial structure—such as the Ugandan NAADS—to guide implementation. Ethiopia’s National Agricultural Extension Program is based on a decentralized “package approach” envisioning a high level of institutionalized farmer involvement in technology development and diffusion in a “Participatory Demonstration and Training Extension System.”

Similar dynamics are underway in other parts of Africa.13 The logic behind these developments is compelling. Privatization of moribund public research and extension systems should lead to greater efficiency. Greater farmer participation and voice in technology development should enhance relevance and thus encourage greater adoption and utilization of research outputs. Greater decentralization of research capacity, greater reliance on market processes, and greater investment in adaptive research capacity relative to that in applied and strategic research should spur the “demand-side” of agricultural technology “markets.”

Actual outcomes will hinge on the capacities of alternative providers, and on the nature of policies and institutions that promote emergence of required results in given contexts.

The largely unrealized potential of agricultural biotechnology in promoting growth and poverty reduction in Africa must be viewed in light of this ongoing search for compatibility among robust technology design, effective dissemination systems, and efficient markets. The nature of policies and institutions that might support such compatibility is as yet unclear. Worldwide, the private sector dominates biotechnology research. This is also the case in Africa. Market failures in harnessing privately funded and privately convened research for the benefit of poor producers and consumers in Africa have been identified. Very few applications with direct benefits to poor consumers or to resource-poor farmers in developing countries have been introduced. The key challenge lies in defining, enforcing, and exchanging property rights over R&D outputs.

Emerging evidence suggests that private property solutions to the coordination problems facing agricultural innovators in Africa are not working well. The public sector clearly has a significant role to play. One crucial role is to develop strategies and capacities for managing intellectual property in ways that not only protect the rights of technology developers and disseminators but also reward innovative activities14. The case studies illustrate that successes are emerging where actors identify viable middle grounds between pure private ownership and the unprotected public domain.

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6. INCENTIVES, PERFORMANCE, AND SCALABILITY

6.1 Rates of return

The sluggish aggregate performance of African agriculture masks the fact that the continent’s farmers and traders are investing heavily in the sector, albeit often at levels inadequate to generate sustained growth in productivity and income. For instance, Kenya imported almost 400,000 tons of fertilizer in 2006 at a cost of no less than $130 million.\(^{15}\) This still translated into rates of application averaging less than 8 kg/ha, compared to close to 400 kg/ha in Asia. Evidence indicates that private incentives for investment in agricultural innovations are greatly enhanced by two factors. First, by the existence of secure output markets; second, by the level of costs incurred while investing in innovations. It is difficult to overestimate the importance of reliable output markets as determinants of technology success. Almost without exception, African technology success stories are associated with well functioning output markets.\(^{16}\) Smallholder farmer-traders lacking market access are often locked in low-input, low-output subsistence-oriented livelihood strategies.\(^{17}\)

High costs in acquisition and operation of innovations are first-order inhibitors of farmer demand for technically feasible agricultural innovations.\(^{18}\)

Aggregate rate of return (ROR) studies indicate that agricultural technology development and deployment (TDD) activities across Africa generate impacts sufficient to justify investments. In a major review of TDD initiatives around the continent, 75 percent registered strongly positive RORs, substantially exceeding those in other sectors (like education and industry).\(^ {19}\) But aggregate performance of Africa’s agricultural sectors remains sluggish due to a number of factors, including the inability to scale up (replicating similar uses of an innovation over wide area) and scale out (applying an innovation to other problems to broaden its use) local successes in innovation.

6.2. Scalability

Myriad local successes in innovation alongside sluggish aggregate performance point to major hurdles to scaling up and scaling out these successes.

The literature and anecdotal evidence point to five dimensions to scalability:

1. Institutional (vertical integration);
2. Geographical/spatial (horizontal spread);
3. Technological;
4. Temporal; and
5. Economic or cost.

\(^{15}\) FAOSTAT. [http://faostat.fao.org/site/405/default.aspx](http://faostat.fao.org/site/405/default.aspx)
Cutting across these five dimensions are imperatives for sustainability, participation and capacity building. Three models (or strategies) for scaling technology innovations emerge from experience:

1. Spontaneous scaling up and out;
2. Scaling up and out after achieving initial local success; and
3. Development of scaling plans at project inception.

In spontaneous scaling processes, there is no explicitly planned or directed intervention to take a successful initiative beyond the project level. Interventions to spread benefits are limited to making sure that the material requirements are available and accessible. Scaling up happens “naturally,” driven by market forces and informal social structures, or because other organizations take up the innovation in new piloting arrangements. The banana tissue culture and oil pressing cases (see case studies section) in Kenya appear to have elements of this model.

Under the second strategic option – scaling based on realized success – the innovation may come from other organizations, or from the organization itself, but the defining feature is that planning to scale up or out is not initiated unless there is proof of local success. The banana tissue culture and oil pressing cases have elements of this model, but the hermetic grain storage bag is the strongest illustration among the six case studies.

A third strategy is to plan to scale up beginning from the time the project is conceptualized. This may happen in one of two ways. First, similar to the second model, the aim can be to start small and plan to grow. The key difference with the second model is the planning. The second option in this model is to start big and stay big. FAO’s experience with the Farmer Field Schools falls into this category, as does the World Bank’s Training-and-Visit approach to agricultural extension.

Clearly, the availability of external funds or the capacity of the organization to access external funding should influence the choice of strategy. If funding is available and assured, organizations can pursue the third strategy with confidence. If funding is contingent on demonstration of impact, then the second model might be appropriate. If funding is not expected after the initial support for one reason or another, the tendency is to let the innovation scale up on its own spontaneous diffusion. Note, however, that in most cases, irrespective of availability of funds, the first option (spontaneous scaling processes) is pursued by default. Given the stringent needs of sustainable spontaneous scaling processes, it is hardly surprising that few locally successful agricultural innovations have gone to scale.

Investments and activities that improve scaling prospects include the following:

1. Effective management of the crucial technology adaptation process implied by the inherent diversity of agro ecological, institutional, and policy contexts in Africa’s agricultural sectors;
2. Proactive strategic research to anticipate and accommodate bottlenecks created by success;
3. Deliberate cultivation of relevant strategic partnerships, emphasizing crucial operational partners;
4. Deliberate development of new market outlets, with an emphasis on shaping consumer tastes; and
5. Careful monitoring and assessment of impacts.

7. SUMMARY GUIDELINES ON THE DO’S AND DON'TS OF AGRICULTURAL TECHNOLOGY DEVELOPMENT AND DEPLOYMENT

If the transfer of economically unviable, unsustainable or inequitable technologies is to be avoided, technology recipients should be able to identify and select technologies that are appropriate to their actual needs, circumstances and capacities. While there is no single strategy for successful transfer that is appropriate to all situations, key actions (do’s) that will foster success in technology deployment include the following.\(^\text{20}\)

1. Careful assessment of the needs of the main users of the proposed technology. Most innovation successes have been those that have addressed existing needs within commodity value chains. Examples include improved (TMS) cassava varieties and the mechanized cassava grater in West Africa, improved maize varieties and the hammer mill in Eastern and Southern Africa, the oil-press machine (*mafuta mali*) in East Africa, and the Rinderpest vaccine across the continent. Innovations that have not addressed existing needs (even though they have been intended to address an apparent constraint) have often failed, e.g. the mechanized cassava peeler in West Africa.

2. It is imperative to ensure that innovations are operationally relevant to the circumstances of intended users. For example, the mechanized cassava peeler failed not only because it was costly, but also because it had high capacity requirements and was not easy to move from place to place.

3. Policies that influence the enabling environment must be evaluated and reformed if needed. Innovations preceded by strengthening of the enabling policy environment have often succeeded (e.g., sorghum processing in Nigeria and smallholder dairy in Kenya). Those introduced without a review of supportive policies have often failed (e.g., the food-grade aluminum milk cans in East Africa, and the community based animal health workers across Africa).

4. Communication, coordination, cooperation and interaction among key partners must be strongly supported. The case of banana tissue culture in Kenya is an excellent example, as is TMS cassava in Nigeria, and oil presses in Kenya.

5. Protection of intellectual property rights is crucial to private sector engagement (which is fundamental to scalability). Such protection has enabled success of the seed industry across Africa (through enforcement of breeders’ rights) and the export flower industry in Kenya (through strict patent laws).

6. Deliberate investment in market development is almost always required—i.e., “organized articulations of supply and demand.” Seed funding can be an important element of such investment, aiming to stimulate private sector interest and

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\(^{20}\) Where the bulleted items refer to specific examples, these are described in the case studies section of the paper.
investments particularly for innovations with strong public good nature. This is exemplified by the Hermetic triple bag storage technology, where the lead agency (Purdue University) has offered seed capital and some form of market guarantee to promote private sector interest in this technology targeting the poor farmers. The success of the oil pressing equipment in Kenya was facilitated by the promotion of sunflower production, extensive publicity of the technology, and making available maintenance spare parts. Similarly, the availability of market for gari has promoted uptake of the grater, similarly, the demand for maize flour drives the adoption of the hammer mill across East and Central Africa.

7. Scaling plans should be developed and budgeted for up-front. Too often this crucial dimension of the innovation process is ignored or honored only in the breach.

In addition to the obvious “don’ts” implied by the above “dos,” some additional “don’ts” in innovation deployment in smallholder African agriculture include:

1. Technology development and deployment should not skip the field testing and adaptation phase of the development cycle. For example, the PRODA cassava peeler was released directly from the laboratory with the expectation that it would be adopted by users. This is believed to have contributed to its failure.

2. An innovation should not be introduced if it does not conform to the existing sub-sector policy. For example, the food grade milk cans were produced for smallholder milk vendors, yet most of them are not recognized in law, and therefore cannot be licensed. Similarly, the community based animal health workers were introduced, yet the existing policy states that only animal health personnel with formal training can offer health services.

3. Full reliance on collectives for diffusion of technologies should be avoided. Collective action organizations (cooperatives, farmer associations, and credit institutions) exist in various kinds and have been important actors in African agricultural innovation systems, ostensibly due to their potential in helping farmers overcome key post-farm hurdles, especially under conditions of poor market development. But having been used by many governments as instruments of oppression and resource extraction from farming communities, these collectives have often been viewed warily by risk-averse farmers, who are more often than not the most vulnerable. The collectives have also faced management challenges leading to increased operational costs to the detriment of the vulnerable farmers.21

4. Full reliance on Non-Governmental Organizations (NGOs) for diffusion of technologies should be avoided. Although NGOs have often relied on participatory approaches, which can often spur innovation uptake at local levels. But these approaches are very difficult and costly to scale up, due to contract design and enforcement problems inherent to rural areas.22

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8. Reading list for further information


Moussa, B., 2006. Economic Impact Assessment of Cowpea Storage Technologies in West and Central Africa M.S. Thesis, Department of Agricultural Economics, Purdue University, West Lafayette, Indiana.


9. CASE STUDIES

9.1. A successful post harvest cassava processing technology – The mechanized grater

a. The technology
In Africa approximately 95 percent of the total cassava production is used as food.²³ Farmers and food processors market three main groups of cassava food processed products: dried roots, pasty products and *gari* (a granulated product). Gari is the most widely processed product due to ease of transport and storability (long shelf-life). It is processed through peeling, grating, water expressing, and toasting of freshly harvested cassava.

*The Cassava Grater*

Traditionally, processing of *gari* entailed pounding cassava in a mortar with a pestle. Later, artisans developed a manual grater in the form of a sheet of perforated metal mounted on a flat piece of wood. But the efficiency of the hand grater was low because of its high labor input. In the 1930s, the French introduced mechanical graters in the Republic of Benin (formally Dahomey) to teach farmers how to prepare *gari* for export markets.²⁴ Later that decade in Nigeria, local artisans introduced and modified this mechanized grater, making it more labor efficient.²⁵

Initially, the mechanized grater spread slowly. In 1969, it was available in approximately 25% of the cassava producing villages in Nigeria. Today, from the most basic manual and pedal operated equipment (with a capacity of about 30kg/hr) through to motorized machines (with capacity exceeding 800kg/hr), graters can be found in virtually all major cassava producing villages in West African countries where cassava is processed into *gari* (i.e. Nigeria, Ghana, Cote d’Ivoire, Benin, Guinea, among others).

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²³ Waste was estimated to be 28 percent of the total cassava production in Africa from 1994 to 1998 (FAOSTAT).
b. Technology diffusion – Organizations, policies and incentives

Total consumption of cassava in Africa doubled from about 24 million tons per year in the early 1960s to about 58 million tons in early 2000s. These increases have been supported by increased production arising from better control of pests and diseases, coupled with the ability to process cassava into *gari*.

However, expanded cassava production and consumption has not been accompanied by commensurate research and development on post-harvest handling. Most governments have focused their agricultural development investments and policies on production and marketing of industrial crops (cocoa, cotton, ground nut, oil palm, and rubber), aiming to raise tax revenues and generate foreign exchange. To redress this constraint, village smiths, welders, and mechanics have over time refined the mechanized grater originally introduced into West Africa from France. These mechanized graters are constructed from old engines and scrap metal at costs ranging from US$200 to US$500.

Most of the graters are owned by village entrepreneurs and operated by young men, who provide grating services to smallholders for a fee based on the quantity grated. The quantity processed for a customer varies from one kilogram to several tons. In some instances, graters are mounted on wheels and moved to the fields or homes of farmers who request the services. Maintenance services are provided by roadside mechanics and welders. Therefore the diffusion of the grater has been a purely private sector undertaking involving the artisans, grater business owners and cassava producers. Its use has been augmented by increasing production of cassava, which has received strong public sector support.

The dominant role of the private sector does not mean that the governments in the cassava producing countries have completely ignored the technology. For example in Nigeria, in the 1970s, several government R&D agencies were established to undertake research into the chemical, biochemical, and engineering/processing of crops including cassava. The agencies include the Fabrication Engineering and Production Company (FABRICO), established in 1971; the Products Development Agency (PRODA), 1971; the Federal Institute of Industrial Research, Oshodi (FIIRO), 1975; the Rural Agro Industrial Development Scheme (RAIDS), 1981; and the African Regional Centre for Engineering Designs and Manufacturing (ARCEDEM)\(^\text{26}\).

The cassava graters developed by these agencies achieved limited adoption because they were expensive and inconvenient compared to graters developed by village artisans. Especially problematic was the fact that they operated at capacities far in excess of the processing needs of the smallholders. As a result, many entrepreneurs who bought them were forced to modify them, or to abandon them altogether.

c. Value generated by the grater

It has been shown that the replacement of hand grating with the mechanized grater cut the cost of *gari* production in half – that is, 51 days of labor were needed to prepare a ton of *gari* by hand and 24 days by mechanized grater, *ceteris paribus* (Nweke, 2004).

d. Impacts

It has been shown that the rapid diffusion of improved Tropical Manioc Selection (TMS) cassava was possible because of the mechanized grater. The mechanized grater reduced the cost of making *gari* and significantly increased its profitability, and the TMS diffusion in

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West Africa. However, one may ask – besides the synergy generated between TMS and grater – from which innovation have farmers derived more benefits? Drawing on the classification, farmers in Nigeria can be divided into four categories based on the cassava variety grown (local vs. TMS) and the grating method used (manual vs. mechanized grating).

Farmers who plant local varieties and grate manually earn a modest net profit of 42 Naira (about US$2.50) per ton of gari. Farmers who plant local varieties and use mechanized grating earn 478 Naira (about US$28.00) net profit per ton of gari as compared with a net profit of 339 Naira (about US$20.00) per ton of gari by farmers using TMS varieties and manual grating. Cassava farmers benefit more from using labor-saving grating technology than from planting improved TMS varieties. However, TMS varieties became significantly more profitable when grating is mechanized. For example, farmers planting the TMS varieties and using mechanized grating earn a net profit of 776 Naira (about US$46.00) per ton of gari.

e. Lessons learned and challenges to further up-scaling
Three lessons can be drawn from the success of the mechanized grater. First, the important role of the private sector in sustainable technology uptake in sub-Saharan Africa cannot be overemphasized. Towards this end, new innovations being introduced should endeavor where possible to integrate a private-sector-driven diffusion process, especially when the technologies have high private benefits.

Second, well packaged simple component technologies aimed at addressing existing needs within value chains will have high likelihood of success. The cassava grater is simple. Different models with varying capacities exist in the market, serving different market segments.

Third, the introduction of an innovation in a value chain requires a re-evaluation of the whole chain to redress emerging bottlenecks. The introduction and diffusion of the mechanical cassava grater has seen the labor bottleneck in cassava processing shift to the peeling stage. Mechanization of peeling will allow grater-entrepreneurs to own higher capacity graters that could permit them to exploit economies of scale, leading to reduced processing costs and higher incomes.

9.2. A failed cassava processing technology – mechanized cassava peeler

a. The cassava peeling technology
The first step in processing of cassava roots is often to remove the peel, which results in a great reduction of the cyanogenic potential of the raw material. This is because the peel represents about 15% of the weight of the root, and its cyanogens content is usually 5 to 10 times greater than the root parenchyma. Peeling is usually done by hand using a knife, a process that is slow and labor intensive, averaging about 25kg per hour. The Post-harvest Engineering Unit of the International Institute for Tropical Agriculture (IITA) has developed a cassava peeling tool that is simple, can be fabricated locally and gives minimum peeling losses.

In 1984, Product Development Agency (PRODA), a government research and development agency in Nigeria developed a prototype cassava peeling machine. One version was designed to run on an electrically driven motor, another on petroleum. This peeling machine had a capacity of 1,000 kg per hour, and cost $6,000.

b. Development of the technology – policies, institutions, and organization
Development of the cassava peeler was a government initiative, informed by the developments in the cassava value chain. The mechanization of grating now meant that the main labor constraint bottleneck had been transferred to three activities namely: harvesting, peeling, and toasting in the production of gari. Based on the success of the grater, the government realized that mechanization of these activities would significantly lower the processing cost and raise cassava income to farmers and in turn drive down the price of cassava to consumers. It was also argued that the mechanization of any of the harvesting, peeling, and toasting operations would encourage further diffusion of the improved TMS varieties and encourage farmers who were already planting them to expand the area under cassava cultivation.

c. Organizations involved in the value chain and development of the technology

It is however important to note that the peel also contains large amounts of the enzyme linamarase that is important in the detoxification of cassava during processing. For instance, grinding cassava without removing the peel, as is done in the manufacture of the Brazilian farinha, ensures an almost total elimination of cyanogens from cassava.
Despite the existence of many partners in the value chain, this technology was driven by PRODA, a government R&D agency.

d. Lessons learned from the failure of the technology
This government-led intervention in cassava processing R&D ignored development of partnerships in technology development and deployment. Despite the technology aimed at addressing an urgent need within the cassava value chain in West African countries, one critical step in its development was missed, namely field testing and modification by value chain partners. This critical step should not have been skipped. The expectation that farmers and processors would adopt the mechanical peelers straight from the engineering laboratory was not realized. Even the earlier lesson that many entrepreneurs who bought the government graters either had the machines modified by local artisans or abandoned them was not taken into consideration.\(^{29}\)Shortcutting the R & D intervention proved to be a constraint to the success of the cassava peeler.

This failure provides an important lesson for future introduction of technologies in commodity value chains in sub-Saharan Africa, that is, existence of an urgent constraint (need) within a value chain does not imply that any innovation aimed at redressing the constraint would succeed. A successful innovation should be aimed at redressing the constraints while fitting into the production circumstances of the actors. Towards this end, users’ participation in testing and modification is important.

e. Opportunities for redeeming the technology
Cassava processing centers are common in major cassava producing areas in West African countries. A processing center is often a village square where village entrepreneurs provide farmers with customized cassava processing services using mechanized graters, mechanical presses, and mechanized food crop mills. This arrangement enables farmers to have access to mechanical grating, pressing and milling services in one convenient location without worrying about buying, operating or maintaining any of the mechanized equipment. It also provides smallholders with access to labor-saving cassava processing equipment, which otherwise would be beyond reach.

The PRODA mechanical cassava peeling technology is therefore suitable for smallholder processors through the processing center arrangement. The necessary intervention is to evaluate the PRODA mechanical cassava peelers for suitability, adaptability and profitability under the processing center arrangement, to modify the technology as necessary and eventually diffuse it. It is apparent that the peeler in the current form is not useful to the smallholders and small-scale processors who need flexibility in the quantity of cassava processed, and close proximity to processing services.

9.3. A successful technology in banana production in Kenya - Tissue-culture

a. Description of the technology
Banana tissue-culture entails rapid and sterile multiplication of banana plantlets by in vitro propagation. It has long been common practice in other parts of the world, but until recently had not been commercially used in tropical Africa. The advantage of the technique is that large numbers of healthy banana plantlets can be produced in the laboratory in a comparatively short period of time. The technology reduces pests and disease problems for banana growers and offers an ideal opportunity to introduce new and superior germplasm quickly on a large scale. Since the plants mature early and uniformly, the technology is especially appealing to smallholders constrained by declined farm sizes since they are able to harvest and sell fairly large quantities of bananas at one time.

b. Introduction of the innovation in Kenya – Prevailing policies, institutions and incentives
In Kenya, the national average size of banana farms is 0.8 acres, indicating that banana production is a small-scale activity. In recent years, most African countries have been registering declines in banana production. One of the major causes of this falling off has been crop infestation by pests and diseases, which have reduced yields by up to 90%.

Conventional methods of generating banana planting materials through suckers are not only inefficient and unable to meet demand, they also promote the spread of pests and diseases.

A tissue culture banana hardening farm and field in Kenya

The tissue culture propagation technique was introduced as a deliberate intervention to redress these problems. Its objective was to avail clean, disease- and pest-free planting materials to farmers. It was introduced to Kenya from South Africa, where the private sector supplies large scale commercial farmers with tissue culture seedling. The challenge was therefore to re-design the technology package to benefit small scale farmers.

c. Organizations involved in the introduction of the technology
In 1997, the public Kenya Agricultural Research Institute (KARI) and the International Service for Acquisition of Agri-biotech Applications (ISAAA) launched a pilot project to introduce tissue culture bananas to 150 smallholder farmers in four major banana growing areas of Kenya. The project was supported by the Rockefeller Foundation and the International Development Research Centre.
ISAAA undertook the initial technology brokering from South Africa; KARI performed on-station and on-farm technology trials and adaptations. A private company, Genetic Technology Laboratory (GTL) handled production of the initial tissue culture banana plantlets. KARI worked with the public extension service and a number of NGOs in an aggressive extension and publicity campaign aimed at farmers. The Institute of Tropical and Sub-tropical Crops (ITSC) of South Africa offered technical backstopping services. Eventually, relationships were initiated with local private entrepreneurs and selected farmers, who served tissue culture plantlet distributors. Credit was offered to private entrepreneurs who were ready to set up distribution farms, and to farmers who were ready to establish the plantations.

d. Value generation through innovation
The adoption of tissue culture bananas conferred several benefits to farmers:

1. It increased the availability of large quantities of clean superior planting materials;
2. It reduced the harvest cycle of the bananas— to 12-16 months compared to 18-24 months for traditional bananas due to early maturity;
3. It yielded bigger bunches of at least 30kg, compared to 10-15 kg for traditional types;
4. It offered a uniform plantation development that eased marketing coordination—the uniform bunches also enhanced market acceptance; and
5. It increased farm net profits from about US$660 for traditional bananas to US$1,800 for tissue culture per average 0.2ha land per year due to increased outputs, increased quality and reduced marketing costs.\(^30\)

Crop establishment costs rose threefold (from US$200 to 600). But not only did the average yield double, the price per ton increased by 66% due to improved quality, generating large positive net returns. In addition, farmers were able to sell directly to large buyers (like supermarkets & hospitals), capture economies of scale, and realize even higher net returns.

e. Impacts
Currently in Kenya, over 500,000 farmers have planted tissue culture bananas, an average of about 50,000 new farmers per year since the introduction of the technology. While more than 2 million Kenyans faced famine in 2008-09, none of the tissue culture banana farmers needed emergency food assistance. The demand for tissue culture banana seedlings continues to surpass existing supply as more and more farmers adopt the technology. By applying a similar model, the tissue culture banana has been successfully introduced in Tanzania, Uganda and Senegal although the extent of the impact in these countries is not well documented. Interest has also been expressed in Malawi, Mozambique and Zambia, but again the level of success is not well documented.

f. Factors influencing success
The success of this innovation has been tied to two important links. First, the laboratory based R&D had been firmly tied to the needs identified through participatory on-farm research, ensuring that priorities had correctly been identified and the technology accurately targeted. Second, the partnership developed worked together to ensure that the technology

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was not only well designed, but also laid strategies for rapid up-scaling, driven by the private sector.

g. Lessons learned
Three lessons can be obtained from the success of this innovation. First, appropriate partnerships need to be forged to introduce new value creating innovations into value chains. Second, the new innovations need to be targeted towards redressing specific needs (constraints) within the value chain. In this case, the strong interest of the private sector means that the innovation is self sustaining. Third, redressing an existing constraint within a value chain leads to emergence of other constraints, calling for an assessment of the whole chain. In the case of tissue culture bananas, incidences of lack of ready markets for increased banana outputs are beginning to emerge. Further up-scaling will require support from the public sector in terms of deliberate policies to expand available banana mass markets, including incentives for production for export.

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9.4. Successful oil processing technologies – KickStart’s *mafuta mali* (oil for wealth) program

*a. Description of the technology*
KickStart *mafuta mali* (meaning “oil wealth” in Kiswahili) is a manually operated oilseed press suited to small-scale sunflower cooking oil businesses in East Africa. It is designed based on an original “ram press” design by Carl Bielenberg, but has been modified to be more efficient, durable and profitable to use. Besides the press, *mafuta mali* comes along with a Gravity Bucket Filter and a complete set of tooling for local mass production of both the press and filter. The press extracts oil from sunflower, sesame, and other oil seeds. The filter produces clear, cold-pressed, nutritious cooking oil ready for sale or consumption. The seedcake by-product is used as a protein animal feed supplement. The KickStart Oilseed Press Business Package includes: a press, a bucket filter, a detailed manual, spare parts and a tool kit. The package costs Kshs 48,000 (US$ 620) per unit.

*b. Development of the technology – Organization, policies, institutions and incentives*
Economic liberalization in Kenya in the early 1990s featured termination of most public support for the agricultural sector. Controls on prices of key commodities were lifted, as were those on sourcing of raw materials for local industry. This led to increase in prices of many commodities, including cooking oil. With funding from the Netherlands government and the British Department for International Development (DFID), KickStart, an international NGO, launched a cooking oil industry market research project. A major finding of the project was that the small-scale production and sale of cooking oil could be profitable if the right technology were made available to local entrepreneurs.

Based on these findings, KickStart trained four local engineering firms to manufacture the new presses. A promotional campaign was launched to increase awareness and sales. Interventions included mobile truck demonstrations, radio and newspaper advertisements, exhibitions at trade fairs, and broad-based media exposure.

A network of retailers for the new presses was established and linked to the manufacturers. The retailers sold the presses. In order to create a market for the oil press, KickStart also implemented projects that promoted increased production and sale of improved varieties of sunflower, sesame, oil-rape and safflower seeds.
c. Value generation through innovation
Although the ram press is a manual device, its enables processing at an output rate of about 10-15 liters per day from about 50-60Kg of oil seed, leading to increased returns of more than 100% when compared to selling the unprocessed seed to processors. The oil is sold to neighbors, boarding schools, hotels and other commercial outlets.

When the new press was first launched, there was much controversy regarding its suitability for smallholders. The original Bielenberg Ram Press could extract 70-80% of the oil in a load of sunflower seeds, and more if the seed was first heated by laying it in the sun. About 100kg of seed could be pressed in 10 hours, yielding 20-30 liters of oil. This output was relatively low for a small-scale press. Questions were raised about the technology’s commercial potential. Those fears would appear to have been misplaced. The press has proven sufficiently productive for rural villages to be able to produce enough oil for their own consumption, with important impacts on health and income diversification.

d. Impacts
Impacts realized from mafuta mali in Kenya include:

1. Three local manufacturers of oilseed presses exist and are fully operational;
2. Over 1,050 presses have been sold;
3. Over 700 oilseed pressing businesses created or expanded;
4. Over 1,500 new jobs in oil pressing businesses created;
5. Sunflower cultivation in Kenya has risen steadily, from about 6,000 mt in 1995 to about 14,200 mt in 2007. The cultivated area has increased from 9,000ha to 13,200 ha during the same period;

Similar trends are observed in Tanzania where the technology has also been introduced, although only anecdotal evidence is available thus far.

e. Lessons learned and factors influencing success
A number of lessons can be drawn from the mafuta mali technology diffusion. First, this case shows that a new technology can be successfully introduced into a value chain to address an existing need so long as a supportive policy environment exists.

Second, the case study also emphasizes the critical role of the private sector in the success of innovations with high private benefits.

Third, the success of the innovation has been supported by the development of strong partnerships not only within the private sector (between KickStart and private entrepreneurs) to support technology development and dissemination, but also between the private sector and donors (KickStart/DFID/Netherlands Government) to support wider market development.

Fourth, the diffusion of the technology was supported by a well designed market development program starting with development and promotion of the technology, development of a retail network to increase access, and investments in production of raw materials by supporting increased production of sunflower, sesame, oil-rape and safflower crops.

f. Scaling-up of the technology
The oilseed press business in Kenya is strongly viable. The machines are available from local manufacturers, entrepreneurs continue to establish profitable small scale cooking oil businesses, and farmers continue to increase the local production of oilseeds. There appears to be scope for industry expansion. The technology is designed to produce a high-demand product at lower cost than was previously available. KickStart’s support has enabled private manufacturers to profitably produce and market the technologies. The technology is available for purchase through over 180 retail stores around the country. KickStart remains in contact with each manufacturer. It has strong relations with the retail stores, and continues to promote these technologies through local shows and exhibitions. It also provides support and training on how to use and maintain them. Given the evolution of the industry, finance and technical support would appear to be the principal bottlenecks to be overcome.
9.5. An unsuccessful technology – low-cost food-grade milk handling cans by informal traders in Kenya

a. The technology

During the 1990s the Kenyan dairy industry was progressively liberalized, starting with milk price decontrol in 1992. This process, together with problems of poor internal management and corruption, led to the gradual collapse of the state-owned Kenya Cooperative Creameries (KCC) through the 1990s, effectively ending their 60-year monopoly on milk processing and marketing in urban areas. This gap was quickly filled by a proliferation of unlicensed and illegal small-scale milk vendors (SSMVs) and large-scale private sector milk processors licensed and regulated by the Kenya Dairy Board (KDB) – the government-appointed body responsible for regulating the dairy industry. SSMVs sell raw milk while private dairy companies sell pasteurized and packaged milk, along with other dairy products (e.g., yogurt and cheese).

The non-legalization of mobile SSMVs (milk hawkers) stemmed from the battle between a few large, specialized, highly organized, and influential producer-processors with significant installed capacity, on one side, and myriad, often part-time, usually haphazardly organized, small-scale producer-traders of raw unprocessed milk, on the other. The competition for market share between the two groups with considerably different levels of investment was being fought on the basis not of price (as it should be) but of perceived quality and safety (even when this was proven false). Differential political power across the two groups played a significant part in the contest.

However, there was a change in policy implemented in 2004 that allowed licensing of SSMVs who, in the first instance have to undergo training delivered through accredited business development service (BDS) providers or milk trader associations. The new policy has given opportunity for SSMVs (estimated at 44,000) to progressively scale up their businesses into fixed premises which can be easily inspected for compliance with milk quality standards. In total, raw milk sales currently comprise about 86% of marketed milk in Kenya, the remainder being shared by 31 private processors of the 47 registered with the KDB.

Most SSMVs transport milk to consumers by bicycle or by public transport, usually in plastic containers. These transport modes and containers compromise the quality and safety of milk. To solve this quality concern, the Kenya Smallholder Dairy Project (a partnership involving the International Livestock Research Institute, the Ministry of Agriculture, the Kenya Agricultural Research Institute, and other stakeholders), developed an "ideal" aluminum milk container for use by SSMVs. Kalu Works Kenya, a local manufacturer agreed to produce the vessel at what was considered an affordable price. The container's size and design allows easy transport on a bicycle. An easy-release clip holds the lid firmly on top, avoiding spillage and contamination. It is important to mention that these containers contributed significantly towards persuading the KDB to initiate the ongoing program of training and licensing SSMVs.

b. Value generation through innovation

Most SSMVs do not operate from fixed business premises, and most proprietors run their businesses personally. The majority sell 50-120 liters of raw milk daily. Most source their milk from farmers residing 30-60 kilometers away, but this distance can be as high as 150 kilometers. The ideal containers, which are available in 5- and 10-litre capacities, are food-grade, leak-proof, easy to sterilize, durable, and, most importantly, are associated with better microbial quality of raw milk. Local regulatory authorities have supported the use of the improved metal cans by small-scale traders. By raising milk quality, the ideal containers
should reduce spoilage and increase quality and hygiene, thereby allowing more SSMVs to qualify for trade licenses from the KDB and operate legally in urban areas.

c. Reasons for failure of the technology
Although the policy innovation to allow licensing of certain SSMVs combined with the institutional innovation to offer training, certification, and licensing has been widely considered successful in creating a bridge between regulated and unregulated markets and expanding market opportunities for SSMVs, the uptake of the ideal containers has been limited. For example, in a follow-up assessment of changes in practice on the ground by SDP and KDB following the policy change, it was found that the proportion using milk cans had not significantly increased beyond the 10% of the SSMVs found to be using them before the intervention. Towards this end, apart from the 47 processors, the board has licensed 1,300 other milk dealers including trader associations with varying numbers of members who operate as producers, SSMVs, milk bars, cottage industries and mini dairies. However, most SSMVs continue to use the plastic containers because the durable metal cans are considered either expensive, inconvenient to carry on alternative modes of transport besides the bicycle they were designed for, or limit the volume of milk a trader can carry.

Food grade milk cans, Kalu Works, Nairobi, Kenya

d. Opportunities for redeeming the technology
Despite this apparent constraint, the financial viability of SSMVs appears to be high. Available studies indicate that Kenyan consumers prefer whole raw milk, even those who could afford pasteurized milk. 50% of marketed raw milk is reported to exceed required levels of bacterial quality standards and zoonotic pathogens. But even though nearly all consumers boil milk before consumption, thereby eliminating microbial threats to health, better and more appropriate containers are still required to enable SSMVs improve the quality of the milk that they sell and reduce losses.

e. Lesson learned
A key lesson learned from low adoption rates of the food-grade aluminum milk cans is that the technology is costly, does not comply entirely with SSMVs transportation requirements and also limits the volume of milk an SSMV can carry. In addition, the technology was initially
introduced for use by the SSMVs against a backdrop of a policy environment that sets stringent criteria for their registration and licensing. Whereas practical mechanisms are now being implemented to redress SSMVs licensing procedure through training and certification, introduction of more affordable and easy-to-carry food-grade plastic or metal containers could help alleviate the problem of poor milk quality.
9.6. A potentially successful technology –The hermetic grain storage bag

a. Description of the technology
Hermetic storage is one of the oldest forms of food preservation in the world that provides an airtight, safe and pesticide-free means of storing dry food commodities by avoiding storage insect and pest damage. One area in which this technology has been used is in the farm-level storage of cowpea grains in West African countries. This has involved the creation of a cowpea hermetic storage bag that involves a triple-layer plastic bag (although other air tight containers are appropriate in some locations).

The technology essentially consists of filling a plastic bag with cowpea grain, tying the mouth of the bag shut, enclosing this bag completely within a second one, and tightly securing that, then repeating the procedure using a third bag. The third bag is added as an insurance measure. The method is simple, uses readily available materials, and is low cost.

Purdue Improved Cowpea Storage- a cheap form of hermetic storage

The mechanism by which triple bagging works involves oxygen depletion and elevation of carbon dioxide levels. Respiration of insects living in seeds stored in a closed space may, together with respiration of the grain itself, in combination with the limited free oxygen available, reduces the oxygen levels to a point where insects are unable to carry out their life processes normally.

The bagging procedure does not appear to kill all insect larvae even in grain that has been stored in triple bags for several months. Insect larvae that survive in the grain presumably are inactive, and resume activity only when oxygen becomes available again.

b. Development of the technology – Organization, policies, institutions and incentives
In sub-Saharan Africa, post-harvest insect pests of cowpeas degrade the nutritional quality and economic value of the grain. Anticipating losses during storage, producers sell at harvest when the price is lowest. The principal storage pest is the cowpea bruchid (or cowpea weevil).

Hermetic storage is an ancient technique that has been variously used to reduce the post-harvest cowpea losses. Its transfer for farm level use can first be traced in Senegal in 1985 where metal drums were used; and in Cameroon around 1990 where plastic bags were used.

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37 A technical bulletin describing the procedure has been published: i.e., Kitch, L.W., Ntoukam, G., 1991. Airtight storage of cowpea in triple plastic bags. Technical Bulletin No. 3. Institut de la Recherche Agronomique du Cameroun (IRA) and Bean/Cowpea Collaborative Research Support Program (CRSP) (Published in English, French, and Fulfulde).
There have also been a few small-scale efforts to increase the use of the technology in a few villages in West and Southern Africa by National Agricultural Research Systems (NARS), non-governmental organizations (NGOs) and extension services. However, significant mileage in refining and packaging the technology was achieved through the intervention of Purdue University at the beginning of the 1980s (under the USAID-funded Bean/Cowpea Collaborative Research Support Program (CRSP)).

The program targeted post-harvest insect pests of cowpea as a constraint meriting an investment in research and development. Subsequently, with funding from the Bill and Melinda Gates Foundation, researchers in Senegal, Cameroon, and the US (Purdue University), are exploring models for disseminating the post-harvest bagging technology in cowpeas utilizing triple plastic bags. The Purdue Improved Cowpea Storage (PICS) program is testing different supply and distribution methods with private sector actors where the project is active, through provision of initial seed financing support to local manufacturers and a form of guarantee during the initial market building process. The PICS technology uses commonly available polyethylene, which has low production costs and can be manufactured by a number of African plastics companies.

c. Value generation through innovation
Cowpea farmers benefit from the hermetic triple bag storage in three ways. First, they avoid the direct loss of damaged cowpea that results from attack by cowpea weevils. A conservative estimate of the physical quantity of harvest lost due to weevil attack is 25%. Second, these farmers benefit by not having to sell at harvest when prices are generally lowest but can hold their cowpeas for later sale when the price is higher. The average price increase from December (right after cowpea harvest) to June ranged from 15% in northern Ghana to 86% in Nigeria.

Third, farmers avoid another source of loss arising from the price discount for cowpeas that are damaged by weevils. Damage discount estimates range from 0.17% to 2.3% of average price for each weevil hole in a sample of 100 grains. Overall, it is estimated that with 50% of cowpeas produced being stored using the triple bag technology, an income increase in the magnitude of US$150 would be realized per household.

d. Scaling-up of the technology
The farm level triple bag hermetic storage technique can be tested in the storage of other farm produce like cereals (Rice, Wheat, Barley, Millet, and Sorghum), and other pulses (Groundnuts, Shelled Beans, Kola Nut and Bambara Groundnut), all of which suffer from storage pests.


Other technologies developed using such partnership included: (1) a highly effective drum storage technology developed at ISRA, Senegal, and now widely adopted in Senegal; (2) a solar disinestation technique developed at Purdue and at IRAD, Maroua, Cameroon, now being disseminated in many African countries; (3) an improved ash storage procedure; and (4) two cowpea cultivars expressing combined seed and pod wall resistance to cowpea bruchids, released by the Cameroon government in 1999.


A number of factors prohibit straightforward adoption. For example, the maize borer is a much larger pest than the cowpea weevil and there is no rigorous research yet to demonstrate whether the maize borer will be more destructive to various types of bags by virtue of their size than the cowpea weevil, which while it still makes damage to the bags in the period that the oxygen is being depleted, it does not incur damage enough to eat through all three layers of the bag.

In addition to potentially wider use at farm level, other forms of modern hermetic storage are evolving that appear applicable to bulk storage (e.g., village or regional-level storage) or higher value commodities. These include the use of large, flexible, plastic envelopes - called Cocoons, or SuperGrainbags, manufactured by GrainPro - to create a sealed environment where any pests present die from lack of oxygen. GrainPro uses an oxygen impermeable plastic which increases the costs and reduces potential for manufacturing the bags in Africa. A growing number of countries, including Philippines, Rwanda, Ghana and Sri Lanka, are storing rice, maize, sorghum, wheat and pulses using this modern means of airtight storage. In Rwanda for example, the government has procured hundreds of Cocoons of 50 and 150 metric tonnes capacity for village-level storage of maize, pulses and sorghum. Therefore, different adaptations of the hermetic technique can be developed to redress post-harvest losses within different commodities.

e. Lessons learned

The hermetic technology was designed by the public sector and its commercialization is being implemented through a public-private sector partnership. The technology is still at an early stage of development and adaptation. But initial analysis and experience point to:

1. The importance of public sector seed investment in generating technologies where the target beneficiaries are poor smallholders; and
2. The need for development of strong partnerships with significant private sector presence for eventual commercialization and up-scaling of technologies, particularly when the public sector exits.

Purdue is testing different supply and distribution methods with private sector actors in the countries where the project is active. Some noteworthy initial insights with regards to supply and distribution in West Africa include:

- Private wholesalers and retailers are the most effective way to get PICS bags to farmers.
- Competition among local manufacturers can help keep the cost of PICS bags down.
- Retailers and wholesalers need to reduce risks associated with expanding distribution, in particular associated with the lack of legal recourse to enforce contractual obligations (approaches include: risk sharing, financing, and market information).
- Agreements with manufacturers must specify PICS bag specifications and farmers must be trained to identify bags that meet minimum standards for hermetic storage.
- Bag sizes should meet different market requirements:
  - Cowpea farmers prefer 100 kg bags because they are standard for commercial grain trade in West Africa; while 50 kg bags can be used for demonstrations and trials because they reduce the farmer’s risk (if a bag of cowpea went bad, they would lose only 50 kg).

43 Source: http://www.new-ag.info/08/01/develop/dev3.php
Government and NGO buyers often prefer 50 kg bags because they are easier to handle by hired laborers and there is less breakage.

The project is providing some initial incentives to local manufacturers to help prove the business case and provide some guarantee during the initial market building period. The true success test will be whether any of the models prove successful enough to the point where the private sector manages the distribution and marketing part of the value chain entirely on its own. This lesson likely carries over to other emerging technologies.