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Enhancing Child Nutrition and Livelihoods of Rural Households in Malawi and Tanzania through Postharvest Value-Chain Technology Improvements in Groundnuts

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I. Overview

Compatible Technology International (CTI), Tanzania's Sokoine University of Agriculture (SUA) and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in Malawi have combined their institutional expertise and resources to implement a project for the purpose of **enhancing child nutrition and livelihoods of rural households in Malawi and Tanzania through postharvest value-chain technology improvements in groundnuts**.

Historically, investments in improved groundnut production through agricultural research and development efforts have been devoted to increased productivity and production in the field (i.e. pre-harvest) whereas much less attention has been paid to postharvest crop processing and value addition. Researchers and development professionals are now realizing that yields cannot simply be measured at harvest time but more importantly must be measured at time of ultimate use. The numerous postharvest processing steps for these crops cumulatively lead to significant food wastage and loss as well as requiring substantial, tedious family labor on a nearly continuous, daily basis. On the food quality and safety side, aflatoxin remains a persistent problem in groundnuts produced in Africa, not only for families consuming groundnuts but also for export. In fact, the EU effectively banned the import of groundnuts from Malawi in the 1990s because of unacceptable aflatoxin levels. If the best-quality groundnuts are exported, either regionally or internationally, and the poorer quality lots are kept for local consumption, then the health impacts of aflatoxin may be worse than many might think. CTI and its partners therefore considered this as a major issue and gave it high priority in evaluating harvest and postharvest technologies and the foods developed for children in the child nutrition studies by SUA.

The project was aimed at identifying major challenges faced during the harvesting and postharvest processes in order to make recommendations on technologies that will address yield losses in terms of both quality and quantity but also reducing labor. This is ultimately expected to improve income generated through sale of high quality processed or raw groundnuts, but more importantly to improve health and well-being of smallholder families in Malawi and Tanzania.

Despite the region's high potential for groundnut production, malnutrition is common among the rural people. It is widespread in Tanzania and Malawi, and is particularly acute among children under five who are weaned onto the staple maize-based diet that is deficient in protein, oils and micro-nutrients. Therefore, there was an urgent need to develop improved nutritious weaning foods using locally-available groundnuts and other crops, and to reduce drudgery associated with food preparation, which is borne mostly by women and children.

PROJECT OBJECTIVES

1) **Reduce losses of food, in both quantity and quality**, incurred by farm families during harvest and postharvest handling, processing, and storage; and through food preparation and consumption.
2) **Improve the nutrition of rural households,** especially for children, through adoption of improved weaning and infant foods using groundnuts and other locally available crops as base ingredients.
3) **Raise household revenues** through the sale and distribution of high-quality groundnuts and/or value-added products such as paste, oil and/or other groundnut–based food products.
4) **Improve productivity and reduce daily labor and physical drudgery borne by women** through utilization of more efficient and rapid postharvest and food-processing technologies for groundnuts.
5) **Empower farm families** (especially women and youth) and their associations or producer organizations in ways that enable them to strengthen their links to markets, manage their farms as enterprises, learn how to find information and external support, identify more beneficial ways to associate, and better defend their interests in the future.
6) **Strengthen local capacity** by transferring technical and manufacturing expertise to African organizations.

APPROACH

Using an integrated value-chain approach, the project addressed the entire postharvest value chain from harvest to consumption or sale. The project started by (1) conducting participatory diagnoses/constraint surveys/analyses of the groundnut value chain and child nutrition and feeding practices with targeted farm families, and sought to (2) adapt existing solutions or develop new ones for participatory testing and evaluation with target families for all the links in the chains, including improved postharvest devices and nutrition–rich foods for children. The groundnut postharvest chain includes harvesting, postharvest handling, drying, stripping pods from plants, storage, shelling, roasting, grinding into paste/butter, extracting oil, making various groundnut-based products (including nutritious foods for children), packaging and distribution, and identifying and developing markets. The project conducted research based on prior information on current technologies and new ones in order to determine the most efficient ones for increasing productivity, livelihoods and nutrition. The project also worked with partners such as Plan Malawi (NGO) and National Smallholder Farmers Association of Malawi (NASFAM) and in Tanzania with Ministry of Agriculture extension personnel, local research scientists, village-level medical staff and TUNAJALI NGO staff.

Child Nutrition

The child nutrition component has the objective of improving the nutrition of children between 6 and 24 months of age in selected villages through the adoption of more nutritious complementary foods as the feeding of breast milk is reduced. Team members from Sokoine University of Agriculture (SUA) have developed complementary food formulations containing groundnuts and other locally available cereals that are higher in protein, fat, vitamins and micronutrients than the typical maize only preparations. Protocol guidelines for evaluating aflatoxin levels in the complementary food formulations have also been developed.

The SUA team has administered educational programs to mothers on nutrition, sanitation, child feeding practices and on how to prepare nutritious complementary foods. The effectiveness of the complementary foods was monitored by recording monthly anthropometric measurements (weight, length, height) as well as the development of gross motor skills (unassisted sitting, standing and walking) of the 320 children and their mothers participating in the study, as well as those in a control group not participating in the study.

Groundnut Technologies

The identification and development of improved groundnut processing technologies focused on the primary harvest and postharvest (HPH) constraints identified by farmers. Collaborating with village co-designers and evaluators, CTI engineers developed manually-operated mechanical technologies for the three HPH groundnut operations that surveyed farmers identified to be the most strenuous, labor-demanding, time-consuming: In collaboration with groundnut growers in Malawi and Tanzania, CTI engineers developed a set of groundnut growing devices that can reduce the time and labor for HPH processing of groundnuts:

1) **Lifter:** An Oxen-powered lifter digs and lifts groundnuts during the harvesting period. It significantly reduces the labor and time required to harvest groundnuts and is 9x more efficient the traditional method of digging with a hand hoe.
2) **Stripper**: A Screen Stripper increases productivity by 1.5x relative to hand stripping in field tests.
3) **Sheller:** Two sheller prototypes were developed. A Disc Sheller, preferred by men, is 24x more efficient than hand shelling, and a Drum Sheller, preferred by women, is 14x more efficient.
4) **Sorter:** A sorter removes broken and split nuts for market sale is 6x more efficient than hand sorting.

If all **of the CTI technologies** tested were implemented in the villages and performed as they did in the on-station and on-farm trials, it is estimated that there could be a **9X reduction in labor** required to harvest and process an acre of groundnuts. This would eliminate much of the drudgery for women, free their time and could potentially increase crop quality.

II. Narrative

A. CHILD NUTRITION

Activities & Challenges

SUA undertook monthly monitoring of nutritional status for the target children (6-12 months) in all 16 villages. The SUA team, assisted by Ward/ Village Medical Personnel, continued taking monthly measurements of weight and height for target children in their respective clinics for remaining 5 months until January 2013. Some of the mothers were not taking their children to clinic every month so this resulted in missing data of height and weight measurements in some months.

SUA monitored the utilization of the developed complementary foods based on groundnuts by mothers of the target children. The SUA team assisted by Ward/ Village Extension Officers and TUNAJALI NGO Staff continued with follow up of the mothers of the target children through home visits to monitor utilization of the developed complementary foods based on groundnuts until January 2013. Home visits (twice per month) were intended to assess how mothers of the target children prepared the cereal-groundnut mixture, preparation of the porridge according to the instructions from the training sessions, feeding frequencies per day of the prepared porridge, how much was prepared and how much the child consumed each day, how much was left, other foods consumed by the target children and the general hygiene conduct of the households.

The groundnuts harvest was not good so some mothers had to buy groundnuts for preparation of complementary food. Target mothers were sensitized on the importance of taking their children to clinic every month and the trend was improving. They were also sensitized to keep some groundnuts for complementary food preparation even if the harvest was not very good, and encouraged them to buy groundnuts for their children if they ran out of their stocks.

SUA determined the microbiological quality of the complementary food by collecting food samples for microbiological and aflatoxin analysis. The SUA team collected food samples (flour mixture and prepared porridge) for bacterial counts and aflatoxin analysis which were kept refrigerated in a cool box. Porridge samples were analyzed immediately after arrival at the laboratory for microbial quality while flour mixture samples were analyzed at a later time for microbial quality and aflatoxin content.

The SUA team held a stakeholders meeting to monitor progress of the project. The SUA project team organized meetings with all the stakeholders in the 16 villages, District Agricultural Extension Officers, Ward/Village Medical Personnel, TUNAJALI NGO Staff, and discussed progress of the project (achievements, challenges and lessons learned).

Insights & Lessons Learned

The Project Team learned that all mothers of the target children are able to prepare and feed their children the four complementary recipes developed by the project and based on groundnuts in all districts depending on what cereal is available. Other members of the families were interested in project activities and even when some mothers were not available, their husbands or older children were attending on their behalf. (Appendix H, Image 4)

Groundnut-based complementary foods improved growth in target children by increasing their weight to a greater extent. However, it showed slight height increase and stunting was only slightly improved. So this means that there is a need to include other nutrients like Vitamin A which can address stunting.

Flour mixture of the complementary food based on groundnuts samples analysed were all safe with aflatoxin content less than 20 ppb, and the microbial count were within acceptable levels.

Plans

Due to the fact that the developed complementary food based on groundnuts did not show great impact on reversing stunting, the project will look into ways of incorporating vitamin A rich foods like Orange Fleshed Sweet Potato (OFSP) to improve stunting in children. OFSP, being drought resistant tubers, will provide a cheap and affordable source of vitamin A in the study villages.

B. GROUNDNUT TECHNOLOGY DEVELOPMENT

Activities & Challenges

Year Four technology development activities, led by CTI and ICRISAT, focused on: (I) Refining technology designs based on the results of Year Three field tests; (II) testing the modified prototypes in village and research station trials in Malawi and Tanzania; and (III) investigating fabricators capable of manufacturing the groundnut equipment locally.

CTI's engineers made design modifications to its prototype Oxen-powered Lifter, Screen Stripper and Disc Sheller at CTI's headquarters, basing design improvements on farmer feedback and data collected during the May 2012 field tests. Engineers also developed new prototypes for Drum Shellers, a Winnower for groundnut shells, and a Groundnut Sorter—a device that sorts broken and odd-shaped nuts from whole kernels.

In May 2013, the groundnut prototypes were tested in six trials at research stations and villages in Malawi and Tanzania. In Malawi, trials were conducted at on-station at ICRISAT offices and on-farm sites in project districts of Kasungu and Lilongwe. In Tanzania, trials were conducted at the Makutopora Research station as well as Makoja and Muungano villages. CTI and ICRISAT collected data on traditional processing methods vs. CTI's prototypes.

Identifying local fabricators for the equipment continued to be a challenge. In 2012, C to C Manufacturing in Malawi fabricated 16 prototype strippers on a pilot basis, but efforts to secure more formal, sustained partnerships with manufacturers has been challenging and thus far unsuccessful. Local manufacturers have been reluctant to even provide quotations for producing equipment, so prototypes used in the 2013 trials were constructed in the USA.

Insights & Lessons Learned

CTI has designed manual mechanized devices that significantly improve the operations of digging and lifting, stripping and shelling and sorting groundnuts. Each of the prototypes designed for these processes have resulted in a 50% reduction in time and labor and, when used together, the devices are 7x more efficient than traditional groundnut harvesting and processing methods. Because the devices significantly reduced processing time, they also represented a reduction in the price of hiring contracted labor to perform harvest and postharvest (HPH) operations.

<u>Lifter</u>

CTI's Oxen-powered Lifter significantly reduced the time and labor required to lift groundnuts. On average, the Oxen-powered lifter performed 9x faster than farmers were able to dig using the traditional hand hoe during the 2013 field and station trials. The lifter performed best in fields relatively free of weeds and with groundnut planted in mounded ridges, a factor that should be taken into account when equipment is distributed.

After testing the Oxen-powered Lifter with representatives from ICRISAT and CTI, 28 farmers in Malawi were given the opportunity to use the lifter independently in their individual fields with the arrangement that they would collect and report data on their production rates. Using the Oxen-powered lifter, farmers increased their production by 700%. Farmers also noted that use of the Lifter would provide significant cost savings in terms of hiring labor to dig groundnuts from their fields. The farmers estimated that hiring oxen would cost half the amount of money per acre than it would cost to hire labor to dig by hand, as the traditional method is significantly more time-consuming. Though few farmers own oxen, oxen teams are available for hire in most villages.

The lifter was consistently the most favored device among both men and women, which is in keeping with the baseline survey findings, where lifting was viewed as the most strenuous task in groundnut production. A manual shovel lifter prototype was also tested for a second year, but farmers again found it slow and awkward to maneuver so the design is no longer being pursued.

Stripper

A modified Screen Stripper constructed with an a-frame was introduced to farmers in Year Four. The previous model's screen was mounted on a flat table, which was strenuous on the back after extended use and difficult for women carrying babies.

In the May 2013 field tests, the new stripper averaged 1.5x more efficient than stripping by hand, however there were significant variations in rates of hand stripping and screen stripping among testing sites. The disparity among production rates can be attributed to several factors, including the experience and technique of the operator as well as the moisture content of the nuts. The new stripper prototype was left with one of the project villages in Kasungu, Malawi for farmers' continued use, and it averaged 3.6x more productive than hand stripping in this village. Farmers reported that use of the Screen Stripper would also significantly reduce the cost of hiring laborers to perform stripping, resulting in a savings of 93%.

The new Screen Stripper was enthusiastically received by farmers, and women ranked it second among the five primary devices tested (men ranked the stripper fourth). The A-frame modification was viewed by farmers as a significant improvement over the flat table model. Farmers commented that it was more comfortable and easier for women carrying babies to strip without becoming tired.

Sheller

Three devices for shelling were evaluated in Year Four: a modified version of the Disc Sheller introduced in Year Three as well as two new prototype Drum Shellers—a large and small version. In field and station trials in Malawi and Tanzania, the Disc Sheller averaged 24x more efficient than hand shelling and the small Drum Sheller (the higher rated version among farmers) averaged 14x more efficient. The small Drum Sheller was left with farmers in one community in the Kasungu district, which enabled farmers to shell nuts 33x faster than by hand (farmer data reflects output per machine, not per person). Farmers estimated that use of the sheller could reduce the cost of hired labor by 92%. Winnowing equipment, though not part of the workplan, was designed to sort shells and unshelled nuts. This device did not work well during the testing exercise, and will therefore need further modifications and testing.

Despite the shellers' high rates of production, the prototypes produced 20-30% unshelled nuts in the first pass, requiring a second pass with unshelled nuts. Even with the additional passes required to fully shell the nuts, the prototypes still represented a significant increase in the rate of production over traditional hand shelling. The shellers also produced a rate of broken or split nuts between 20 and 30%. The level of broken nuts produced is determined by a number of factors, including the moisture content of the pods, quality of pods, nut and pod size, and operator technique. Many women remarked that rate of broken nuts was acceptable, as these nuts are used for home consumption. However, broken or split kernels are less desirable for market sale and have storage shelf-life limitations, so future design modifications will concentrate on reducing the rates of both broken and unshelled nuts.

Farmers commented on the ease of use, adaptability and portability of the Disc and Drum shellers. They were perceived to be durable and long-lasting. There was some disagreement among men and women in regard to the preferred sheller model. Based on initial data, women and older men seemed to prefer the small Drum Sheller for its ease of use and ranked it 3rd of the 5 devices. Men seemed to favor the Disc Sheller, ranking it 2nd and noting its entrepreneurial potential because of its higher output.

In the project villages, men who used to avoid shelling operations are now participating in shelling. This is because it is now seen as somewhat a business operation rather than a simple subsistence activity mainly done by women. These lessons will help future activities in that gender dimension should be taken into account in all interventions as the groundnut value chain becomes attractive.

Recognizing the potential of shelling technologies, traders are now buying groundnuts in pod and are shelling by themselves in bulk, a practice that had not been observed before. Local fabricators of shellers are increasing due to increased sheller demand by farmers. There is increasing investment in shellers whereby individuals are hiring out shellers bought in bulk for hiring purposes only.

Sorter

A groundnut Sorter prototype was first introduced to farmers in Year Four. The device separates broken and whole nuts in preparation for market sale. In trials, the sorter produced sorted nuts more than 3x faster than hand sorting. Of the 5 prototypes tested, the sorter was favored 3rd among men and 5th among women.

Requirements for Harvest and Postharvest Groundnut Processes*

	Time/labor			**Cost of hired labor**		
Activity	**Hand Methods** (Person hours / acre)	**CTI Equipment** (Person hours / acre)	**Advantage of CTI Tools**	**Hand Methods** (Malawian Kwacha)	**CTI Equipment** (Malawian Kwacha)	**Advantage of CTI Tools**
Lifting	40-80	6.6	6x – 12x	5,000 / acre	2,528 / acre	2x
Stripping	80	25	3.2x	750 / bag	50 / bag	15x
Sm. Drum Sheller	400	9	44x	750 / bag	60 / bag	12.5x
Disc Sheller	400	4	100x	-	-	-
Sorting	80	25	6x	-	-	-
Total	**600-640 person hrs/acre**	**69 person hrs/acre**	**9x person hrs/acre**	**5,000 MK / Acre + 1,500 MK/ Bag**	**2,528.2 MK/Acre + 110 MK / Bag**	**50% savings per acre, 92% per bag**

*Assuming an average yield of 400 kg/acre

Additional Insights

Identifying, qualifying and training fabricators are significant undertakings that require a more sustained local presence from staff pursuing this objective. Convincing fabricators that developing the technologies is worthwhile may require more evidence demonstrating the market demand or other incentives.

Although all equipment performed at least twice as efficiently as traditional methods, there was significant variation in production rates depending on the skill and technique of the operator. Therefore, training will be an essential component in the distribution plan for the tools.

Adoption of the technologies, while presenting positive economic opportunities for those with access, may also potentially lead to negative economic repercussions for laborers who may see a decreased demand for their services. Additionally, the team observed that when evaluating the devices, women tended to prefer technologies that reduced their labor while men tended to focus on the entrepreneurial opportunities the technologies presented, reflecting the men's growing interest in operations traditionally dominated by women. These and other socioeconomic implications should be monitored in future phases of the program.

Plans

CTI's engineers will make final modifications to the groundnut equipment—optimizing the designs for pilot manufacturing. The shellers will be modified to reduce the rate of unshelled and broken nuts and will undergo additional field testing, after which a single design will be selected for pilot manufacturing based on its performance, farmer preference and estimated manufacturing cost. CTI will finalize the designs for the winnower and sorter as well as a means to offer a complete technology package with numerous options for farmers.

A comprehensive analysis for manufacturing, marketing and distributing the technologies will be developed. Securing permanent local manufacturing may not be possible until after the devices have been distributed to farmers on a pilot basis and local demand for the equipment has been demonstrated. Research will also be undertaken to better show the role of technology in reducing aflatoxin levels and improving health. This will include testing of the processed groundnuts for aflatoxin levels. Locally-based staff will engage farmers and other potential partners, including health partners, for distribution, and will provide technical and training to move in the direction of technology adoption. .

III. Appendices

A. RESEARCH REPORT

*Improving Groundnut Production in Malawi and Tanzania
through harvest and post-harvest appropriate technologies*

Groundnut is a nutritious and valuable crop with immense untapped potential to improve food security, nutrition and economic well-being among smallholder farmers in Africa. In Malawi and Tanzania, groundnuts are widely cultivated in the drier, less favorable regions of the countries, where smallholder farmers perform labor-intensive harvest and postharvest operations by hand, without the use of mechanized agricultural machinery. Despite the crop's many positive attributes, very little agricultural research and development has concentrated on improving postharvest groundnut productivity among smallholder groundnut producers.

With a 4-year grant (2009-2013) from the McKnight Foundation through the Collaborative Crop Research Program and its Southern Africa Community of Practice, Minnesota-based NGO Compatible Technology International (CTI), Tanzania's Sokoine University of Agriculture (SUA) and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) combined their institutional expertise and resources to implement a research & development project for the purpose of enhancing livelihoods and child nutrition of rural households in Malawi and Tanzania through post-harvest value-chain technology improvements in groundnuts.

RESEARCH METHOD & DESIGN

Project research focused on:

1) Identifying the most laborious and time-intensive harvest and postharvest (HPH) groundnut processing operations performed by farmers in selected villages in Malawi and Tanzania.
2) Identifying or developing appropriate technology to improve the primary constraints identified by farmers.

To collect qualitative and quantitative data about smallholders' primary harvest and postharvest (HPH) processing practices, the research team conducted a global literature search, interviewed local experts, and surveyed and interviewed farmers in sixteen groundnut-growing villages Malawi.

Project researchers analyzed the data to identify farmers' primary processing constraints and define design targets for technologies that meet the socio-economic needs of smallholder groundnut farmers. Next, team researchers and engineers with CTI reviewed existing groundnut HPH practices and developed new technologies for field trials with smallholder groundnut producers in Malawi and Tanzania. Prototype technology was evaluated by smallholder famers and their designs were modified and improved based on their input.

Literature search

CTI and its partners conducted a global literature search, review and assessment traditional methods and mechanized tools used by smallholder groundnut producers. An online journal and publication search was conducted along with a library search using the UMN database. Databases utilized included AGRICOLA, with more than 600 agricultural journals; AGRIS, the International System for the Agricultural Sciences and Technology; ASABE, the American Society of Agricultural and Biological Engineers; FSTA, Food Science and Technology Abstracts. Google Scholar was also utilized to gain access to full text articles from publishers, professional societies, universities and patents.

To ensure thoroughness, the literature search examined more than published sources. Experts in groundnut cultivation and processing technologies were consulted and information was discovered from unpublished articles, reports, memos, fact sheets, design drawings and other documents from various national and international agricultural research, extension, training and development organizations, including ICRISAT.

Baseline and Needs Assessment survey

An in-depth survey was conducted in 2010 of groundnut-producing families in selected regions of Malawi to understand the current harvest and post-harvest (HPH) groundnut technologies and constraints as well as the basic socio-economic and agricultural context of the groundnut-growing communities. Researchers wanted to avoid pre-conceived assumptions and instead learn about groundnut production constraints directly from farmers, in their own words.

The survey was designed with input from the program partners at CTI, ICRISAT and SUA, as well as Plan Malawi and the National Smallholder Farmers Association of Malawi (NASFAM). Dr. Roger Stern of the Statistical Services Centre of the University of Reading assisted in developing the questionnaire and data collection methods. The questionnaire was pre-tested in one of the project villages in Lilongwe, Malawi to assess the suitability and applicability of the. Enumerators were hired in Malawi based on academic qualifications and language fluency. The Enumerators were trained in data collection and in creating a rapport with the respondents to ensure that farmers were forthcoming with ideas.

248 households (including men and women) in the Lilongwe and Kasungu districts of Malawi participated in the survey. The survey consisted of a questionnaire and follow up focus group meetings with villagers. Questions concentrated on economic indicators, eating habits, harvesting and post-harvest processes and associated labor requirements, and access to markets.

As expected, the majority of the groundnut processing operations were reported to be carried out by women, as well as children in many cases. Groundnut production and other agricultural activities is the basis of the farmers' livelihoods. Agriculture was reported as the primary source of income for the farmers surveyed, and at least 95% of the respondents had no other formal employment and supplement their incomes with labor sales, remittances, and petty trading.

The farmers recognized that improving groundnut production could result in increased incomes. 85% of the farmers reported earning money directly through groundnut sales, but they stated that the time and labor required to produce groundnuts were barriers preventing them from increasing the land area of groundnuts under cultivation.

ESTABLISHING CONSTRAINTS AND DESIGN CRITERIA

Farmers participating in the survey were asked to indicate the level of difficulty for each groundnut HPH process. The levels of difficulty were recorded on a scale of 1 to 5, five being the most difficult process and 1 being the least difficult process. The following HPH groundnut operations were perceived by more than 50% of the survey participants to be the most tiresome, labor demanding and time consuming[1]:

1. **Digging-lifting** with a hoe during the harvesting process
2. **Stripping** groundnuts by hand to removing pods from plants
3. **Shelling** to remove nuts and winnowing by hand to sort shells and diseased nuts.

The survey, in addition to revealing farmers most labor-demanding practices, also provided valuable insight into the socio-economic conditions that would help set the criteria for potential solutions or new designs for each of the constraints identified. **Primary design targets included:**

[1] Baseline Survey Report – Malawi, ICRISAT, September 2010

- **Scale and affordability:** While large-scale operations may benefit from investing in costly mechanically powered handling machinery and high-tech post-harvest treatments, these options are usually not practical for small-scale farmers and handlers. Instead, simple, low-cost, hand powered technologies are more appropriate for small-volume, limited-resource commercial operations. Technology solutions should be affordable for limited-resource farmers as well as farmer groups/organization and entrepreneurial "custom" service providers. Affordability must be view in the eyes of these farmer whose annual income is only $300-350 per year. The equipment should also be priced to provide a reasonable return on investment.

- **Power Source:** Manual power is the preferable source of power for new technologies, as none of the villages targeted in the baseline survey had access to electricity. Hand-operated technologies identified or developed should be capable, to the extent possible, of modification to accommodate bicycle or treadle power, small solar powered electric motors, and animal traction.

- **Participatory evaluation and co-design:** Successful technology development cannot be measured by the quality of the design alone, but should be judged by the degree of ultimate adoption and sustained, productive utilization by intended users. There are many instances of new, so-called "improved" devices that have been designed, introduced, and demonstrated—and in some cases even donated — and have not been accepted by smallholder farmers. The lack of adoption is not necessarily caused by of flaws or inadequacies in the design, but rather because the technology development process used was not sufficiently participatory and interactive. To strengthen the chances of adoption, farmers for whom the technologies are being developed must, in a sense, become co-designers. Since cultural concerns are as important, if not more important than technological design, these co-designers will identify and help "design around" any such impediments.

- **Simple and sturdy:** In Malawi and Tanzania, the vast majority of project farmers have little experience with mechanical devices (probably also the case for small farmers throughout rural Africa.). As a result, they generally express a strong preference for new technologies which are simple and not overly complicated or with a lot of moving parts. Farmers tend to avoid devices that they think may require frequent adjustments and/or be difficult to fix or have parts needing replacement. From an engineering design perspective, increasing the complexity most often leads to higher sophistication of maintenance needs, so technologies should be sturdy, reliable and designed to avoid the need for maintenance or replacement parts.

IDENTIFYING AND DEVELOPING IMPROVED GROUNDNUT TECHNOLOGIES

The researchers reviewed technologies discovered in the research and to determine whether they met the design criteria. They did not discount existing designs that have failed to be adopted because non-adoption could be due to a variety of reasons, including insufficient marketing-distribution and technical support systems.

Technology solutions identified through research and developed by project engineers underwent several rounds of testing and evaluation in 2011-2013. New designs were and are continuously being evaluated throughout the design process, first through "proof-of-concept" tests for preliminary design ideas, and later through on-station trials with researchers and finally field trials with farmers in their villages. On-station, controlled testing helps establish the viability of each technology solution via timed trials and replicated testing that was more quantitative. In field trials, where farmers from the selected project villages used the devices, more qualitative data was collected on relevant indicators and farmers were queried to obtain their assessment and input on possible equipment changes to improve performance and user acceptability.

Examples of indicators measured:

Indicator	On-Station Measurements	Farmer Field Measurements
1. Capacity (output/time)	3 or more replications w/stop watch, measured output	Demonstration, farmer operated, estimates made for discussion
2. Output quality	Samples taken and hand separated and weights recorded	Qualitative assessment: what damages, losses, etc. are acceptable
3. Durability/reliability	Evaluate multiple cultivars, plant/pod/nut conditions, soil type and conditions	Qualitative assessment of equipment performance under village conditions. Farmer's opinion is critical.
4. Simplicity and ease of use	Use the "keep it simple" principle. Test operation by gender and physical size. Minimize adjustments where parts can be lost, and minimize need for tools. Determine optimum operating procedures	Can both women and men perform the operation? Can they make appropriate adjustments? Are operating procedures satisfactory for both sexes?
5. User safety	Design for safety, Evaluate for safety while testing	Explain/discuss issues and concerns about safety and health when using the equipment — and beforehand.
6. Social-cultural acceptability		Is the equipment gender neutral? Will adoption of equipment have a negative impact on women or children? Are there religious/cultural issues?

Groundnut Lifting

Digging and lifting operations, or harvesting, are among the most time and labor-intensive operations associated with groundnut production. When plants are ready for harvest, rural smallholders traditionally dig their crop using a hoe to sever the tap root and lift the groundnut plant by hand (see fig. 1). Nearly all the smallholders surveyed reported harvesting their crop using this method — 97%.[2] The process typically takes one to two weeks for both husband and wife to complete lifting an acre of groundnut. Men reported participating more in the lifting process than during other groundnut processes, with 70% participating.

The process of lifting (harvesting) groundnuts was identified by 75% of the surveyed farmers as being of among the most difficult processes in groundnut production because it's extremely labor and time intensive. 65% of respondents also felt it resulted in lost quality and 74% believed it caused losses in quantity.

Figure 1: Harvesting with a hand hoe in Malawi, 2013

Digging & Lifting Design Concepts

Researchers evaluated various peanut digging blades designs discovered during the literature search (flat-type, curved type, V-shaped type) and engineers pursued two approaches for lifting design concepts:

[2] Baseline Survey Report – Malawi, ICRISAT, September 2010

a manual shovel model and an animal-powered lifter.[3] The shovel-modeled lifting mechanism was designed with a fulcrum made of small tires at base of the blade. The shovel concept underwent proof-of-concept testing in five groundnut growing villages in Malawi in 2012 and a modified design was again tested in Chitedze in 2013. The shovel was compared with the traditional farmer practice (the hand hoe), measuring the speed of lifting in terms of time taken to lift a given row/ridge length. In all trials, both men and women agreed that the shovel did not make lifting easier. It took three times longer than the traditional hoe. Based on the data and farmer feedback, the researchers decided not to pursue the shovel concept.

Figure 2: Shovel lifter tested at ICRISAT Chitedze Station in Malawi, 2012

Figure 3: Oxen-powered lifter field tested in Malawi, 2013

Oxen-powered Lifter

Because of the significant force required to dig and lift groundnuts, engineers pursued animal power as an alternative to manual power. Though none of the villagers surveyed used mechanical devices or animal traction equipment to lift their groundnuts, researchers encountered one farmer in a non-targeted village in Malawi who sometimes used a moldboard plow pulled by a pair of oxen and slanted sideways to dig up groundnut plants. Though they are not normally used for harvesting, oxen are owned by a small proportion of farmers and are available for hire in most villages. Typically, they are used to plow fields and pull oxcarts for transporting crops and other goods. In Tanzania 70% of farmers do land preparation by the hand hoe, 20% by animal traction and 10% by tractor.[4]

CTI engineers developed several versions of an Oxen-powered Lifter during June - October 2012. Early prototypes were tested at CTI's headquarters in Saint Paul with a tractor and oxen. It was determined that lifter worked well, had a simple design was light enough to be carried by one person.

The lifting equipment was designed with a frame pulled by two oxen, followed by a farmer who guides the frame along the ridge of groundnuts. The frame has forks affixed to a blade, which dig beneath the ground, severe the plant taproot and lift the nuts out of the ground.

In 2013, CTI collected data on lifting performance at 6 trial sites on farms in Malawi and Tanzania. Comparing the Oxen-powered Lifter to the traditional hand hoe, performance was measured in terms of length lifted per hour (see Table 1). The Oxen-powered Lifter significantly reduces the time and labor required to lift groundnuts. On average, the Oxen-powered Lifter performed 9x faster than farmers can dig using the traditional hand hoe. Researchers noted that the lifter was much most effective in fields

[3] Omer, Elnougomi A. Gadir and Desa Ahmad. Comparative Study on Different Peanut Digging Blades.
[4] Government of the United Republic of Tanzania, 2010

relatively free of weeds and with groundnuts planted in mounded ridges. The lifter was least effective in fields with intercropping and weed presence.

After testing the Oxen-powered Lifter with representatives from ICRISAT and CTI, 28 farmers were given the opportunity to use the lifter independently in their individual fields with the arrangement that they would collect and report data on their production rates. Using the Oxen-powered Lifter, farmers increased their production by 700%.

Farmers also noted that use of the Oxen-powered lifter would provide significant cost savings in terms of hiring labor to dig groundnuts from their fields. The farmers estimated that the cost of hiring oxen would cost half the amount of money per acre than it would cost to hire labor to dig by hand, as the traditional method is significantly more time consuming. Though few farmers own oxen, oxen teams are available for hire in most villages.

Table 1: Performance of Lifting methods

Method	Production Rate		Cost of hired labor or oxen
	2013 Trials	Farmer Data	
Hand hoe	272 m/hr	.025 acres/hr	K2,528 / acre
Animal-Powered Lifter	2,480 m/hr	.2 acres/hr	K5,000 / acre
% change	**112% increase**	**700% increase**	**50% savings**

Of the groundnut processing devices field tested with groundnut growers, the Oxen-powered Lifter was the most favored device among both men and women. This is consistent with the survey findings, where lifting was viewed as the most strenuous task in groundnut production.

Stripping

Only manual methods are currently used by small farmers to strip groundnut pods from plants. Among the villages surveyed, 73% of farmers identified stripping as among the most difficult operations (hard on the hands and time consuming) in groundnut production and 100% plucked the groundnut pods from the plants by hand, one-by one. Stripping was performed by women and children 80%-90% of the time.[5]

Stripping Design Concepts

In 2011-2012, CTI engineers developed and compared design concepts for stripping groundnuts. Design concepts included a Belt Stripper that used a rubber conveyor belt to drag groundnut plants against expanded metal and a Drum Stripper that removed groundnuts by snagging them on a rotating drum. In field trials in Malawi and Tanzania in 2012, neither the Drum nor Belt Stripper showed a significant improvement in production compared to hand stripping. Farmers also tended to dislike them because they were difficult to use and had too many moving parts. However, a Screen Stripper, a device consisting of a frame covered in expanded metal, was unanimously preferred by farmers because of its simplicity, cost, and functionality. CTI engineers concentrated their efforts on improving the Screen Stripper concept.

Screen Stripper

The Screen Stripper was discovered during the research phase at ICRISAT's Chitedze Research Station in Malawi. The device's origin is unknown and it was never widely adopted in Malawi despite village-level demonstrations and public promotional events by high-level government officials. Screen Strippers had been donated to villagers in Malawi with little pre-consultation or training or follow-up. Several villagers

[5] Baseline Survey Report – Malawi, ICRISAT, September 2010

told researchers that the strippers were being used as racks for drying kids' clothes, even fish — none as groundnut strippers.

The Screen Stripper's design originally consisted of a waist-high metal frame topped with woven metal, similar to chain link fencing. To operate the stripper, the user simply drags a groundnut plant across the woven metal putting pressure on the pods with one hand allowing the metal to snag the groundnut pods away from the plant and drop through the screen to the ground or collecting receptacle. In 2012 field tests in Malawi, the flat Screen Stripper prototype increased farmers' productivity by a factor of 2-3 times. In May 2012, thirty two Screen Stripper prototypes were manufactured in Malawi by C to C construction and by a private farmer in Tanzania and delivered to villages for ongoing use and evaluation. In 2012, CTI engineers modified the stripper design so the screen was mounted on an A-frame, which made the stripper much more comfortable to use, especially for women carrying children.

Figure 4: Screen Stripper with A-frame field tested in Malawi in 2013

Several rounds of on-station and field trials with farmers have been conducted to evaluate stripper prototypes and compare them with traditional hand-stripping. In timed trials, data was collected on whole stripped pods produced, pods still remaining on the haulms, damaged pods, percent pods still on the haulms and percent pods damaged. Hand stripping was also measured as a control.

In six separate trials at farms and research stations in Malawi and Tanzania in 2013, the new (A-frame) Screen Stripper produced the highest volume of stripped groundnuts in the shortest amount of time. When accounting for the time required for sorting clean nuts from the shells and plant debris, one person using the Screen Stripper was able to produce an average of 3.6 kg per worker per hour. In contrast, one farmer was able to produce 2.4 kg of clean pods per hour hand stripping—meaning the stripper increases efficiency by 50% (see Table 2). However, the stripper produced a wide range of outputs depending on moisture content of the plant material as well as the technique and experience of the operator.

In 2013, the Screen Stripper was left with one of the project villages in Kasungu, Malawi for farmers' continued use, and it averaged 3.6x more productive than hand stripping in this village. Farmers reported that use of the Screen Stripper would also significantly reduce the cost of hiring laborers to perform stripping, resulting in a savings of 93%.

None of the stripping methods tested reduced pod losses due to pods remaining on the haulms compared to hand stripping. In field tests, hand strippers missed about 3% on the groundnut pods. In contrast, the Screen Stripper missed 6%.[6] Although it is tedious work, hand picking is the most effective way of ensuring the maximum pod removal from the plants during the stripping process.

Table 2: Performance of Stripping methods

Method	**2013 Trials**	**Farmer Data**	**Cost of hired labor / oxen**
Hand Stripping	2.4 kg/hr	3 bags /day	K750 / acre
Screen Stripper (A-Frame)	3.6 kg/hr	7 bags /day	K50 / acre
% change	**50% increase**	**133% increase**	**93% savings**

2013 groundnut stripping trials in Malawi & Tanzania

[6] 2012 Groundnut stripping trials in Malawi

Figure 5: Output with Screen Stripper (left) vs hand stripping (Right), 2013 field trials.

The new Screen Stripper was enthusiastically received by both men and women in the 2013 trials. The A-frame modification was viewed by farmers as a significant improvement over the flat table model. Farmers commented that it was more comfortable and easier women carrying babies to strip without becoming tired. The screen stripper also has the added advantage of being capable of being operated by either one or two people. No significant design changes were recommended.

Shelling

Shelling is extremely difficult work and was identified by 84% of the farmers surveyed as among the most difficult groundnut processing steps. Women were responsible for shelling in 80% of the villagers surveyed. Nearly all smallholders shell their groundnuts by hand, followed by winnowing and handpicking to remove shells and other foreign matter, broken, moldy nuts and other undesirable material.

Nuts are shelled for both home consumption and for market sale. For groundnuts to be used for home consumption (the great majority of the crop), small quantities of pods are shelled by hand and by women on an as-needed, often daily basis. Because it's such difficult work, before shelling large quantities for market sale, it's common for farmers to wet their pods to soften their shells. This practice may cause significant losses in quality and result in and cause considerable risk of aflatoxin contamination. Some villages surveyed have access to a mechanical, hand-powered sheller, usually operated for a fee by in a nearby village. However, most project farmers in Tanzania Mullally complained about the high degree of broken kernels caused by these shellers. Moreover the fact that the output is a mixture of whole, sound kernels as well as broken nuts, shell pieces and other trash is also a problem for many. Though considered expensive by most farmers, they still use this service if they need to shell large amounts of groundnuts (one bag or more) in a short period of time to sell.

Sheller Designs

A number of manual-powered mechanized shellers discovered in the research. Two designs were chosen to compare to designs developed by CTI engineers: (1) The *C to C Sheller, a* device developed in South Africa that has a rotating drum with wooden paddles which rubs the pod together over slotted screen; and (2) *the Arc Zenengeya Sheller, a* device is sometimes referred to as the "rocker" sheller. It has a base shaped like an arc and a handle pivoted at the center point rocks back and forth to rub the pods. The shelled nuts and pods fall out the bottom screen.

Figure 6: CTI Disc Sheller in 2013 field tests

CTI engineers designed two sheller concepts:

A *Disc Sheller* has a vertical, rotating disc rubs the pods against a woven metal screen to gently crack the shells without damaging the nut. The opening between the screen and the disc becomes narrower as the pods work their way down the screen. The disc sheller was tested with farmers in 2012 and was the design was subsequently modified with a larger disc plate, increasing the shelling surface area by almost 25%.

A *Drum Sheller* uses a drum made from a large section of PVC pipe covered with expanded metal. The drum runs against a sling made of expanded metal which serves both as a shelling surface and allows the shelled nuts to fall through. A large and a small Drum Sheller prototype were developed.

Figures 7 & 8: Small and large Drum Sheller prototypes, 2013

Shelling trials were conducted in 2012 and 2013 in tests with farmers in Malawi and Tanzania and in on-station trials at ICRISAT's research facility in Malawi. Data was collected on the weight of whole shelled kernels produced per hour, as well as the rate of damaged and unshelled pods produced. The time required to sort the nuts from their shells was also recorded. The results showed highly significant differences in output rate and quality among shelling methods. There were also several factors that caused significant variance between the output rates of the various shelling methods, including the moisture level of the nuts, the size of the nuts and the technique of the operator. The tables below reflect data from 2013 trials.

Table 3: Performance of shelling methods for all locations tested in Tanzania and Malawi - 2013

Shelling method	**Production Rate**		**Benefit of Machine**	**Unshelled Rate**	**Damage Rate**	**Cost of hired labor or oxen per bag**
	Range kg/hr/ worker	**Mean kg/hr/ worker***				
Hand/person	.6 - 1.02	.88	1x	-	-	750 MK
Small Drum Sheller	11.25 - 11.35	11.3	12.8x	4.3%	22%	60 MK
Large Drum Sheller	11.6 – 41.7	21.35	24.25x	0%		-
Disc Sheller	4.84 – 25.2	24	27x	35%	33%	-

*Values represent winnowed seed, no unthreshed pods.

Table 4: Machine output per hour in ICRISAT trials conducted in February 2013 with dry pods

Shelling Method	Whole Nuts, kg/hr	Unshelled Pods, kg/hr	Damaged Nuts, kg/hr	Total Through Put, kg/ hr
Hand	1.1	0	0	1.1
C to C	28.1	10.6	5.6	44.3
Arc Zenengeya	27	11.1	0.9	39

As expected, hand shelling produced the smallest volume of shelled nuts, approximately .88 kilograms per hour. Mechanized devices were measured in terms of kilograms sheller per hour per worker, as the technologies run more efficiently when operated by two people. The Small Drum Sheller produced 11.3 kilograms per hour per worker. The Large Drum and Disc shellers produced similar outputs at 21 kg/hr/person and 24 kg/hr/person respectively. The C to C (44.3 kg/hr) and Acr Zenengeya (39 kg/hr) shellers produced the outputs in the same range (per person), but also produced a high volume of unshelled and broken nuts.

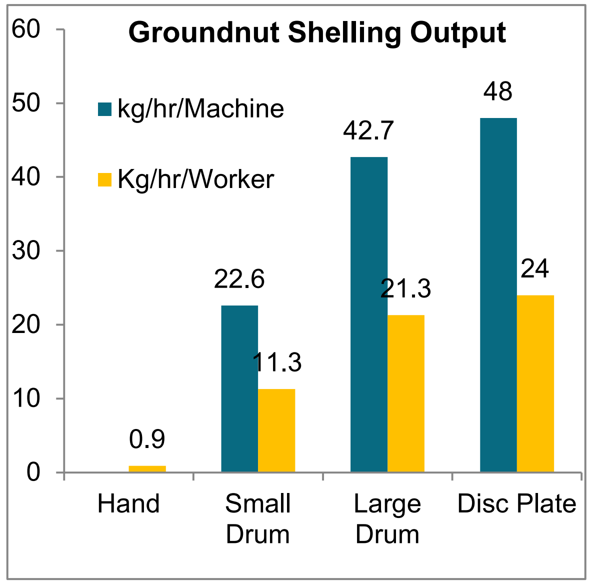


Figure 9

All mechanical shellers produced 20-30% unshelled nuts. Engineers designing new prototypes found that design modifications that reduced the rate of unshelled nuts often caused an increased rate of damaged nuts, so engineers determined that it would be preferable to avoid damaging the nuts and run unshelled nuts through the devices for a second pass. Even with the additional passes required to fully shell the nuts, the mechanized shellers still resulted in a significant increase in the rate of production over traditional hand shelling.

The shellers also produced a rate of broken or split nuts between 20 and 30%. Many women remarked that rate of broken nuts was acceptable, as these nuts are used for home consumption. However, broken or split kernels are less desirable for market sale.

Following the 2013 field tests, the small Drum Stripper was left with farmers in one community in Kasungu district of Malawi. Farmers recorded number of bags, time taken and estimated cost if labour was hired for Drum Sheller and hand shelling. Data recorded by farmers show that on average, 10 bags were shelled per day using a drum sheller compared to 0.3 bags per day by hand. In terms of cost, it cost 60 Kwacha to shell one bag for drum sheller compared to K750 for hand shelling. This implies that there is high cost saving if a farmer uses a drum sheller.

Farmers commented on the ease of use of the Drum and Disc Shellers, and noted liking that both devices could be mounted on a bench, table or on poles depending on the height of the operator. They felt all shellers were portable and were perceived to be solid enough to be used for a long time before they need to be replaced. For the shellers evaluated in the villages in 2013 there was a preference expressed by the women for the small Drum sheller, while the men preferred the Disc Sheller. Discussion seemed to suggest men were thinking of entrepreneurial opportunities in their ranking while women were thinking in terms of their personal work load.

Sorting

Sorting is not a strenuous task, only time consuming. Sorting is done to remove diseased nuts, insect bored nuts in addition to the shrunken and broken. There is a degree of sorting that begins with the hand stripping of pods where immature pods, over ripe pods and moldy pods are rejected and never enter the stripped pod pile. Even with hand shelling there is a certain percent of broken nuts that need to be removed. Storage of shelled nuts is improved when the broken and damaged seeds have been removed. Mechanical sorting is a distinct benefit when working with mechanical shelled nuts due the increase in the number of broken nuts.

Figures 10 & 11: CTI's Incline Belt Sorter - Good kernels roll down, broken kernels ride up the belt

CTI engineers developed a prototype sorter, which was field tested with farmers in Chitedze, Malawi in 2013. By hand, the farmers averaged about 5 kg/worker/hr and with CTI's sorter they yielded over 30 kg/worker hr.

Insights

The baseline survey provided valuable information to researchers on the primary constraints associated with smallholder groundnut production: harvesting, stripping and shelling. Farmers surveyed indicated that the removal of these barriers would enable them to improve their lives by reducing their drudgery and increasing their time to pursue new economic opportunities.

Increased Efficiency

Four technologies that can cause significant time savings have been identified. The **Oxen-powered lifter** is capable of providing more than a 9X advantage in time savings compared to the traditional hoe. In addition, it reduces one of the most physically demanding aspects of growing groundnuts. The **Screen Stripper** was 1.5 - 2.5X more efficient than traditional hand stripping methods. CTI shellers increased the per worker output from 14X - 27X, depending on the sheller model tested. **Sorting,** using the incline belt sorter increased work out put by more than 3X compared to hand sorting.

If all **of the CTI technologies** tested were implemented in the villages and performed as they did in the on-station and on-farm trials, it is estimated that there could be a **9X reduction in labor** required to harvest and process an acre of groundnuts. This would eliminate much of the drudgery for women, free their time and could potentially increase crop quality.

Increased Incomes

With the reduction in the time and labor required to harvest and process groundnuts, farmers that hire laborers for these services could see a significant cost savings. Compared to hiring laborers, farmers estimated they could see a 50% savings per acre to harvest groundnuts with hired oxen using CTI's lifter and a 92% savings with the Screen Stripper and small Drum Sheller.

Table 6: Requirements for Harvest and Postharvest Groundnut Processes*

	Time/labor			Cost of hired labor		
Activity	**Hand Methods** (Person hours / acre)	**CTI Equipment** (Person hours / acre)	**Advantage of CTI Tools**	**Hand Methods** (Malawian Kwacha)	**CTI Equipment** (Malawian Kwacha)	**Advantage of CTI Tools**
Lifting	40-80	6.6	6x – 12x	5,000 / acre	2,528 / acre	2x
Stripping	80	25	3.2x	750 / bag	50 / bag	15x
Sm. Drum Sheller	400	9	44x	750 / bag	60 / bag	12.5x
Disc Sheller	400	4	100x	-	-	-
Sorting	80	25	6x	-	-	-
Total	**600-640 person hrs/acre**	**69 person hrs/acre**	**9x person hrs/acre**	**5,000 MK/Acre + 1,500 MK/Bag**	**2,528.2 MK/Acre + 110 MK / Bag**	**50% savings per acre** **92% savings per bag**

*Assuming an average yield of 400 kg/acre

Findings from the baseline survey with farmers indicate that more efficient groundnut production could have a direct impact on local incomes and nutrition. About 97% of farmers interviewed stated that they would increase the land area of groundnut cultivation if the post-harvest problems were minimized. 45% of the farmers reported that they could increase their production area by 50% while 42% indicated a 100% increase in groundnut production area. Farmers pointed out the better groundnut processing efficiency could provide them with increased cash income (49.7%), enough time for other socio-economic activities and resting which will improve their quality of life (38.7%), improved nutrition and also provide cash for buying farm inputs such as seed and fertilizer.

Future technology development activities will continue to focus on increasing groundnut efficiency and quality by modifying technologies based on farmer feedback.

Selected References

Baseline Survey Report – Malawi, ICRISAT, September 2010

Food and Agriculture Organization of the United Nations, 1998
(http://www.fao.org/ag/AGP/AGPC/doc/counprof/malawi/Malawi.htm)

Groundnut Equipment Trials, 2011-2012

Government of the United Republic of Tanzania, 2010 (http://www.tanzania.go.tz/agriculture.html)

Omer, Elnougomi A. Gadir and Desa Ahmad. Comparative Study on Different Peanut Digging Blades. Japan: Agricultural Mechanization in Asia, Africa and Latin America , 2001.

Wesley, B.J. et al. Modification of Groundnut Thresher for Decorticating Groundnut Pods and Castor. Agric. Sci. Digest 30 (1): 23-25, 2010.

Gresham J.R., W.A., C.E. Collum and R.J. Kyle. Bibliography on the Technology of Peanut Production, 1896,1956. Georgia Institute of Technology, Atlanta, 1957.

Enhancing Child Nutrition in Tanzania through Groundnut-based complementary Foods

A. Statement of the problem

Malnutrition is widespread in the countries targeted by the Southern Africa Community of Practice, and is more acute among children under five who are weaned onto the staple cereal-based diet that is deficient in protein, oils and micro-nutrients. The purpose of the project was to promote utilization of groundnuts using simple technologies that are affordable by rural community. The project aimed at formulating complementary foods for children aged 6-24 months based on groundnuts in combination with locally available cereals. It is well established that the period of complementary feeding from 6 to 24 months of age is the most critical period for preventing malnutrition (World Bank 2005). Growth at this particular period is uncertain (Shrimpton *et al.* 2001) especially during the first six months (6–12 months) of complementary feeding because these complementary foods are either of low nutrient content or are not given in required quantities to meet the demand of the growing children and also the incidences of diarrhoea due to unhygienic practices are high (Villapando, 2000). After two years of age, it is not easy to reverse stunting that occurred at earlier ages (Martorell *et al.* 1994). Hence, improved complementary feeding is important for attractive development in children (Lutter and Dewey, 2003).

B. Literature Review

Sufficient diet and wellbeing during the initial years of living is essential for child survival and avoidance of undernourishment (Maltel 2008). It is important to know that it is during infancy and early childhood that permanent poor linear growth and cognitive deficit occurs (Engberg-Pederson, 2007). Growth during the first year of life is greater than at any other time after birth, hence it is important to follow the recommended breastfeeding and complementary feeding practices and access to the appropriate quality and quantity of foods for optimum growth of infants and young children (Lutter and Rivera, 2003). The incidence of stunting is the highest in this period as children have high demand for nutrients and there are limitations in the quality and quantity of available foods, especially after exclusive breastfeeding (Dewey and Adu-Afarwuah, 2008).

Feeding practices play a vital role in determining the growth development of children. Generally poor feeding practices in children affect their health and nutritional status, which in turn have consequences on their physical development. The growth patterns of healthy and well-fed children are reflected in positive changes in their heights and weights (Ajieroh, 2010).

Anthropometry is a technique used to assess and predict performance, health and survival of individuals and is more often applied to children with several variables being taken into account such as child's age, sex, height and weight. These measurements are used to generate height-for-age, height-for-weight and weight-for-age indices which are in turn used to assess children nutritional status. The indices generated are compared with standard reference values of the WHO standards to obtain the Z-scores which are used to determine nutritional status of the child. Deviations of the indicators between below -2 and -3 standard deviations (SD) indicate that the children are moderately affected, while deviations below -3 SD indicate that the children are severely affected (Ruwali, 2011).

Wasting or thinness (weight-for-height) expresses a low body weight relative to height as a result of a current significant loss of weight observable by a deficit in tissue and fat mass. Wasting is a result of insufficient nutrient intake (lack of access to food) or absorption (poor health status and disease) and is an indicator of short-term fluctuation in nutritional status. Children with weight-for-height Z-score less than minus 2 standard deviation from the median of the reference population are classified as wasted.

Stunting or shortness (height-for-age) expresses a low height relative to age as a results of poor dietary intake over time as well as poor health conditions and reflects a failure to reach growth potential. It is a measure of chronic or long term malnutrition and an indicator of cumulative growth retardation and a child whose height-for-age Z-score is below minus 2 standard deviation from the median of the reference population are classified as stunted.

Underweight (weight-for-age) a combination of both wasting and stunting that expresses a low weight for age which results from either a failure to gain weight relative to age or a loss of weight relative to height. Children having weight-for-age Z-score less than minus 2 standard deviation from the median of the reference population are regarded as underweight (Lodhi *et al.,*2010).

Wasting and stunting although are often jointly observed, they result from different processes and patterns. Wasting is observable in populations where children are exposed to dietary deficiencies and diarrhoeal diseases causing rapid weight loss whilst stunting reflects a slower and longer process of deprivation. Z-score units derived from height and weight measurements based on growth standards published by the WHO in 2006 are used to measure and determine the nutritional status of a child (Olagunju *et al*., 2011).

Nutritional status is the result of complex interactions between food consumption and the overall status of health and care practices. Poor nutritional status is one of the most important health and welfare problems facing a number of African countries including Tanzania. Young children are especially vulnerable to nutritional deficits and micronutrient deficiency disorders. At the individual level, inadequate or inappropriate feeding patterns lead to malnutrition (WFP 2009**)**.

References

Ajieroh, V. (2010). A Quantitative Analysis of Determinants of Child and Maternal Malnutrition in Nigeria.IFPRI Nigeria Strategy Support Program Brief No. 11, 2010.

Dewey K.G, Adu-Afarwuah S (2008) Systematic review of the efficacy and effectiveness of complementary feeding interventions in developing countries. Matern Child Nutr 2008, 4 (Suppl 1):24-85.

Engberg-Pederson, P (2007). Achievement freedom from child hunger and under nutrition: what the bilateral partner can contribute. SCN News. 34:20-22

Lodhi, H. S, Mahmood-Ur-Rehman*, Lodhi, F.S, Wazir, S and Jadoon, H (2010). Assessment of Nutritional Status of 1–5 Year Old Children in an Urban Union Council of Abbottabad. J Ayub Med Coll Abbottabad 22(3), pp 124-127.

Lutter C.K, Dewey K.G (2003). Supplement nutrient composition for fortified complementary foods. J. Nutr. 133: 3011s-3020s.

Malla S and Shrestha SM (2004). Complementary Feeding Practices and its Impact on Nutritional Status of under Two Years Old Children in Urban Areas of the Kathmandu, Nepal. Journal of Nepal Health Research Council Vol. 2 No. 1, pp1-4.

Maltel (2008) Infant Feeding Guidelines: Birth to six months. htt://www.fisherpricecom/fp.aspx?st=6638e=printadviceandcontent=179919.

Martorell R., Khan L.K. & Schroeder D.G. (1994) Reversibility of stunting: epidemiological findings in children from developing countries. European Journal of Clinical Nutrition 48 (Suppl. 1) S45–S57.

Olagunju, F.I., Fakayode, S. B., Sola-Ojo, F. E., (2011). Prevalence and determinants of malnutrition among under-five children of farming Households, Kwara state, Nigeria. *Journal of Agricultural Sciences.*

Rana A, Qureshi FA, Hansotia MF, Randell J, Rash (2004). Nutrition Ecology International Center. Under nutrition and malnutrition in the world. NEIC, Geneva.

Ruwali D, (2011). Nutritional Status of Children Under Five Years of Age and Factors Associated in Padampur VDC, Chitwan. *Health Prospect* Vol.10 2011, pp.14-18.

Shrimpton, R., Victora C.G., de Onis M., Lima R.C., Blossner M. and Clugston G. (2001) Worldwide timing of growth faltering: implications for nutritional interventions.

Pediatrics 107,E75.

Villapando S (2000). Feeding mode, infections, and anthropometric status in early childhood. Pediatrics. 106 (5 Supplement) pp. 1282-1283.

WFP (2009). Children's Nutritional Status. The World Food Programme Report.

World Bank (2005) *Repositioning Nutrition as Central to Development: A Strategy for Large Scale Action*. The World Bank: Washington, DC.

C. Research design and method

Ward/Village Medical Personel took monthly measurements of weights and heights of the children in their villages for 12 months (From Feb-2012- Jan 2013). This involved 320 intervention children in the 16 villages and 80 control children from four villages. These measurements were used to calculate Z scores for weight for age (WAZ), Height for age (HAZ) and weight for height (WHZ) which are the determinants for nutritional status of children

TUNAJALI NGO together with Ward/Village Extension Officers visited the intervention mothers in their homes twice per month to follow up the utilisation of the complementary food during the intervention period (12 months)

Samples of the flour mixtures (One cup of flour) were collected randomly from the households and analysed at SUA quarterly for microbiological quality and aflatoxin. Cooked samples of porridge were collected from the last villages visited, stored in a cold box to prevent spoilage en route to the laboratory.

Samples were tested for; Total Plate Count, *Coliforms, Salmonella* and *Bacillus cereus* according to International Commission on Microbiological Specification for Foods (1996) procedure.

All were carried out based on procedures recommended in the International Commission on Microbiological Specification for Foods (1996). Appropriate serial dilutions of the formulated complementary foods were carried out and 0.1 ml of the selected dilution was spread on triplicate plates using sterile glass spreader. This technique was used for the enumeration of Total Aerobic Bacteria, *Coliform*, *Salmonella and Bacillus* counts, Eosin Methylene Agar, Salmonella and Shigella Agar, and Sabourand Glucose Agar Media used were prepared according to the manufacturer's instructions and all cultures were incubated at 37°C for 24 h.

The following viable cell counts were performed by the spread-plate method after 10 fold serial dilutions in 0.1% (W/V) peptone solution: aerobic total counts on Plate count agar, fecal coliform counts on violet red bile lactose agar, *Salmonella and Bacillus* counts The plates were incubated at 37°C for 18-24 h before counting. Microbial counts were then transformed and represented as log 10 cfu g^{-1} of the sample.

Aflatoxin in flour mixture samples were determined using RomerAgraStrip Total Aflatoxin Test Kit with detection cut off level of 20 ppb from Romer Labs Singapore. This is a one step lateral flow immunochromatographic assay that determines a qualitative level for the presence of total aflatoxin (B1, B2, G1 and G2).

D. Findings

Results:

1.0 Types of cereals used in complementary foods in the study area (Dodoma region)

The results of our study have shown that cereals are used variably in complementary foods in all the four districts. Maize and sorghum are fairly used in all four districts, while finger millet is highly used in Kondoa and pearl millet is more used in Dodoma Municipal and Bahi districts

Table 1**.** Percent of respondents using cereals in complementary foods in Dodoma region

Name of cereal				
	Chamwino	Bahi Percent	Kondoa	Dodoma Municipal.
Maize	24.7	17.6	31.3	26.4
Sorghum	23.8	25.4	23.0	27.9
Finger millet	8.8	23.8	61.2	6.2
Pearl millet	17.4	32.6	8.7	41.3
Others[1]	25.5	17.0	2.1	55.3

[1]Other foods include non-cereal foods like roots and tubers.

2.0 Types of Legumes used in complementary foods in the study area

The results have shown that groundnuts are fairly used for complementary foods in all the four districts whereas pigeon peas were only used in Kondoa. Other legumes like cowpeas were highly used in Bahi district while beans, Bambara nuts and soybeans were common in Kondoa than the rest of the districts

Table 2. Percent of respondents using legumes in complementary foods in Dodoma region**.**

Types Legumes used in complementary foods**.**	Districts			
Name of legume	Chamwino	Bahi (Percent)	Kondoa	Dodoma Municipal
Groundnuts	20.5	22.2	32.4	24.9
Cowpeas	12.5	62.5	12.5	12.5
Pigeon peas	0.0	0.0	100.0	0.0
Beans	15.3	23.1	51.3	10.3
Bambara nuts	27.2	9.1	45.5	18.2
Soybeans	10.0	10.0	70.0	10.0

3.0 Formulation of complementary foods based on groundnuts for children aged 6-24 months.

Four recipes of complementary food based on available cereals (maize, sorghum, pearl millet and finger millet) and grounduts in Dodoma region were formulated for children aged 6-24 months. Cereals and groundnuts were mixed in a ratio of 2:1(cereals: groundnuts) based carbohydrate, protein and fat content. Then the amount of flour mixture used to prepare porridge was calculated based on energy requirements for the three groups of children (6-8), (9-11) and (12-24) months respectively as shown in Table 3.

Table 3. Measurements for cereal/groundnut and water for preparation of complementary food (porridge).

	Child age groups		
Daily requirements and recommended quantities	6-8 months	9-11 months	12-24 months
Energy requirement (kcal)	280	450	750
Flour mixture requirement (g)	86	138	232
Recommended flour (cups of 200ml)	0.75	1.5	2

4.0 Nutrient content of the formulated complementary food based on groundnuts for children 6-24 months

The macronutrient and mineral composition of the formulated complementary foods based on groundnut are shown in Table 4 and 5 respectively.

According to Table 4, all four recipes had a high protein content with finger millet-groundnut mixture having the lowest content of 12.23 g/100 while mixtures with pearl millet-groundnut (15.70 g/100g) and sorghum-groundnut with 15.58 g/100g showed the highest protein content. The results in table 1 indicated that the protein content was significantly different ($p \leq 0.5$) from the maize-groundnut mixture.

The formulated recipes had high fat content with pearl millet-groundnut (20.52 g/100g) and maize-groundnut (20.15 g/100g) having highest fat content. Finger millet-groundnut mixture had the lowest fat content (17.10g/100g) showing significant difference ($p \leq 0.5$) from sorghum- groundnut which had (18.19 g/100g).

Table 4. Chemical Composition (wet basis) of complementary flour mixtures based on groundnuts (g/100g).

Recipe	Moisture	Crude Protein	Crude Fat	Crude Ash	Crude Fiber	Carbohydrate	Energy (Kcal)	Tannin
Maize:Gnut	7.41 ±0.14 [c]	14.78±0.83 [b]	20.15±0.35 [c]	2.37±0.05 [a]	2.60±0.03 [b]	52.70±1.97 [a]	399±3.15 [c]	0.53±0.03 [a]
Sorghum:Gnut	7.32±0.57 [b]	15.58±0.67 [c]	18.19±0.43 [b]	2.90±0.07 [bc]	2.24±0.06 [a]	53.77±2.43 [a]	383±4.18 [b]	0.74±0.01 [c]
Pearl millet:Gnut	5.58±0.32 [a]	15.70±0.65 [c]	20.52±0.52 [c]	2.73±0.08 [b]	2.17±0.04 [a]	53.30±2.05 [a]	422±3.22 [d]	0.58±0.01 [b]
Finger millet:Gnut	7.30±0.24 [b]	12.23±0.71 [a]	17.10±0.80 [a]	3.10±0.05 [c]	3.15±0.08 [c]	57.12±2.55 [b]	378±4.08 [a]	0.50±0.04 [a]

Table 5. Mineral and Vitamin A content of complementary food formulations based on groundnuts (mg/100g).

Recipe	Fe	Ca	Mg	K	Na	Zn	Vitamin A (µg/100g Retinol)
Maize:Gnut	5.33	66.91	93.23	287.80	34.20	4.76	11.85
Sorghum:Gnut	4.81	37.66	157.00	136.86	9.54	2.7	11.05
Pearl millet:Gnut	7.10	60.44	129.32	367.46	13.73	3.13	24.30
Finger millet:Gnut	3.72	297.00	121.90	399.62	14.97	2.1	8.66

According to Table 5, recipe with pearl millet had highest iron and vitamin A content 7.10 mg/100g and 24.30 (µg/100g Retinol) respectively. Recipe with finger millet had highest content of Calcium, 297 mg/100g and Potassium 399.62 mg/100g while recipe containing maize had highest content of Sodium 34.20 mg/100g and Zinc 4.76 mg/100g. Sorghum recipe had highest Magnesium content 157.00 mg/100g.

5.0 Effect of complementary food based on groundnuts on children (6-24 months) growth over 12 months

Changes in growth of children (6-24 months) consuming the complementary food based on groundnuts was monitored by taking height and weight measurements for a period of 12 months. These measurements were used to calculate z scores corresponding to weight and height for respective ages of the children for the study period and compared with the control group of children not given the treatment. The growth trend was established by plotting the weight or height for age z scores against the study period as shown below. The general trend observed was that the weight for age z-scores of the intervention children was increasing with time from -0.73 baseline (results not shown) to + 0.32 at the end of intervention. Similarly the height for age z scores increased from -1.87 (baseline) to +1.02 at the end of intervention as shown in Table 6a and 6b respectively. The trend in changes in weight and height z scores is shown in figure 1 and 2 below. These results show that there was improvement in growth of the intervention children 6-24 months as a result of eating the complementary food based on groundnuts.

Table 6a. Summary of Weights and Weight gains at conclusion of study

	Variable	Control (N = 77)	Treatment (N=274)	p-value
Month 12	**Weight (cm)** *Mean (SD)*	9.82 (0.97)	12.16 (1.37)	<0.001
	Weight-for-Age Z Score *Mean (SD)*	-1.24 (0.84)	+0.32 (0.95)	<0.001
	Underweight %	15.6%	1.5%	<0.001
Change over 12 Months	**Weight (cm)** *Mean (SD)*	1.33 (1.00)	3.52 (0.98)	<0.001
	Weight-for-Age Z Score *Mean (SD)*	-0.77 (0.84)	+1.02 (1.03)	<0.001
	Underweight *Percentage Points*	+2.6	-12.4	<0.001

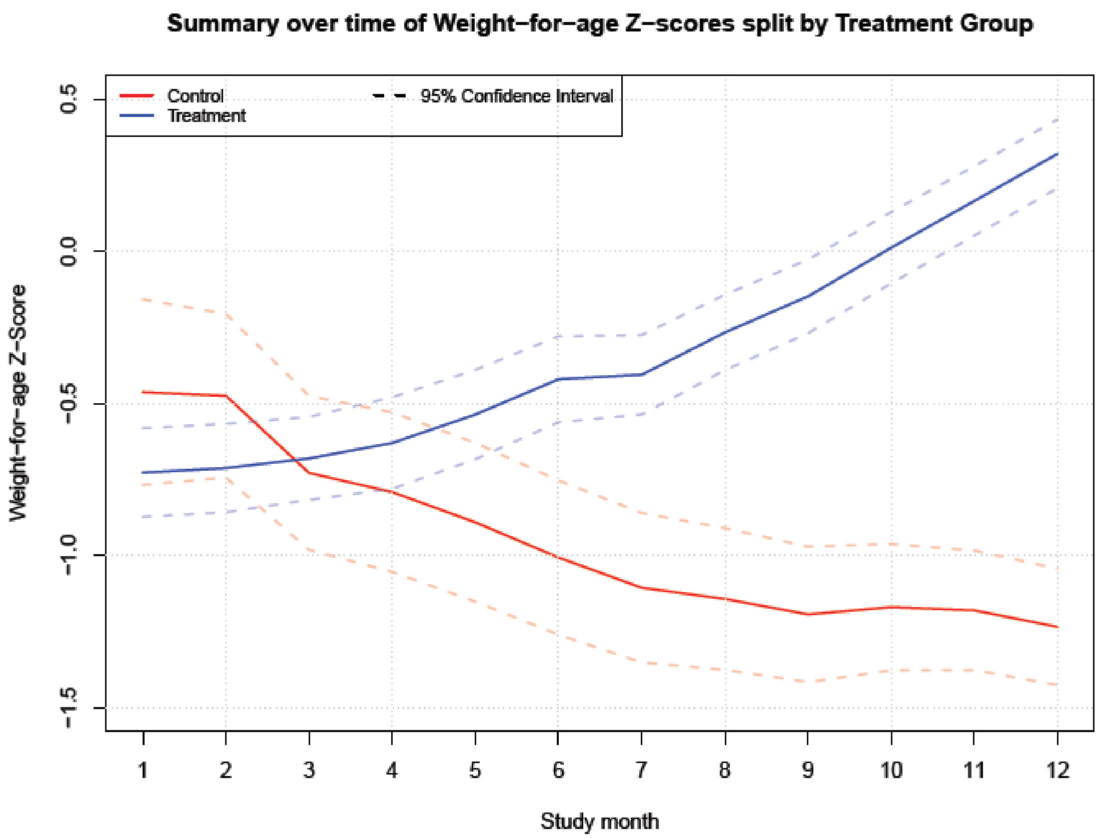


Figure 1. Graph of weight for age z-score against feeding duration for treatment and control groups.

According to Figure 1, a trend of weight for age z -scores for treatment group was increasing and went above zero indicating improvement in growth in terms of weight increase. In case of the control group, the trend was declining showing no improvement in growth with time.

Table 6b. Summary of heights and height gains at conclusion of study

	Variable	Control (N = 60)	Treatment (N=269)	p-value
Month 12	**Height (cm)** *Mean (SD)*	69.78 (4.53)	80.22 (5.41)	<0.001 [1]
	Height-for-Age Z Score *Mean (SD)*	-4.96 (1.29)	-1.87 (1.50)	<0.001
	Stunting	92.2%	46.8%	<0.001

	%			
Change over 12 Months	**Height (cm)** *Mean (SD)*	3.75 (2.23)	11.57 (4.24)	<0.001 [1]
	Height-for-Age Z Score *Mean (SD)*	-2.12 (1.13)	+1.02 (1.03)	<0.001
	Stunting *Percentage Points*	+23.9	-13.8	<0.001

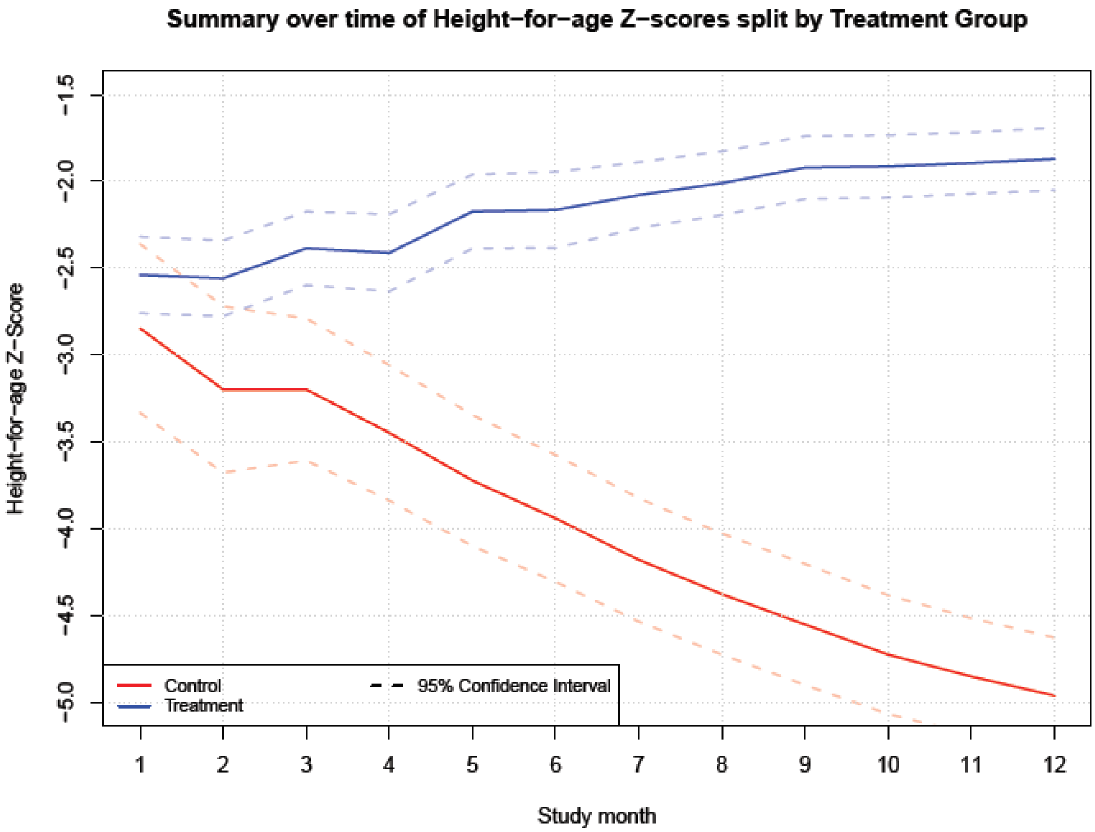


Figure 2. Graph of height for age z-score against feeding duration for treatment and control groups.

Figure 2 shows that height for age z-scores of treatment group increase at a lower rate. It was indicated that children were stunted already and even after feeding although the z-score showed an increase, they did not reached zero. This means that the developed complimentary food did not have much influence on stunting. The control group stunting became even worse.

6.0, Microbilogical quality of the formulated complementary foods

Microbial contamination of samples was within the acceptable range. The numbers of Colon forming units were higher in flour mixtures than in cooked porridge. The difference between wet and dry season was not significant at $p \leq 0.05$. (Table 8 and 9).

Table 8. Mean log_{10} bacteria counts in complementary food flour mixtures based on groundnuts.

	Bacterial counts (log_{10} cfu/g)							
	Aerobic bacteria		Coliforms		Salimonella spp. (log_{10} cfu25/g)		Bacillus cereus	
Place	Wet season	Dry Season	Wet season	Dry Season	Wet season	Dry Season	Wet season	Dry Season
Dodoma Municipality	5.13±1.03	4.73±1.25	3.34±0.38	2.51±0.06	0	0	3.36±0.74	2.59±0.04
Bahi District	5.15±0.56	4.80±0.31	3.49±0.67	2.60±0.54	0	0	3.53±0.24	2.74±0.23
Chamwino District	5.23±0.42	4.71±0.13	3.40±0.77	2.85±0.65	0	0	3.50±0.43	2.94±0.78
Kondoa District	4.98±0.84	4.52±0.09	3.25±0.48	2.48±0.33	0	0	3.33±0.18	2.52±0.41

Table 9. Mean log_{10} bacteria counts in porridge made from formulated recipes based on groundnuts.

	Bacterial counts (log_{10} cfu/g)							
	Aerobic bacteria		Coliforms		Salimonella spp. (log_{10}cfu/25g)		Bacillus cereus	
Place	Wet season	Dry Season	Wet season	Dry Season	Wet season	Dry Season	Wet season	Dry Season
Dodoma Municipality	2.39±0.16	2.15±0.25	1.51±0.53	1.20±0.14	0	0	0.74±0.04	0.69±0.22
Bahi District	2.40±0.31	2.42±0.28	1.41±0.27	1.38±0.33	0	0	0.63±0.12	0.60±0.02
Chamwino District	2.68±0.30	2.25±0.44	1.54±0.65	1.32±0.52	0	0	0.80±0.26	0.79±0.40
Kondoa District	2.04±0.48	1.98±0.39	1.13±0.78	1.09±0.60	0	0	0.51±0.10	0.52±0.11

7.0 Aflatoxin determination in complementary food based on groundnut.

Flour mixture of the complementary food based on groundnuts samples analysed all were safe with aflatoxin content less than 20 ppb. This is because mothers were trained on how to do sorting of the groundnuts, to get rid of all those showing mould signs.

E. Implications of the research findings

Developed formula based on groundnuts and cereals which are locally available and affordable has significant increase on growth rate for both weight and height. Availability of ingredients makes the intervention feasible.

Effects are large enough to show 'real' impact - stunting and underweight rates were high & are improved by formula. But effect on height growth not enough to recover from stunting. Something further needed in terms of incorporating Vit. A source in the complementary food.

Microbial contamination and aflatoxin content were within safe levels. This is due to the training given to mothers on good hygienic practices and proper sorting of groundnuts.

B. PUBLICATIONS SUMMARY & TRAINING AND OUTREACH SUMMARY

1. Publications Summary

- Final Year powerpoint presentation report delivered at annual McKnight CoP meeting in Malawi.

- Regular internal Project meetings held by the three main partners (once or twice annually) held variously in Malawi and Tanzania to which local partners including staff of development NGOs, Universities (Bunda and SUA), Ministry of Agriculture and farmer organizations (NASFAM) were often invited.

SUA Publications in Draft Form:

- Assessment of the effect of complementary food based on groundnuts intervention on growth of children aged 6-24 months in Dodoma Region, Tanzania.

- Development of Complementary Foods based on Groundnuts for children between 6-24 Months.

- Assessment of Complementary foods and child feeding practices in Dodoma region.

2. Training and Outreach Summary

No degree training has been approved or funded by the grant. Non-degree training activities have included the following:

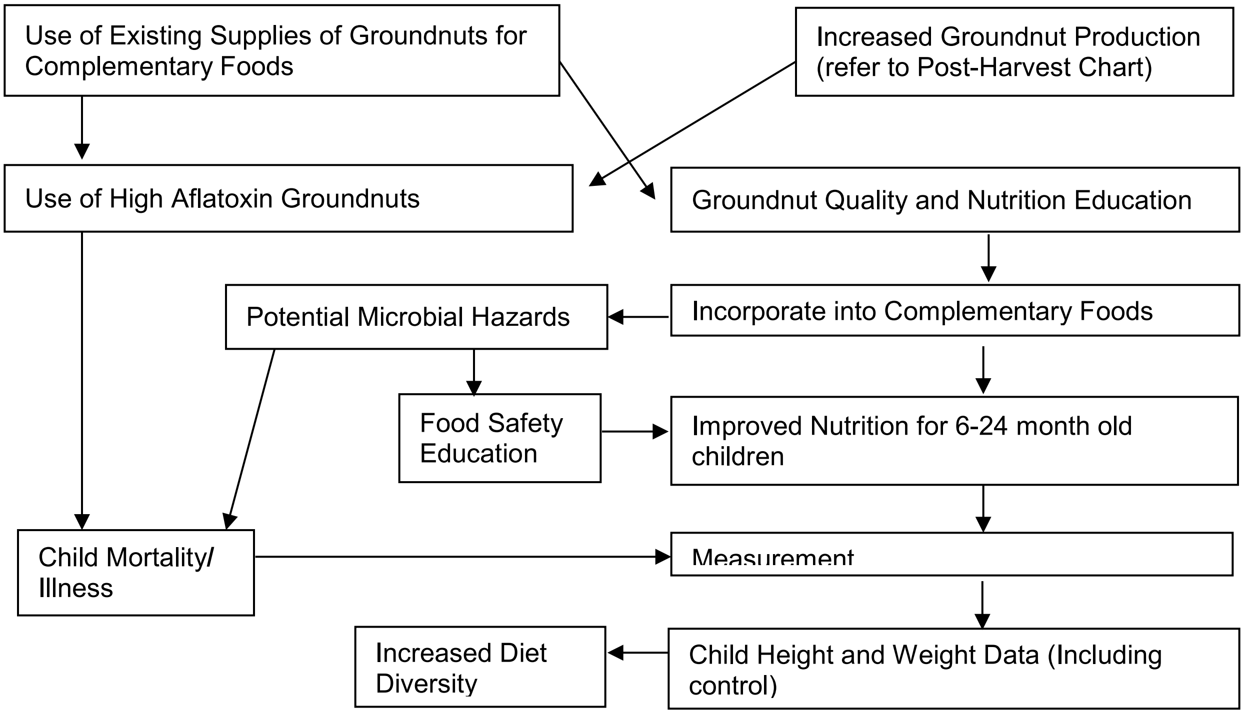
- Harvest and postharvest capacity building through meetings and in-the-field learning experiences for ICRISAT and SUA research staff and field technicians involved in the Project and their local partners (e.g., PLAN/Malawi and Ministries of Agriculture). This included the process for identifying and understanding constraints faced by farmers as well as the process involved in technology design and development, replicated controlled on-station trials, and participatory in-field equipment evaluations with Project farmers.

- Field demonstrations for small groups of farmers (men and women) in selected Project villages, coupled with practical hands-on training for farmers on concepts and use of equipment prototypes being tested. The objective was a process of co-evaluation and even co-design of the equipment by the ultimate users of the technologies.

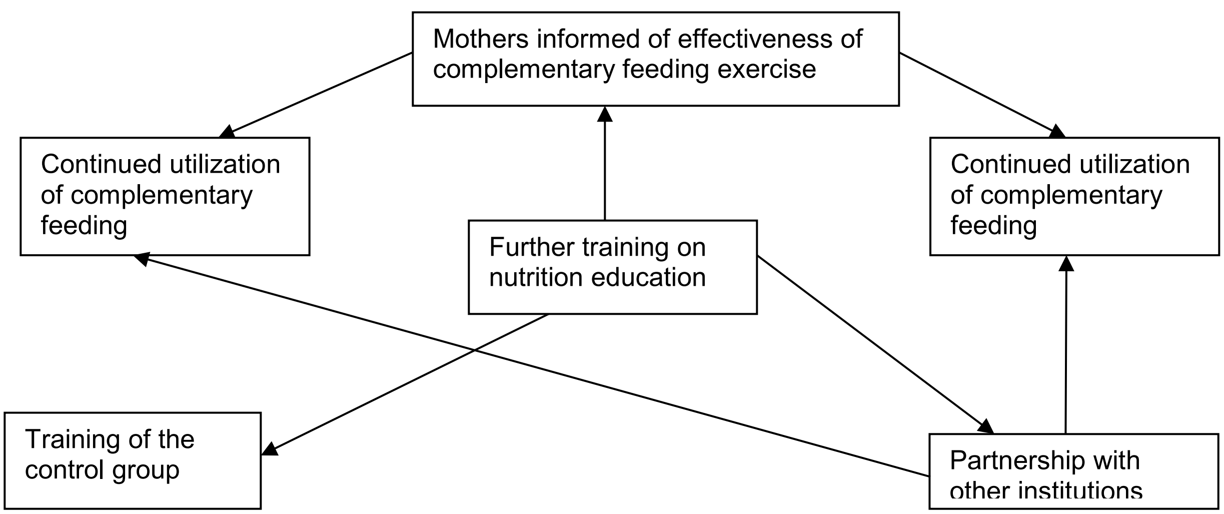
- Periodic extension-type discussions with men and women farmer groups in the Project villages to review Project objectives and current Project activities, explain results to date, seek input and validate priorities and plans going forward, and solicit ideas for Project improvements. A concerted effort was made during each CTI mission to organize these kinds of farmer meetings in several villages, which were then repeated in other villages by the in-country staff.

C. THEORY OF CHANGE

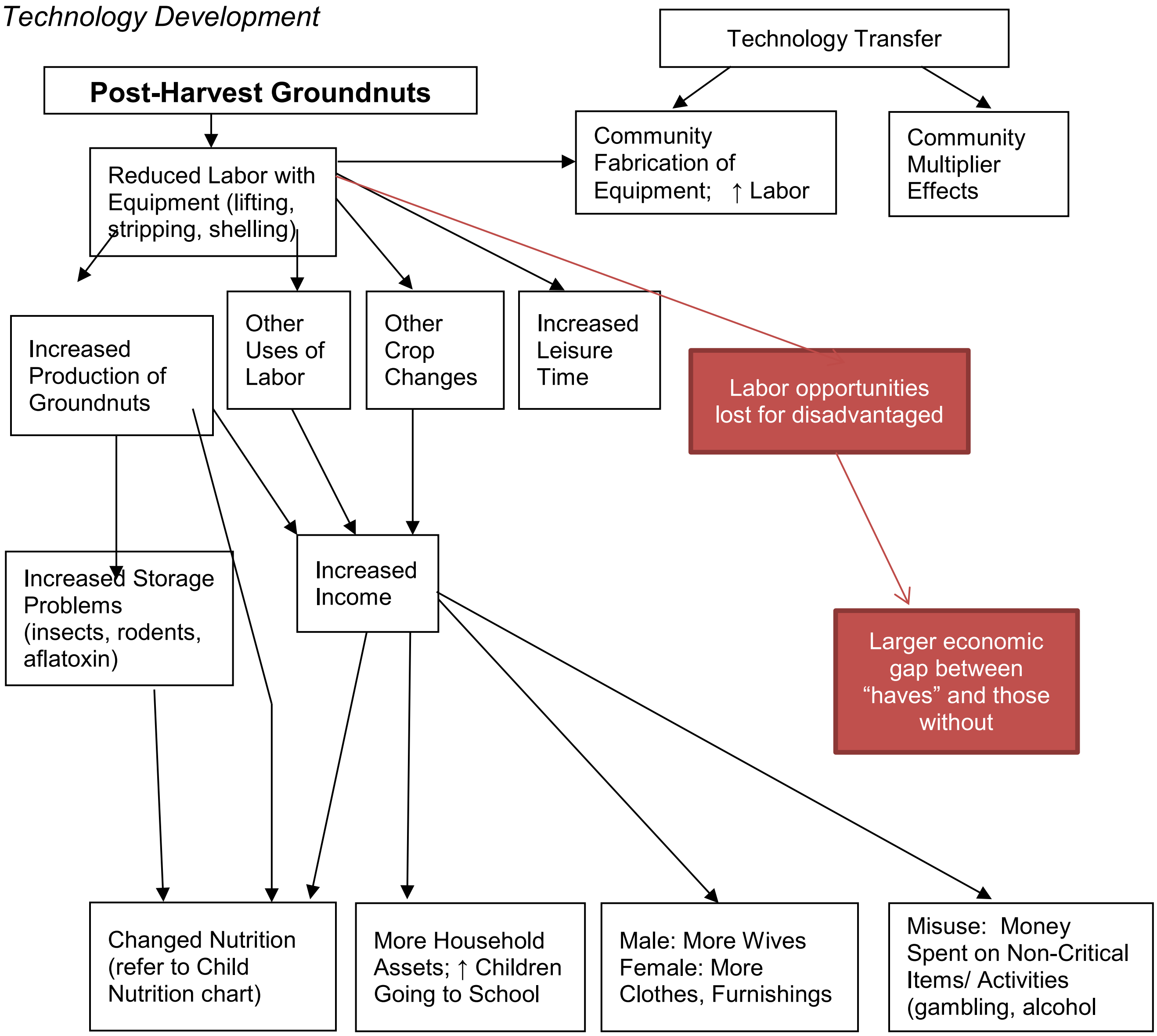
Child Nutrition Complementary Foods



Extension Period Activities



Technology Development



D. MONITORING AND EVALUATION PLAN

Enhancing Child Nutrition and Livelihoods of Rural Households in Malawi and Tanzania through Postharvest Value-Chain Technology Improvements in Groundnuts

Compatible Technology International (CTI), Tanzania's Sokoine University of Agriculture (SUA) and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in Malawi have combined their institutional expertise and resources to implement a project for the purpose of **enhancing child nutrition and livelihoods of rural households in Malawi and Tanzania through postharvest value-chain technology improvements in groundnuts**. The **primary beneficiaries** of this project are rural smallholder farm families in selected communities, especially women and children under five in groundnut-producing households.

Project Objectives:

1) **Reduce losses of food, in both quantity and quality** (including aflatoxin contamination), incurred by farm families during postharvest handling, processing, and storage; and through food preparation and consumption.
2) **Improve the nutrition of rural households,** especially for children, through adoption of improved weaning and infant foods using groundnuts and other locally available crops as base ingredients.
3) **Raise household revenues** through the sale and distribution of high-quality groundnuts and/or value-added products such as paste, oil and/or other groundnut–based food products.
4) **Improve productivity and reduce daily labor and physical drudgery borne by women** through utilization of more efficient and rapid postharvest and food-processing technologies for groundnuts.
5) **Empower farm families** (especially women and youth) and their associations or producer organizations in ways that enable them to strengthen their links to markets, manage their farms as enterprises, learn how to find information and external support, identify more beneficial ways to associate, and better defend their interests in the future.

Objectives of the evaluation

Project evaluation will serve to help the project team measure and evaluate what, if any, impact the program is having on communities through the analysis of the indicator data. The program team seeks to learn how their activities are impacting both the nutrition and economic status of smallholders and their families.

Baseline Survey

To establish initial baseline data, during the project's first year (2010), an in-depth survey was conducted of a representative group of roughly 500 groundnut growers in Malawi and Tanzania to understand the current harvest and postharvest (HPH) groundnut technologies and constraints as well as the basic socio-economic and agricultural context of these farming communities. Based on individual household questionnaires together with focus group discussions, the survey also included child feeding and nutrition practices. Together these survey results have been used to determine priority areas for development of improved HPH groundnut technologies as well as improved groundnut-based complementary food formulations and child nutrition education programs.

Objective 1: Reduce losses of food (in quality and quantity)
Objective 2: Improve the nutrition of rural households

Outcome: To established nutritional status of target children utilising developed complementary food based on groundnuts.
Output: Took monthly weight and height measurements of the target children

Evaluation question	Has the use of formulated complementary food improved the nutritional status of children?
Evaluation indicator/measure	Height and weight measurements
Evaluation methods (How)	Taking Weight and Height measurements
Evaluation & Implementation plan (who, what and when)	Medical personnel took weight and Height measurements of children on monthly basis after starting feeding with formulated complementary food
Existing data	Initial weight and Height measurements before start feeding with formulated complementary food
Use of information and who needs it	Researchers will use the information to evaluate the nutritional status of children Information will also be used by Researchers for publication, share with CoP members and other stakeholders Researchers will use the information to evaluate the effectiveness of the formulated complementary food

Outcome: To compile data on consumption of the developed complementary food based on groundnut by children (6 and 24 months).
Output: Visited homes to monitor utilization of the developed complementary food based on ground nuts by target children

Evaluation question	**Evaluation indicator/measure**	**Evaluation methods (How)**	**Evaluation & Implementation plan (who, what and when)**	**Existing data**	**Use of information and who needs it**
Were mothers competent in preparing the complementary mixture?	Ratios of cereals and groundnuts in the mixture Ingredients availability	Responses given to the monitoring staff Household visits	Ward/Village Ext. Officers and TUNAJALI NGO Staff visited households twice per month.	Recipes in Training Manual	Researchers to decide whether more training is needed or not.
Were mothers competent in preparing porridge using the flour mixture?	Amount of flour mixture and water according to the age of a child	Responses given to the monitoring staff Household visits	Ward/Village Ext. Officers and TUNAJALI NGO Staff visited households twice per month	Recipes in Training Manual	Researchers to decide whether more training is needed or not.
Were mothers feeding their children according to recommended requirements?	Amount of porridge fed and frequency of feeding	Responses given to the monitoring staff Household visits	Ward/Village Ext. Officers and TUNAJALI NGO Staff visited households twice per month	Recipes in Training Manual	Researchers to decide whether more training is needed or

					not.

Outcome: To determine microbiological quality of the developed complementary food based on groundnuts.
Output: Collected food samples from households and analysed for microbial (bacterial and aflatoxin) contamination.

Evaluation question	Were the developed complementary food based on groundnuts safe for consumption?
Evaluation indicator/measure	Level of bacterial count and aflatoxin recorded
Evaluation methods (How)	Lab analysis for of bacterial count and aflatoxin contamination
Evaluation & Implementation plan (who, what and when)	SUA Researchers collected samples quarterly and analysed for bacterial count and aflatoxin contamination
Existing data	WHO /Codes Alimentarius Guidelines
Use of information and who needs it	Researchers to judge on the safety of the complementary food.

Objective 3: Raise revenues

Indicators:

a. **Increased incomes through sale of nuts:** Through sale and distribution, by these households, of high-quality groundnut paste, oil and/or new R&D-created, added-value, groundnut–based food products for local markets. At the commencement of the marketing season, ICRISAT started talking to the commercial arm of NASFAM on the possibility of buying groundnuts from the target communities in Lilongwe and Kasungu districts. NASFAM accepted in principle, but when the marketing started many buyers were competing for the commodity and prices kept changing over time. In the end, three more buyers including CARENTH Investments, CACTUS Trading and Peacock Enterprises were identified, making a total of four buyers.
   i. **Measuring:**
      - **Establishing baseline data:** Prices varied from buyer-to-buyer, but the range during the marketing period was between 210 to 240 MK per kilogram. At that time, ICRISAT negotiated for a higher price, and CARENTH Investments offered to buy at 275 MK per kilogram. This price offered by CARENTH Investments was the highest. Therefore, CARENTH Investments was the one that farmers were happy to choose and their price was accepted as the best at the time.
   ii. **Results:** Selling of groundnuts collectively benefited farmers in two ways:
      1) One point sale which allowed them to get all the cash at once. This is in comparison to selling to vendors in small quantities;
      2) The price was much better compared to the prevailing prices at the time. The collective marketing approach has the potential to make groundnut marketing sustainable through private sector involvement, profit incentives and market links;

   At the end of the marketing exercise, CARENTH Investments bought a total of 9,690 kg of CG7 from the collaborating farmers of Lilongwe and Kasungu districts at a total value of MK 2,664,750 (see Table 1 below). The price of MK 275 per kg was higher by MK 35 as compared to the price outside this linkage. A deliberate effort to compare quality of groundnuts in project target villages/communities and non-target sites was made by including non-project villages in the process. The process of rejection, due to poor grading and wet nuts, showed that the project intervention community (Kanyunya) had the least rejects due to either poor grading or wet nuts (Table 1 below). This shows the potential of the project interventions for changing farmer behavior with regard to groundnut marketing. This will ultimately improve the quality and safety of food products made from groundnuts.

Table 1. Lilongwe and Kasungu districts' collective groundnut market data

Community / Area	No. of farmers benefited	Reject due to poor grading & mixture	Reject due to wet nuts	Kilograms purchased @ K275.00 per Kg.	Amount earned in MK	Moisture content
Pitala	71	14 (20%)	5 (7%)	3302	908, 050	8.4 – 14.6
Chinjoka	36	9 (25%)	7 (19%)	1371	377, 025	8.9 – 13.4
Kanyunya	76	3 (4%)	1 (1%)	2549	700, 975	8.8 – 13.8
Mende	10	6 (60%)	1 (10%)	386	106, 150	8.9 – 12.5
Ofesi	41	9 (22%)	12 (29%)	2082	572, 550	8.6 – 16.6
Totals	234	41 (18%)	26 (11%)	9, 690	2, 664, 750	

b. **Increased income through reduction cost of hired labor:**
   i. **Measuring:**
      - **Establishing baseline data:**
         - **Cost of Hiring Digging Labor:** 5,000 MK/acre
         - **Cost of Hiring Stripping Labor:** 750 MK/acre
         - **Cost of Hiring Shelling Labor:** 750 MK/acre
   ii. **Results (2013 Trials):**
      - **Cost of Hiring Oxen-Powered Lifter Labor:** 2,528 MK/acre — a 50% savings
      - **Cost of Hiring Screen Stripper Labor:** 60 MK/acre — a 92% savings
      - **Cost of Hiring CTI Drum Sheller Labor:** 50 MK/acre — a 93% savings

<u>Objective 4: Improve productivity and reduce daily labor and physical drudgery borne by women</u>

Indicators:

a. **Groundnut productions speed/yield volume**
   i. **Measuring:**
      - **Establishing baseline data:**
         - **Traditional Lifting:** 272 m/hr
         - **Traditional Stripping:** 2.4 kg/hr
         - **Traditional Shelling:** .88 kg/person hour
         - **Traditional Sorting:** 4.9 kg/hr

ii. **Results (2013 Trials):**
- **CTI Oxen-Powered Lifter:** 2,480 m/hr — 811% increase in production rate
- **CTI Screen Stripper:** 3.6 kg/hr — 50% increase in production/reduction in labor
- **CTI Small Drum Sheller:** 11.3 kg/person hour — 1,184% increase in production/reduction in labor

Objective 5: Empower farm families

(See measurements for objective 3)

E. RESEARCH QUESTIONS AND PROTOCOLS

Microbiological analysis

Microbiological quality involved flour mixtures and cooked porridge.

Samples of cooked porridge taken from pot/cup/bowl were collected from the last villages, stored in a cool box and sent to the laboratory at SUA.

Samples were collected quarterly by a microbiologist during wet and dry seasons to assess weather influence on microbial contamination.

MICROBIOLOGICAL PROTOCOL

Microbiological analyses of the samples will be carried out to test for coliform bacteria before cooking (indicator of sanitary quality).

Total plate count after cooking (to indicate potential spore-forming bacteria such as Clostridia or Bacillus species which may cause gastrointestinal illness).

Random sampling of the food preparation environment for Salmonella bacteria (indicate animal faecal contamination.

Detection of Coliform bacteria in food samples collected: (raw ingredients (flour mixture), Cooked samples of porridge (from the pot/ feeding cup).

Escherichia coli (*E. coli*) is a bacterium, which is found in the gut of man and animals. It may be transmitted through fecal contamination at slaughter or through poor personal hygiene of food handlers. Their presence in cooked foods is indicative of poor personal hygiene – not washing hands after going to the toilet.

Detection of coliforms is also used as an indicator of sanitary quality of water or as a general indicator of sanitary condition in the food-processing environment

Detection of Coliform in flour mixture and porridge

Mix the flour mixture thoroughly, using a sterile spoon and take five (5) sample units (100g) at random into the sterile wide mouth glass bottles and replace the lid quickly.

Collect such similar samples randomly from five HH

Repeat the procedure for the cooked sample from the HH by collecting about 100-200ml ml of cooked porridge from the cooking pot or feeding cup if possible.

Place the samples in the cool box and transfer to the laboratory within six hours a the following day.

Preparation of the food samples:

Mix each individual sample thoroughly

Weigh aseptically 10g / 10 ml of the food sample into a sterile glass stopper and add 90 ml of the available diluents (eg. 0.1 % peptone water, Quarter Strength Ringers solution) to homogenize and mix thoroughly (to give a 1: 10 dilution) w/w or v/v

Prepare further decimal dilutions as necessary (up to 10^6) so that isolated colonies can be obtained when plated).

Transfer 1 ml aliquots of each dilution to sterile Petri dishes.

Prepare Violet Red Bile Agar (VRBA) according to manufacturer's instructions. Cool to 48°C before use.

Pour 10 mL VRBA tempered to 48°C into plates, swirl plates to mix, and let solidify.

To prevent surface growth and spreading of colonies, overlay with 5 mL VRBA, and let solidify and incubate at room temperature for 2 ± 0.5 h.

Then overlay with 8-10 mL of melted, cooled VRBA and let solidify.

Invert solidified plates and incubates 18-24 h at 35°C.

Examine plates under magnifying lens and with illumination.

Count purple-red colonies that are 0.5 mm or larger in diameter and surrounded by zone of precipitated bile acids.

Plates should have 25-250 colonies.

To confirm that the colonies are coli forms, pick at least 10 representative colonies and transfer each to a tube of BGLB broth. Incubate tubes at 35°C. Examine at 24 and 48 h for gas production

Detection of Salmonella

Salmonella species are food poisoning bacteria which can be found in the intestines of animals, humans and in polluted waters. Salmonella may be present in food due to insufficient cooking, cross contamination from raw food to cooked foods, or due to poor personal hygiene. Are useful indicators of hygiene and of post-processing contamination of heat processed foods. Their presence in high numbers (>10^4 per gram) in ready-to-eat foods indicates that an unacceptable level of contamination has occurred or there has been under processing (e.g. inadequate cooking)

Detection of *Bacillus cereus*

Bacillus species and specifically *Bacillus cereus*, are food poisoning bacteria.
Bacillus is widely distributed in the environment, and therefore found on grains, beans, pulses etc. It is essential that foods are cooked thoroughly, and if not being served immediately they must be cooled rapidly. Many food can be expected to contain small numbers of *B.cereus* because it is such a common environmental contaminant as such selective enrichment techniques will usually provide information of much value. However if it is suspected that a food sample may represent a potential hazard because of proliferation of *B.cereus* has occurred (like in the present study) it may be useful to employ a selective and differential medium such as Mannitol Egg-yolk Phenol Red Polymyxin (MEPP) agar with direct plate counts

Procedure:

Weigh /measure aseptically 10g/10 mls of the food sample into a sterile glass stopper and add 90 ml of 0.1 % peptone water to homogenize and mix thoroughly (to give a 1: 10 dilution) w/w or v/v.
Prepare further decimal dilutions as necessary (up to 10^4C) so that isolated colonies can be obtained when plated).

Transfer 0.1 ml amounts in duplicate plates of poured well dried Mannitol Egg-yolk Phenol Red Polymyxin (MEPP) agar .

Spread the inoculums evenly over the surface of each plate with a sterile bent glass rod

Incubate the plates for 48 h at 30^{o}C.

Presumptive *B.cereus* colonies are rough and dry with a violet red background and a halo of dense white precipitate these reactions result from absence of attack on mannitol and presence of lecithinase activity against the egg yolk

To confirm colonies of *B.cereus:* purify by streaking (loopful) on egg yolk agar plate and prepare pure cultures on nutrient agar slopes

Examine for the presence of Gram positive rods which will usually be capable of sporulation, the spores being ellipsoidal and not enough to cause swelling of the vegetative cells.

Aflatoxin Analysis Protocol

Protocol for Evaluating Aflatoxin Levels in complementary food formulations based on groundnuts.

Objective and Basic Approach:

The objective of the proposed testing procedures is to conduct periodic, random quality checks of test formulations to identify and remove any foods that may have aflatoxin levels above those generally considered safe for human consumption (20 ppb), especially for children.

According to US safety regulations, levels of aflatoxin in foods other than milk, is 20.0 ppb. This level is therefore proposed as the threshold for the Child Nutrition Study in Tanzania.

Samples of flour mixtures will be collected from 5 out of 16 villages.

Sampling period/frequency: will be conducted quarterly.

For a variety of reasons, sampling for aflatoxin should be combined as much as possible with that for pathogenic bacteria. This will reduce sample collection costs, ensure better preservation for sample preservation during transport to the lab, and provide multiple results on food quality and safety from the same samples. Currently the SUA protocol for microbial analyses calls for sampling once a quarter, which does not seem frequent enough, at least for aflatoxin testing.

Sources of Variability

It is important to be aware of potential sources of variability when designing the protocol for determining aflatoxin contamination (Whitaker, 2006). In particular, three sources of variability -- sampling, sample preparation, and analytical testing -- need to be taken into account so that the data obtained from analysis are accurate.

1) <u>Sampling</u>

According to Whittaker (2006), sampling is the largest source of variability. The sample obtained from the complementary food at each household must be representative and large enough for the test to be used. It is recommended that 100 g can be sampled from the 5 kg preparation. The 100 g (of the combined, blended dry flour ingredients composing complementary food)should be obtained from incremental 20 g sub-samples taken from different parts of the container; hence 5 sub-samples to make one representative composite sample of 100g. *Every individual item in the lot to be sampled should have an equal chance of being chosen.* However if the container has flour that is already reasonably well blended, then 100 g can be obtained from any part of the container (based on the assumption that any contamination is uniformly distributed). FAO/WHO (1993) recommends that each incremental sample portion be about 200 g, based

on one incremental portion being taken from 200 kg of product. As a result, 100 g in the proposed study is deemed to be adequate. Sampling flour/grain should give a good indication of contamination levels and thus it is not considered necessary to sample food after cooking.
Annex I contains a proposed sampling form.

2) Sample preparation/handling

Depending on how the sample has been blended by the mothers, additional blending may be required for proper aflatoxin determination. Particles need to be small enough to pass through a no. 20 sieve (which can be bought). If mothers use different methods to make flour, particles may not be small enough for accurate determination of contamination. *Comminuting (reducing particle size) the samples further is highly recommended. If analyzed without further comminuting, the different preparation methods or pounding efficiencies from households would be a major source of variability, and therefore analyzing without further grinding will not give reliable results*.
Samples need to be handled in a way to prevent further deterioration. It is critical that samples be kept dry and away from moisture, other test results will not accurately reflect the condition of the food formulation sampled. Use good moisture-proof bags for holding and transporting the samples from the field to the testing facility. Putting the samples in a cooler containing frozen ice packs (to keep internal cooler temperature 4 to 10^{o}C) should help preserve them in the field and during transport and until they can be stored in a refrigerator or freezer. Obviously, a good labeling and data recording system needs to be in place from the field onward so the identity of the samples is maintained.

3) Sample analysis for aflatoxin contamination

Ideally, samples should be analyzed within 24 hours, not only to ensure accuracy (minimization of changes over time) but also quick follow-up action if test results are high. Because of the conditions in the field, it is not thought practical to conduct the tests on site near or at the point of sampling.

Recommended Aflatoxin Testing Procedure

We believe that the RomerAgraStripAfla Test is the most suitable test given the stated purpose and conditions of the Child Nutrition Study in Tanzania. Developed and manufactured by Romer Labs, Inc. of Union, Missouri USA (www.romerlabs.com), the test is rapid (5-10 minutes), inexpensive, relatively simple and user-friendly, especially compared to more complicated, sophisticated and higher-cost tests like the ELISA. It has been approved by the US Dept of Agriculture for corn/maize and peanuts/groundnuts.

The RomerAgriStriptest is a one-step, rapid, lateral flow assay (immunochromatographic) for the detection of total aflatoxin (B1, B2, G1, G2). It is a qualitative test, hence does not quantify the level of aflatoxin present.Instead, a visible line appears in the test zone of the test strip if the results are less than the cutoff level, and no line if above that level. Depending on the kit used, there are three different cutoff levels from which to choose: 4, 10 and 20 ppb. The 20 ppb kit is recommended in this case given the objectives. Each kit consists of all the materials needed for 24 tests.The analyses should be done in triplicate. Three aliquots per sample preparation should be analyzed to obtain a more reliable estimation of the contamination.

Annexes II and III provide a detailed description of the test kit, assay principles, test procedures, interpretation of results and other pertinent information. Annex IV provides a price quotation from Romer. Although Romer has a European distributor based in Austria that serves Africa, CTI could arrange for a discount if the initial set of kits was purchased directly from Romer's headquarters in the US, shipped to CTI in Minnesota, and then shipped by CTI to SUA in Tanzania.

The essential equipment and materials for the Romer test are as follows:

(1) Test strips

(2) Microliter wells
(3) Diluent
(4) Alcohol (methanol)
(5) Grinder well
(6) Shaker bags
(7) Balance (400 g)
(8) Mini-pipette (50 microliter)
(9) Graduated cylinder (50 ml)

Notes:

(1) The kits will include everything except the methanol extraction solution and balance/scale, both of which should be readily available locally.
(2) Romer technicians do not believe any additional grinding of the samples will be necessary since the food formulations will already be quite well processed, and further grinding or sieving of groundnuts may cause problems.
(3) The kits include shaker bags (whirlpak plastic bags) that are used in the extraction process; vigorous shaking of the solution in these bags is sufficient for blending and replaces the need for a motorized blender.
(4) Whatman (trademark/ brand) paper, funnels, and filtrate collecting vessels are not needed since, according to Romer, it is best to let the extraction briefly settle (approx. 30 seconds).
(5) Shelf-life: Romer says that the shelf-life of the test kit materials is 18 months from the date of manufacture, assuming they are stored at 25 C. or below (best to refrigerate).
(6) Disposal of test materials: According to Romer, the test strips, bags, etc. are typically disposed of in normal waste. The methanol/extraction solution is also typically disposed of in normal waste although local regulations on the disposal of methanol/ethanol/alcohol should be followed (they have about the same toxicity as rubbing alcohol).

Proposed Protocol Outline

1. Collect small samples (roughly 20 g) from different parts of the container holding the complementary food. Total weight of sample to be collected is roughly 100 g, assuming that the women have ground 5 kg of total ingredients; less is acceptable as indicated above
2. Keep samples in a cooler box out of the sun and heat as much as possible, and hold at low temperature until delivered to testing facility.
3. Preserve samples in a refrigerator until aflatoxin tests are conducted (store at -20C if aflatoxin analysis will be delayed)
4. Comminute samples further and sieve through a no. 20 sieve. Clean the blender between samples using the protocol in Annex V.
5. Analyze samples in triplicate (if the procedure from the test kit calls for 20 g for analysis, then weigh 3 20g samples and analyze for aflatoxin contamination)
6. Safely dispose of samples after testing completed (see note above)
7. Resample from households when a new batch of ingredients has been made.

Urgent-Action Plan for Samples Testing> 20 ppb:

1. Immediately re-sample the dry complementaryfood of thehousehold. At same time, sample individual ingredients used in that food so as to identify if possible the specific source ofthe aflatoxin contamination

2. Urge mothers to discard contaminated food and any contaminated ingredients

3. Advise and assist mother(s) in finding safe alternative sources for their complementary food

4. Immediately test new food formulation

5. Document how contaminated food was handled and record days of formulation feeding skipped and substitute foods used.
6. If both households in a village test high, then sample and test all households in that village to determine if there is a common problem specific to that village

Technology

Research Questions

What are the most labor intensive and inefficient steps in harvesting, processing/preparation for sale of groundnuts by farmers in selected villages in Malawi and Tanzania? Current conditions include minimal hand tools and unassisted hand labor resulting in low productivity, physical drudgery, and low economic return/revenues.

Can the development of appropriate technology (low maintenance, inexpensive replacement parts, and simple manual operation with adaptability for mechanization) addresses the most labor operations identified?

Protocol for Equipment Testing – Appendix E8

APPENDIX E1

Aflatoxin Sampling Form

(*revised 16 June 2011*)

Country -- District	
Village (and GPS coordinates if available)	
Farmer	
Groundnut Variety Sampled	
Approximate Harvest Date (Month/1st or 2nd half)	
Sampling Location (Field, Storage Structure, Other)	
Drying Method, Location and Approx. Duration	
Type of Storage Structure or Container	
Sampling Procedure Used	
HPH Stage at Time of Sampling (unharvested, field drying, post-stripping, entering storage)	
Approximate Weight of Sample (gms)	
Moisture Content (in %)	
Date Sample Collected	
Date Sample Shipped	
Shipping Method (Project vehicle, bus, mail, other)	
Person Who Sampled	
Date Received in Lab	

APPENDIX E2

Romer AgraStrip Total Aflatoxin Test Kit (flyer)

ROMER
Romer Labs®

Making the World's Food Safer ®

AgraStrip™ Total Aflatoxin Test Kit

Romer Labs® has developed a rapid lateral flow assay test kit for the detection of total aflatoxin (B1,B2,G1,G2) in corn and peanuts. This test was specifically formulated for grain elevators and peanut buying points.

AgraStrip™ is available in kits of 24 tests. Detection cut off levels of 4 ppb, 10 ppb and 20 ppb are available. Each test comes complete with all test accessory materials such as, pipette tips and diluent.

AgraStrip™ Aflatoxin Kit Performance

- *Accurate* – results are comparable with published HPLC method
- *Reproducible* – consistent results obtained in intra- and inter-laboratory settings
- *More Selective* – three cutoff levels are available.

Test Kit Item No.	*Cutoff Level*
COKAS1100 AgraStrip™ Aflatoxin	4ppb
COKAS1200 AgraStrip™ Aflatoxin	10ppb
COKAS1000 AgraStrip™ Aflatoxin	20ppb

Benefits

- *Rapid* – Less than 5 minute method
- *Stable* – 12 months shelf-life.
- *Cost Effective* – No expensive equipment required
- *All Inclusive* – Accessory materials and reagents included
- *User Friendly* – Easily train technicians in minutes
- *Performance Tested* – USDA/GIPSA approved method

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e-Mail: office-europe@romerlabs.com

www.romerlabs.com

Assay Procedures*:

1. Pipette 50µL of assay diluent into each conjugate well

2. Add 50µL of sample extract into each well and mix

3. Put one strip into each well

4. Allow 5 minute reaction time

Interpret results:

- Negative results are confirmed as soon as two lines appear – within 1 minute (20ppb cutoff kit only).
- Positive results are confirmed 5 minutes.

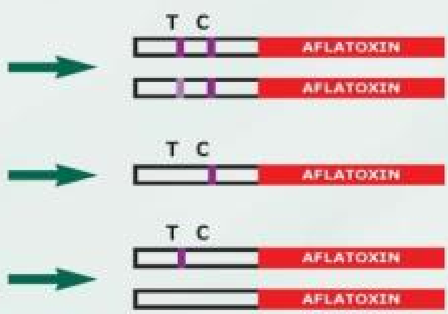
** Please refer to the package insert for sample preparation.*

Results Interpretation:

Negative: Aflatoxin less than cutoff level (two color lines)

Positive: Aflatoxin distinct results below or above the cutoff level (one control line)

Invalid results: no control line



For further information, please contact:

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www.romerlabs.com

PI_GB_792_03_GGU / US

APPENDIX E3

Romer AgraStrip Total Aflatoxin Test – 20ppb Cutoff (information sheet)

ROMER
Romer Labs®

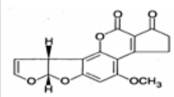
AgraStrip® Total Aflatoxin Test (20ppb Cutoff)

Order #: COKAS1000

Intended Use

The AgraStrip® Total Aflatoxin Test is a one-step lateral flow immunochromatographic assay that determines a qualitative level for the presence of total aflatoxin (B_1, B_2, G_1 and G_2) and is intended for use in grains, cereals and other commodities.

The AgraStrip® Total Aflatoxin Test has been validated for corn, cottonseed, peanuts and rice. It is the USDA/GIPSA approval method for corn.



Aflatoxin B_1

Aflatoxins

Aflatoxins are toxic and carcinogenic. They are metabolites of the fungi *Aspergillus flavus* and *Aspergillus parasiticus*. There are four principle types of aflatoxin: B_1, B_2, G_1 and G_2, which are named for their respective innate fluorescent properties. Aflatoxin B_1 is the most frequently encountered of the group and the most toxic. Aflatoxins can be found mainly in cereals, corn, peanuts, cottonseed and nuts.

Aflatoxins can cause liver disease in animals and may cause decreased production (milk, eggs, animal weight, etc). Aflatoxin B_1 is a potent human carcinogen, and may contribute to human liver cancer.

The US Food and Drug Administration action levels of aflatoxin are as follows: (1) 300ppb for feeder cattle; (2) 200ppb for finishing swine; (3) 100ppb for breeding beef cattle, swine and mature poultry; and (4) 20ppb for humans, and for immature animals and dairy animals.

Assay Principles

The AgraStrip® Aflatoxin Test Method is a one-step lateral flow immunochromatographic assay with a cutoff level of 20ppb aflatoxin based on an inhibition immunoassay format. Antibody-particle complex is dissolved in assay diluent and mixed with sample extract. The mixed content is then wicked onto a membrane, which contains a test zone and a control zone. The test zone captures free antibody-particle complex, allowing color particles to concentrate and form a visible line. A positive sample with aflatoxin above the cutoff level will result in no visual line in the test zone. Alternatively, a negative sample with aflatoxin below the cutoff level will form a visible line in the test zone. The line will always be visible in the control zone regardless of the presence of aflatoxin.

Precautions

1. Store test kits at 2-25°C (36-77°F) when not in use, and do not use beyond the expiration date.
2. Test strips and microwells must be kept inside their original tubes.
3. All reagents must be at room temperature before assay is running.
4. Adhere to the instructions of test procedures.
5. Do not re-use test strips.
6. Methanol is flammable. Caution must be taken in its use and storage.
7. Consider all materials, containers and devices that are exposed to the sample to be contaminated with toxin. Wear protective gloves and safety glasses when using the kit.
8. The components in this test kit have been quality control tested as a standard batch unit. Do not mix components from different lot numbers.

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Procedure

Sample Preparation / Extraction

1. Obtain a representative sample and grind it using a Romer Series II® Mill so that 75% will pass through a 20-mesh screen, then thoroughly mix the subsample portion.
2. Weigh out 10 g of ground sample into a clean jar that can be tightly sealed.
3. Add 20 mL of 70% methanol extraction solution (i.e. 70/30 (v/v) methanol/water) or 20 mL of 50% ethanol extraction solution (i.e. 50/50 (v/v) ethanol/water) and seal jar. **Note:** Samples should be extracted in a ratio of 1:2 (w:v) of sample to extraction solution respectively.
4. Vigorously shake, blend or vortex for 1minute.
5. Allow sample to settle, or filter the top layer of extract through a Whatman #1 filter and collect the filtrate. Proceed to the test procedure. (For cottonseed extract, after filtration, place 3 mL of extract into a 12 x 75 mm cuvette and push the mycosep112 column completely through. Proceed to the test procedure).

Note: Commodity extracts should have a pH of 6-8. Excessive alkaline or acidic conditions may affect the test results and should be adjusted before testing.

Test Procedure

Note: All reagents and kit components must be at room temperature 18-30°C (64-86°F) before use.

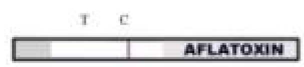
1. Remove microwell sealer, and place the appropriate number of microwells in a microwell holder. Re-seal those un-used microwells.
2. Using a single channel pipette, add 50µL of assay diluent to each microwell. Dissolve the coating conjugate in the microwell by pipetting the content up and down 5 times.
3. Add 50µL of sample extracts to each microwell, mixing the content in each well by pipetting it up and down 3 times.
4. Put one test strip into one well.
5. Allow the test strip to develop color for 5 minutes.
6. Interpret test results immediately.

Interpretation of the Results

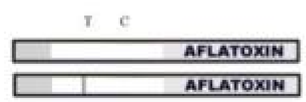
A color line always appears in the upper section of the test strip to indicate that the test strip is working properly. This line is the Control Line (C). A line in the lower section of the test strip indicates the test results. This line is the Test Line (T).

Results less than 20ppb: 2 lines are visible. This indicates the sample contains total aflatoxin less than 20ppb (negative sample). A negative sample may be determined as soon as 2 lines are visible on the strip (1 min). (Please see right-hand side image)

Results greater than 20ppb or equal to 20ppb: 1 line is visible. This indicates the sample contains total aflatoxin great than or equal to 20ppb (positive sample). (Please see right-hand side image).



Invalid results: If there is no line in control zone, the test is invalid and the sample should be re-tested by using a valid test strip. (Please see right-hand side image).



NOTE: For some samples, a third line may appear on the strip at a position of approximately 0.4cm from the bottom portion of the AgraStrip. Please note that if the line at the bottom of the strip appears, it is not a valid line and can be ignored. Only the

Method #: PI-000061-1 ROMER Romer Labs Methods

Test line and the Control line, which correspond to the letters "T" and "C" on the back of strip respectively, are used in interpreting results. The Control line must always be present for the test to be valid.

Performance Characteristics

AgraStrip® Total Aflatoxin Test has been validated to screen total aflatoxin in corn, cottonseed, peanuts and rice at 20ppb cutoff level.

Materials Supplied With Kit

- 1 tube containing 24 aflatoxin test strips
- 1 tube containing 24 microtiter wells coated with antibody-particle complex
- 1 bottle of 1.8mL assay diluent

Materials Required But Not Provided With Kit

Extraction Procedure

- *EQMMS2010: Romer Series II® Mill or equivalent
- *EQOLE1025: Blender or a tightly sealing jar with lid
- *EQOLE1010: Balance, 400 g
- *EQOLE1050: Graduated cylinder: 100mL
- *70% methanol or
  - ACS grade methanol for making 70 % methanol
  - Distilled or de-ionized water for making 70 % methanol
- *50% ethanol or
  - Formula 3A ethanol for making 50 % ethanol
  - Distilled or de-ionized water for making 50 % ethanol
- Container with a minimum 50mL capacity
- COCMY2112: MycoSep® 112 clean-up column (for cottonseed only)
- *Whatman#1 filter paper, or equivalent (optional)
- *Filter funnel (optional)

Assay Procedure

- *Single channel pipettor capable of pipetting 50µL with tips
- *EQOLE1300: Timer

*Items available from Romer Labs, Inc.® - Americas Division

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Warranty

The user assumes all risk in using Romer Labs, Inc.® products and services. Romer Labs, Inc.® will warrant that its products and services meet all quality control standards set by Romer Labs, Inc.®, and Romer Labs, Inc.® will, at its option, repair or replace any product, components, or repeat services which prove to be defective in workmanship or material within product specific warranty periods or expiration dates and which our examination shall disclose to our satisfaction to be defective as such. This warranty is expressly in lieu of all other warranties, expressed or implied, as to description, quality, merchantability, fitness for any particular purpose, productiveness, or any other matter. Romer Labs, Inc.® shall be in no way responsible for the proper use of its products. Romer Labs, Inc.® hereby disclaims all other remedies, warranties, guarantees or liabilities, expressed or implied, arising by law or otherwise, and it shall have no liability for any lost profits or damage, direct, indirect or otherwise, to person or property, in connection with the use of any of its products or services. This warranty shall not be extended, altered or varied except by a written instrument signed by an authorized representative of Romer Labs, Inc.®

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APPENDIX E5

Procedures for Cleaning a Sample Blender

The section below on cleaning the blender between samples is taken from the USDA aflatoxin testing handbook.

A small amount of ground sample will remain in the grinder after the total sample has been ground. To prevent the contamination of subsequent samples, clean the grinder using one of the following cleaning procedures:

A. <u>If a Vacuum Cleaner is Available:</u>

After a sample has been ground and collected, with the unit turned on, use a vacuum cleaner with an attachment that will fit over the mouth of the chute. Place the attachment at the bottom of each chute for about 30 seconds. After all the chutes have been cleaned, turn the power off and prepare for the next sample.

B. <u>If a Vacuum Cleaner is Not Available</u>:

Clear the grinder by discarding a small portion (first 10 to 15 grams) of the next sample to be tested.
(1) Pour the sample into the grinder and turn it on long enough to collect the first 10 to 15 grams.
(2) Turn the power off, and discard the 10-15 grams ground sample.
(3) Turn the power back on and finish grinding the sample to collect the remaining subsample for analysis.

APPENDIX E6

Selected References

1. Dohlman, Erik. 2004. Mycotoxin Regulations: Implications for International Agricultural Trade. US Department of Agriculture, Economic Research Service. Ag Info Bulletin No. 789-6.

2. FAO (United Nations). 1993. Sampling Plans for Aflatoxin Analysis in Peanuts and Corn. FAO Food and Nutrition Paper 55.

3. Isakeit, Thomas. 2006. Sampling for Aflatoxin. AgriLIFE Extension. Texas A&M University.

4. Magan, Naresh and Monica Olson (eds). 2004. Mycotoxins in Food: Detection and Control (see especially the chapter on Sampling Plans)

5. Monyo, Emmanuel S. 2010? Assessing Occurrence and Distribution of Aflatoxins in Malawi. Project Final Report, ICRISAT and NASFAM. McKnight Foundation Grant No. 08-598.

6. Mutegi, C.K. et al. 2009. Prevalence and factors associated with aflatoxin contamination of peanuts from Western Kenya. *International Journal of Microbiology.* 130: 27-34.

7. Siambi, Moses et al. 2008. Ovecoming Market Challenges for Smallholder Farmers: The Case of Groundnuts in Malawi. ICRISAT.

8. Whitaker. T.B. 2006. Sampling Foods for Mycotoxins. *Food Additives and Contaminants,* January 2006; 23(1): 50-61.

9. Williams, Jonathan H. et al. 2004. Human aflatoxicosis in developing countries: a review of exposure, potential health consequences, and interventions. *American Journal of Clinical Nutrition.* 80:1106-22.

Appendix E7

McKnight Postharvest & Child-Nutrition Groundnut Project

CTI/SUA/ICRISAT—Malawi & Tanzania

Protocol for Evaluating Aflatoxin Levels in Farmer Groundnut Stocks

(Rev. June 2011)

Purpose: Determine aflatoxin levels in farmer stocks of unshelled groundnuts in selected project sites in Malawi and Tanzania, comparing aflatoxin status (1) over time from shortly after harvest (within one month) to up to six months of storage, and (2) between visibly good quality (whole, sound) and poor quality (broken, damaged, shriveled, moldy) kernels.

Hypotheses:

1. Aflatoxin levels increase significantly over time in farmers' groundnut stocks
2. Aflatoxin levels are much lower in visibly sound, good quality groundnuts than in visibly unsound, poor quality groundnuts
3. Aflatoxin levels in groundnuts are directly related to farm-level harvesting and postharvest handling and storage practices.

Dates:

1. Preliminary testing program (2010)
2. Full comprehensive testing program (2011)

Sampling Periods:

1. Within one month after harvest (April-May)
2. After three (3) months of storage (July-August)
3. After six (6) months of storage (October-November)

Sites for Full Program in 2011: 5 households selected randomly in each of the 16 villages used for the Project's survey in each country, thus a total of 80 households per country. This will consist of 8 villages per District in each of 2 Districts in Malawi (Lilongwe and Kasungu) and 4 villages per District in each of 4 Districts in Tanzania (Chamwino, Bahi, Kondoa and Dodoma Municipality).

Number of Samples for Full Program: For sampling at households: 80 households X 3 dates (immediate postharvest, after 3 months of on-farm storage, and after 6 months of on-farm storage) = 240 household samples per country. For testing at ICRISAT lab: 80 households X 3 dates (household sampling dates) X 2 quality levels (described below) = 480 laboratory samples per country.

Estimated cost: 480 samples @ $5/sample = $2,400 per country and $4,800 total for the countries, excluding any shipping or transportation costs as well as costs of shelling samples and sorting kernels into two quality categories in lab.

Sampling Procedures:

1. Take 10 samples of roughly 100 gms each from each of 10 different locations in groundnut stocks of unshelled pods (example: if farmer stocks consist of 5 bags, take 2 samples from each bag but purposely probe different sides and top and bottom areas across the 10 samples)
2. Combine the 10 samples together and mix thoroughly to form one representative composite sample of approximately one (1) kg in weight of unshelled groundnuts (exact weight measurement not necessary)
3. Place this composite sample in the sample bag provided by the Project (recommended bag is a sturdy, durable Kraft paper bag that is readily available in Kenya)
4. Fill out a pre-prepared duplicate sample information form/label using a pencil (not a pen or marker) and containing the following information:
    - Sample number
    - Name of groundnut variety
    - Farmer name
    - District name
    - Village name
    - Date of sampling
    - Name of sampler
5. Place one copy of the sample form inside the sample bag, and retain the other copy (duplicate) for initial data entry and records
6. Close and seal the bags using staples
7. Place bags in a sturdy cardboard box (not a cooler)
8. Give participating household one (1) kg of good quality shelled groundnuts as a gesture of appreciation
9. Prepare box for shipping or transportation (tape box shut, perforate box with a dozen small holes to allow aeration, and affix a proper address shipping label)
10. Deliver or send sample to the Project's designated aflatoxin testing laboratory (ICRISAT in Lilongwe, ICRISAT in Nairobi).

Sample Processing in the Lab

1. Remove sample from bag and weigh
2. Shell all pods in sample by hand
3. Separate kernels from shells and weigh each component
4. Separate whole, sound kernels from damaged, unsound kernels to create 2 "lots"
5. Weigh each lot

6. Sub-sample each lot and conduct aflatoxin tests on each sub-sample according to the established ICRISAT protocol.

Quality Definitions: Quality determination (whole, sound vs. damaged, unsound kernels) will be based on the definitions for defects (section 3.6 on page 2) of the Kenya Standard for Shelled Groundnut (*Arachis hypogaea* Linn.) – Specification, Part 1: Raw groundnut for table use, Second Edition, 2007, published by the Kenyan Bureau of Standards.

Proposed Protocol for Preliminary Program in 2010: In order to avoid Project staff from being diverted from supervising and analyzing data from the baseline surveys planned for this period in 2010 and to gain valuable experience with the procedures and logistics, the sampling and testing program in 2010 will be limited to a few selected households. This will allow the Project to test and validate the methodology, including preservation of sample integrity during shipment, as well as generate some preliminary results to help guide further testing. A larger, more comprehensive program would then be planned and implemented in 2011. The protocol for this preliminary program is as follows:

1. Select 8 villages at random with equal representation from each targeted District in each country. In Malawi, this would mean four villages per District (Lilongwe and Kasungu). In Tanzania, this would mean two villages per District (Chamwino, Bahi, Kondoa and Dodoma).
2. Select 2 households at random in each of these 8 villages in each country from among the households who participated in both the Postharvest and Child Nutrition surveys (N=160) for a total of 16 households (i.e., 10% of all households in that group).
3. Take samples as soon as possible after harvest and then at 3-month intervals. (It is likely that some households will no longer have any groundnut stocks at the third sampling, perhaps even at the second, depending on the size of the harvest and the household's economic circumstances.)
4. Take all the samples for each sampling period within 2-3 days.
5. Deliver or ship all samples to the designated lab at the same time and as soon as possible following the prescribed sampling procedures (see above)

Appendix E8

PROTOCOL FOR EQUIPMENT TESTING

May 09, 2012

Chitedze Research Station, Malawi

GENERAL INSTRUCTIONS

1. Set up equipment in locations where the workers cannot view each other.
2. Obtain and assign supervisory personal who can direct the work teams and assure that the data is collected accurately.
3. Give training to these supervisors so that they can instruct the workers.
4. Assign a weighing and recording team to record all the information to be collected as note below.
5. Assign teams of three to perform the work. Each team should be composed of the same gender balance.
6. Have a general meeting with all the worker to:
    a. Explain the purpose of the trials
    b. Emphasis that these trials are not a race, but are to determine what could be obtained at a normal work pace. One that could be sustained for a whole day's work.
    c. Explain the need for accurate work, decisions on equipment selection could be determined based upon their measurements.
7. Assign the first teams for the first rotation.
8. We will break for lunch at the appropriate time. And wrap up with the works as assigned even if all the testing is not completed today.

EVALUATION OF STRIPPERS

1. We will evaluate the strippers first:
    a. Hand stripping (control)
    b. Screen stripper
    c. New drum stripper
2. Work will commence on a start or "go" signal and will proceed uninterrupted for 20 minutes.
3. At the end of the 20 minutes teams will be instructed to stop processing and collect their products as follows:
    a. Hand stripper
        i. One pile with prime pods,
        ii. Relook at haulms to see if any prim pods are left on the haulms.

        iii. Take to the weighing station the two piles of pods.

   b. Screen stripper – supervisor to start a time measurement to establish how long the following actions take:

      i. Go through the pile of debris which includes the pods stripped and separate into:

         1. Prime pods,
         2. Damaged pods
         3. Pods left on the haulms
         4. Take the three piles to the weighing station

   c. New drum stripper – again, supervisor will note the time to perform the operations outlined in b) above and ensure that the three piles are weighed.

EVALUATIION OF SHELLERS

IMPORTANT - Keep the debris (trash) in a bag and tagged with the sheller that it came from. We will be attempting to evaluate the ease of winnowing at a later time.

1. We will evaluate the shellers next:
   a. Hand shelling (control)
   b. Large CtoC sheller
   c. CTI sheller
2. Work will commence on a start or “go” signal and will proceed uninterrupted for 20 minutes.
3. At the end of the 20 minutes teams will be instructed to stop processing and collect their products as follows:
   a. Hand shelling
      i. One pile with prime kernels,
      ii. One pile with damaged kernels,
      iii. Take to the weighing station the two piles of kernels.
   b. CtoC sheller – supervisor to start a time measurement to establish how long the following actions take:
      i. Go through the pile of debris which includes the kernels shelled and separate into:
         1. Prime kernels,
         2. Damaged kernels
         3. Pods not shelled
         4. Take the three piles to the weighing station

c. CTI Sheller – again, supervisor will note the time to perform the operations outlined in b) above and ensure that the piles are separately weighed.

F. DATA AND DOCUMENT STORE

Statistical data from the baseline surveys has been stored by Harry Msere, Scientific officer at ICRISAT. Mr. Msere has was also responsible for the statistical analysis of Documents Manager following his participation in the CCRP sponsored Data Flow Management seminar.

CTI has stored and maintained data associated with the technology literature search and field testing data. Literature search data is stored in a Google Drive folder that is accessible to all team members: http://bit.ly/10QNP7l

The team at Sokoine University of Agriculture is storing the data on the nutritional trials in Tanzania.

Team reports are being collected by and stored by Compatible Technology International on a private and secure server.

G. PHOTOGRAPHS AND GRAPHS

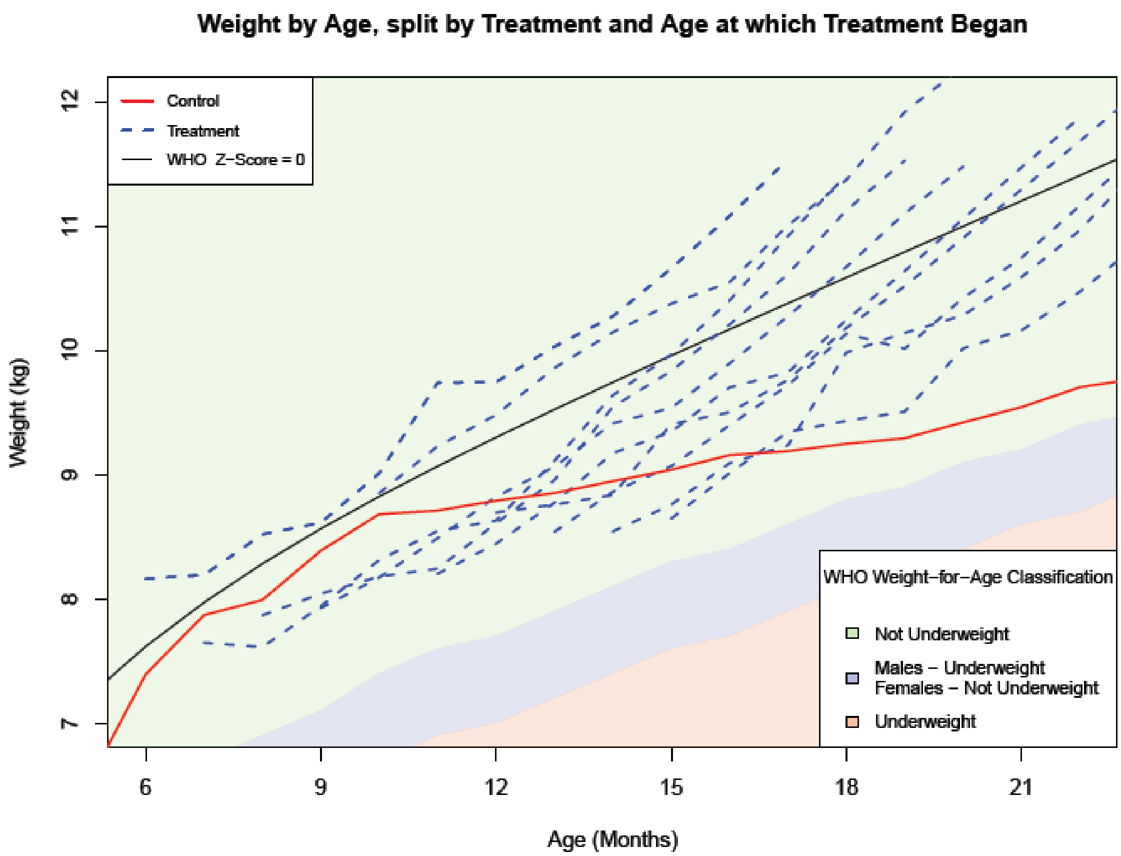
Note: Additional photos and high-resolution images and video are available upon request.

Plate 1: Project Mothers and their children during Stakeholders Meeting.

Plate 2: Project Mothers paying attention during Stakeholders Meeting.

Plate 3: Project Mothers and their children waiting for their children to be measured.

Plate 4: Project Mothers and a father waiting to take weight and height measurement for their children at one of the clinics. An arrow shows a man representing his wife to project activities.


Weight by Age, split by Treatment and Age at which Treatment Began
Control
Treatment
WHO Z−Score = 0
WHO Weight−for−Age Classification
Not Underweight
Males − Underweight
Females − Not Underweight
Underweight
Weight (kg)
Age (Months)
7
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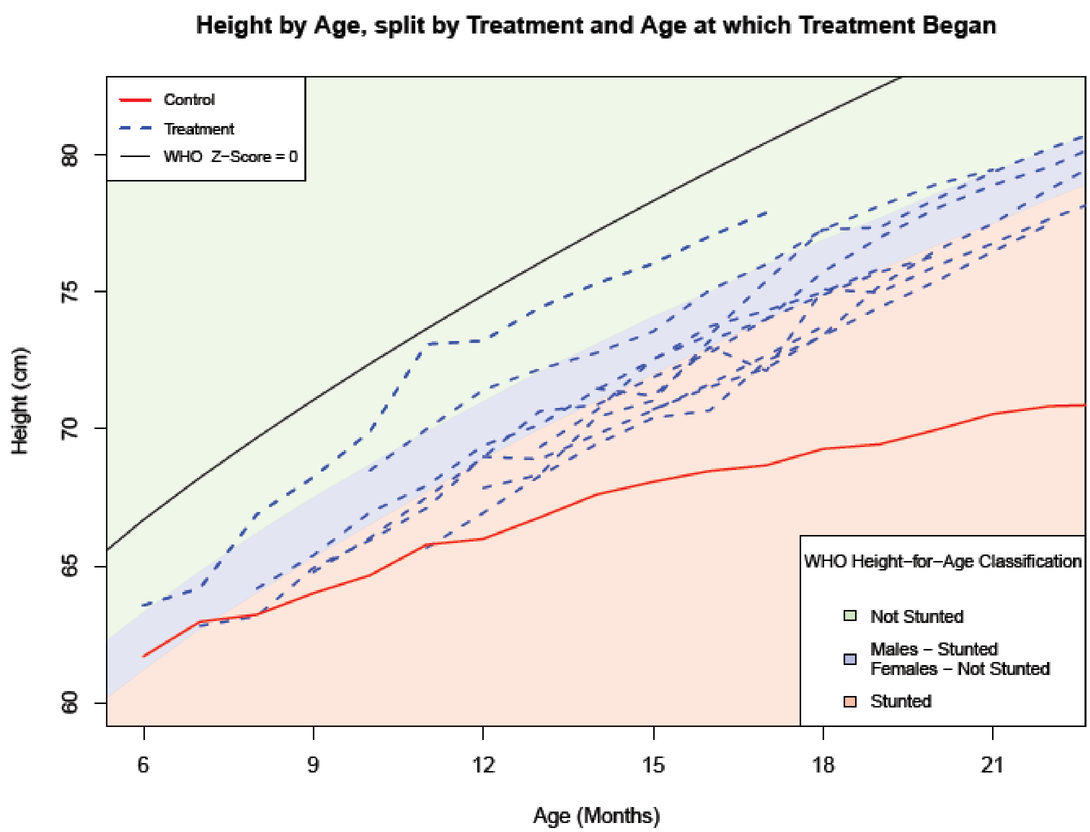

Groundnut Equipment Trials

Table 1: Requirements for Harvest and Postharvest Groundnut Processes*

	Time/labor			Cost of hired labor		
Activity	**Hand Methods** (Person hours / acre)	**CTI Equipment** (Person hours / acre)	**Advantage of CTI Tools**	**Hand Methods** (Malawian Kwacha)	**CTI Equipment** (Malawian Kwacha)	**Advantage of CTI Tools**
Lifting	40-80	6.6	6x – 12x	5,000 / acre	2,528 / acre	2x
Stripping	80	25	3.2x	750 / bag	50 / bag	15x
Sm. Drum Sheller	400	9	44x	750 / bag	60 / bag	12.5x
Disc Sheller	400	4	100x	-	-	-
Sorting	80	25	6x	-	-	-
Total	**600-640 person hrs/acre**	**69 person hrs/acre**	**9x person hrs/acre**	**5,000 MK/Acre + 1,500 MK/Bag**	**2,528.2 MK/Acre + 110 MK / Bag**	**50% savings per acre 92% savings per bag**

*Assuming an average yield of 400 kg/acre

Table 2: Performance of Lifting methods

Method	Production Rate		Cost of hired labor or oxen
	2013 Trials	Farmer Data	
Hand hoe	272 m/hr	.025 acres/hr	K2,528 / acre
Animal-Powered Lifter	2,480 m/hr	.2 acres/hr	K5,000 / acre
% change	**112% increase**	**700% increase**	**50% savings**

Lifting trials in Malawi & Tanzania, 2013

Table 3: Performance of Stripping methods

Method	2013 Trials	Farmer Data	Cost of hired labor / oxen
Hand Stripping	2.4 kg/hr	3 bags /day	K750 / acre
Screen Stripper (A-Frame)	3.6 kg/hr	7 bags /day	K50 / acre
% change	**50% increase**	**133% increase**	**93% savings**

2013 groundnut stripping trials in Malawi & Tanzania

Table 4: Performance of shelling methods for all locations tested in Tanzania and Malawi - 2013

Shelling method	Production Rate		Benefit of Machine	Unshelled Rate	Damage Rate	Cost of hired labor or oxen per bag
	Range kg/hr/ worker	Mean kg/hr/ worker*				
Hand/person	.6 - 1.02	.88	1x	-	-	750 MK
Small Drum Sheller	11.25 - 11.35	11.3	12.8x	4.3%	22%	60 MK
Large Drum Sheller	11.6 – 41.7	21.35	24.25x	0%		-
Disc Sheller	4.84 – 25.2	24	27x	35%	33%	-
C to C	-	44.3		24%	12.6%	-
Arc Zenengeya	-	39		28.5%	2.3%	-

*Values represent winnowed seed, no unthreshed pods

Table 5: Machine output per hour in ICRISAT trials conducted in February 2013 with dry pods

Shelling Method	Whole Nuts, kg/hr	Unshelled Pods, kg/hr	Damaged Nuts, kg/hr	Total Through Put, kg/ hr
Hand	1.1	0	0	1.1
C to C	28.1	10.6	5.6	44.3
Arc Zenengeya	27	11.1	0.9	39

Table 6: Summary 2012 Shelling Trials, May and February—Output per Worker Hour

Shelling Method	Whole Nuts Kg/Hr	Unshelled Kg/Hr	Broken Nuts, Kg/Hr	Total through put, Kg/Hr	Machine—Whole nut Output/Person *Machine wt./ (No. worker) (mean of hand wt.)*
Hand	1.01	0	0	1.01	1X
CTI	25.6	5.2	7.2	38	25.3 X
C to C	29	5.4	9.9	44.3	28.7X

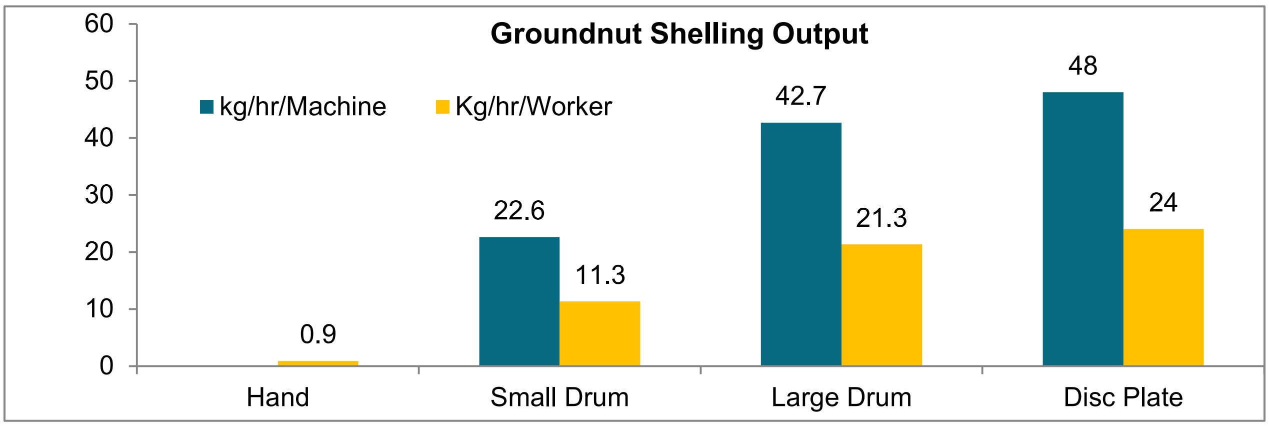

Table 7: Groundnut lifting trials at ICRISAT Chitedze Station in Malawi, 2012

Lifting Method	Gender	CTI Shovel (Minutes)	Conventional Hand-hoe (Minutes)
Test No. 1	Male vs. Female	2.44	1.02
	Male vs. Male (Swarp)	2.52	0.56
Test No. 2	Female vs. Female	6.12	1.48
	Female vs. Female (Swarp)	4.34	1.45
Test No. 3	Male vs. Female	2.44	1.32
	Male vs. Female (swarp)	1.49 (M)	1.22
Test No. 4	Male vs. Female	3.5	1.22
	Male vs. Female (swarp)	1.43	1.08

(Groundnut lifting test duration in all trials of 10.0 meters in minutes)

Table 8: Groundnut stripping trials, ICRISAT — Malawi in May 2011

Stripping method	Whole stripped pods (kg/hr)	Pods still on haulms (kg/hr)	Damaged pods (kg/hr)	% of pods still on haulms	% of pods damaged
Hand picking (control)	11.49	0.615	0	4.97	0

Stationary screen	29.58	2.715	0.66	8.3	1.99
Roller belt	10.17	1.215	2.52	9.34	18.12
Drum beater	18.96	3.936	0.3	16.64	0.16

(20 minute stripping data multiplied by 3)

Table 9: Groundnut stripping trials, ICRISAT — Malawi in May 2012

Stripping method	Output per worker with adjustment for sorting time (Kg/hr)	Efficiency of pods removed
Hand picking (control)	4.02	96.98
Stationary screen	5.80	94.25
Drum	3.26	89.37

Table 10: Groundnut stripping trials — On-Station, ICRISAT-Malawi, May 2012

Stripping method	Whole stripped pods (kg)	Pods still on haulms (kg)	Damaged pods (kg)	% of pods still on haulms	% of pods damaged
Hand picking (control)	13.5	0.402	0	2.89	0.00
Stationary screen	25.5	1.56	0	5.76	0.00
Drum beater	10.26	1.398	0.8802	10.72	7.05

(10 minute stripping data multiplied by 6)

Table 11: Groundnut shelling trials -- On-Farm, Malawi, May 2012

Shelling method	Whole shelled kernel (kg/hr)	Damaged kernels (kg)	Unshelled pods (kg)	% damaged nuts	% of unshelled pods
Hand shelling (control)	5.52	0	0	0.00	0.00
C to C Sheller	31.02	7.2	3.12	17.42	7.55
CTI Sheller	23.22	3.78	4.92	11.84	15.41

(10 minute stripping data multiplied by 6)

Table 12: Groundnut shelling trials -- On-Station, ICRISAT-Malawi, May 2012

Shelling method	Whole shelled kernel (kg)	Damaged kernels (kg)	Unshelled pods (kg)	% damaged nuts	% of unshelled pods
Hand shelling (control)	3.36	0	0	0.00	0.00
C to C Sheller	18.6	5.658	0.54	22.82	2.18
CTI Sheller	12.18	2.382	8.7	10.24	37.4

(10 Minute stripping data multiplied by 6)

Table 13: Length of ridge lifted per hour, , ICRISAT-Malawi, 2013

Type of equipment	Performance (in meters lifted per hour)	Farmer comments
Animal powered lifter	2400-3000	Fast and excellent
Shovel lifter	Very poor	very difficult to work with
Hand hoe (control)	272	Normal

Table 14: Number of farmers that used animal powered lifter, area lifted, duration of lifting and cost of lifting by method of lifting

Farmer No.	Area lifted (acres)	Duration (days)		Cost of hired oxen per acre	Cost of hired labour per acre
		oxen (6 hrs/day)	Hand hoe (8 hrs/day)		
1	2	1.5	12	5000	10000
2	2	1.5	12	5000	10000
3	1.5	1.3	8	3750	7500
4	1.5	1.3	8	3750	7500
5	1	0.75	6	2500	5000
6	1	0.75	6	2500	5000
7	1.5	1.3	8	3750	7500
8	1	0.75	6	2500	5000
9	1	0.75	6	2500	5000
10	1.5	1.3	8	3750	7500
11	1.5	1.3	8	3750	7500
12	1.5	1.3	8	3750	7500
13	1	0.75	6	2500	5000
14	1	0.75	6	2500	5000
15	0.5	0.38	3	1750	2500
16	1	0.75	6	2500	5000
17	1	0.75	6	2500	5000
18	1	0.75	6	2500	5000
19	1	0.75	6	2500	5000
20	1.5	1.3	8	3750	7500
21	1	0.75	6	2500	5000
22	0.5	0.38	3	1750	2500

23	2	1.5	12	5000	10000
24	1.5	1.3	8	3750	7500
25	2	1.5	12	5000	10000
26	1	0.75	6	2500	5000
27	1.5	1.3	8	3750	7500
28	1	0.75	6	2500	5000
Totals	35.5	28.21	204	89750	177500
Average area (acres) lifted per day	1.3		0.2		
Average cost per acre				2528.2	5000

Table 15: Number of farmers that used A-farm stripper, Number of bags stripped per day, duration of stripping and cost of stripping by method of lifting

Farmer No.	Number of of unshelled bags sripped	Duration (days)		A-Frame stripper hiring cost	Hand stripping hiring cost
		A-Frame (6 hrs/day)	human (8 hrs/day)		
1	20	3	8	1000	15000
2	21	3	8	1050	15750
3	15	2	6	750	11250
4	11	2	4	550	8250
5	17	3	6	850	12750
6	10	2	4	500	7500
7	15	2	6	750	11250
8	9	1	3	450	6750
9	8	1	3	400	6000
10	10	2	4	500	7500
11	11	2	4	550	8250
12	7	1	3	350	5250
13	10	2	4	500	7500
14	25	4	9	1250	18750
15	15	2	6	750	11250
16	26	4	10	1300	19500
17	18	3	7	900	13500
18	17	3	6	850	12750
19	12	2	5	600	9000
Totals	**277**	**42**	**104**	**13850**	**207750**
Average bags per farmer	**13.85**				
No of bags per day for A-frame stripper	7				
No of bags per day for hand stripping	3				
Time (days) taken to strip one bag		0.15	0.37		
Stripping cost per	(MK/bag)			**50.0**	**750.0**

bag					

Table 16: Output (kg shelled) per person per hour for different types of shellers by gender

Type of sheller	**Out put (kg/hr)**	
	Male	Female
Hand	1.2	0.98
Larger disc sheller	21.3	23.1
Small drum sheller	22.62	11.31
Larger drum sheller	12.36	26.74

Table 17: Farmers, bags shelled, duration of shelling and cost of of labour

Farmer Number:	Bags in pod	Duration (days)		Cost of hired drum sheller	Cost for hand shelling
		Drum sheller (6 hrs/day)	Hand shelling (8 hrs/day)		
1	20	2	60	1200	15000
2	21	2.1	63	1260	15750
3	15	1.5	45	900	11250
4	11	1.1	33	660	8250
5	10	1	30	600	7500
6	10	1	30	600	7500
7	15	1.5	45	900	11250
8	9	0.9	27	540	6750
9	8	0.8	24	480	6000
10	12	1.2	36	720	9000
11	7	0.7	21	420	5250
12	11	1.1	33	660	8250
13	7	0.7	21	420	5250
14	10	1	30	600	7500
15	25	2.5	75	1500	18750
16	15	1.5	45	900	11250
17	26	2.6	78	1560	19500
18	17	1.7	51	1020	12750
19	12	1.2	36	720	9000
Totals	**261**	**26.1**	**783**	**15660**	**195750**
Average no. of bags per farmer	**13.7**				
Bags shelled per day by drum sheller	**10.0**				
Bags shelled per day by hand	**0.3**				
Cost of shelling per bag (MK)				**60.0**	**750.0**

Traditional digging vs. shovel lifter tested at ICRISAT Chitedze Station in Malawi, 2012

Oxen-powered lifter field tested in Malawi, 2013

Screen Stripper with A-frame field tested in Malawi in 2013

Stripped nuts output with Screen Stripper vs hand stripping

Disc Sheller

Small Drum Sheller

Large Drum Sheller


CTI Sorter


CTI Sorter