

# **VT 134: Improving the health and livelihood of people of East Africa by addressing aflatoxin and gender-related constraints in peanut production, processing and marketing**

## **Peanut CRSP five year report on activities: 2007 - 20012**

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- Importance of Technical Achievements-Host Country, US
- Importance of physical and human capacity development-Host Country, US
- Heritage left from workshops and short-term training-Host Country, US
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## **Final Summary of Accomplishments by Objective-for each objective active for all or part of 2007-2012 phase.**

- **Objective 1:** Food Science/Risk assessment: Carry out aflatoxin risk assessment in the region in order to get exposure data and how hazardous aflatoxins are to local consumers.
- **Objective 2:** HACCP and Certification: Evaluate aflatoxin contamination and physico-chemical composition of locally processed peanut products during storage and develop HACCP plan for small scale peanut processors and cottage industries.
- **Objective 3:** IEC: Develop information Education and Communication (IEC) materials for Aflatoxin awareness at grassroot and higher level as well as conduct training workshops to address the issue.
- **Objective 4:** Build capacity to identify and address aflatoxin issues through training of students, researchers, processors, women's groups, farmers and government/extension personnel.
- **Objective 5:** FTIR: Develop Non-destructive Rapid Deduction System to Test for AF in Peanuts and Peanut Products using Fourier Transformation Infrared spectroscopy with Attenuated Total Reflection (FTIR-ATR) or Photo Acoustic Spectroscopy (FTIR-PAS).
- **Objective 6:** Ethnographic research: Qualitative, ethnographic research in selected households in urban and rural areas of Kenya and Uganda to document cooking practices involving peanuts, clay-eating practices, and identify opportunities for mitigating or reducing aflatoxins in diet
- **Objective 7:** Identify clays in the region that can bind to AF and reduce its toxicity, building on prior Peanut CRSP research. Explore the feasibility of using locally available clays in Kenya and Uganda as a product to supplement in animal feed and human diet for mitigating aflatoxin poison.
- **Objective 9:** Livelihoods - Working with women's organizations and cooperatives, develop livelihood strategies and models for reducing poverty and malnutrition in rural areas via value addition in peanuts.

## **Overall Goal**

The overall goal of the project was to improve food security and nutritional value for families producing peanuts through reduction of aflatoxin contamination throughout the crop's value chain. The project activities focused on assessing the role of peanut production

practices, handling, transportation, storage, processing and packaging on aflatoxin contamination, and proposed necessary intervention strategies on minimizing the contamination. The role of regulatory agencies on aflatoxin management and raising awareness among the stakeholders was also assessed. The project also identified and documented value-added opportunities with small-scale peanut growers and processors and recommended how women who are the main players in peanut production and trade could be empowered. By working with women's organizations, it sought to directly empower women as well as use women's networks to extend information and education materials about peanuts and aflatoxins.

### ***Significant challenges***

Two primary challenges stand out. One is in regards to students: weak institutional support in host country universities, poor advising, and poor entry level of education in several cases, which affected students' abilities to complete their work. The second is the uncertainty of funding and timing of release of funds due to USAID.

### **Capacity Development, i.e. Laboratory, Field, Equipment:-Host Country, US**

#### **Human Capacity/Training:**

Name	Gender	Country	Degree	Completion Date	Where Trained	Significant Employment
Charity Mutegi	F	Kenya	PhD	9/30/2012	Host Country	
Hande Kaya Celiker	F	USA	PhD	9/30/2012	US	
Sophie Nansareko	F	Uganda	MSc	2012	Host Country	
Helene Nyirahakizimana	F	Kenya	MSc	January 2013	Host Country	
Johnson Weru	M	Kenya	MSc	Mid 2013	Host Country	
Rose Kabagyenyi	F	Uganda	MSc	January 2013	Host Country	
Rosina Wanyama	F	Kenya	MSc	Mid 2013	Host Country	
Winifred Nyambura Selle	F	Kenya	MSc	July 2013	Host Country	
Sylvia Tereka	F	Kenya	MA		Host Country	

Caroline Bazarrabusa Horn	F	Uganda	MA		Host Country	
Ruth Muwesa	F	Uganda	MA	Completed	Host Country	
David Tumwesige	M	Uganda	MSc		Host Country	
Lydia Nakagiri	F	Uganda	BSc	2010	Host Country	
Henry Momanyi	M	Uganda	MSc	Mid 2013	Host Country	
Carlyn Ray	F	USA	PhD	9/30/2009	US	
David Makori	M	Kenya	MSc		Host Country	
Ayub Kimani	M		Short-term	9/30/2009	Host Country	
Lucy Karanja	F		MSc		Host Country	

#### Key Workshops/Short-Term Trainings:

Location of Training	Training Type	Number of Male Participants	Number of Female Participants
Nairobi, Kenya	HACCP workshop	10	9
Nairobi, Kenya	Student sharing	2	3
Kampala, Uganda	Workshop	20	15
Nairobi, Kenya	HACCP workshop	11	7
Busia, Uganada	Workshop	2	0
Kampala Uganda	HACCP workshop	7	9
Kampala Uganda	HACCP workshop	8	12
Mubende Uganda	Workshop	6	31
Kamuli Uganda	Workshop	5	10
Makerere Uganda	Workshop	0	2
Uganda	Short-term training	27	66
Bulogo Uganda	Short-term training	10	20

Kamuli Uganda	Short-term training	22	18
Kamuli Uganda	Workshop	15	12
Kampala Uganda	Seminar	1	8
Nairobi Kenya	Seminar	12	13
Kampala Uganda	Workshop	10	10
US	Workshop	1	0
Kampala Uganda	Workshop	20	20
Kampala Uganda	Short-term training	5	15
Kampala Uganda	Short-term training	5	15
Kampala Uganda	Short-term training	5	15
Kampala Uganda	Short-term training	5	15
Kampala Uganda	Short-term training	5	15
Kampala Uganda	Short-term training	5	15
	<b>Totals:</b>	219	355

## Uganda - Report on activities: July 1, 2008 to December 31<sup>st</sup>, 2012

**Technical achievements** - Fourteen main activities were implemented during the five years period as follows highlighting the major achievements: (1) four activities under objective 1 – Conducted a survey to established peanut consumption in the country in order to estimate aflatoxin exposure risks, sampled peanut-based products and established the safety in terms of aflatoxin contamination, documented for the first time, locally processed peanut food products and determined their aflatoxin and physico-chemical characteristics. We also determined the microbial contamination of selected infant peanut-based food products found on the market. In addition, the results obtained enabled us to write and present papers in a number of international meetings. (2) Two activities under objective 2 – Achievements included training of over 50 small-scale peanut processors in HACCP principles, establishment of Critical Control Points along the peanut value chain as well as generating a Master of Science thesis on application of HACCP in

managing common hazards in small-scale peanut paste processing industries in Uganda. Linkage was also established with two important organizations in the country: VECO and UCA who joined the project in the implementation of HACCP. (3) Four activities under objective 3 - These centered on people's awareness of aflatoxin problem and management strategies and included holding meetings with farmers, processors and traders, development of simple IEC materials (calendars and posters) as well as use of media (radio and newspapers) to convey messages on aflatoxin dangers and management to the public. (4) Two activities under objective 4 - Training of scientists at undergraduate and graduate level as well as training of technical personnel on various aspects of aflatoxin research and gender-sensitive, qualitative, participatory research methods. (5) One activity under objective 5 - Acquisition of FTIR equipment and its use in analyzing aflatoxin content in peanuts. (6) Several activities in conjunction with the National Association of Women Organisations in Uganda (NAWOU) and with the Women and Gender Studies Department at Makerere University to investigate the gender aspects of peanut post-harvest activities and empower women to improve management practices to reduce the contamination through strengthening women's network. (7) One activity under objective 7 - Testing for bentonite among the clays sampled Uganda and its ability to bind aflatoxins.

**Capacity development** - The project, through purchase of the FTIR equipment and aflatoxin analytical consumables, strengthened infrastructure and operations for analyzing aflatoxins at the Department of Food Technology and Nutrition, Makerere University. These consumables enabled us to determine aflatoxin content of peanut based foodstuffs farmers, traders and processors who participated in the study. This information formed the basis upon which Uganda National Bureau of Standards (UNBS) set its 10 ppb aflatoxin regulatory limits in grains in Uganda.

**Human capacity/training** - One undergraduate and eleven post graduate students (6 MSc, 3 MA, and 2 PhD: 1 male and 10 females) were supported. These included the undergraduate student of Food Science and Technology, Ms Lydia Nakagiri, who researched on physico-chemical and aflatoxin content as well as shelf life of peanut-based processed food products and graduated in 2010, the MSc student, Sophie Nansereko who completed her MSc in Applied Human Nutrition at Makerere University in 2012 and researched on application of HACCP in managing common hazards in small scale peanut paste processing industries in Uganda, the MSc student, Rose Kabagyenyi ( yet to complete) at Makerere University and evaluated the communication strategies used by Peanut CRSP in aflatoxin prevention and control in peanuts in Mubende district, the MSc student, David Tumwesige (yet to complete) at Makerere University, researching on Enhancement of the nutrient content of peanut butter using Moringa Leaf Powder. Three other Masters students (Ms. Ruth Muwesa, Caroline Bazarrabusa Horn and Ms. Sylvia Tereka) from the School of Women and Gender Studies, Makerere University were supported by the Project to undertake their field research in aflatoxin-related ethnographic studies. A PhD student, Hande Kaya Celiker completed her training in 2012 at Virginia Tech and her studies were on Rapid evaluation of Aflatoxin in Peanuts using FTIR. A Ph.D. student at Virginia Tech's Human Nutrition, Food, and Exercise Department, Carlyn Rae, completed coursework but

did not pass preliminary exams to carry out fieldwork; she was not funded by Peanut CRSP, though she was advised by the team of PIs and was aiming to work in our site in Uganda.

The other person who was trained and also got fully engaged in project activities was Mr. Benjamin Sentongo, a Chief Technician from the Department of Food Technology and Nutrition, Makerere University. He received a one-month hands-on training on the use of the FTIR equipment in the Department of Biological Systems Engineering, Virginia Tech.

**Key workshops/short term training** – The project supported its scientists to participate in national and international meetings and short term training. By the end of five years, a total of six (6) Scientific papers had been presented in international meetings in Europe, Africa, USA and South America while over 10 scientific papers were presented in meetings held in Uganda. This enabled sharing of information with scientists as well as establishment of collaborative linkages. Several short term training courses were organized by Kumar and Kaaya to train peanut processors and traders from Kampala, Busia, Mbale, Tororo and Kumi on HACCP Principles. The skills gained have helped the trainees to improve the quality of their peanut products thus now supplying supermarkets.

**Publications** – The following is a list of publications from the project findings and their status:

- Farmers' Stories from Kamuli: Groundnut knowledge, recipes and everyday life. A book published by DESIGNiT, Ltd. Kampala-Uganda. 2010.
- Farmers' Stories from Mubende. Importance of groundnuts in our daily lives. A book published by DESIGNiT, Ltd. Kampala-Uganda. 2011.
- Barriers and motivational factors to HACCP implementation in small scale peanut processing industries in Uganda: a case study of Kampala district. To be submitted to Journal of Biological Sciences.
- Kaya-Celiker, H., Mallikarjunan, P., Dalay, O. and Kaaya, A.N. 2013. Determination of aflatoxin level in peanut paste using Fourier transform mid-infrared spectroscopy with attenuated total reflection. Submitted for publication in Food Chemistry.
- Kaya-Celiker, H., Mallikarjunan, P., Schmale III, D., and Kaaya, A.N. 2013. Mid-infrared spectroscopy for discrimination and classification of *Aspergillus* spp. contamination in peanuts. Submitted to Food Microbiology.
- Kaya-Celiker, H., Mallikarjunan, P., Schmale III, D., and Christie, M.E. 2013. Classification and discrimination of moldy peanuts with respect to aflatoxin contamination level using Fourier transform infrared spectroscopy coupled with attenuated total reflectance unit. Submitted to Food Control.

## **Final Interpretation**

### **Importance of technical achievements**

- Peanut is a very important crop in Uganda, and is included in the Ugandan diet at least once a day. Based on the consumption studies conducted, women and children consume most of the peanuts.

- Aflatoxin contamination of peanuts in Uganda is still a problem and thus, consumers of this crop are at high health risk. However, we believe that with continued awareness campaigns and technical advice on management strategies, the economic and health effects of this problem can be minimized. Fortunately, farmers, traders and processors are willing to participate in the management strategies.
- UNBS which is the Government of Uganda regulatory body needs to come out strongly in the implementation of the standards set for aflatoxins in staples in Uganda including peanut. This can work hand-in-hand with the extension arm in the Ministry of Agriculture (NAADS) with support from ministry of Trade, Industry and Cooperatives (MTIC) and Ministry of Health (MoH).
- Peanut processors and traders need to implement HACCP principles as a major tool in aflatoxin management. However, this requires a holistic approach since there are so many key players in the peanut value chain.
- Peanut is a feminine crop in Uganda. Thus, women are the key players in peanut production and trade. There is therefore need for capacity building of women at all levels: farmers, students, district and village level women's organization leaders, members of parliament and other policy makers to help boost this sector of agriculture in the country.
- There is potential in peanut value addition as a possibility to raise farmers' household incomes above the poverty line. Policies should therefore be put in place to empower small-scale growers, particularly women both in production and value addition.
- A diversity of value adding options should be explored and adopted to sustainably improve peanut farmers' livelihoods.

### **Importance of physical and human capacity development**

- In Uganda, it is only Makerere that has a laboratory for aflatoxin analysis. However, this lab is not yet accredited and the methods used are expensive, not affordable to small-scale processors. Thus, the support given through purchase of consumables and equipment needs to continue. More aflatoxin simple and rapid tools need to be purchased to enable routine testing of foodstuffs.
- More scientists in Uganda need to be trained in the area of aflatoxin management to enhance awareness and research. The training can be at postgraduate level as well as short courses using simple IEC materials and targeting specific stakeholders like technicians, farmers and traders. Special emphasis need to be put on training women who are major players in the peanut value chain.

### **Heritage left from short-term training**

- Increased awareness about aflatoxin in peanuts and how to manage it throughout the production chain using simple IEC materials and cost effective methods (HACCP) as a preventive strategy.

### **Heritage left in publications**

- Kamuli and Mubende Handbooks – Have been distributed to farmers and farmer groups in the country, libraries at Makerere University, NAWOU, NARO and Ministry



of Agriculture among others. These will spread the message on how farmers value peanut in their daily lives and how aflatoxin can negatively impact on the values attached to peanut.

## **Kenya - Report on activities: February 1, 2009 to to December 31<sup>st</sup>, 2012**

**Technical achievements** - Eleven main activities were implemented during the four years period as follows highlighting the major achievements: (1) Two activities under objective 1 – Determination of fungal infection and levels of aflatoxin in various peanut products marketed in Kenya. The health risk posed to consumers of products which did not meet regulatory standards set by the Kenya Bureau of Standards was also assessed. (2) Six activities under objective 2 – Achievements included HACCP training; determination of effects of storage conditions on the population of *Aspergillus* section *Flavi* and aflatoxin levels in peanuts and peanut products; determination of genetic diversity of peanuts in Kenya and the possible role of the diversity as a source of resistance to aflatoxin contamination; comparative advantage of different statistical analysis approaches in handling complex data on factors influencing aflatoxin contamination and their interaction. (3) Three activities under objective 3 – development of awareness raising materials (video and a handbook) on aflatoxin management. (4) Two activities under objective 4 – Training of scientists and other personnel on various aspects of aflatoxin research. (5) One activity under objective 9 – Role of gender in peanut value addition and how women can be empowered to strengthen peanut production and trade in Kenya.

**Capacity development** – The project through purchase of various equipment and consumables, strengthened infrastructure and operations at the Centre for Agricultural Bioscience International (CABI) aflatoxin analysis laboratory. Some of the equipment purchased through the project funds include: ELISA reader, incubator, shaker, oven, autoclave and two digital balances. Other institutions such as CIMMYT and KARI have used the lab to conduct research on aflatoxin and microbial analysis on maize during the project's lifespan.

**Human capacity/training** - Five post graduate students (4 MSc and 1 post-doc – 4 females and 2 males) have been supported by the project under the HACCP objective and one (MSc) under the livelihoods objective. These include: (i) Dr. Charity Mutegi - Post-doc at ICRISAT-Nairobi (2009 – 2012), female – working as the Kenya Country Coordinator, Aflasafe Project with IITA in Kenya. (ii) Rosina Wanyama (Female) – pursuing MSc. in Agricultural and Applied Economics at Egerton University, Kenya, (2011 – to date) – Female. (iii) Helene Nyirahakizimana (Female) - Pursuing MSc. in Microbiology at Chepkoilel University College, a constituent college of Moi University, Kenya (2010 – to date). (iv) Winifred Selle (Female) - pursuing MSc. in Genetics at Jomo Kenyatta University of Agriculture and Technology, Kenya (2010 – to date). (v) Johnson Weru (Male) - pursuing MSc. Food Science and Technology at the Jomo Kenyatta University of Agriculture and Technology, Kenya (2010 – to date). (vi) Henry Momanyi (Male) - pursuing MSc. in

Research Methods at Jomo Kenyatta University of Agriculture and Technology Kenya (2011 – to date).

Other personnel who have been trained by or engaged in the project include: (i) Dr. Maina Wagacha - Visiting Scientist at ICRISAT-Nairobi (2010 – 2012), Male – working as a Lecturer at the school of Biological sciences, University of Nairobi, Kenya. (ii) Ayub Gikaru (Male) – Holds a BSc in Biological Sciences from Moi University and he worked as a technician for the project. He was trained on the Indirect Competitive Elisa technique for aflatoxin analysis and microbial analysis. He is currently pursuing MSc. in Crop Protection at the University of Nairobi. (iii) Gordon Otieno (Male) – Holds MSc in Agricultural Entomology, and he was trained on the Indirect Competitive Elisa technique for aflatoxin analysis and also in collection of survey data as well as simple analytical tools for analyzing baseline data. (iv) Lucy Karanja (Female) - pursuing MSc in Microbiology and Biotechnology at the University of Nairobi. She was trained in isolation and identification of *Aspergillus* section *Flavi*.

**Key workshops/short-term training** – Training on HACCP in Nairobi where 19 traders and processors participated. The training was facilitated by Dr. Kumar Mallikarjunan (From Virginia Tech, USA) and Ms. Margaret Kroma (Kenya Bureau of Standards).

**Publications** – The following is a list of publications from the project findings and their status:

- i. Incidence of aflatoxin in peanuts (*Arachis hypogaea* Linnaeus) from markets in Western, Nyanza and Nairobi Provinces of Kenya and related market traits - Published in the Journal of Stored Products Research.
- ii. Market attributes and their effect on levels of aflatoxin in peanuts (*Arachis hypogaea* Linnaeus) from Nairobi and western Kenya - presented at the Biennial KARI conference held between 8<sup>th</sup> and 12<sup>th</sup> November 2010.
- iii. Fungal species isolated from peanuts in major Kenyan markets: Emphasis on *Aspergillus* section *Flavi* – To be submitted to the Journal of Phytopathology.
- iv. Effect of storage conditions on quality, fungal population and aflatoxin contamination of peanuts - to be submitted to the Journal of Stored Products Research.
- v. Factors that predispose peanut butter to aflatoxin contamination in the cottage industry in Nairobi, Kenya – Drafted from the findings of Johnson Weru; in the final stages for submission to the Journal of Applied Biosciences.
- vi. Principal Component and Multiple Correspondence Analyses in Dimensionality Reduction: A Study on Aflatoxin Contamination of Peanuts in Kenya - Drafted from the findings of Henry Momany for submission to Statistical Methodology Journal.
- vii. A gendered analysis of the determinants and effect of peanut value addition on household income in Rongo and Ndhiwa districts, Kenya - Drafted from the findings of Rosinas Wanyama for submission to the Current Research Journal of Social Sciences.
- viii. Other publications:

- a. Tackling the aflatoxin menace in groundnuts in Kenya – A video. 500 copies produced and distributed to partners in 17 institutions.  
Link: <http://youtu.be/FfDuryYjkMU>
- b. Aflatoxin management along the groundnut value chain in Kenya – A Handbook. An advanced draft has been generated and shared with the publisher; the draft is in the final stages of formatting and editing.

## **Final Interpretation**

### **Importance of technical achievements**

- Sufficient data has been collated to develop an integrated approach to handling aflatoxin contamination in peanuts in Kenya.
- Based on the diverse fungal pathogens isolated from the peanut samples, there is a risk of contamination of peanut products by other mycotoxins. Future initiatives should focus on management of the diverse fungal pathogens and associated broad spectrum of mycotoxins contaminating peanuts.
- Consumers of peanuts and peanut products in Kenya are at a health risk from consumption of aflatoxin contaminated products which do not meet the 10 µg/kg regulatory standards set by the Kenya Bureau of Standards. Awareness raising of the health risks and efforts by stakeholders along the peanut value chain on reduction of aflatoxin levels are required.
- Proper targeting for awareness raising established.
- There is need for strengthening government regulatory agencies associated with aflatoxin management for more efficient monitoring and enforcement of safety standards in Kenya.
- Women are the key players in peanuts production and trade. There is therefore need for capacity building of women at all levels: students, farmers, district and village level women's organization leaders, and a national network.
- There is potential in peanut value addition as a possibility to raise farmers' household incomes above the poverty line. Policies should therefore be put in place to empower small-scale growers, particularly women both in production and value addition.
- A diversity of value adding options should be explored and adopted to sustainably improve peanut farmers' livelihoods

### **Importance of physical and human capacity development**

- The CABI aflatoxin analysis laboratory established with the support of the Peanut CRSP project provides necessary infrastructure for aflatoxin research in Kenya. However, it needs to be pointed out that there is still need to a fully operational aflatoxin analysis lab based in a public institution for access of services to the general public.
- Strengthened capacity for research on and management of aflatoxins in Kenya through the training of post-graduate scientists and a technician in diverse disciplines.

- Highlighting the role of gender in peanuts production, trade and the possible role of women in improving peanut production and management of aflatoxin contamination.
- The trained personnel are expected to play an advisory role to the Government of Kenya on how to approach the aflatoxin contamination in the country.

### **Heritage left from short-term training**

- Increased awareness about aflatoxin in peanuts and how to manage it throughout the production chain using cost effective methods (HACCP) as a preventive strategy.
- Success of the HACCP workshop also led to the inclusion of HACCP training in other key commodities in KARI, especially in the horticultural sector.

### **Heritage left in publications**

- Video – A long-term training tool/material in raising awareness among stakeholders on integrated strategies on aflatoxin management in peanuts along the crop's value chain; the effects of aflatoxin on the human health as well as on economic development and trade.
- Handbook – A long-term training material to be used by various players (mainly extension officers) in the peanut value chain and consequently raising awareness on aflatoxins and aflatoxin management strategies bot pre and post-harvest. It is anticipated that the extension workers will use the handbook in their extension services sensitizing farmers, traders and end users on peanut handling aspects, quality and market. It is hoped that by using this teaching tool, aflatoxin contamination of peanuts in Kenya will be minimized.
- Publications in peer-reviewed journals and presentations in conferences – This will primarily communicate to the scientific community and it is hoped that this will create greater interest in aflatoxin research in Kenya. The findings will also be shared with relevant government institutions (mainly Kenya Bureau of Standards, Ministries of Agriculture and Public Health & Sanitation – who have been partners in the project) with a view to prompting action and guiding future policy in aflatoxin management in peanuts and peanut products.

## **Final Summary of Accomplishments by Objective-for each objective active for all or part of 2007-2012 phase.**

**Objective 1:** Food Science/Risk assessment: Carry out aflatoxin risk assessment in the region in order to get exposure data and how hazardous aflatoxins are to local consumers.

### **Uganda:**

Four activities were conducted under objective 1.

**Activity 1:** A survey was conducted in four major peanut growing regions of Uganda i.e. western, central, eastern and northern and Kampala district as as urban area. This activity had the following objectives: 1) To generate peanut consumption data in Uganda in order

to predict exposure of people to aflatoxin contamination; 2) To establish individuals more exposed to aflatoxin risk in the community; 3). To establish the season when most people are exposed to aflatoxin hazard; 4) To document peanut products sold in Uganda and 5) to establish aflatoxin contamination of peanuts from households and markets in Uganda..

In each survey region, districts with the highest peanut production data were purposively picked after adjusting for other factors. These were Hoima, Mukono, Kamuli, and Lira districts in western, central, eastern and northern regions respectively. In addition, Kampala district as an urban area was also surveyed. Since one of the end-results of this study was to disaggregate peanut consumption data in terms of gender and age (children, men and women) within the selected districts, the survey targeted two population groups: women of reproductive age (15-49 years) and children 2-5 years. Two types of data were collected. The food frequency technique was used to collect qualitative information as to the number of days in the 7-day period preceding the interview; the reference woman and reference child had consumed peanuts in any form. The survey also collected quantitative consumption of peanuts and peanut-based dishes by the reference woman and reference child using a modified 24-hour recall method. Sampling of peanut from households and markets was done and these were analyzed for aflatoxin contamination.

**Achievements** –The study revealed that peanut is highly consumed by the majority of households in the in all regions in Uganda. The harvest peak seasons are July – August and December – January. The results further indicated that the number and proportion of households where peanut are consumed are almost the same for women and children. This is mainly because children quite often eat what their mothers consume. In fact, sometimes they eat from the same plate. In the majority of the districts, it was established that the highest proportion of children had consumed peanuts 1 – 2 days prior to the interview while the least proportion had consumed peanuts 6 – 7 days.

Results further indicated that peanuts are consumed in three broad forms: 1). As snacks as raw, boiled/steamed and roasted seeds; 2). As sauce/stew either alone as a single ingredient dish or in combination with legume seeds especially beans, green leaves, meat and fish as a mixed dish and 3). In combination with staple roots, tubers and plantain as a mixed dish. Out of these three, most of the peanut is consumed in form 2, perhaps explaining equal proportions in which women and children consume it since sauces are often shared meals.

Results of aflatoxin contamination showed that majority of the samples (85%) were contaminated with aflatoxin and of these almost half (48%) had levels above 20 ppb FDA recommended levels. These results further confirmed earlier findings when aflatoxin content in peanuts from farms in Uganda was determined, proving that aflatoxin contamination of peanuts starts from the farm.

**Consequences/Significance** – As a consequence of the peanut survey and the levels of aflatoxins established in the nuts, the Uganda National Bureau of Standards (UNBS) took key interest in using the data to develop standards for the agricultural produce in Uganda.

In addition, these results were the basis for the development of the HACCP Plan to use by processors as part of the aflatoxin management procedures.

**Activity 2:** Sampling of peanut-based products and establishment of their quality and safety. In this activity, we wanted to achieve 3 objectives: 1) Document peanut-based products sold on Ugandan market; 2) Establish aflatoxin contamination and their changes during storage; 3) Establish whether processing peanut into products is an important activity in comparison to other products like those of soya, corn, and other cereals 4) Establish the physico-chemical composition (nutrients) of the peanut-based products and their changes during storage. The peanut-based foods were sampled from markets and processing companies in Uganda and stored for three (3) months simulating conditions under which they are stored in retail stores, in order to establish changes in aflatoxin and physico-chemical composition. The products were documented and also analyzed for aflatoxins and physico-chemical composition. .

**Achievements:-** The study documented a total of 20 locally processed peanut food products susceptible to aflatoxin contamination . Their processors and target groups were also documented. The results show that, peanut is a major ingredient in many of these products. The majority of these food products are targeting infants who are the most susceptible to aflatoxin poisoning. Thus, there is the need to ensure that processors of these foods are assisted to produce products free from aflatoxin contamination. Results also showed that aflatoxin contamination of some of the processed products especially those containing soya was more contaminated than peanut-based products. Aflatoxin content increased in more than 50% of the products with storage time which makes them unsafe for consumption. One sample had 240 ppb aflatoxin levels. This increase may be attributed to failure of the package to resist moisture entry and subsequent mould growth. It was observed that in many products (10 out of 15), moisture content increased while in a few products it slightly reduced implying that either the packages used were not appropriate or the sealing was not properly done.

Results of the physico-chemical composition analyses showed a significant decrease in all the major nutrients (fat, protein and fiber) which is a sign of deterioration. This decrease may also be associated with the package integrity. For example, fat reduction could be as a result of rancidity following exposure to light. Indeed, when opened, most of the products produced an offensive off-odor characteristic of rancidity. Majority of the packages used could not prevent light and, together with entry of air and moisture, fat and protein degradation were inevitable.

Some of these foods had expiry dates indicated on the package ranging from six months to one year. Since the nutrients are changing within a period of three months, it may imply that these dates need to be revised by the manufacturers. This was the first time shelf life studies were conducted on these products in Uganda and therefore this information is very relevant to manufacturers who just guess the expiry periods of their products.

The results of this activity led to writing a paper entitled “Fungal and aflatoxin contamination of processed peanut-based products of Uganda and was presented at the

International Society for Mycotoxicologists (ISM) conference in Vienna/Tulln, Sept. 9 – 11, 2009.

**Consequences/Significance:** Documentation of peanut-based products in this country was done for the first time and provided information to Government of Uganda that peanut processing is an important activity in the country which should be promoted to reduce importation of peanut processed products. Since some of the processed products especially those containing soya are more contaminated with aflatoxin than peanut-based products, aflatoxin management strategies should be holistic than focusing on peanut alone.

The study also established that most peanut processors do manufacture other products which are susceptible to aflatoxin contamination. It is therefore important that Good Manufacturing Practices (GMP) as well as Standard Operation Procedures (SOP) are followed by processors to avoid cross-contamination.

During the ISM meeting, sharing of information was done with other scientists and, linkages were established with scientists from South African Medical Council and MYCORED Club which is a global network on mycotoxins and toxigenic fungi control. Dr. Kaaya became a member of the International Society of Mycotoxicologists (ISM) during this meeting.

**Activity 3.** We determined the microbial contamination of selected infant peanut-based food products identified in activity 2. Although not included in the work plan, it was deemed necessary to further determine the safety of these foods by establishing the range of microorganisms that contaminate these foods including those that produce mycotoxins. This formed the objective of this activity. Furthermore, this information is important since fungal incidence predicts the extent of aflatoxin contamination of the food products. Two methods were used to determine microbial contamination; the direct plating technique for food samples in form of solid bars or grain/kernel form, and the dilution technique for food samples in granular or flour form. Thus, in the former, microbial contamination was reported as incidence (%) while in the latter, microbial contamination was reported in colony forming units per gram sample (cfu/g).

**Achievements:** Microbiology results showed that the peanut-based infant food products are contaminated with a wide range of microorganisms including bacteria, yeasts and moulds. Some of these products had incidence as high as 100% implying that the processing and packaging of these products should be improved to reduce on the levels of these organisms. The contaminated products can be dangerous to the infants who consume these products.

**Consequences/Significance:** Manufacturers of peanut-based infant foods were advised on ways of aflatoxin management in their products starting from raw materials; Kaaya received an award from UNBS in form of a certificate and UGSH 2,500,000/= (\$1500) cash in recognition for the work done towards generating aflatoxin data that has been used to develop national standards on mycotoxins in grains and other food products; Peanut CRSP was recognized in Uganda for contributing aflatoxin contamination data in peanuts.

**Activity 4.** Establishment of the impact of aflatoxin awareness among famers and traders: The objectives of this activity were: 1) to establish aflatoxin reduction following sensitization of farmers and traders and 2) to monitor farmers in order to ensure that the aflatoxin management strategies trained are put into place. This activity was performed in assistance with NAWOU. Sampling of peanuts and peanut-based products from households in Kamuli and Mubende and peanut processors in Kampala, Tororo, Mbale and Kumi was done during Fiscal Year 3, 4 and 5 and samples were analyzed for aflatoxin content. The monitoring involved among others, assessment of the groundnut farming practices by scientists from Makerere and NAWOU, to establish whether aflatoxins management procedures trained were put in place. Thus, farmers' gardens and homes were visited and several meetings were held with farmers. In addition, an MSc. student was recruited to study the effect of aflatoxin awareness tools and training on aflatoxin management. The farmers were also encouraged to register with NAWOU.

**Achievements:** It was established that overall, aflatoxin results continued to be low in samples obtained from farmers and traders implying that training helped to reduce aflatoxins. The MSc student established that more farmers became aware of the problem following the training.

The results of this activity resulted in writing and presentation of several papers:

- The need for aflatoxin management in grains in Uganda: Presented by Kaaya at Makerere University the Faculty of Agriculture Seminar series (October, 2010),
- Strategies to manage aflatoxin contamination in food: Presented by Kaaya in the Department of Food Technology Seminar Series (Dec 2010). University of Leeds Africa College Food Security, Health and Impact Knowledge Brokering Conference, UK, 22<sup>nd</sup>-24<sup>th</sup> June, 2011 and the Mycotoxin research impact on human health, agriculture and disease prevention" workshop 25th June 2011.
- Efforts to reduce aflatoxin contamination of groundnuts in Uganda: role played by the Peanut Collaborative Research Support Program (Peanut CRSP): Presented by Kaaya during the 10<sup>th</sup> African Crop Science Society Conference, 10 – 13 October, 2011-Maputo, Mozambique.
- Farmers' knowledge and perceptions on aflatoxins effects and control in peanuts. Presented by Rose Kabagyenya during the CRSP Council Meeting in Uganda, July 2011.

**Consequences:**

- Reduced aflatoxin levels in peanuts from farmers and traders
- More scientists sharing information about the efforts used to manage aflatoxin problem in Uganda.

**Kenya:**

Two activities were conducted under objective 1.



**Activity 1**– The link between market traits and aflatoxin contamination in peanuts was studied in the major peanut producing and consuming regions of Kenya - Western, Nyanza and Nairobi Provinces. Data was collected from 1263 vendors in various market outlets using a structured questionnaire, and peanuts and peanut products sampled from each vendor and analyzed for aflatoxin levels. The study addressed the following objectives: i) characterized market traits of peanuts in Nairobi, Western and Nyanza Provinces of Kenya ii) established the incidence and contamination levels of aflatoxin in peanut products from major markets in Kenya, iii) determined the effect of peanut market traits on the levels of aflatoxin in peanuts from Kenyan markets, iv) studied the effect of lowering tolerance levels for aflatoxin in peanut products in Kenya on trade and availability of these products for human consumption.

**Achievements** – Microbial assays were carried out at the ICRISAT labs in Nairobi while aflatoxin analysis was carried out at the ICRISAT labs in Patancheru, India. Thirty seven per cent of the samples exceeded the 10 µg/kg regulatory limit set by the Kenya Bureau of Standards (KEBS). Raw podded peanuts had the lowest ( $\chi^2=167.78$ ;  $P<0.001$ ) aflatoxin contamination, with 96% having levels of less than 4 µg/kg and only 4% having more than 10 µg/kg of aflatoxin. The most contaminated products were peanut butter and spoilt peanuts with 69% and 75%, respectively exceeding 10 µg/kg. Peanuts in the country were mainly (44%) traded through informal open air markets; and there was a significant ( $\chi^2=95.13$ ;  $P<0.001$ ) association between aflatoxin contamination and the type of peanut market outlet. Packaging material significantly ( $\chi^2=73.89$ ;  $P<0.001$ ) influenced the amount of aflatoxin in the stored commodity, with the majority (68%) of peanut samples stored in plastic jars having >10 µg/kg of aflatoxin. Thirty seven percent of the sampled peanuts would have been declared unfit for human consumption under the KEBS regulatory limit of ≤10 µg/kg.

Data generated from this activity has been published as an article in the Journal of Stored Products Research. The title of the manuscript is: “Incidence of aflatoxin in peanuts (*Arachis hypogaea* Linnaeus) from markets in Western, Nyanza and Nairobi Provinces of Kenya and related market traits”. A second paper titled “Market attributes and their effect on levels of aflatoxin in peanuts (*Arachis hypogaea* Linnaeus) from Nairobi and western Kenya”, was presented at the Biennial KARI conference held between 8<sup>th</sup> and 12<sup>th</sup> November 2010.

**Consequences/Significance** – Data generated from the study has helped highlight the importance of strict monitoring systems and educating masses to ensure that the standards set by the Kenya Bureau of Standards are upheld and only products that meet the standards access the Kenyan market. Additionally, the study provided data on variability in contamination of various peanut products by aflatoxins in Kenya.

The activities also assisted in raising awareness and creating interest in aflatoxin research in Kenya. The persons used in data collection exercises managed to identify areas within which they are pursuing further studies (not financially supported by the Peanut CRSP project). David Makori who was involved in both data collection and entry is pursuing MSc in Environmental studies at Kenyatta University; Lucy Karanja is in the final stages of her

MSc programme (Microbiology and Biotechnology) at the University of Nairobi while Ayub Kimani is pursuing MSc in Crop Protection at the University of Nairobi. Rosina Wanyama, one of the five MSc students supported by Peanut CRSP project has made remarkable progress pursuing MSc in Agricultural and Applied Economics at Egerton University (details of her progress provided under objective 9 – livelihoods).

**Activity 2:** A field survey was conducted in Nairobi, Nyanza and Western provinces in Kenya with the objective of determining the incidence of fungal species - emphasis on *Aspergillus* section Flavi - associated with different peanut products. This study has been completed and a manuscript drafted for submission to the Journal of Phytopathology. Data of 705 out of the 1263 peanut products sampled from various market outlets for the larger project was considered. The samples were also analyzed for aflatoxin levels. The objectives of this study were to (i) determine the incidence of fungal species - with emphasis on *Aspergillus* section Flavi - associated with peanuts and peanut products in three provinces in Kenya; (ii) To screen *A. flavus* and *A. parasiticus* isolates for production of aflatoxin B1, B2, G1 and G2 and; (iii) determine whether the incidence of *A. flavus* and *A. parasiticus* is associated with the level of aflatoxin in peanuts.

**Achievements** – Eight fungal species were commonly isolated from the peanut samples and were in decreasing order of CFU/g of sample: *A. flavus* S-strain (467), *A. flavus* L-strain (341), *Penicilium* spp. (326), *A. niger* (156), *A. tamari* (27), *A. alliaceus* (21), *A. parasiticus* (10), and *A. caelatus* (5). Peanuts and peanut products sampled from Nairobi were more infected than samples from Nyanza and Western regions. The incidence of *A. flavus* and *A. parasiticus* in different peanut products was significantly ( $p \leq 0.05$ ) varied in various peanut products as follows: peanut flour (69%), shelled raw peanuts (53%), spoiled peanuts (49%), boiled podded peanuts (45%), podded peanuts (39%), peanut butter (31%), fried peanuts (22%) and roasted peanuts (20%). Seventy three percent of *A. flavus* and *A. parasiticus* isolates produced at least one of the four assayed aflatoxin types – AFB1, AFB2, AFG1 and AFG2 - with 66% producing aflatoxin B1. The total aflatoxin level among peanut products ranged from 0 – 1629 g/kg; and there was a positive correlation ( $r = 0.2711$ ) between the incidence of *A. flavus* and *A. parasiticus* and total aflatoxin level.

Data generated from this activity has been used to draft a manuscript to be submitted to the Journal of Phytopathology. The title of the manuscript is: “Fungal species isolated from peanuts in major Kenyan markets: Emphasis on *Aspergillus* section Flavi”.

**Consequences/Significance** – The high incidence of aflatoxin producing fungal species in peanuts and peanut products traded in the Kenyan markets poses a risk of aflatoxin contamination and hence the need for stakeholders to promote sound practices at all stages of the peanut value chain in order to minimize market access by non-complying products.

- Sufficient data collated to develop an integrated approach to handling aflatoxin in peanuts in Kenya.
- The possibility of having other mycotoxins in peanuts confirmed due to the types and numbers of fungi isolated.

- Proper targeting for awareness raising established. This information has guided the Peanut CRSP activities in Kenya in development of awareness raising material (video and Aflatoxin management Handbook).

**Objective 2: HACCP and Certification: Evaluate aflatoxin contamination and physico-chemical composition of locally processed peanut products during storage and develop HACCP plan for small scale peanut processors and cottage industries.**

**Uganda:**

Two activities were conducted under objective 2

**Activity 1.** Training of peanut processors on HACCP Principles. This activity was conducted by Kumar from Virginia Tech assisted by Sophie Nansereko (MSc student) and Kaaya. The objective of the activity was to introduce peanut small-scale processors on HACCP as a tool for controlling aflatoxin contamination of peanuts. It was earlier observed that peanut products, including peanut butter were highly contaminated with aflatoxins. Thus, three workshops were conducted. The first was in January 11 – 12, 2010 and involved 20 processors from Kampala and Tororo. The second one was a follow-up in August 16, 2010 and assessed the implementation of HACCP by the trained processors and was attended by 16 processors while the third was held in February 2012 and was attended by 30 processors and 20 researchers. HACCP materials developed from Virginia Tech were given to the processors for further use. Prior to the third training workshop, the project had established linkages with Vredeseilanden East Africa-Uganda program (VECO Uganda), where Kaaya conducted research in the districts of Busia, Tororo, Pallisa, Iganga, Luuka, Lira and Kumi to gather data on the critical points where peanut aflatoxin contamination takes place, in order to come up with a generic HACCP Plan. Monitoring of small-scale processors (those trained by Peanut CRSP) in HACCP implementation continued together with sampling of peanut products to establish the efficiency of the HACCP Plans recommended to these processors. The samples were used to determine aflatoxin and microbial contamination (hazards) of the products and, this activity was done by the MSc student, Sophie Nansereko. Further linkages were made with Uganda Cooperative Alliance (UCE) which involved HACCP training of processors, farmer leaders and Extension agents from Busia, Tororo, Mbale and Kumi districts.

**Achievements**

Over 50 small-scale peanut processors trained in HACCP principles. They received certificates and training materials which have empowered them to supply peanut products to supermarkets due to improved quality of their peanut products. Twelve (18) processors out of the 50 trained are now comfortably supplying processed peanut products to supermarkets.

The critical control points (CCPs) for aflatoxins were established at farmer level. These formed the basis of the training during the third workshop. A HACCP Plan was established and presented to farmers, processors and extension agents from Kampala, Busia, Tororo, Pallisa, Iganga, Luuka, Lira and Kumi.

Five meetings have been held with processors in Kampala, Tororo and Busia to discuss challenges faced by processors who were trained in HACCP Principles. Several visits were made to monitor the implementation of HACCP by the traders

Results of this activity enabled the write up and presentation of a paper by Kaaya in November 2010, "Conducting aflatoxin analysis tests on groundnut based products along the value chain and developing hazard analysis critical control points" to the Uganda National Bureau of Standards and VECO staff.

### **Consequences**

Processors, farmer leaders and extension agents were exposed to HACCP principles and more than 90% of them had never had about HACCP. Participants received certificates and training materials to use during HACCP applications in their industries. A generic HACCP Plan for peanut handling and processing sectors has been developed. This plan has been recommended for use by the peanut stakeholders including NGOs, UNBS, Ministry of Agriculture, National Agriculture Research Organization, small scale processors and farmer groups. Majority of the processors trained are endeavoring to apply HACCP principles and are supplying supermarkets. Processors' income has increased following improvement of the quality of their products. Activities involving VECO and UCE enabled the project to cost-share the expenses of HACCP training. By linking the project to VECO and UCE, activities involving peanut aflatoxin management are likely to continue (sustainability) in the absence of the project. This is because VECO East Africa (Uganda programme) has accepted to work hand-in-hand with UCE to implement HACCP training in Uganda.

A group of farmers in Mubende was linked to a buyer (Ms. Betty Kisiki). Betty was among the processors trained and signed up a contract with these farmers to supply her with aflatoxin-free peanuts. In this way, the farmers' income was enhanced since Betty buys peanuts at premium price.

**Activity 2:** Application of HACCP in managing common hazards in small-scale peanut paste processing industries in Uganda. This study was undertaken by the MSc student, Sophie Nansereko. The objectives of the study were 1) To develop a HACCP Plan for small-scale peanut processing industries in Uganda; 2) Assess knowledge, Attitudes and Practices in relation to HACCP implementation; 3) Identify barriers and motivational factors to HACCP implementation in small-scale peanut processing industries; 4) Assess the physical hazards, microbial hazards and aflatoxin levels in raw, roasted and peanut paste products; 5) Evaluate the effectiveness of HACCP in reducing physical, chemical and biological hazards in groundnut products.

Eighteen peanut processors from 10 peanut processing industries from within central region of Uganda were randomly selected, 8 of whom were previously trained under activity one above. Both the trained and untrained were monitored throughout the study. A semi-structured questionnaire was administered to peanut processors to establish the existence of quality assurance programs, their understanding of HACCP, whether HACCP was formulated and implemented and if not, establish reasons why. Data on benefits and motivation factors to HACCP implementation and adherence to the HACCP plan was

collected. Several samples of raw and roasted peanut and peanut paste were sampled from each processor and analyzed for physical, microbial (total plate count) and aflatoxin content.

### **Achievements:**

Majority (75%) of processors trained were implementing HACCP programs including Good Operation Practice (GOPs), Good Manufacturing Practices (GMPs), Good Hygiene Practices (GHPs) and Sanitation Standard Operating Procedures (SSOPs). None of the processors not trained were found to be implementing HACCP although 63% had heard about it. Motivational factors to HACCP implementation were established and, improvement in quality of the products was the most reported factor. All processors (100%) reported having experienced challenges to HACCP implementation which included weak prerequisite programs, time consuming, lack of equipment and additional costs involved.

Results of existence of physical and biological hazards as well as aflatoxin content were significantly lower in samples obtained from trained processors than those sampled from untrained processors indicating that HACCP training offered a positive impact to quality of products.

Results of this study were used to write a poster that was presented during the CRSP Council Meeting in Kampala, July, 2011.

### **Recommendations:**

- HACCP should be implemented by all small-scale processors in Uganda
- More training in HACCP principles with incorporation of basics in aspects of food processing is strongly needed
- It is important that training and associated literature be developed in local language to ease comprehension of the technical aspects
- A multidimensional approach should be used in light of the fact that there are many players in the peanut chain right from farmers, through transporters, wholesalers, retailers and processors.
- There is need for stringent monitoring and supervision to ensure that HACCP measures are in place and adhered to.

### **Consequences/Significance (Key)**

- Challenges faced by small-scale processors as far as implementation of HACCP discussed and solutions sought
- Aflatoxin levels and microbial contamination of peanut products from small-scale processors who practice HACCP established
- More processors aware of the need to implement HACCP as a tool to quality control and assurance

### **Kenya:**

Six activities were conducted under objective 2.

**Activity 1** - A HACCP workshop which took place between 11 - 13 August 2010.

**Achievements** – The workshop was jointly facilitated by Dr. Kumar Mallikarjunan and Ms. Margaret Kroma of the Kenya Bureau of Standards (KEBS) and involved a total of 19 participants from Nairobi, who were either traders or processors. The main topics covered included: HACCP in Kenya and its application; Introduction to hazards; Designing safety into products and processes; Developing a HACCP plan; Identification of Critical Control points; Implementation of a HACCP plan; and Verification and maintenance of HACCP plans. The report is given in detail elsewhere by Dr. Kumar Mallikarjunan.

**Consequences/Significance** –

- Increased awareness about aflatoxin in peanuts and how to manage it throughout the production chain using cost effective methods (HACCP) as a preventive strategy.
- Success of the HACCP workshop also led to the inclusion of HACCP training in other key commodities in KARI, especially in the horticultural sector.

**Activity 2:** An experiment on assessment of peanut storage at different environmental conditions and in different containers - jute bag, polypyrene bag and polythene bag - in households and markets in Kenya, and their effect on quality of peanuts has been completed. The experiment was conducted in ICRISAT labs in Nairobi and in the Food Science, Nutrition and Technology Department at the University of Nairobi. The objective of this study was to assess the effect of storage conditions and bags – commonly used in households and markets in Kenya - on the quality, fungal population and aflatoxin contamination of peanuts. The spectrum and diversity of aflatoxin types produced by *Aspergillus* section *Flavi* were also determined.

**Achievements** – Moisture content of the samples varied from 3.3 to 6.9% implying that all the samples met the standards set by KEBS. There was a significant inverse relationship between temperature and physical damage, while the bag type did not significantly ( $p \geq 0.05$ ) influence physical damage. Rancidity ranged from 0.8 to 5.3 and increased with storage duration from a mean of 1.5 before storage to a peak of 2.5 after 5 months of storage. Rancidity development was significantly affected by the storage temperature and R.H. but not by the type of storage bag.

Six fungal pathogens were commonly isolated from the peanut samples and occurred as follows in decreasing order: *Penicilium* spp. (106.6 CFU/g), *A. flavus* L-strain (4.8), *A. flavus* S-strain (2.9), *A. niger* (2.6), *A. parasiticus* (1.7) and *A. tamari* (0.2 CFU/g). Ninety one percent of *A. flavus* and *A. parasiticus* isolates from peanuts produced at least one of the four aflatoxin types – AFB1, AFB2, AFG1 and AFG2 - with 36% producing aflatoxin B1. Total aflatoxin levels ranged from 0 – 47.8 µg/kg; and peanuts stored in polythene bag were 7.3 and 13.4% more contaminated than samples stored in polypropylene and jute bags, respectively.

Data generated from this activity has been used to draft a manuscript (in the final stages of editing and formatting) to be submitted to the Journal of Stored Products Research. The

title of the manuscript is: “Effect of storage conditions on quality, fungal population and aflatoxin contamination of peanuts”.

**Consequences/Significance** – Results from this experiment indicate that the storage conditions and containers of peanuts significantly influence the quality of peanuts and aflatoxin contamination. The data generated will help in creating awareness both at household level and markets in Kenya on storage conditions which would help maintain peanut quality during storage. This information would also be useful in planning for intervention strategies. It was observed that peanuts should be packaged in a container which will delay critical increases in moisture content, fungal population and aflatoxin contamination and then stored in a well-ventilated, dry room.

**Activity 3:** Henry Momanyi, a student pursuing MSc. in Research Methods at Jomo Kenyatta University of Agriculture and Technology (JKUAT) undertook a study entitled “Principal component and multiple correspondence analysis in dimensionality reduction: a study on aflatoxin contamination of peanuts in Kenya”. The study objectives included: i) To identify the most appropriate statistical technique(s) for handling several quantitative and categorical variables to facilitate statistical analysis of aflatoxin contamination of peanuts; ii) To evaluate the applicability of principal component and multiple correspondence analysis in interpretation of aflatoxin contamination of peanuts compared to contingency table analysis; iii) To determine the variables that play a significant role in aflatoxin contamination of peanuts.

Henry has submitted his thesis for examination at JKUAT. He has also drafted a publication which will be submitted to the Statistical Methodology Journal. Although the publication is at an early stage of development (some co-authors have made their input in the first draft), the earliest the paper can be submitted to the journal will be end of January 2013.

### **Achievements**

The following were the key findings from the study:

- Multiple regression analysis (MCA) was the most appropriate statistical technique for handling several quantitative and categorical variables in facilitating the statistical analysis of data on aflatoxin contamination of peanut samples collected through field surveys. It could give predicted values for modeling aflatoxin contamination in peanuts and could determine significant variables that play significant role in aflatoxin contamination of peanuts.
- Multiple correspondence analysis was more robust in generating information from a large categorical data set compared to contingency table analysis.
- Principal component analysis was useful in reduction of the large data set into a lower dimension of few variables and in constructing data composites for MCA.

Recommendations from the study:

- a. There are three types of multiple correspondence analyses - Indicator matrix MCA, Burt matrix MCA and Joint MCA - which could be used for studies on aflatoxin

contamination of peanuts. Therefore, further studies should be conducted to identify the most applicable type in terms of accuracy and interpretation.

- b. Further studies are also recommended on the use of R statistical software with FactorMineR package for removing overlapping MCA data points that pose challenges in interpretation of analyzed results.
- c. Multiple regression should be applied with other statistical techniques like multiple correspondence analysis for complete understanding of the categorical variables.
- d. Long term studies should be conducted on variables that were identified from this study as having played a significant role in aflatoxin contamination of peanuts.

**Consequences/Significance** – The findings of the study highlight the best approach(es) in data analysis of a study involving numerous variables. More significantly, the study recommended the need for using a combination of several statistical approaches of analyzing data for best interpretation and to assess levels of interaction of various variables and their effect on aflatoxin contamination of peanuts.

**Activity 4:** A study that aimed at determining the factors that predispose peanut butter from the cottage industry in Nairobi to aflatoxin contamination started in June 2011. The specific objectives of the study were to: (i) establish the characteristics of peanut butter cottage industry in Nairobi; (ii) establish the handling practices in groundnut market outlets and peanut butter cottage industry in Nairobi; and (iii) determine whether the characteristics and handling practices predispose peanut butter to aflatoxin contamination.

This study was undertaken by a postgraduate student, Mr. Johnson Weru pursuing MSc. Food Science and Technology at the Jomo Kenyatta University of Agriculture and Technology (JKUAT). Johnson has finalized his thesis which is ready for submission to JKUAT for examination. However, the University revised its regulations and all MSc. students must publish at least one manuscript in a peer-reviewed Journal before they can submit a thesis for examination. Johnson's draft publication is in the final stages and will be ready for submission to the Journal of Applied Bioscience by mid-January. The title of the publication is "Factors that predispose peanut butter to aflatoxin contamination in the cottage industry in Nairobi, Kenya".

**Achievements** – A field survey was conducted and 78 samples collected from the cottage industry, whole sellers and retailers in Nairobi as well as vendors from Western Kenya. The samples were analyzed for moisture content, microbial load and aflatoxin levels. Additionally, all the raw nut samples were sorted to examine the presence of undesirable kernels. The following were the key findings of the study:

- The peanut butter cottage industry in Nairobi is informal in nature and is characterized by poor hygiene in processing. There are no standard operating procedures (SOPs) and requirements for food safety are not observed. The workers are not trained in food processing or in good hygiene practices. There is no effective monitoring for compliance to set standards by Kenya Bureau of Standards (KEBS) and hence the industry is broadly unregulated.



- All the raw groundnuts used in the cottage industry in Nairobi were imported from Malawi through the groundnut wholesalers operating in Nairobi. The aflatoxin levels in raw groundnuts sampled from Nairobi were significantly higher than samples from Nyanza. The source of groundnuts was significantly associated with aflatoxin contamination levels.
- The moisture content of raw groundnuts and peanut butter met the KEBS regulations. Thus the groundnuts traded in Nairobi and Nyanza had safe moisture content levels implying that groundnuts were properly dried after harvest. Additionally, moisture content of the peanuts was not correlated with aflatoxin levels.
- The proportion of defective nuts in raw groundnuts was higher than the KEBS threshold. Broken nuts were the most prevalent type of defect from unsorted groundnuts in Nairobi and Nyanza. The presence of defective nuts was positively associated with aflatoxin levels. Therefore, lack of proper sorting of raw groundnuts in Nairobi was a factor that predisposes the peanut butter cottage industry to aflatoxin contamination.
- The population of *Aspergillus* section *Flavi* was higher in raw groundnuts from Nairobi than from Nyanza. The most frequently isolated fungal species were *A. flavus* (S and L strains) and *A. parasiticus* whose population was positively correlated to aflatoxin levels.
- Aflatoxin levels ranged from 0 to 2377 µg/kg with samples from Nairobi being significantly ( $p \leq 0.05$ ) more contaminated than samples from Nyanza. In the cottage industry, raw groundnuts were the least contaminated followed by roasted nuts whereas peanut butter was the most contaminated. Overall, aflatoxin level in 43% of the groundnut samples was higher than the 10 µg/kg regulatory limit set by the Kenya Bureau of Standards.

#### Recommendations from the study:

- a. Measures should be instituted to streamline the peanut butter cottage industry and enforce compliance to code of practice for hygiene in the food and drink manufacturing industry of KEBS.
- b. KEBS should strengthen monitoring for compliance to set standards in the Nairobi peanut butter cottage industry. Additionally, mechanisms for inspection and certification of imported groundnuts should be established accompanied by regular monitoring for aflatoxin levels of the imported groundnuts to ensure that they comply with set limits.
- c. Further studies should be conducted to assess the level of exposure of the populace to aflatoxin as a result of consumption of contaminated products. This will also help assess the health risk posed to consumers of aflatoxin contaminated products.

**Consequences/Significance** – The high microbial load in peanuts sampled from whole sellers implies that peanuts in the distribution channel to retailers and consumers are at a risk of aflatoxin contamination. The high contamination of peanuts sampled from the cottage industry with *Aspergillus* spp. implies a health risk of aflatoxin contamination of the peanut butter made from such nuts. Since the groundnuts used in the cottage industry in

Nairobi are imported from neighbouring countries, there is need to devise mechanisms for inspection and certification of imported groundnuts. In addition, traders should be encouraged to sort their groundnuts before selling them as an effective method of reducing aflatoxin contamination. Kenya Bureau of Standards officials should also intensify monitoring for compliance to set standards in the industry. The data generated will contribute to development of a HACCP plan for the cottage industry in Kenya and building capacity of small scale processors to implement HACCP. The study has also identified key points in the peanut value chain where intervention is required for production of safer peanut products.

**Activity 5** – Helene Nyirahakizimana, a post graduate student pursuing MSc. in Microbiology at Chepkoilel University College (a constituent college of Moi University), carried out a field survey covering two towns in the Rift Valley region. Helene collected 228 raw and roasted peanut samples from informal markets (municipal markets and hawkers) and supermarkets in Eldoret and Kericho towns. The field survey was conducted from June through July 2011 with a second sampling in December 2011 and January 2012; and aimed at: i) establishing the mycotoxigenic fungal agents in raw and roasted groundnuts; ii) determination of the total aflatoxin level in raw and roasted groundnuts.

Helene has shared the third (and hopefully final) draft of her thesis that will be submitted to Chepkoilel University College for examination in January 2013.

**Achievements** – Microbial assays were carried out in the Microbiology lab, Chepkoilel University College in Eldoret while analysis for total aflatoxin was conducted in Patancheru, India. Identification of fungal pathogens was based on cultural and morphological characteristics. The Key findings from Helene’s study are:

- The major fungal pathogens isolated from peanut products marketed in different outlets in Eldoret and Kericho towns included *A. flavus* L strain, *A. flavus* S strain, *A. parasiticus*, *A. tamaritii*, *A. caelatus*, *A. alliaceus* and *A. niger*. The incidence of aflatoxin producing fungi was 76%. Other pathogens isolated in lower frequency included *Fusarium*, *Penicillium* spp., *Mucor* spp. and *Rhizopus* spp.
- The incidence of aflatoxin producing fungi was highest in raw peanuts from informal market outlets, with *Aspergillus flavus* L strain dominating (68%) in different peanut products.
- Eighty one percent (185 out of 228) of the peanut samples analyzed had detectable levels of aflatoxin ranging from 0 to 2345 µg/kg. Aflatoxin contamination in 43% of the samples was higher than the 10 µg/kg limit set by Kenya Bureau of Standards (KEBS).
- The type of market outlet and peanut processing (roasting, de-coating) significantly influenced aflatoxin contamination of peanuts.
- Peanut processing by roasting and de-coating significantly reduced fungal and aflatoxin contamination. Overall, roasted de-coated peanuts were the least contaminated with 78.2% and 60% complying with the KEBS regulations in formal and informal markets, respectively. On the other hand, more than 50% of raw peanut samples had higher than the 10 µg/kg aflatoxin level allowable by KEBS.

- Overall, there was a positive significant correlation between aflatoxin levels and the population of major aflatoxin producing fungal species - *Aspergillus flavus* (L and S strains) and *A. parasiticus*.

Recommendations based on Helene's findings:

- a. Processing of peanuts (roasting and /or de-coating) should be promoted as an intervention aimed at reducing fungal and aflatoxin contamination.
- b. Awareness should be raised among peanut vendors on proper handling of peanuts and peanut products as well as among consumers on the health risks associated with consumption of unsafe peanut products.
- c. The Kenya Bureau of Standards should strengthen mechanisms of monitoring and enforcement of aflatoxin standards in Kenya to ensure only products that meet the set standards access the market.
- d. Controlled experiments should be conducted to establish specific factors that influence fungal and aflatoxin contamination of peanuts during storage.

**Consequences/Significance** – Raw groundnuts were more contaminated with fungal pathogens and aflatoxin than processed (roasted and decoated) nuts. Additionally, groundnuts traded in formal markets were less infected with fungal pathogens with lower levels of aflatoxin contamination. Therefore, trading of peanuts in formal markets as well as processing reduces the incidence of aflatoxin producing fungi and aflatoxin levels. Awareness should be raised among groundnut vendors on the implications of handling practices on quality of their products and associated health risks.

**Activity 6** – The objectives of this study were to establish DNA finger printing for specific peanut varieties, determine purity of peanuts sold in the market, and establish whether peanuts with different names are the same genotypically. Ms. Winifred Selle, a student pursuing MSc. in Genetics at Jomo Kenyatta University of Agriculture and Technology is undertaking a study entitled “A precise strategy based on SSR markers to measure diversity and identify of cultivated groundnuts in Kenya”. The objectives of the study were to determine the groundnut genetic resources in Kenya in order help improve the groundnut breeding programs enhancing utilization and quality of the crop as well as providing effective conservation of the crop.

**Achievements** – A set of twenty-one Simple Sequence Repeats (SSR) markers were used to identify a total of 96 groundnut accessions collected from various Agro-ecological zones in Kenya. The following were the key findings of the study:

- Of the 21 markers that were used, 157 alleles were revealed across all the 96 accessions with an average of 7.46 per locus. The allele size ranged from 101 base pairs marker 14-TC6G09 with (CT)<sub>18</sub> repeat motif to 375 base pairs marker 15-TC7H11 (AG)<sub>18</sub>. The allelic richness varied widely among the locus ranging from 4 to 12 alleles. In total, there were 54 unique alleles that were detected at the 17 loci across all the 96 groundnut germplasm analyzed. A total of 239 rare alleles were detected, and are important in breeding programs.

- The PIC value ranged between 0.41 to 0.85 with an average of 0.70. Nineteen (90.5%) SSR marker loci revealed PIC values >0.5. Cluster analysis grouped the 96 accessions into 5 clusters, indicating high level of genetic diversity of groundnuts in Kenya. Genetic fingerprints were developed from the nineteen SSR markers revealing PIC values >0.5, which are the most viable for purity testing.

Recommendations from the study:

- a. There is need to streamline the groundnut seed system in Kenya to enhance production. The genetic fingerprints developed from this study can be used to sort the different groundnut genotypes in Kenya. These fingerprints can be adapted by the Kenya Agricultural Research Institute (KARI) to standardize seed distribution.
- b. Based on the developed est-ssrs markers for aflatoxin resistance in groundnut, a study should be conducted to determine whether there exist aflatoxin resistant groundnut genotypes in Kenya and the East African region.
- c. The extraordinary level of natural genetic variation reported in this study provides opportunities to stakeholders in the groundnut industry to make more informed decisions and define suitable strategies for harnessing the genetic variation in groundnut breeding in order to improve groundnut production in Kenya.

**Consequences/Significance** – The hands on training in DNA extraction techniques and fingerprinting is an important achievement in capacity building in Kenya. The extraordinary level of natural genetic variation from the study provides opportunities to the groundnut breeders in Kenya to make more informed decisions and define suitable strategies for harnessing the genetic variation in groundnut breeding especially to address the biotic and abiotic strains facing groundnut production in Kenya. The findings may also play a role in search of peanuts with useable sources of resistance against aflatoxin contamination.

**Objective 3: IEC: Develop information Education and Communication (IEC) materials for Aflatoxin awareness at grassroot and higher level as well as conduct training workshops to address the issue.**

**Uganda:**

To address this objective, 4 activities that centered on people’s awareness of aflatoxin problem and management strategies were undertaken. These included meetings/workshops, development of simple IEC materials, use of media and use of CONCENT

**Activity 1:** Aflatoxin awareness and management campaigns by farmers, traders and processors in selected districts of Uganda were done thorough routine meetings/workshops. This activity was conducted together with the National Association of Women Organizations in Uganda (NAWOU) in Mubende and Kamuli and together with VECO in Busia, Mbale and Tororo. In addition, during the Uganda manufacturers’ Association (UMA) Trade Show/exhibition Kaaya demonstrated aflatoxin free and contaminated peanut products and explained the danger of aflatoxin and management practices to participants. The objectives of the strategy were: 1) To enhance aflatoxin

awareness by farmers, traders and processors in Uganda; and 2) To train farmers, processors and traders on aflatoxin management procedures in order to reduce exposure to the problem. Simplified handout materials designed during first phase of the project were used to inform participants about aflatoxins including the crops commonly contaminated. Participants were trained on basic methods of pre and postharvest controlling aflatoxin contamination on produce, emphasis being put on peanuts.

**Achievement:** - Over 1000 farmers, traders and processors were trained and became aware of aflatoxin problem and management. Practices for managing aflatoxin in staple crops put in place

Results of this study were used to prepare several papers:

1. "Building a healthy nation through working with women groups in Uganda: A case study of peanut CRSP" Presented by NAWOU during the CRSP Council Meeting in Uganda in July 2011. The second was by Kaaya titled
2. "Peanut collaborative research support program (peanut CRSP) in Uganda: Efforts to reduce aflatoxin contamination of peanut" Presented by Kaaya during the CRSP Council Meeting in Uganda in July 2011.
3. "The need for gender considerations during management of aflatoxins in peanuts". Presented by Kaaya during the Peanut CRSP Strategic Research Conference in Malta 10 – 15 December, 2011
4. On 25 April 2012, a scientific paper was presented during the CRSPs' joint meeting in Uganda held at Makerere University Senate Building. This meeting gathered Co-PIs of all CRSPs in the country and, Kaaya presented a comprehensive report of what Peanut CRSP VT134 has accomplished in Uganda and Kenya.
5. During the period August 4 - 9, 2012, Kumar presented a scientific paper entitled "Aflatoxin mitigation support in Uganda: Role played by Peanut CRSP" during the International Union of Food Science and Technology (IUFoST) meeting in Iguassu Falls, Brazil.

**Consequences/Significance:** More farmers, traders and processors are avoiding consumption of aflatoxin contaminated peanuts and other food products. Those farmers that have been trained are putting into practice the recommended procedures of aflatoxin control, especially timely harvesting, drying and storage practices. Aflatoxin levels in peanuts have reduced at farm level and in processed products. UNBS continued to use results of aflatoxin generated to come up with aflatoxin standards in the country. More women registered with NAWOU and do get benefits from this organization. More scientists are aware of the activities done by the Peanut CRSP on management of aflatoxins. This led to establishment of collaboration with the Nutrition and Horticulture CRSPs scientists. Kaaya has also joined the efforts of PACA (Partnership for Aflatoxin Control in Africa) in the management of aflatoxins in foodstuffs.

**Activity 2.** Development of simple IEC materials to use during training. The objective of this activity was to develop simple, easy to understand communication materials about aflatoxin management in produce, building on what was done during Peanut CRSP Phase 1.

**Achievements:** This activity involved development of calendars and posters mainly in English, Luganda, Luo and Ateso, the languages most understood by the people in the districts where the project operated. These were distributed to farmers, traders and processors in the districts and also during the UMA Trade Show/Exhibition in Kampala.

**Consequences:**

- Over 1000 calendars were printed in 2 years. Over 6000 posters were developed and are being used by farmers, processors and traders. Templates of these materials can be used in future by any organization for example Ministry of Agriculture as training materials for their farmers/processors/traders to manage aflatoxin.
- More stakeholders able to understand aflatoxins and management strategies
- Overall, there is more reduction of aflatoxin levels among trained farmers, traders and processors

**Activity 3:** Use of media in the awareness of aflatoxin problem:

**Achievement:** In this activity, radio and newspapers were used to publicize aflatoxin problem. Live talk shows were presented by Kaaya on FM radios in areas of Mubende, Kampala, Tororo, Busia, Mbale and Kumi. Aflatoxin information in newspapers (Farmers' media, New Vision, Bukedde and Monitor) was also publicized.

**Consequences:** Since FM radios are listened to by almost all farmers in Uganda and newspapers read in the majority of urban and peri-urban areas of the country, it is anticipated that most people in Uganda have some knowledge about moulds and aflatoxin problems in foods especially the staples. The information obtained has been used by the Uganda/WHO/FAO/FERG food borne burden of disease studies coordinated by Ministry of Health and The national Drug Authority in Uganda

**Activity 4.** Drafting of a petition on aflatoxin management in Uganda. This activity targeted specifically consumers and policy makers in Uganda.

**Achievement:** Together with Uganda Consumer Education Trust (CONSENT) a draft petition entitled "Millions at risk of death from poison in our food: A wake-up call to stem exposure of vulnerable people to deadly aflatoxin in the food value chain" was written by Mr. Kimera of CONSENT, Kaaya and edited by Sekitoleko of UNBS.

**Consequences:** The petition was taken to parliament of Uganda and to other relevant policy makers including Government Ministries and NGOs for action towards aflatoxin elimination campaigns. More consumers and policy makers including parliamentarians aware of aflatoxin problem

**Kenya:**

To address this objective, three activities that focused on development of awareness raising material were carried out and aimed at educating people about aflatoxins, how they contaminate foods and how they can be avoided both at pre and post harvest stages. The activities undertaken included:

### **Activity 1 - Development of leaflets**

**Achievements** - Leaflets were produced with the assistance of an intern from Dartmouth College in 2012. The leaflets were produced with the aim of educating people about aflatoxins, how they contaminate foods and how they can be avoided at pre and post harvest stages. Once drafts of the leaflets were produced, they were subjected to a pre-testing exercise, to gauge the perception of the target audience on the information presentation. This took place in Busia district of western Kenya, the main peanuts producing region in Kenya. However, after consultations with extension personnel and other key stakeholders, it was agreed that a Technical Handbook and a video would be handier for long term utilization (including training stakeholders) compared to leaflets. Based on the same view, the idea of designing posters that were to be used by extension staff during awareness raising activities was dropped in favor of a Handbook and a video. Most of the information in the leaflets was incorporated in the handbook.

### **Consequences/Significance**

- An understanding of peanut farmers' perception of their knowledge about aflatoxin.
- Farmers improved understanding about aflatoxin, with regard to causative factors, consequences and management options.
- Deliberations on leaflets and posters as awareness raising material resulted in consensus on development of a video and a Handbook for long term utilization as materials that could be used even after the project is over.

**Activity 2 - Development of a video on management of aflatoxin in peanuts** – This activity was undertaken in order to have a video that can be used as a tool in awareness campaigns and stakeholders training aimed at reducing aflatoxin contamination of peanuts. The shooting of the video covered the entire value chain of peanuts from production to end products.

**Achievements** - The video was shot in September and October 2011 where various experts, farmers, traders and technicians were interviewed. Among those interviewed were Dr. Said Silim, ICRISAT Director, Eastern and Southern Africa and Dr. Charity Mutegi, Co-PI in the project. Others interviewed were farmers, traders, peanut processors as well as experts from the Kenya Bureau of standards, Ministry of Public Health and Sanitation, Kenya Plant Health Inspectorate, and Kenya Agricultural Research Institute. Activities which were documented during the video shooting included peanut production systems in Kenya; samples handling from the field to the lab and in the lab; peanut handling by traders; microbial assays (isolation and identification); and aflatoxin analysis (extraction, detection and quantification) using TLC and ELISA. Additionally, information on the role of peanuts in Kenyan diets and trade; mode of aflatoxin contamination; the impact of aflatoxin contamination on trade, health and food security; aflatoxin management options and benefits of aflatoxin management were also documented. Five hundred copies of the video were produced and distributed to various partners as follows:

- i. Ministry of Agriculture – Western province (80), Nyanza province (110)  
- Agriculture Secretary (2)

- Director of Agriculture, Crop Management Directorate (2)
- Deputy Director of Agriculture, Plant Protection Services (2)
- ii. Ministry of Public Health – Western, Nyanza and Nairobi regions (185)
  - Chief Public Health Officer (5)
- iii. Kenya Agricultural Research Institute, KARI
  - Deputy Director, Research and Technology (3)
  - Assistant Director, Horticulture and Industrial Crops (12)
  - Principal Research Officer - Horticulture and oil crops agronomy, Kisii (5)
- iv. Kenya Bureau of Standards (9)
  - Assistant Manager, Quality Assurance (1)
- v. Kenya Plant Health Inspectorate Services, KEPHIS (9)
  - Chief Analytical Chemist (1)
- vi. ICRISAT- Nairobi (5)
- vii. ICRISAT-Malawi (5)
- viii. International Institute of Tropical Agriculture, IITA – Nairobi (3)
- ix. The African Agriculture Technology Foundation, AATF (2)
- x. Jomo Kenyatta University of Agriculture and Technology (2)
- xi. ACDI/VOCA (3)
- xii. Dr. Maria Elisa, Virginia Tech, USA (3)
- xiii. Prof. Archileo Kaaya, Makerere University, Uganda (2)
- xiv. Dr. Charity Mutegi (10)
- xv. Director, ICRISAT, Eastern and Southern Africa (1)
- xvi. Dr. Alastair Orr, ICRISAT (1)
- xvii. Dr. Maina Wagacha, University of Nairobi (2)
- xviii. Non-allocated copies – for future distribution (35)

**Consequences/Significance** – in order to effectively manage aflatoxin contamination in Kenya, it is important to raise awareness among stakeholders on the effects of aflatoxin on the health status of humans as well as on economic development. The video is intended to be used as a long-term supplementary material to achieve this goal. The video will be used in awareness campaigns and training of stakeholders in future activities. Feedback from the Ministry of Agriculture in Western Kenya indicates that several (number not established) extension officers have watched the video.

**Activity 3 - Development of an aflatoxin management Handbook** – A handbook has been developed and will be used as a teaching tool primarily for extension workers in the ministries of Agriculture and Public Health & Sanitation and also key farmers. It will also be used to sensitize traders and end users on peanut quality and market aspects. This activity had been put on hold after slashing of the year 5 budget by \$10,000. However, after reinstatement of the slashed project funds in July 2012, the project team revised and improved the handbook draft which is at the final stages of editing by the publisher in consultation with the project team. Overall, the handbook will be a tool used by extension personnel to train stakeholders (especially farmers) in the peanut value chain on handling aspects in order to avoid or minimize aflatoxin contamination. The training aims at raising awareness on aflatoxin and aflatoxin management.



**Achievements** - A team of five scientists was constituted to develop an aflatoxin handbook for the groundnut value chain in Kenya. Membership to the team was drawn from ICRISAT, Kenya Agricultural Research Institute (KARI), Kenya Bureau of standards, Ministry of Agriculture and the Ministry of Public Health & Sanitation. The handbook covers crucial topics such as definition of aflatoxin and causal agents; crops which are highly prone to aflatoxin contamination; role of peanuts in the Kenyan diets and trade; mode of aflatoxin contamination; impact of aflatoxin contamination on trade, health and food security; aflatoxin detection methods; aflatoxin standards; aflatoxin management benefits; and demystifying myths about aflatoxins. A advanced draft has been generated and shared with the publisher who is in the final stages of formatting and editing.

**Consequences/Significance** – completion of the handbook will be critical in achieving one of the project’s main objectives regarding long-term training of various players in the peanut value chain and consequently raising awareness on aflatoxins and aflatoxin management. Copies of the handbook will mainly be distributed to extension personnel in the ministries of Agriculture and Public Health & Sanitation as well as to key farmers (opinion leaders) in major peanut production regions. It is anticipated that the extension workers will use the handbook in their extension services sensitizing farmers, traders and end users on peanut handling aspects, quality and market. Additionally, the anticipated training and awareness raising will sensitize stakeholders on the health implications of aflatoxin on humans, animals and economic development. It is hoped that by using this teaching tool, aflatoxin contamination of peanuts in Kenya will be minimized.

**Objective 4: Build capacity to identify and address aflatoxin issues through training of students, researchers, processors, women's groups, farmers and government/extension personnel.**

**Uganda:**

Two activities were conducted under objective 4.

**Activity 1.** Training of undergraduate and postgraduate students

**Achievements:**

- The undergraduate student of Food Science and Technology, Ms Lydia Nakagiri, was supported for her Special Project Research on physico-chemical and aflatoxin content as well as shelf life of peanut-based processed food products and graduated in with an Upper Second Class Honours in 2010.
- The MSc student, Sophie Nansereko completed her MSc in Applied Human Nutrition in the Department of Food Technology & Nutrition, Makerere University in 2012. Her research/thesis title was “Application of HACCP in managing common hazards in small scale peanut paste processing industries in Uganda”.
- The MSc student, Rose Kabagyenyi is yet to complete, but registered for a MSc. Degree in Extension, in the Department of Agriculture Extension and Innovations, Makerere University. She conducted research on Evaluation of the communication strategies used by peanut CRSP in aflatoxin prevention and control in peanuts. A case of Mubende district in Uganda.

- The MSc student, David Tumwesige, is pursuing a MSc. in Food Science and Technology, is also yet to complete but registered in the Department of Food Technology & Nutrition, Makerere University. His research is on Enhancement of the nutrient content of peanut butter using Moringa Leaf Powder. This student received partial funding from Peanut CRSP towards lab analyses.
- Three other Masters students (Ms. Ruth Muwesa, Caroline Bazarrabusa Horn and Ms. Sylvia Tereka) from the School of Women and Gender Studies, Makerere University were supported by the Project to undertake their field research in aflatoxin-related ethnographic studies.
- A PhD student, Hande Kaya Celiker completed her training in 2012. She had registered in the Department of Biological Systems Engineering, Virginia Tech and her studies were on Rapid Evaluation of Aflatoxin in Peanuts using FTIR.
- A Ph.D. student at Virginia Tech's Human Nutrition, Food, and Exercise Department, Carlyn Rae, completed coursework but did not pass preliminary exams to carry out fieldwork; she was not funded by Peanut CRSP, though she was advised by the team of PIs and was aiming to work in our site in Uganda.

#### **Activity 2: Training of a Technical person on aflatoxin analysis using FTIR method**

**Achievements:** Benjamin Sentongo, a Chief technician from the Department of Food technology and Nutrition, Makerere University, traveled to Virginia Tech from September 14 to October 10, 2009 and had training on the use of the FTIR equipment in the Department of Biological Systems Engineering. He carried along with him processed peanut samples (12) which he analyzed for aflatoxin contamination.

**Consequences:** Eight scientists and one technician have been supported thus greatly contributing to the aflatoxin research and training capacity in Uganda. The technique of use of FTIR equipment to analyse aflatoxins can be operated in Uganda.

#### **Kenya:**

Two activities were conducted under objective 4.

#### **Activity 1 – Training of post-graduate scientists**

**Achievements** – Five post graduate students (4 MSc and 1 post-doc) have been supported by the project under the HACCP objective and one (MSc) under the livelihoods objective. Dr. Charity Mutegi, the post-doc supported by Peanut CRSP, has been effectively working as Co-PI in Kenya and coordinating activities with students and potential collaborators in the country. Dr. Mutegi has been working closely with Dr. Maina Wagacha in supporting the project activities.

The MSc students were trained in relevant areas directly related to their laboratory experiments and data management including statistical analysis. All the students (except Winifred Selle) are in the final stages of their respective studies. Two of the students (Rosina Wanyama and Henry Momanyi) have submitted their theses to their respective Universities for final examination. The thesis for one student (Johnson Weru) is ready for

submission but he must first meet the University requirement of publishing a manuscript in a peer-reviewed Journal. One student (Helene Nyirahakizimana) is finalizing her thesis, has sent intent to submit to the University and her thesis will be ready for submission in January 2013. However, one student (Winifred Selle) is lagging behind, showing minimal progress and it is difficult to predict when she will be ready to submit her thesis. The other four students are expected to graduate in mid-2013 (Universities in Kenya conduct two graduation ceremonies in a year – May or June and November or December).

Each student is also expected to generate a manuscript from their research project for publication in a peer-reviewed Journal. Rosina Wanyama has drafted a publication which will be submitted to the Current Research Journal of Social Sciences. Rosina is also working on a second paper to be presented at the African Association of Agricultural Economists Conference in September 2013, at Hammamet, Tunisia. Henry Momanyi has also drafted a publication which will be submitted to the Statistical Methodology Journal by end of January 2013. Johnson Weru's draft publication is in the final stages and should be ready for submission to the Journal of Applied Bioscience by mid-January. Although Helene Nyirakizimana has not completed her draft publication, she is making remarkable progress and the academic advisory team shares a common view that Helene will have the draft ready by end of January 2013. Once again, our concern regards Winifred Selle whose progress is uncertain.

The 5 MSc. students – 3 females and 2 males - come from diverse disciplines but which are related to aflatoxin, its effects on human health and trade, and management. The 5 students specialize in Food Science and Nutrition, Genetics, Microbiology, Research Methods and Agricultural and Applied Economics. Two of the students (Helene Nyirahakizimana and Johnson Weru) were trained for two days on isolation and identification of fungal pathogens with special focus on *Aspergillus* section *Flavi* as well as on extraction of aflatoxin from peanut kernels. The training was conducted at the ICRISAT microbiology lab with the input of three scientists from ICRISAT and CAB International as well as the ICRISAT technician specializing in aflatoxin analysis.

### **Activity 2 – Training personnel on aflatoxin analysis and microbial assays**

**Achievements** - Two people were trained on the Indirect Competitive Elisa technique for aflatoxin analysis and played an important role in the analysis of peanut samples collected from the field. These were: i) Ayub Gikaru (BSc Biological Sciences from Moi University) – he was engaged by the project as the full time technician as he had fully mastered the protocol and, ii) Gordon Otieno (MSc in Agricultural Entomology). His thesis (not funded by Peanut CRSP) was on evaluation of storage methods and integrated post harvest pest management of maize in Siaya district in Kenya. He was also trained in collect survey data as well as simple analytical tools for analyzing baseline data. Lucy Karanja (pursuing MSc in Microbiology and Biotechnology at the University of Nairobi) was trained in isolation and identification of *Aspergillus* section *Flavi* and has worked closely with Ayub in microbial assay of peanut samples collected from the field and also samples from *in vitro* experiments.

**Consequences/Significance** – Through the postgraduate training of eight students and a Technician, the project has made a significant contribution in strengthening capacity for research on and management of aflatoxins in Kenya. The training has also incorporated the role of gender in peanuts production, trade and the possible role of women in management of aflatoxin contamination. It is also expected that the trained personnel will play an advisory role to the Government of Kenya on how to approach the aflatoxin problem in the country. The diversity of training in different disciplines will be useful in future research efforts.

**Objective 5. FTIR: Develop Non-destructive Rapid Deduction System to Test for AF in Peanuts and Peanut Products using Fourier Transformation Infrared spectroscopy with Attenuated Total Reflection (FTIR-ATR) or Photo Acoustic Spectroscopy (FTIR-PAS).**

One activity was done under this objective

**Achievements** - The study explored the possibility of using vibrational spectroscopy (FTIR) as a tool to understand chemical changes in peanuts and peanut products to *Aspergillus* invasion or aflatoxin contamination. The best spectral region to describe aflatoxin contamination were 3028-2752, 1800-1707, 1584-1424, and 1408-1127  $\text{cm}^{-1}$  giving correlation coefficient of 0.99 and prediction error of 19.5 ppb. Applying the constructed partial least squares models, 95% of the samples were correctly classified while the percentage of false negative and false positive identifications were 16% and 0%, respectively. Aflatoxigenic and non-aflatoxigenic strains of *A. flavus* and *A. parasiticus* were further studied for separating the toxic streams from just moldy and clean samples. Clean (having aflatoxin level lower than 20 ppb), only moldy (having aflatoxin level lower than 300 ppb) and toxic samples (having aflatoxin level greater than 300 ppb) were separated into appropriate classes (with a 100% classification accuracy). The overall results of current study proved the potential of FTIR, equipped with either ATR or PAS, in identification, quantification and classification at varying levels of mold density and aflatoxin concentration. The method developed could be able to differentiate and discriminate peanut samples based on mold infestation and aflatoxin contamination levels successfully in lab experiments. Without any additional sample preparation step, the samples can be analyzed and characterized rapidly. The method developed also has acceptable prediction error for removing moldy and toxic peanuts and peanut products and could classify correctly 95% of the time for aflatoxin and 100% of the time in separating moldy and toxic products from clean products.

**Consequences** - The FTIR system had been shipped and installed in the Food Science Department of Makerere University and will be able to provide rapid evaluation capability to detect aflatoxin and molds in peanut and peanut products. The savings from not needing any special chemicals or sample preparation procedures, the cost of analysis could be minimized and provide an affordable testing service to peanut processors in Uganda. Ms. Hande Kaya Celikar completed her Ph.D. at Virginia Tech working on research related to the method development. In addition, three individuals from Makerere University had been trained on the use of the FTIR system. Benjamin Setango, a technician from Makerere

University, spent a month at Virginia Tech and worked with Ms. Kaya Celikar and analyzed the peanut samples from Uganda. After shipping and installing the unit in Makerere University, Ms. Kaya Celikar and Dr. Mallikarjunan trained several individuals in the University including Ms. Sophie Nanseranko, Mr. Abel Atukwase, and Dr. Archileo Kaaya.

### **Uganda:**

#### **Objective 6. Ethnographic research: Qualitative, ethnographic research in selected households in urban and rural areas of Kenya and Uganda to document cooking practices involving peanuts, clay-eating practices, and identify opportunities for mitigating or reducing aflatoxins in diet**

**Summary** - Ethnographic activities consisted of initial meetings and agreements with collaborators, a training seminar on qualitative and participative methodologies, fieldwork data gathering, and selection and advising of graduate students. Initial planning meetings were held with the Women and Gender Studies (WGS) Department at Makerere and with the National Association of Women's Organizations in Uganda (NAWOU). Three graduate students in WGS were selected for funding of fieldwork costs pending the approval of their research proposals by Makerere, and were trained in data collection techniques. Field work was carried out in 5 villages, with participative mapping and interviews carried out in each. 48 exercise workbooks and pencils were distributed for farmers to record cooking practices, recipes, and information and stories about peanuts in their lives and living spaces.

**Achievements** - The qualitative ethnographic research conducted as part of this objective intersects with several other of the project related objectives; (1) IEC – Objective 3, (2) Training – Objective 4 (3) Clay – Objective 7 (4) Livelihoods – Objective 9. This research emphasizes a collaborative people-based approach that serves to support the goals of the project while also specifically working with women and addressing gender issues. As part of this ethnographic research three WGS students from Makerere University were recruited for field research related to gender, peanuts, and aflatoxin. These students and others were trained in how to apply various gender research methodologies to collect data relevant to this objective. NAWOU (National Association of Women Organizations in Uganda) was a primary research partner with their existing leadership and social networks facilitating access and participation of farmers in research and outreach. The primary achievement of the ethnographic research conducted under this objective was the publishing of the book *Farmers' Stories from Kamuli: Groundnut Knowledge, Recipes, and Everyday Life*.

An impact assessment of this publication showed that the publication has been shared with over 1,298 farmers just by the Kamuli farmers and a total of nearly 2000 not including the people reached through the different media organizations involved in the launch of the book. One finding was that through the different activities Kamuli farmers had been made aware of the dangers of AF and of techniques to reduce its incidence and impact: they stored peanuts off the ground, put peanuts out to dry directly after harvest (rather than

storing until the harvest was complete and then putting out to dry), sorted carefully, and did not purchase already pounded flour at the market. The latter has increased women's labor at the same time as it has created a small market for flour made by our trained farmers who pound clean peanuts. Men have asked for a machine to facilitate pounding and reduce labor. Women have said the labor is made easier by working together and with family members. The challenge will be how to facilitate this simple value-added process while keeping the revenue in women's hands; the hypothesis is that as long as it is pounded by women (by hand) and is produced in small amounts, this will be the case. NAWOU will explore how to increase benefits to women by providing training in basic accounting and organizational issues.

Additionally, ethnographic research has been conducted in Mubende district, Uganda to document peanut cooking practices and the importance of peanuts to farmer's everyday lives. These practices can then be compared with those reported in other districts of Uganda and serve in continued efforts in the management of aflatoxin and the enhancement of improved utilization of peanuts by women. As in Kamuli, a book entitled *Farmer's Stories from Mubende: Importance of Groundnuts in our Daily Lives* was published and distributed to the farmers of the district.

**Consequences** - 1. The project has interested both men and women and activism within women groups in Kamuli. 2. Through NAWOU mobilization, district officials have developed interest in the project. A sub-county extension Officer attended the last meeting. 3. Raising awareness among the community on the importance of women's work, knowledge and skills even if it is in the kitchen, 4. The Cookbooks/ Kitchen stories assignment to the women is building a number of skills- for instance, writing, observation and recording, and note making, 4. There has been confidence built among and for women from the fact that someone, and especially from a university, is asking for information that has over time been taken for granted on a crop that is an everyday item in their lives. 5. The training on aflatoxins was done twice and the fact that there were more participants at the second meeting shows that there is interest growing in the community. 6. There is positive response (testimonies and stories) on how farmers are trying to avoid aflatoxins.

Empowering women through research: While usually researchers working in mixed groups find few women in proportion to men, and usually sitting in the back and quiet, in the exercise with NAWOU the opposite was true. At the February meeting, there were 48 people (31 were women and 17 men). The men were seated at the back and mostly next to each other, a small group was at one side as if they knew it was not their meeting. This is true even of the meeting with Dr Kaaya. However, the men still wanted to dominate the discussions but NAWOU facilitators made sure women were encouraged to talk. Where a man would raise an issue that was not true, for instance claiming that both men and women participate equally in growing peanuts, women would make noise and you could see the men smiling.

Working through women's groups, linking with research institutions, Makerere and Virginia Tech, that deals with a food / cash crop is one way of making the work of researchers practical, real and relevant and it gives an opportunity to women to express

their views, be heard and documented. It would be difficult to get women participating in a research program, because due to gender marginalization women may not be approached for their views, and as individuals they may fear / hesitate or be prohibited from answering questions and giving their views. Working with groups of women means that one can reach many women at a time and that the women would already be gathered with similar objectives. This means that the researcher's work is made easier and more credible as women's views reflect household/ family realities.

The Kamuli book was published, launched, and will continue to be distributed inside the district and beyond in order to share knowledge. NAWOU networks have allowed this to be distributed beyond the scope of the district, and even to other countries in Africa. -The Kamuli booklet, due to its hand-drawn images and photographs, and in conjunction with the hands-on training provided by Dr. Kaaya, is an effective way to reach the more illiterate portions of the population, especially women.

**Objective 7: Identify clays in the region that can bind to AF and reduce its toxicity, building on prior Peanut CRSP research. Explore the feasibility of using locally available clays in Kenya and Uganda as a product to supplement in animal feed and human diet for mitigating aflatoxin poison.**

**Uganda:**

**One activity was done under this objective.**

**Activity :** Testing for bentonite among the clays in Uganda

**Achievements:** Sampling of clays was done in Rukungiri, Kasese and Hoima districts, Western part of Uganda. Specifically, clay samples were obtained from Nkondo-Ssebugoro (Hoima), Katwe and Kibuku (Kasese) and Burama (Rukungiri). Laboratory tests were conducted with the Geology Department, and results indicated that the clays from these areas contain sufficient quantities of Bentonite. The clay samples were sent to Texas A & M University USA for further confirmation and determination of the binding capability. The binding capabilities of these clays were expressed in  $Q_{\max}$  (mol AFB<sub>1</sub>kg<sup>-1</sup>) and were as follows:

- Bundibugyo: 0.13
- Hoima: 0.16
- Lukungiri: 0.12

The conclusion about these results is that based on several animal studies done, commercial clays with  $Q_{\max}$  less than 0.2 are not effective *in vivo*.

**Consequences:**

- The binding potential of the bentonite clays in Uganda was established.

- The safety of these clays has been established
- The clays from Uganda have poor binding aflatoxin properties and thus, more samples could be obtained in other areas of the country.

**Objective 9: Livelihoods - Working with women's organizations and cooperatives, develop livelihood strategies and models for reducing poverty and malnutrition in rural areas via value addition in peanuts.**

**Kenya:**

One activity was conducted under objective 9.

**Activity 1-** A field survey was conducted in two divisions - Ndhiwa and Rongo - in Nyanza province where 310 randomly selected peanut producers were involved. Despite the known benefit of higher incomes for farmers' through processing, few farmers in the region carry out value addition activities. The objectives of this study were therefore to: (i) characterize the value adding activities and opportunities for peanuts disaggregated by gender for peanut producers in selected districts of western Kenya; (ii) determine the factors influencing peanut value addition by gender; (iii) assess the gendered effect of peanut value addition on household income. A logistic regression model was used to determine the factors that influence the decision of households to add value while Propensity Score Method (PSM) was used to determine the gendered effect of peanut value addition on household income.

This study was undertaken by a postgraduate student; Ms. Rosina Wanyama pursuing Masters in Agricultural and Applied Economics at Egerton University. As part of collaborative program, Rosina successfully completed part of her coursework in December 2011 at the University of Pretoria in South Africa. Rosina has submitted her thesis to Egerton University for examination. Additionally, she has drafted a publication which will be submitted to the Current Research Journal of Social Sciences. The paper should be ready for submission to the Journal by end of January 2013.

**Achievements**

The following were the key findings from Rosina's study:

- Households who had access to credit had a low probability of participating in peanut value addition. This implies that the loans were allocated to other activities apart from peanut production.
- The quantity of peanuts produced had a significant positive effect on the decision to participate in value addition. Higher productivity can be achieved with increasing the size of land allocated to peanut production, adoption of good agricultural practices and efficient disease and pest management.
- Higher production of value added products without an assured market is not sufficient. Households located closer to the market had a higher probability of participating in value addition.



- Contact with extension agents had a significant positive effect on the decision to participate in value addition. Farmers who had more frequent contacts with the extension agents had a higher probability of participating in value addition.
- There was a significant difference in income between male and female headed households. A significant difference further existed between the number of male headed households who participated in value addition and female headed households who did participate (69% and 31%, respectively). While gender as a variable did not significantly explain the differences, this can be explained in terms of gender-linked differences in resource access.
- Lack of machines and equipment – including Sheller machines, milling and decorticating machines - for processing was a major constraint in value addition. Although the machines can be made locally, they are not affordable for individual farmers.

#### Recommendations from the study:

- a. The government should consider credit support packages to peanut farmers to avoid credit diversion. The move will help enhance peanut productivity and value addition. In addition, the credit services should be made available at reasonable interest rates and timely to help farmers purchase the necessary inputs.
- b. The government and other development partners should develop high yielding seeds which are also resistant to pests and diseases. Suitable pesticides should also be made available to farmers at affordable costs. In addition, training on new and effective methods of cultivation should be done especially in areas where intercropping is the common feature of cultivation.
- c. Policy makers should focus on market development in terms of improving road infrastructure and creation of ready markets, both locally and internationally to facilitate market participation for all farmers. To expand their market niche, farmers should also be empowered and advised on compliance with safety standards set by the Kenya Bureau of Standards (KEBS).
- d. The government through the Ministry of Agriculture should develop an organized system where farmers would have frequent contacts with extension agents. This could be in form of farmers' field days, farmer trainings, on and off farm demonstration among others.
- e. Policies that promote equal access to resources should be adopted to reduce disparities in income between male and female headed households. This will help increase the participation of female headed households in value addition which in turn will boost the income in these households.
- f. Effective farmer groups should be formed so that farmers can acquire machinery needed at fair prices. When in a group, farmers have a higher bargaining power and can access wider market niche for their products as well as reasonable returns from their sales. In addition farmers groups will provide a better opportunity for farmers to access extension services through trainings and demonstrations.

**Consequences/Significance** – There is need for capacity building of women at all levels: student, farmers, district and village level women's organization leaders, and a national

network. Policies should be put in place to empower women both in production and value addition. This is based on the findings of this study which showed that value addition raises household per capita income by Kshs.82 (equivalent of \$1) per day. Potential therefore exists in peanut value addition as a possibility to raise farmers' household incomes above the poverty line. A diversity of value adding options should be explored and adopted to sustainably improve peanut farmers' livelihoods.

As a result of her budding research efforts, Rosina also qualified for an African Women in Agricultural Research and Development (AWARD) fellowship, a competitive grant that sets to develop the careers of promising scientists, and steer them into leadership. More importantly, they are taken through a formal mentoring period of two years. She is also guided through honing her scientific skills, including attending a regional conference, which she will be able to present her MSc research findings. She works under the mentorship of Dr. Charity Mutegi, the Co-PI in the project. Rosina is also working on a second paper to be presented in the African Association of Agricultural Economists Conference from September 23-25, 2013, at Hammamet, Tunisia.