FEED THE FUTURE INNOVATION LAB FOR FOOD PROCESSING AND POST-HARVEST HANDLING

ANNUAL REPORT

OCTOBER 31, 2015

LEAD UNIVERSITY

Purdue University

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LIST OF COUNTRIES WHERE THE PROJECT WORKS

Kenya and Senegal

LIST OF PROGRAM PARTNERS[1]

- ***USA:*** North Carolina A&T State University
- ***Kenya:*** University of Eldoret; The Cooperative University College of Kenya; and CIMMYT, Kenya
- ***Senegal:*** Institut de Technologie Alimentaire and Institut Senegalais de Recherches Agricoles.
- ***Others:*** University of Pretoria, South Africa and A to Z Textiles, Tanzania.

[1] U.S. universities and international partners by country.

ACRONYMS

AC	Advisory Council
CUCK	The Cooperative University College of Kenya
DDL	Development Data Library
DMP	Data Management Plan
DOIs	Digital Object Identifiers
DV	Dietary value
EAR	Estimated Average Requirements
EMC	Equilibrium Moisture Content
FGD	Focus Group Discussion
FPL	Innovation Lab for Food Processing and Post-harvest Handling
KALRO	Kenya at the Kenya Agricultural and Livestock Research Organization
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
INGENAES	Integrating Gender and Nutrition within Agricultural Extension Services
ISRA	L'Institut Sénégalais de Recherches Agricoles
ITA	Institut de Technologie Alimentaire
JKUAT	Jomo Kenyatta University of Science and Technology
NC A&T	North Carolina A&T State University
NGOs	Non-governmental Organizations
OTC	Office of Technology and Commercialization
PICS	Purdue Improved CROP Storage bags
PURR	Purdue University Research Repository
SC	Steering Committee
SOPs	Standard Operating Procedures
WEAI	Women's Empowerment in Agriculture Index

I) EXECUTIVE SUMMARY

The Food Processing Innovation Lab's goal is to increase access to safe and nutritious foods along the value chains by improving the drying and storage capacity of smallholder farmers and expanding market opportunities through diversified processed products that address quality in the market and nutritional needs. The program focuses on cereals and grain legume value chains in Kenya and Senegal. Locally available nutrient-rich value chains are also targeted for enhancing the nutrition of processed products. The activities covered in this report cover the period of April 1, 2015 to September 30, 2015. Limited reference is made to the activities reported in the semi-annual report (May 19, 2014 to March 30, 2015) to provide a full perspective of the annual activities. Progress has been made in the following key project areas including: 1) development of simple moisture determination methods; 2) development of low-cost drying technologies; 3) testing of efficacy of hermetic storage bags such as PICS for moisture and pest control in hot and humid tropics; 4) assessment of market drivers for processed food products, with and without micronutrient fortification; 5) collecting and archiving dried nutrient-rich plant sources including analyses for provitamin A, Iron, and Zinc, and establishing standard operating procedures for plant material procurement and handling; 5) development of demand-driven food products for Kenyan and Senegalese markets; and 6) establishment of effective dissemination platforms for food technologies.

Year 2 work will build on the successes of year 1 in all four project component areas of drying, storage, food processing, and nutrition including optimizing and field testing developed technologies and continued research and development of new technologies. These efforts also provide a framework for capacity building, scientific exchange and strengthening/building of public private partnerships for effective technology adoption. As a main outcome, this project seeks to develop and disseminate technologies that are replicable, cost-effective, scalable, and commercially viable for smallholder farmers, food processors, and consumers in Kenya, Senegal, and other Feed the Future countries.

II) PROGRAM ACTIVITIES AND HIGHLIGHTS[2]

- Installation of weather stations in Kenya and Senegal for weather data collection.
- Survey of post-harvest practices for maize in Kakamega, Kenya to determine the moisture content and quality (kernel disease, insect count and aflatoxin contamination) as maize moves from the field at harvest to the barn or home for storage.
- Development of low-cost moisture measuring devices – the Xikar thermo-hygrometer equipped with a calibration feature has been found to provide consistently accurate measurements
- Designing two grain dryers: a portable solar dryer and a drying stove.
- Evaluation of the efficacy of PICS hermetic bags to provide a moisture barrier under hot and humid conditions. Effects of routine opening of the PICS bags was also tested, with maize stored at various moistures (15%, 16%, 18%, 20%) under warm tropical conditions.
- Collection of baseline data to assess market demand and drivers for processed food products, with and without nutritional enhancement in Kenya and Senegal.
- Analysis of micronutrients content of local nutrient-rich plant materials collected in Kenya and Senegal.
- Screening for micronutrient bioaccessibility (optimizing delivery) from model food products - using both *in vitro* and *in vivo* methods.
- Establishment of Standard Operating Procedures (SOPs) for material procurement and handling related to micronutrient screening and product development.
- Development of new and improved food products (fortified and non-fortified) for Kenya and Senegal markets using the extrusion method.
- Assessment of the impact of co-extrusion on physical properties and micronutrient stability of blended instant millet products.
- Establishment of a food processing "Incubation Center" at University of Eldoret in Kenya for training processor entrepreneurs. An old building was renovated and equipped it with food processing equipment.

[2] Summary of program activities for the year, no more than one page in length.

III) KEY ACCOMPLISHMENTS[3]

- Two HOBO weather stations manufactured by Onset Computer Corporation, Bourne, MA, USA were installed in Kakamega, Kenya at the Kenya Agricultural and Livestock Research Organization (KALRO) field station and in Velingara, Senegal at the Institut Senegalais de Recherches Agricoles (ISRA) field station in April and June, respectively. Data collected will be used in evaluating the impact of weather on both drying and storage in the regions, and help design best management practices for smallholder maize cropping systems.
- Xikar thermo-hygrometer that has a calibration feature has been found to provide consistently accurate moisture measurements comparable to a commercial grain moisturemeter (Dickey-John). The device is slightly expensive at $30 on-line retail, but cheaper than the commercial one.
- A counting plate was developed for quickly and accurately counting required maize kernels based on kernel dimensions from a bulk sample for moisture determination. Moisture measurement of the grain is based on the pre-determined dry weight of 1000 kernels.
- Two grain dryers were designed: a portable solar dryer and a drying stove. Prototypes are being fabricated for testing at Purdue.
- Experimental protocols for determining fungal species community associated with stored maize have been developed. The protocols rely on "next generation sequencing" method and informatics to identify and quantify fungal species.
- Market assessment studies have identified potential drivers for processed and nutritionally enhanced processed products among different socio-economic groups. They include: nutrition, cost, satiety value of products, convenience and energy-saving potential.
- A dataset of 30 distinct dried plant materials from Senegal and Kenya that have been screened for provitamin A and mineral content has been established and is available at Purdue. Select materials have been prioritized for further product testing including carrot, mango, and papaya for vitamin A, and baobab fruit, Lam (*Moringa sp.*), Oule, Nere, and Roselle (*Hibiscus sp.*) for iron and zinc content.
- Established Standard Operating Procedures (SOPs) for material procurement and handling related to micronutrient screening and product development.
- Food products developed under FPL include:
    - Senegal - Instant extruded weaning foods enriched with mixed fruits. Sensorial analyses showed preference for formulas enriched with papaya, followed by mango, then carrots. Analyses of beta-carotene content showed that the formula with carrots with significantly higher in amount than with papaya or mango.
    - Pretoria: a ready-to-eat instant extrusion cooked sorghum-based porridge with enhanced protein quality and mineral micronutrients through compositing with micronized (infrared cooked) cowpeas and a cowpea leaf relish. The product's contribution to protein and lysine RDAs is similar to that of commercial fortified corn-soy blend products and the bioaccessibilty of its iron and zinc is much higher. Product will be adopted for Kenya and Senegal.
- A building provided by the University of Eldoret was renovated by FPL to house the food processing Incubation Center. The building has been fitted with basic food processing equipment and a lab for basic tests on grain for processing.
- 15 graduate students recruited: 8 male and 6 female; 11 Ph.D. and 4 Masters. The students are from Kenya, Senegal, Ethiopia, Botwana, Nigeria, South Africa, Ecuador, and USA.

IV) RESEARCH PROGRAM OVERVIEW AND STRUCTURE

The project has two core research components: 1) Grain drying and storage involves development and dissemination of affordable and efficient drying and storage technologies for use by smallholder farmer, and 2) Food processing and nutrition involves development of high quality, market-competitive food products,

[3] Concise statement of achievements, limited to one page in length that focuses on outputs, not process, such as Feed the Future indicators and distillation of program achievements across all program activities. Reporting on numbers of project meetings is not an output.

including products with improved nutrition and dissemination through incubation training centers. Building of local capacities (human and institutional) and partnerships among public and private sector are also major components of the project. Gender and environment are taken into account at all stages of the project cycle.

V) RESEARCH PROJECT REPORT[4]

a) Theme A: Drying & Storage (Improve moisture measurement, drying, and storage of cereals and grain legumes in the humid tropics of Africa)

i) Project 1:

(1) Name: Grain dryers and moisture meter development

(2) Description: Development of grain dryers and moisture content determination methods for dried grain.

(3) Collaborators[5]: Klein Ileleji (lead), Charles Woloshuk, Jess Lowenberg-DeBoer, Corinne Alexander & Jake Ricker-Gilbert (Purdue, USA); Douglas Shitanda (CUCK, Kenya); Hugo DeGroote (CIMMYT, Kenya); Makhtar Samb (ITA, Senegal); Ibrahim Sarr & Katim Toure (ISRA, Senegal); Guibing Chen (NC A&T, USA); Cheryl O'Brien (San Diego State University, USA)

(4) Achievements:

(a) **Development of simple grain moisture methods:** We continued to work on developing a low-cost moisture-measuring device. The AcuRite® brand thermo-hygrometer that had shown good potential was further evaluated and found to be unacceptably inaccurate over grain moisture ranges between 10 and 15 %. Five low-cost digital thermo-hygrometers with salt solutions that equilibrate to known air relative humidities (RH) were tested. Results indicated that the Xikar thermo-hygrometer equipped with a calibration feature (though more expensive than other devices at $30 on-line retail) was consistently accurate over a range of temperatures. The Xikar thermo-hygrometer was tested on grain samples collected during a farm survey conducted in Kakamega, Kenya in September 2015 (Figure 1). Moisture values were comparable to those obtained with a commercial grain moisture meter (Dickey-john). FPL researchers (Drs. Ileleji and Chen) are developing a simple method to determine grain moisture content from the weight of 1000 randomly picked corn kernels based on their pre-determined dry weight. If kernels are accurately counted, the absolute error in moisture content was about ±1%. Since this method depends on a certain number of corn kernels (1000 kernel weight), it is important to accurately and quickly count the required number of corn kernels. Dr. Chen of North Carolina A&T State University in Greensboro, NC has developed a fast counting plate for counting 1000 kernels from a bulk sample. The fast counting plate was designed to count out 100 kernels each time from a bulk sample based on kernel dimensions of the yellow-dent corn samples harvested from North Carolina A&T State University (Greensboro, NC) experiment farm. Additionally, the absolute error (AE) in moisture content resulting from the number counting was determined to be about ±1% when the error in the counted number of corn kernels is ±10 based on 13% (dry basis) corn. Future work would be to test this counting methodology with a range of kernels from several popular maize varieties in Kakamega, Kenya and Velingara, Senegal.

[4] Summaries of project activities, highlights and outcomes, not scientific reports or long detailed research papers, no more than one page per project.

[5] Provide institutional affiliation and country.

Figure 1. Testing grain moisture with the Xikar thermo-hygrometer

(a) **Development of grain dryers**: Dr. Ileleji and his team have designed two grain dryer prototypes: a portable solar dryer (Figure 2) and a drying stove. The portable solar dryer is currently being fabricated and will be ready for full scale testing in December. Due to some unexpected design delays, fabrication of the drying stove will begin in December and testing will proceed thereafter sometime in January 2016. Patent disclosures have been filed for both technologies with Purdue Office of Technology and Commercialization (OTC) with plans to commercialize both technologies through a private business enterprise. The commercialization goal is to produce these technologies at scale for the market in Africa, Asia and the Americas, thereby reducing the final cost to the farmer. The prototypes will be tested at Purdue first then deployed field testing at research stations in Kenya and Senegal by April 2016 in preparation for testing during the harvest season of 2016. Additionally, feedback on the technologies from farmers will be obtained in the Fall of 2016. Other on-going research work conducted as part of the dryer R&D effort involves evaluating thin-layer drying of maize and other food products including carrots and mangoes. The work with carrots and mangoes is in collaboration with FPL's processing and nutrition group (Drs. Hamaker and Ferruzzi).

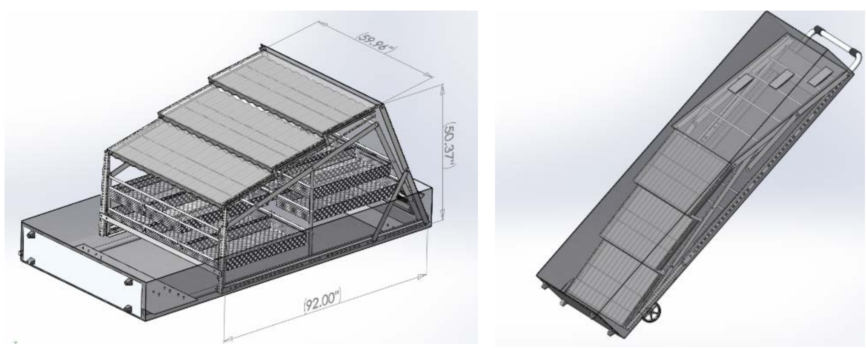


Figure 2. Portable solar crop dryer in both usage and towage configurations.

(b) **Deployment of weather stations a field stations in Kenya and Senegal**: Irrespective of the crop drying and storage method used, weather plays a major role in post-harvest operations and greatly impacts post-harvest losses (PHL). As part of Year 1 deliverables, two HOBO weather station manufactured by Onset Computer Corporation, Bourne, MA, USA were installed in the Kenya Agricultural and Livestock Research Organization field station in Kakamega, Kenya and Institut Senegalais de Recherches Agricoles (ISRA) field station in Velingara, Senegal in April and June 2015, respectively. The weather stations consist of a HOBO U30 NRC data logger, Temperature/RH sensors, rain gauge, wind speed and direction sensor, solar shield for Temperature/RH sensors, solar radiation (pyranometer) sensor, small solar panel kit (1.2 W), data logging software/cable and a 2 meter tripod stand/cross harm with accompanying mounting accessories. Data from the sensors are logged hourly and sent to the team at Purdue. The data will be used in evaluating the impact of weather on both drying and storage in the regions, and help design best management practices for smallholder maize cropping systems, which would be disseminated via the local Extension service and NGOs.

(c) **Survey of post-harvest practices in Kenya and Senegal**: The drying and storage team led by Ileleji and Woloshuk in collaboration with De Groote's team at CIMMYT and Shitanda's team at CUCK conducted a survey of farmer's post-harvest practices for maize in the target region of Kakamega, Kenya in September 2015. The goal was to understand farmers' post-harvest cultural practices and how they affect grain quality and losses. About 313 farming households were interviewed during the survey, in addition to collecting samples of maize to determine the moisture content and quality (kernel disease, insect count and aflatoxin contamination) as maize moves from the field at harvest to the barn or home for storage. About 40% of the cobs had disease, mainly due to *Fusarium* species. A few were infected with *Diplodia (Stenocarpella* species*)* and *Aspergillus flavus.* There was low incidence of insect damage. Over half the cobs sampled had bar tips due to poor pollination, insect feeding and/or disease at a count of 663 cobs. Aflatoxin testing was conducted on 116 samples from all location areas, mostly on unharvested and in storage corn. All samples had an aflatoxin content under 6 ppb (acceptable limit) except one sample with 58 ppb which appeared to have *A. flavus* infected kernels. The mean for unharvested corn was at 0.42 ppb and corn in storage had a mean of 0.26 ppb. There is no significant difference between any aflatoxin amounts from any location. The max concentration for unharvested corn was 3.02 ppb and the max concentration for stored corn was 5.58 ppb. The maize moisture profile at various stages from field to storage barn is shown in Table 1. Farmers dried their maize crop to relative low moistures (14.3% wet basis on average). However, drying from about 33% to below 14% could take from 2 to 4 weeks depending on the size of the crop harvested and the inclement weather. Maize was predominantly dried in both cobs and shelled forms by spreading on a bag or tarp using open air solar drying (Figure 3). Contamination and quality losses were high due to unsanitary handling methods, fecal and feeding by domesticated livestock and storing in insect infested barns. A similar survey is currently being undertaken with our collaborators in Velingara, Senegal.

Table 1. Moisture content of maize sampled from various post-harvest stages (field to storage barn) in Kakamega, Kenya (September 2015)

Sample type	Sample ID	# of samples	Average moisture content (%)
Not harvested	1	68	33.41±3.18
Cobs in stalks	2	5	30.34±3.42
Cobs in piles	3	12	32.78±4.12
Cobs being dried outside	4	46	26.58±5.69
Cobs being dried inside	5	93	24.65±5.38
Shelled grains being dried outside	6	92	18.03±5.48
Shelled grains inside (being dried)	7	87	18.33±5.94
Stored (dry) grains	8	136	14.27±5.22
	TOTAL	539	

Figure 3. Typical drying practice of smallholders in Kakamega, Kenya

(5) Capacity Building: A PhD student from Nepal, Ravindra Shrestha is working on the drying stove project and a staff engineer from Nigeria, Jesumayokunmi (Mayo) Olasubulumi, a recent BS graduate in mechanical engineering is working on the solar grain dryer. Additionally, two visiting undergraduate students from Columbia (not paid on the USAID grant) have assisted with the research on moisture sensor development and the solar crop dryer. A lecturer at Jomo Kenyatta University of Science and Technology (JKUAT), Alfayo Anyangu is working with Drs. Shitanda and Ileleji to address some key challenges and research questions that came up during the post-harvest practices survey in Kenya. Also, a student and staff (Makhtar Samb) with ITA and ISRA, respectively, will conduct research work in support of the project objectives related to drying and storage.

(6) Lessons Learned: For the moisture determination using the low-cost measuring device for indirect determination of moisture in maize using the equilibrium moisture content method (EMC), it is essential to have a digital thermo-hygrometer that has a calibration feature to assure precision. Most smallholder farmers in Kakamega grow maize for subsistence and not to trade for cash. A number of post-harvest practices, which are conducted to speed up drying such as leaving ears on the stalk in a pile for 7 to 14 days after cutting, might not be really beneficial under daily precipitation conditions, which occurs during harvest in Kakamega. Our immediate goal is to develop training and Extension tools to address adequate training of farmers on good post-harvest practices, which has to do more with a change in behavior.

(7) Presentations and Publications: None

ii) Project 2

(1) Name: Grain storage
(2) Description: Storage methods in Senegal and Kenya – Begin to identify storage methods used and assess potential for aflatoxin development in hermetic bags
(3) Collaborators[5]: Jess Lowenberg-DeBoer (Purdue, USA) (lead), Charles Woloshuk (Purdue, USA); Douglas Shitanda (JKUAT, Kenya); Hugo DeGroote (CIMMYT, Kenya); Makhtar Samb (ITA, Senegal); Ibrahim Sarr (ISRA, Senegal)
(4) Achievements: An experiment was conducted between the period of June 24 and September 30 to evaluate the efficacy of PICS hermetic bags to provide a moisture barrier under hot and humid condition. Two environments were chosen for the experiment, ACRE in West Lafayette, IN (Purdue University) and the Lon Mann Cotton Research Center in Marianna, AR (University of

Arkansas). Marianna is around 900 Km south of West Lafayette. The West Lafayette location is cooler with a lot of rain while Marianna is hot and humid. At both locations, three woven bags and three PICS bags were filled with 40 kilograms of maize. Each 40 kilogram contained three satchels containing 100 grams of *Aspergillus flavus* colonized maize contaminated with aflatoxin and three satchels of non-colonized, aflatoxin-free maize placed in close proximity. The rationale for satchels was to test whether aflatoxin accumulates higher and whether A. flavus spreads to the clean grain. Preliminary results indicate that moisture and heat increased in the grain stored in mesh bags at both locations, with little change in grain in the PICS bags. Also insect (weevils) counts were very high in the mesh, with essential none in the PICS.
Effects of routine opening of the PICS bags were also tested, with maize stored at various moistures (15%, 16%, 18%, 20%) under warm tropical conditions (~28°C). The bags were opened weekly for 30 min inside a humidity chamber (RH = 85%) for 2 and 6 months. Results from 2 month indicate that fungal growth increase dramatically when grain moisture is 16 % or higher.

Table 2. Fungi growth at different layers in PICS bags after 2 months of storage.

		Layer		
Nominal Moisture (%)	Initial cfu/g	Top cfu/g	Middle cfu/g	Bottom cfu/g
15	427	484	273	167
16	427	18,444	57,111	38,667
18	427	81,111	114,444	85,333
20	427	93,334	110,666	233,778

(5) Capacity Building: These projects are part of the MS degree research of Tim Tubbs and Brett Lane at Purdue University. Furthermore, during Dr. Woloshuk's visit to Kakamega, Kenya (Sept 2015), he discussed possible research with Dr. Shitanda's graduate student Michael Mukolwe. Tim Tubbs trained Mr. Mukolwe on the Vicam Aflatoxin test-strip reader. We left Dr. Shitanda with the Vicam test-strip reader for his analysis of aflatoxin.

(6) Lessons Learned: Based on Kakamega survey experience, it is apparent the climate temperature in the region is cool (especially during night), thus much less conducive for preharvest aflatoxin accumulation. Our research confirms the ability of hermetic (PICS) bags to seal out the environment moisture that can potentially rewet the grain to dangerous levels. Routine opening of PICS bags containing dry grain (15%) will not increase spoilage due to fungi for at least 2 months.

(7) Presentations and Publications: An abstract has been submitted for a poster presentation at the annual meeting of the American Phytopathological Society (August 2015) entitled: Simple Devices for Determining Grain Moisture, by Timothy Tubbs and Dr. Charles Woloshuk (as reported in semi-annual report, April 2015).

b) Theme B: Processing & Nutrition (Drive the value chain through processing to increase commercialization and improve nutrition)

i) Project I

(1) Name: Food processing

(2) Description: Assessment of market demand and drivers for processed and nutritionally enhanced products, and development of processes and products with potential for the marketplace.

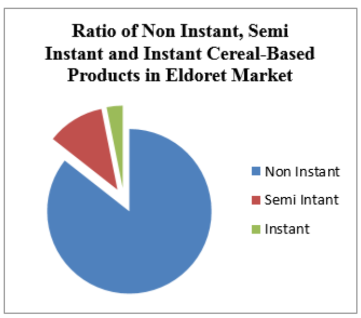
(3) Collaborators[5]: Bruce Hamaker - lead & Mario Ferruzzi (Purdue); Violet Mugalavai & Augostino Onkware (University of Eldoret, Kenya); Djibril Traore (ITA, Senegal); John Taylor & Gyebi Duodu (University of Pretoria); Hugo DeGroote (CIMMYT, Kenya)

(4) Achievements:

(a) Kenya:

University of Eldoret: In the late spring of 2015, renovation of a building begun to house the food processing Incubation Center. The building was provided by the university and FPL provided financial support for the renovation and for additional basic equipment to the ones they already had. In August 2015, an extruder for the project was purchased in the USA and is awaiting custom's paperwork in Kenya for shipment. The FPL team at Eldoret have started developing a training manual that will be used at the Incubation Center.

Nutrient-rich plant sources were identified, including orange-fleshed sweet potato, cowpea, amaranth grain and leaves, carrots, pumpkin seed and flesh, baobab, mango and whole banana flour, for potential use as natural fortificants for nutritional enhancement of food products developed by the project. Nutritional analysis is being conducted at Purdue and Pretoria. Trials have been run on prototype baked and fried products.



A survey of available commercial composite cereal products (instant and non-instant) was conducted and completed in Eldoret. The instant weaning products that were in the market and preferred by customers were imported and expensive (Nestle's Cerelac and Dannone's Purity). The products that were fortified by natural fortificants were also expensive (Figure 4).

Figure 4. Ratio on non-instant, semi-instant, and instant cereal-based products Eldoret market.

A survey was also conducted in September 2015 on sorghum grain use and consumer preferences in Western Kenya. Three focus group discussions were carried out in rural western Kenya areas of Sega, Matayos and Koyonzo. Sorghum is the most consumed cereal in this area. Factors related to its frequent consumption are cultural, nutritional value, taste and availability. Consumption of the grain can be enhanced with products that are nutritious, healthy, affordable, and that have traditional flavors that have high preference among the community. Each household in the communities carries out their own flour processing without fortifying the flours. Upcoming work will focus on introducing better processing techniques and the practice of using natural fortificants found within the community. These will be determined on the basis of nutritional evaluation, but include whole banana flour, amaranth leaf and flour, pumpkin flesh and seed, avocado seed flour, and mango flour.

CIMMYT: In April 2015, a team (H. DeGroote, CIMMYT; G. Duodu, Pretoria; V. Mugalavai, U. Eldoret; B. Hamaker and B. Bugusu, Purdue), under the direction of Dr. DeGroote, met in Nairobi and Eldoret to conduct a market assessment of processed cereal products and to understand potential drivers for nutritionally enhanced products among low and medium-to-high socio-economic groups. Women from both income groups were interested in instant foods, for time and fuel savings. Most consider nutrition, cost and satiety value of products before purchase. Both groups are interested in natural fortification, but only medium-to-high income groups said that they would pay a premium for fortified products. This suggests that it may be difficult to market nutrient-fortified foods with a premium attached to low-to-middle income groups solely on that basis, and that other drivers (e.g. fullness, instant) be used to market fortified products.

A meeting was held with food processors in Nairobi, and input on opportunities and constraints were gathered particularly regarding instant and fortified products. In another exercise, a list of food processors in the Nairobi area was established.

(b) Senegal:

Institut de Technologie Alimentaire (ITA): The team had already been working on commercially viable fortified instant local cereal products with high protein quality and high micronutrient bioaccessibility for porridge applications, and this work has continued in this period. Sensory analysis results showed good progress in terms of food preference, with millet instant porridge faring best compared to other local cereals (Figure 5). The Nestle brand (Cerelac) received the highest score and was significantly different from the other three; however millet received a score of 6.55, which is higher than the critical threshold of 6 that is indicative of marketability of a new product.

In February 2015, Purdue PIs (B. Hamaker and M. Ferruzzi) visited ITA and Touba, and the ITA-Purdue group made the final decision that the extrusion technology will be transferred to Mme. Mbacké, a local woman entrepreneur in Touba who has been trained through the ITA Incubation Center. The extruder was purchased and shipped in August 2015 and will be moved to Touba in the Fall 2015, for training.

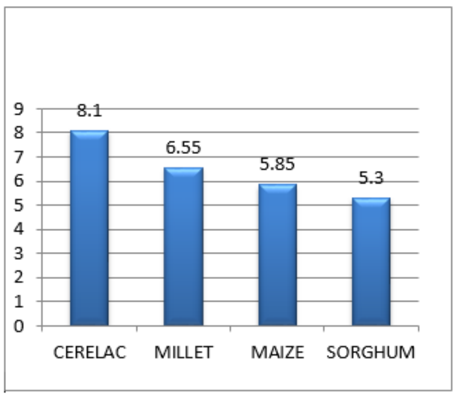


Figure 5. Customer food preference tests: Cerelac vs. blended millet, maize and sorghum.

A summary of FPL activities at ITA, Senegal are as follows:

Weaning foods enriched with mixed fruits. Instant extruded weaning foods were developed using an extruder procured approximately 5 years ago through the USAID INTSORMIL CRSP project (same model extruder as purchased in this period through FPL). Sensorial analyses showed that cereal formulas enriched with papaya were preferred, followed by mango and then carrots. Analyses of beta-carotene content at Purdue showed that the formula with carrots was significantly higher in amount that with papaya or mango. Current work is on enrichment of instant millet flours with combined fruits so as to retain both likability and high beta-carotene content. Sensorial analysis will be conducted in late 2015, following FPL-supported sensory training for 2 ITA scientists at U. Pretoria in November 2015.

Food processing/nutrition work and findings. The common millet variety used in Senegal, Souna, was used to determine the magnitude of nutrient loss after decortication (debranning). Decortication rate of 20% significantly decreased micronutrient contents. Zinc and iron contents agreed with the results obtained by U. Pretoria. Souna is a fairly soft grain, and decortication was found to be incomplete.

Development of instant arraw (agglomerated non-cooked millet product, used as an ingredient in many food products) begun in Senegal in collaboration with Maria Production, a Dakar processor. Fully and half-gelatinized millet flours were produced by extrusion and the processor is now fabricating products and testing in the Dakar market. Arraw is used for many types of food in Senegal, Mali and other Sahelian West African countries.

CIMMYT-Kenya: In June 2015, a team (H. DeGroote, CIMMYT; J. Taylor, Pretoria; D. Traore, ITA, and B. Hamaker, Purdue U.) convened in Senegal under the direction of H. DeGroote to conduct a Senegal market assessment of processed cereal products and to understand potential drivers for nutritionally enhanced products among low and medium-to-high socio-economic groups. The protocol of gaining feedback from low and medium-to-high consumer groups was similar to that used in Kenya. Consumer focus group discussions were had in Dakar and Touba. Feedback was similar to the one in Kenya: the lower economic groups in Dakar and Touba were interested in low-cost instant millet flours and related that to energy savings from cooking, and to a lesser extent but still noted convenience and time saving. Fortification was of less interest in the low than the medium-to-high income consumer groups at both sites. In the medium-to-high income groups, there was a lot of interest in locally made instant flours that would compare to imported ones of Nestle and Dannone.

(c) University of Pretoria

PhD student Nokuthula Vilakati under the leadership of Prof John Taylor, Dr. Johanita Kruger and co-workers has developed a ready-to-eat instant extrusion cooked sorghum-based porridge with enhanced protein quality and mineral micronutrients through compositing with micronized (infrared cooked) cowpeas and a cowpea leaf relish. The product's contribution to protein and lysine RDAs is similar to that of commercial fortified corn-soy blend products and the bioaccessibilty of its iron and zinc is much higher. The protein work has been published in LWT-Food Science and Technology (see under publications) and the mineral work submitted for publication.

Eighteen pearl millet traditional landraces and improved varieties from Senegal and Zimbabwe, and high iron and zinc types developed by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) have been characterised in terms of grain and processing quality. They differed substantially in grain size, weight, endosperm texture, dehulling loss, and colour. Mil Souna, a widely cultivated landrace in Senegal, had the lowest thousand kernel weight, highest proportion of small grains and highest dehulling loss, while Dhanashakti, a high iron and zinc variety from ICRISAT, had the highest thousand kernel weight, highest proportion of large grain size and lowest dehulling loss.

Research into improving the retention and bioaccessibility of iron and zinc and other nutrients and reducing antinutrients in pearl millet and sorghum grain during food processing has commenced. Several technologies are being investigated, including: parboiling (whole kernel steaming), grain steeping (soaking in water or lactic acid), traditional lactic bacteria fermentation and acidification with organic acids.

(5) Capacity Building:
- (a) Long-term training: All students are working to develop various products (fortified and non-fortified) and processes for the targeting the FPL focus countries.
  - (i) Purdue University - Pablo Cesar Torres-Aguilar (advisor, B. Hamaker) started in Fall 2014 (supported through Purdue cost-share), Hawi Debelo (advisor Ferruzzi) is supported on research funds only and started fall 2014.
  - (ii) ITA/Senegal – Fallou Sarr (Food Science) is supported through FPL for his PhD programs at Cheikh Anta Diop University in Dakar (advisors D. Traore and B. Hamaker).
  - (iii) University of Eldoret/Kenya - two Kenyan students (Rose Likoko, University of Eldoret and Harriet Nyakecho, Pwani University) are on the FPL project.
  - (iv) University of Pretoria – 3 PhD, and an undergraduate honors student are supported on the FPL project in the processing area (Ayodeji Falade, Nokuthula Vilakati, Adeoluwa Adetunji, and Renee van der Merwe).
    1. A. Adetunji graduated with his PhD in this period. Title of thesis - Cell wall and tannin treatments for increased utilisation of cassava and sorghum in beverage and bioethanol production. He is undertaking a short post-doctoral fellowship to end

2015 at the University of Pretoria within the FPL project investigating the effects of ultrasonication on polyphenols in pearl millet and sorghum.

2. R. van der Merwe finished her BSc. Her honors research project was titled - Effects of fermentation and acidification with citric acid and ascorbic acid on the iron and zinc uptake from a traditional African finger millet beverage. She will continue with MSc project within the PFL project in 2016.

(b) Short-term training:

(i) In March 2015, Dr. Mugalavai underwent a one week training at ITA in Dakar, Senegal to get exposure on how cereal and legume processing is carried at the ITA Incubation Center, and how the facility is operated and managed.

(ii) ITA is working closely to build expertise and capacity at 3 Dakar processing enterprises: Touba Darou Salam directed by Mme. Mbacke, FreeWork Services directed by Mme. Deme, and Maria Distribution directed by Mme. Diouf.

(6) Lessons Learned:

(a) Kenya:

- Most processors and consumers require food processing and nutrition knowledge for a win-win situation: processors are interested in expanding their line of products while consumers are willing to try new products, including the instant products which are less time consuming, easy to prepare and nutritious, with high satiety value as long as they are not too expensive.
- Focus group discussions (FGD) - Many women consumers are interested in instant food; low-income groups because of fuel-use reduction and higher-income groups for time and convenience. Criteria for choosing cereal products are cost for low-income groups and nutritional quality and convenience for high-income groups. The rural households are interested in nutritionally enhanced fortified flours for their staple foods, processed at household level and also by women and church groups.
- While sorghum is commonly used in Western Kenya, there are few commercial products made from it. A survey indicated good interest in processed products.

(b) Senegal:

- Instant flours are not only used in thin and thick porridges, but entrepreneurs in Dakar have interest in using them to make instant agglomerated products.
- There is good interest in instant flours and fortified foods among consumer groups, though lower income women have little interest in paying even a small premium for fortified products. Marketing of fortified millet products might be done on other attributes such as convenience, saving of cooking fuel, and food factors such as satiety.

(7) Presentations and Publications:

(a) Taylor J.R.N., and Kruger J. 2016. Millets. In: 'The Encyclopedia of Food and Health vol. 3' (B. Caballero, P. Finglas, and F. Toldrá, eds.). Academic Press, Oxford, pp. 748-757.

(b) Vilakati, N., MacIntyre, U., Oelofse, A. and Taylor J.R.N. 2015. Influence of micronization (infrared treatment) on the protein and functional quality of a ready-to-eat sorghum-cowpea African porridge for young child-feeding. LWT Food Science and Technology 63:1191-1198.

ii) Project 2

(1) Name: Nutrition

(2) Description: Screening of nutrient-rich plant materials for use in consumer based food products in Senegal and Kenya

(3) Collaborators[5]: Mario Ferruzzi - lead (Purdue); (Violet Mugalavai & Augostino Onkware (University of Eldoret, Kenya); Djibril Traore (ITA, Senegal); Johanita Kruger (University of Pretoria, South Africa)

(4) Achievements:

(a) Purdue University:

Collection and archiving of 30 distinct dried plant material from Senegal and Kenya was completed in fall 2014 using established SOPs and FPL tracking forms. These materials were screened for provitamin A by High Performance Liquid Chromatography (HPLC) and mineral content by Inductively Coupled Plasma- Mass Spectroscopy (ICP-MS) methods (Table 3). Select plant materials have been prioritized for further product testing including carrot, mango, and papaya for vitamin A, and baobab fruit (*Adansonia digitata*), Lam (*Moringa oleifera*), Oule (*Parkia biglobosa*), Nere (*Parkia africana*) and Roselle (*Hibiscus sabdariffa*) for iron and zinc content (Table 3).

Table 3. Concentration of iron and zinc in select African native plant materials collected in 2014-2015. Data represent the mean from 3 independent analyses by ICP.

	Mean	
	Analyte Name	
	Fe	Zn
Sample Name	Concentration (mg/g)	Concentration (mg/g)
Baobab	0.120	0.000
Bouy (10)	0.117	0.000
Bouy (11)	0.020	-0.010
Ipomoea b.	0.010	-0.007
Lam	0.240	0.003
Mango	0.010	-0.010
Nere	0.263	0.000
Oule	0.113	0.000
Peach Palm flesh	0.010	-0.010
Peach Palm peel	0.020	0.000
Roselle	0.073	0.048

Building on previous efforts, product formulation work on thin porridges has been based on millet/sorghum and dried plant materials. Our focus in Year 1 has been extensively on stability and bioaccessibility of provitamin A (Purdue). The bioaccessibility of thin porridges formulated with differing levels of pre-gelatinized sorghum/millet flour, fruit/vegetable blend and milk powder were assessed to determine the impact of formulation on carotenoid bioaccessibility in our three-stage *in vitro* digestion model. Initial results suggest that bioaccessibility for provitamin A carotenoids is poor (3-14%), (Figure 6). Presence of milk protein had a modest negative effect on carotenoid bioaccessibility. Despite low relative bioaccessibility, thin porridges were able to deliver 17.3-24.7% Estimated Average Requirements (EAR) for Vitamin A from a 200 g serving (Figure 7).

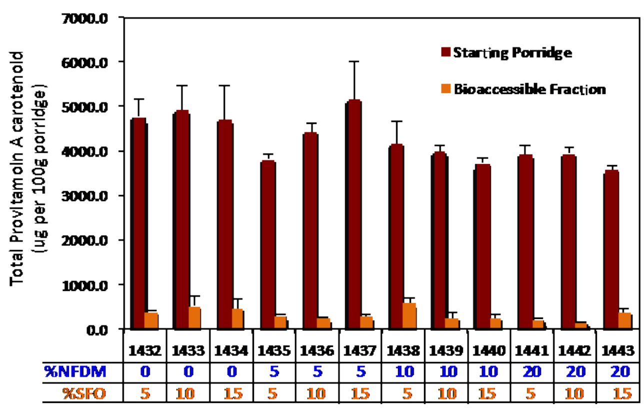
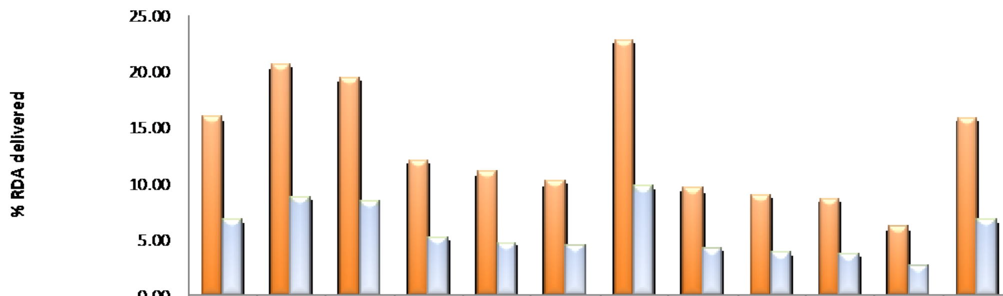


Figure 6. Levels of provitamin A carotenoids in test porridges formulated with sorghum, millet, dried carrot, dried mango, and variable levels of nonfat dried milk and sunflower oil.



	1432 (0:5)	1433 (0:10)	1434 (0:15)	1435 (5:5)	1436 (5:10)	1437 (5:15)	1438 (10:5)	1439 (10:10)	1440 (10:15)	1441 (15:5)	1442 (15:10)	1443 (15:15)
Infants - (1-3yrs)	15.91	20.50	19.48	12.03	10.96	10.26	22.64	9.53	8.97	8.54	6.03	15.82
Female - (14-18yrs)	6.82	8.78	8.35	5.16	4.70	4.40	9.70	4.09	3.84	3.66	2.58	6.78

Figure 7. Percent of the vitamin A EAR to be delivered by a 200g serving of experimental porridge described in Figure 6.

Bioaccessibility of African nutrient-rich plants

Select plant materials were further assessed for bioaccessibility. Figure 8 shows a dose dependence of carotenoid bioaccessibility to level of fortificant. Bouy (or baobab) increased carotenoid bioaccessibility from 18.3% to 31.7% as the amount of bouy added in the dry mix was increased from 5% to 25%. This increase in bioaccessibility was found to be approximately 3 times higher than the control. Higher amounts of Moringa and hibiscus seemed to have a negative impact on carotenoid bioaccessibility compared to the control. Results suggest suitable levels of bouy, moringa and hibiscus for product formulation. In addition, these results suggest that Bouy might have an emulsifying property that facilitates the efficient micellarization of carotenoids. Further studies are needed to determine the functional properties of Bouy and optimize its use as a fortifying agent.

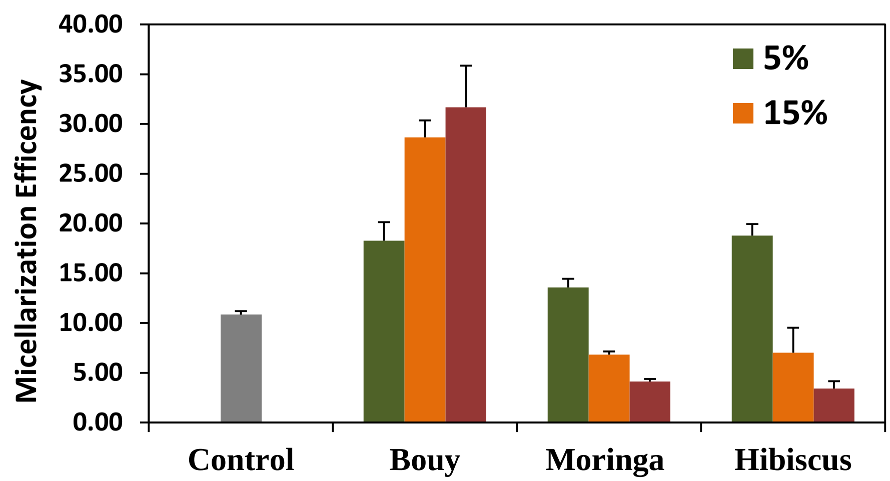


Figure 8. Relative differences in *in vitro* bioaccessibility of beta-carotene of candidate plant sources.

Assessing the impact of co-extrusion on physical properties and micronutrient stability of blended instant millet products

In order to better define processing and formulation parameters for instant porridges experiments have been initiated between ITA Senegal and Purdue to determine if dry blending or co-extrusion of millet with fruit and vegetable powders or pulp impacts physical properties and/or stability of provitamin A carotenoids. Millet varieties including Souna and 8735 (biofortified land race from Senegal) were selected as the cereal background for experiments. Carrot, papaya, and mango fruit pulp or powders (generated at ITA Senegal) were selected as provitamin A sources as previously assessed. Blends of 75:25 millet:fruit were chosen for experiments. These ratios were previously determined by assessment of provitaminA content with the target to deliver ~20% of the DV for vitamin A in a finished reconstituted porridge (200g). Blends were mixed and brought to 30% moisture by addition of water prior to extrusion with a screw speed of 900 rpm yielding a die temperature between 89-106°C. Finished products were dried to a final moisture content of 8.5-10%. Products are currently undergoing testing for physical and chemical properties (extent of gelatinization, rheological parameters, color) and well as recovery of provitamin A nutrients relative to dry blended products. Storage stability testing of co-extruded products is also underway at Purdue.

(b) University of Pretoria:

The distribution of minerals in pearl millet kernel was investigated using the micro Proton Induced X-ray Emission (micro PIXE) technique. It was found that most minerals were located in the germ (scutellum and embryo) and outer grain outer layers (aleurone and pericarp). Iron had a distinctive distribution pattern (Figure 9). It was confined to the dorsal end of the scutellum, and highly concentrated in the outer grain layers. The hilar region was also revealed as a site of high accumulation of minerals, particularly calcium, magnesium, iron and zinc. The work has been published in Nuclear Instruments and Methods in Physics Research B (see under Publications).

Mineral analysis (iron, zinc, calcium and phosphorus) of the 18 pearl millet varieties and lines and the effect of decortication (dehulling) on mineral contents is being undertaken. Preliminary results show that ICRISAT biofortified varieties ICMB 04999 and Dhanashakti contain some 50-100% higher levels of iron and zinc than the popular Senegal landrace Mil Souna. Decortication of the both the normal and biofortified pearl millet types to an 80-90% extraction rate removed the much of pericarp and some the distal end of the germ but did not substantially affect mineral levels.

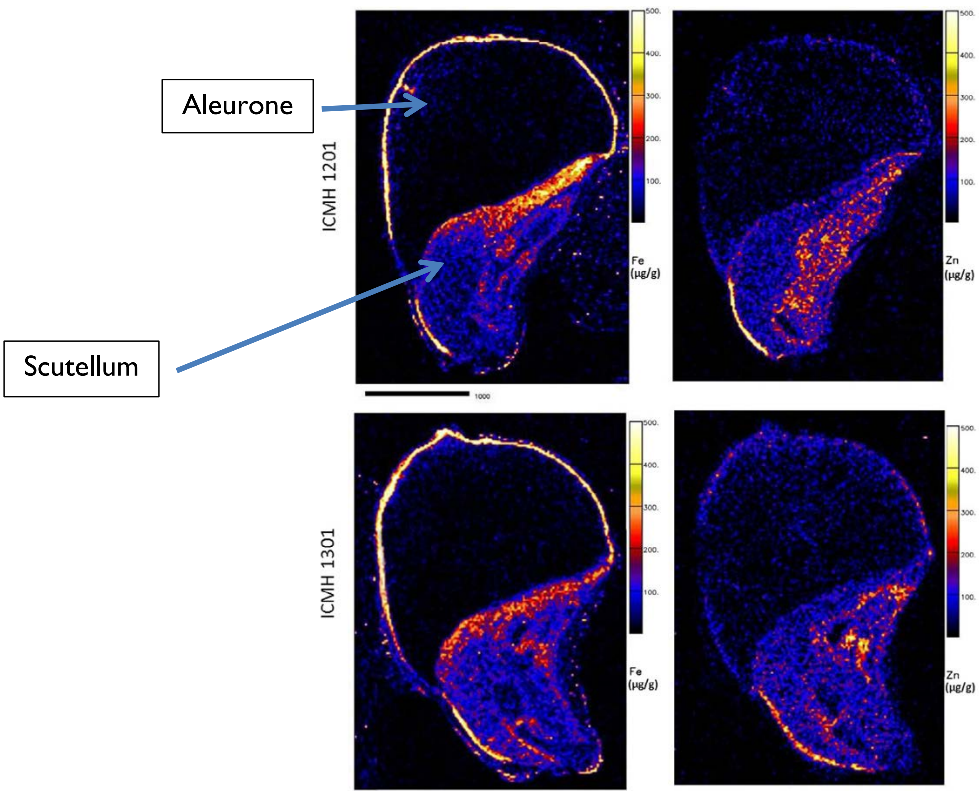


Figure 9. Distribution of iron, zinc and manganese in two pearl millet varieties as detected by micro PIXE analysis

(5) Capacity Building:

(i) Long-term training: All students are working to develop various products (fortified and non-fortified) and processes for the targeting the FPL focus countries.

1. University of Pretoria - a Master's student (John Gwamba) was admitted on the FPL project in the nutrition science area.
2. ITA - Maty Diop is supported through FPL for her PhD programs at Cheikh Anta Diop University in Dakar.

(6) Lessons Learned:

(a) Achievement of greater that 20-25% dietary value (DV) for vitamin A is possible with native fruits and vegetables, but delivery will require assessment of processing to enhance bioaccessibility. Leveraging of biofortified millet will enhance the ability to deliver on iron and zinc product content. Furthermore, select plant materials such as hibiscus and bouy (baobab) appear to be good candidates for co-formulation for iron and zinc.

(b) Bouy increased bioavailability of beta-carotene possibly through an emulsifying action and suggests greater provitamin A utilization when added to millet instant flours.

(c) Co-extrusion of millet and fruit pulps produces desirable products; this, 1) minimize the need for drying capacity, and 2) may enhance the bioaccessibility of minerals in millet and carotenoids from fruits.

(d) Concentration of iron in the scutellum of the grain (upper germ part) means that normal decortication (debranning) may be adjusted to retain most of the mineral. Zinc is more widely distributed in the grain.

(7) Presentations and Publications:

(a) Minnis-Ndimba, R., Kruger, J., Taylor, J.R.N., Mtshali, C. and Pineda-Vargas, C.A. 2015. Micro-PIXE mapping of mineral distribution in mature grain of two pearl millet cultivars. Nuclear Instruments and Methods in Physics Research B (in press).

VI) HUMAN AND INSTITUTIONAL CAPACITY DEVELOPEMENT[6]

a) Short-term training

i) Kenya:

(1) Trainee: Violet Mugalavai, PI, University of Eldoret, Kenya (female)

(2) Purpose: To learn about the Incubation Center concept and develop a plan for establishing a similar Center at the University of Eldoret.

(3) Home institution: University of Eldoret

(4) Training institution or mechanism: Institut de Technologie Alimentaire (ITA) in Dakar, Senegal

ii) Others

(1) Staff engineer from Nigeria, Jesumayokunmi (Mayo) Olasubulumi, a recent BS graduate in mechanical engineering is working on the solar grain dryer.

(2) A lecturer at Jomo Kenyatta University of Science and Technology (JKUAT), Alfayo Anyangu is working with Drs. Shitanda and Ileleji to address some key challenges and research questions that came up during the post-harvest practices survey in Kenya.

(3) Also, a student and staff (Makhtar Samb) with ITA and ISRA, respectively, will conduct research work in support of the project objectives related to drying and storage.

(4) Adeoluwa Adetunji who recently graduated with his PhD (partially supported by FPL) is undertaking a short post-doctoral fellowship to end of 2015 at the University of Pretoria within the FPL project investigating the effects of ultrasonication on polyphenols in pearl millet and sorghum.

(5) R. van der Merwe completed her BSc. Her honors research project was titled - Effects of fermentation and acidification with citric acid and ascorbic acid on the iron and zinc uptake from a traditional African finger millet beverage. She will continue with MSc project within the PFL project in 2016

[6] This section is to serve as a compilation of all program training activities and not meant to duplicate the Capacity Building section under individual Research Project Reports. It can be in chart format.

(6) ITA is working closely to build expertise and capacity at 3 women directed Dakar food processing enterprises: Touba Darou Salam directed by Mme. Mbacke, FreeWork Services directed by Mme. Deme, and Maria Distribution directed by Mme. Diouf.

b) Long–term training

i) Use the following chart to report all U.S. citizens/permanent residents and third country nationals currently receiving Innovation Lab funds (regardless of percentage), include post-docs and individuals being trained outside of the U.S.

Table 4: List of higher degree students admitted under FPL program

Name	Gender	University	Degree	Major	Grad Date	Home Country	Institutional Home
Rose Likoko	Female	University of Eldoret	MS	Food Science	2018	Kenya	Kenya
Harriet Nyakecho Omutimba	Female	Pwani University	PhD	Social Ethics & Gender	2016	Kenya	Kenya
Michael I. Mukolwe	Male	Jomo Kenyatta Univ. of Agric. & Technology	PhD	Processing Engineering	2019	Kenya	Kenya
Adeoluwa Adetunji	Male	Universty of Pretoria	PhD	Food Science	2015	Nigeria	South Africa
Nokuthula Vilakati	Female	University of Pretoria	PhD	Food Science	2017	South Africa	South Africa
Ayodeji Falade	Male	University of Pretoria	PhD	Food Science	2017	Nigeria	South Africa
John Gwamba	Male	University of Pretoria	MS	Nutrition Science	2016	Botswana	South Africa
Fallou Sarr	Male	Cheikh Anta Diop University	PhD	Food Science	2019	Senegal	Senegal
Maty Diop	Female	Cheikh Anta Diop University	PhD	Nutrition Sceince	2019	Senegal	Senegal
Tim Tubbs	Male	Purdue University	MS	Plant Science	2016	USA	USA
Brett Lane	Male	Purdue University	MS	Plant Science	2016	USA	USA
Stacy McCoy	Female	Purdue University	PhD	Agricultural Economics	2019	USA	USA
Pablo Cesar Torres-Aguilar	Male	Purdue University	PhD	Food Science	2018	Ecuador	USA
Hawi Debelo	Female	Purdue University	PhD	Nutrition		Ethiopia	USA
Ravindra Shrestha	Male	Purdue University	PhD	Agricultural & Biological Engineering		Nepal	USA

ii) For students who have completed their training and returned to their home country, indicate if they are employed in their field and the name of their employing organization if known. N/A

c) Institutional Development
   i) Description: A building was renovated by FPL to house the food processing Incubation Center at the University of Eldoret. The building has been fitted with basic food processing equipment and a basic laboratory to test grain for processing. An extruder has been ordered from the USA. The Incubation Center will be used to train food processors in Kenya.
   ii) Partners: University of Eldoret

VII) TECHNOLOGY TRANSFER AND SCALING PARTNERSHIPS

a) Plan of Action: Training of women food processors in the Dakar, Senegal.
   i) Steps taken: ITA team has identified three women-led Dakar processing enterprises for capacity building in new product developemtn. They include: Touba Darou Salam directed by Mme. Mbacke; FreeWork Services directed by Mme. Deme; and Maria Distribution directed by Mme. Diouf. Some product development work is already on-going.
   ii) Partnerships made: The three enterprises have agreed to work with ITA and to help in product distribution in Senegal
   iii) Technologies transferred: New products (fortified and non-fortified) and extrusion technology for instant foods
   iv) Technologies scaled – None
   v) Technologies ready to scale: extrusion technology

VIII) ENVIRONMENTAL MANAGEMENT AND MITIGATION PLAN (EMMP)

a) FPL is committed to put the mechanisms in place for environmental mitigation as outlined in the Environmental Mitigation and Monitoring Plan (EMMP). All activities conducted to date have not required environmental management strategies.

IX) OPEN DATA MANAGEMENT PLAN

a) The FPL Data Management Plan (DMP) was submitted to the activity manager in August 2015. A total of 9 datasets were identified for the program for eventual submission to the USAID Data Development Library (DDL), after publication or at the end of the project life cycle. In the meantime, all collected/de-identified data is stored on the Purdue University Research Repository (PURR) website managed by Purdue Libraries. PURR provides project space to manage data, and publishes datasets with Digital Object Identifiers (DOIs) and citations for Purdue PIs.

X) PROJECT MANAGEMENT ACTIVITY

The FPL Steering/Technical Committee (SC) meets once a month to discuss the strategic direction of the project, review and approve potential funding initiatives, and resolve logistical issues. The SC also advise on the development, implementation, and monitoring & evaluation of the project, including strategic linkages and partnerships. The Advisory Council (AC) provides strategic guidance to the project and supports development of collaborative, efficient, effective science and management. The AC also helps FPL identify future trends and opportunities in post-harvest research and development. The first AC face-face meeting was held on December 12, 2014. A teleconference was also held on September 1, 2015 to provide updates on Year 1 activities and outcomes and to outline plans for Year 2.

XI) OTHER TOPICS[7]

FPL has engaged a gender expert, Dr. Cheryl O'Brien, Assistant Professor, San Diego State University (formerly from Purdue University) as a consultant to address gender issues. She works closely with the FPL PIs to ensure incorporation of gender aspects in their work. Dr. O'Brien has held extensive discussion with the USAID gender specialists (Drs. Farzana Ramzan and Krista Jacobs) regarding opportunities for FPL to conduct extensive gender studies that could contribute to the Women's Empowerment in Agriculture Index (WEAI) database. A concept note has been prepared on additional gender activities. FPL is exploring opportunities to collaborate with Integrating Gender and Nutrition within Agricultural Extension Services (INGENAES) program whose goal is to assist Feed The Future (FTF) missions to strengthen gender and nutrition integration in agricultural extension and advisory services. The program led by the University of Illinois at Urbana-Champaign and focuses in 4 countries of Bangladesh, Honduras, Senegal, and Zambia.

XII) ISSUES AND HOW THEY ARE BEING ADDRESSED[8]

a) Issue: delay in processing sub-agreements by some collaborators, mainly due to their limited experience in filing for US government required paperwork. Solution: some Year 1 activities and funding were shifted to Year 2. Note: all collaborator sub-agreements have been signed and research work initiated accordingly.
b) Issue: Programmatic year (May 19 – May 18) did not align US Government fiscal year (Oct. 1 to Sept. 30). Solution: Re-alignment to US Government fiscal year, which resulted into a longer Year 1 (16.5 months) and a shorter year 5 (7.5 months). The program workplans and budgets have been revised to reflect this re-alignment.
c) Issue: Problems with collaborators financial reporting that was based on cash advance. Solution: FPL switched from cash advance to cost-reimbursement. The Business Management team visited all the subs to help with implementation of the changes.
d) Issue: Full-time equivalent (FTE) for Management Unit personnel. FPL reviewed the FTE for management and made changes to meet the workload for each personnel starting in Year 2 as follows:
   i) Increased FTE for Principal Director, Betty Bugusu - 60% FTE Year 1 to 80% FTE Year 2.
   ii) Decreased FTE for Program Manager, Heather Fabries. 50% FTE Year 1 to 20% FTE Year 2.
   iii) Added Barbara Doremire for Clerical Support at 7% FTE.
   iv) No change in Clerical Support, Lonni Kucik. Remains at 10% FTE.

XIII) FUTURE DIRECTIONS

The FPL looks to be effective and relevant in the two focus countries of Kenya and Senegal through development of practical and cost-effective solutions for grain drying, storage, and food processing in the humid topics. The solutions will be beneficial to end-users including smallholder farmers, food processors and consumers. They will also be profitable for the manufacturers of the technologies, helping to create non-farm jobs. The FPL is also working to improve nutrition through food fortification strategies that are both market-driven and for use at the household level in food preparations. The strategies take advantage of the high-nutrient plant sources that are readily available but underutilized in the focus countries. FPL will help to develop these value chains for markets

The FPL is also working to identify trends and opportunities for post-harvest grain research and engagement over the next 5 to 10 years, to expand the program and keep it relevant to the stakeholder needs.

[7] Such as Regional Centers of Excellence, impact assessment, gender initiatives

[8] Such as financial, management, regulatory

APPENDIX

A. Three distinct success stories[9].

[9] Each should: a) be limited to 500 words, b) be results oriented, c) written in layman's terms, d) avoid acronyms, e) address Feed the Future priorities, and f) include a high resolution digital photo with caption and photo credit. It is okay to reference a website for more detailed information.