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

SEMI-ANNUAL REPORT

APRIL 30, 2016

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

ABE	Agricultural and Biological Engineering
AC	Advisory Council
CRT	Powdered carrot
CUCK	The Cooperative University College of Kenya
CRSP	Collaborative Research Support Program
DC	Decorticated grain
DDL	Development Data Library
DIV	Development Innovation Venture
DMP	Data Management Plan
DOIs	Digital Object Identifiers
DURI	Discovery Park Undergraduate Research at Purdue
DV	Dietary value
EAR	Estimated Average Requirements
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
INTSORMIL	International Sorghum and Millet
ISRA	L'Institut Sénégalais de Recherches Agricoles
ITA	Institut de Technologie Alimentaire
MAN	Mango
NC A&T	North Carolina A&T State University
OTC	Office of Technology and Commercialization
PAP	Papaya
PICS	Purdue Improved CROP Storage bags
PURR	Purdue University Research Repository
SC	Steering Committee
SSA	Sub-Saharan Africa
WG	Whole grain
WTP	Willingness-to-Pay

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 in this report cover the period of October 1, 2015 to March 30, 2015. 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) quantitative assessment of market demand and drivers for instant food products, with and without nutritional enhancement; 5) development and/or refinement of food products and processes to drive Senegal and Kenya markets; 6) Leveraging local agriculture commodities to produce nutritionally-enhanced food products and to create a sustainable market-led fortified processed grain foods; and 7) establishment of effective dissemination platforms for food technologies. The next half of the fiscal year will continue to focus on these activities with more emphasis on field testing of developed technologies through trainings. 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]

- Engineering & biological assessment of smallholder farmer grain storage practices in Kenya and Senegal completed with a preliminary data analysis.
- Economic baseline study of smallholder farmer grain storage practices in Kakamega, Kenya completed. Initial analysis of the data completed.
- Comprehensive design of a scalable solar dryer system consisting of the dryer and meshed drying baskets to hold the crop or product to be dried fabricated at Purdue. The baskets can used separately as a form of sanitary dryer by laying on pebble rock bed, concrete floor, or ground in the open-air for open-air drying applications. Other accessories include cell phone charging ports on the electronics control. The system was tested on various crops including maize, fruits, and vegetables.
- Use of a low cost hygrometer for grain moisture measurement is calibrated and tested in the US.
- Experimental auction implemented in Senegal to test differences in trader and consumer willingness to pay for wet and dry maize. Data being analyzed.
- 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.
- Extruder technology with its instant flour capability was transferred Touba Darou Salam Processing Unit belonging Madame Mbacke a long-time, partner with ITA involved in technology dissemination.
- Consumer studies for instant flour-based products.
- Assessment of consumers' interest in instant food products (product attributes and willingness-to-pay) in Senegal.
- Completion of building renovation to house the food processing "Incubation Center" at the University of Eldoret in Kenya for training processor entrepreneurs. The center was equipped with food processing equipment including an extruder for instant flour production.
- Collection of baseline data to assess market demand and drivers for processed food products, with and without nutritional enhancement in Kenya

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

III) KEY ACCOMPLISHMENTS[3]

- Low-cost hygrometer (1.50 US) calibrated and tested in the US for grain moisture measurement.
- Comprehensive design of a scalable solar dryer system consisting of fabricated and successfully tested at Purdue on various crops including maize, fruits, and vegetables
- Extruder technology with its instant flour capability was transferred to Touba, Senagal though a local food processor Mme Mbacke.
- Completed building renovation to house the food processing "Incubation Center" at University of Eldoret in Kenya for training processor entrepreneurs. Building has been equipped modestly with new processing equipment and an extruder.
- 18 graduate students have been recruited: 12 male and 6 female; 12 Ph.D. and 6 Masters. An additional 4 students are supported on research only. The students are from Kenya, Senegal, Ethiopia, Uganda, 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, 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) **Baseline survey in Kenya**. A study was conducted in Kakamega County, Kenya in collaboration with local partners CIMMYT and KALRO. The goals of the study were: i) to measure the moisture and aflatoxins levels of the maize during drying and storage and ii) to understand the current maize drying and storage practices from the time of harvest to the final storage point. The first objective was led by the engineers and plant pathologists of Purdue University. The second objective was led by CIMMYT economists. A representative sample of households was selected in Kakamega County. A questionnaire was used to collect basic household information and maize post-harvest operations during the visit to

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[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.

[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.

take grain samples for objective 1. Topics covered in the survey included maize harvesting, transport, drying and storage technologies used. Data analysis and report writing were done in October, 2015. Because the households were still harvesting in September 2015, the survey was preliminary: a full overview of their harvest and post-harvest activities could not be collected at that time. Therefore, they were visited again in December 2015 by a team of enumerators from CIMMYT, in collaboration with KALRO. The objectives of the survey were:

1. To identify the current drying and storage methods, practices and challenges
2. To identify the moisture testing methods used by the farmers
3. To examine the farmers knowledge of aflatoxin
4. To assess the knowledge and use of hermetic storage technologies.

Data were collected using a structured questionnaire, which was digitized using the CS Pro software on tablets.

Lessons learned: Results showed that most farmers in the study area were small-scale semi-subsistence farmers. Maize was the main crop grown mostly for home consumption. Although the county has two rainy seasons, maize was mostly grown in the first season (March season). Maize production accounted for two thirds of the total maize consumption hence need for on farm storage. The farmers took on average one month to carry out all the maize post-harvest activities (up to the time the maize is ready for storage). They were using open-air solar to dry their maize by mostly spreading it on the ground on a tarpaulin or a mat. Testing of the maize moisture content before storage was mostly done using the local methods. The maize was then stored using polypropylene bags (half added pesticides) and stored in the main house. Although some few farmers had heard about the hermetic technologies, none of them was using them to store maize at the time of study.

(b) **Baseline survey in Senegal.** A study similar to the Kenya one (above) was conducted in Velingara region, Senegal. The survey involved both US and local collaborators from ISRA and ITA, and enumerators recruited from the local agricultural extension service. Additionally, samples were collected at various stages of post-harvest operations from 310 farming households for analysis of moisture content, pest infestation, and insect and mold damage. Samples were also assessed for pre-harvest maize ear rot diseases and aflatoxin contamination.

Lessons Learned - Preharvest aflatoxin associated with Aspergillus ear rot disease was not an issue in the 2015 maize crop. Farmers in the Velingara region barely used any appropriate post-harvest equipment. Laying crops on the bare ground in the open air was primarily the method used for drying resulting in soil contamination. This practice appears to be the major source of the *Aspergillus* fungus and subsequent aflatoxin accumulation during drying and storing. Farmers need training on sanitary drying methods such as use of plastic sheets or tarpaulins to prevent grain contamination.

(c) **Development of solar grain dryers (design, testing and prototyping) -** Ileleji and his group of students (a graduate student in ABE, two visiting students from Columbia and Haiti, and a staff engineer) conducted several thin-layer drying experiments to simulate thin-layer drying conditions for maize in a solar dryer prototype. They determined the drying rates of three different layer thicknesses of maize (0.4 in (500 g), 0.56 in (700 g) and 0.72 in (900 g) dried at three different possible temperatures (95°F, 35°C; 109°F, 42°C; 130°F, 54°C) that could be achieved in the dryer. Thin-layer drying tests were also conducted for maize dried in a basket made of shade cloth mesh and one made of wire mesh to determine whether the mesh material affected the drying rate of maize. All experiments were conducted using rewetted maize from 30% to 13%, wet basis. Drying rates determined were modeled using the Page equation (1949). Results showed that there were no differences between the drying rates for maize dried in a basket made of shade cloth compared with maize dried in a basket made of wire mesh. While 500 g, the thinnest layer gave the fastest drying rate, about 3 h and 27 min, drying 900 g of maize at all the temperatures were quite close, ranging from 4h 40 min to 5h 5 min. Other thin-layer drying experiments were conducted on carrots and mangoes in collaboration with the food processing and nutrition group, with the goal of utilizing the solar dryer to dry fruits and vegetables for food fortification purposes.

A comprehensive design of a scalable solar dryer concept was staged and implemented at Purdue. The basic drying system consists of a meshed drying basket, which holds the crop or product to be dried, and allows upward airflow from bottom through the product. The basket can be laid on a pebble rock bed, concrete floor, or ground in the open-air for open-air solar applications and enables air contact with the product in all directions. The drying baskets prevent product contamination from foreign materials such as rocks and soil and also facilitates fast handling in case of inclement weather. The dryer also has data access for downloading to the cloud using an Android device and other accessories include cell phone charging ports on the electronics control console. Research activities included the fabrication of a mini-solar thermal collector to determine collector design and performance, drying basket design, drying rack design, drying test bed design, and analyses of airflow patterns in the solar dryer using FLUENT Computational Fluid Dynamics (CFD) software. A test-bed prototype has been built and is currently used to test various fan configurations, drying tray configurations and airflow patterns.

Lessons Learned - Weather conditions were a primary bottleneck for testing the drying system in Indiana because they do not match the humid tropics conditions where the dryers will be used. Prototyping of the final dryer design has been challenging due the difficulty in getting fabricators to complete and deliver the dyers on time.

(d) **Experimental Auction of willingness to pay for wet vs. dry maize in Kolda and Velingara, Senegal -** To assure no fungal growth occurs in stored maize it should be dried within 3 days of harvest to ≤ 13% moisture content. Damp weather at harvest in maize growing regions of Senegal such as Kolda and Velingara complicates maize drying. Storing damp maize increases the risk of spoilage by fungi. Several Aspergillus fungal species (primarily A. flavus) produce aflatoxins, which are potent liver toxins associated with increased cancer risk as well as negative effects on nutrition and immune systems in humans and animals. Given the importance of moisture content to safe maize storage, maize buyers and producers in the U.S. and Europe measure maize moisture content with relatively high-cost moisturemeters. These meters are not readily available in most rural markets in Senegal or elsewhere in SSA. A study was conducted to determine the reliability of local methods of maize moisture determination and the value of maize moisture in a tropical savannah climate through experimental auctions conducted in Kolda; 184 traders and 236 consumers (422 participants) were randomly surveyed. Two different incentive-compatible auction mechanisms to elicit the true values of participants for six types of maize (labeled and unlabeled maize with ≤ 13, 14.0% - 15.9%, and 17.0 - 19.0% moisture content). In the auction, two practice rounds were used before eliciting maize values to help participants understand two key concepts. 1) They would bid on six types of maize, but only one type would be randomly selected for sale to avoid diminishing marginal returns on subsequent bids. 2) That their bid would be compared to all other bids that day (traders) or to a randomly determined amount (consumers) to determine if they had the 'high' offer for the randomly selected maize type. The experimental auction data is being analyzed.

(5) Capacity Building: An MS ABE graduate, Ravindra Shrestha, and staff engineer Jesumayokunmi (Mayo) Olasubulumi, were involved in the solar dryer development work. They were also involved in conducting the surveys, laboratory measurements, and analyses of the data in Kenya and Senegal. A visiting undergraduate student from Universidad Nacional de Columbia spent 6 months working on the project conducting all the thin-layer drying experiments and the design of the drying basket. Also a visiting recent graduate of the Earth University from Haiti worked on fruits and vegetable drying and tests for maize drying on the test-bed. Both students were/are not supported on FPL funds. A Purdue undergraduate senior in Electronic Technology is working on the project as a Discovery Park Undergraduate Research Intern (DURI). Another DURI

intern spent a semester working on the project. DURI interns are supported by Purdue's Discovery Park Research Fellowships.

(6) Lessons Learned: see under individual activities.

(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 (CUCK, Kenya); Hugo DeGroote (CIMMYT, Kenya); Makhtar Samb (ITA, Senegal); Ibrahim Sarr (ISRA, Senegal)

(4) Achievements:

(a) **Develop and evaluate moisture content testing protocols that use inexpensive humidity/temperature devices -** A device for measuring grain moisture, developed by a graduate student at Purdue, and was further optimized and a protocol was developed. Five low-cost hygrometers were examined and one costing about 1.50 US was selected for use in train-the-trainer workshops for Senegal and Kenya. The device will determine if grain is dry enough for storage in approximately 15 to 30 minutes.

Lessons Learned – A simple device equipped with a temperature/humidity sensor can be used to determine moisture content by applying moisture equations to a temperature and humidity readout. The simple moisture meter will be tested in the field in the summer.

(b) **Impact of opening hermetic storage bags during storage -** An experiments at Purdue that examined the impact of opening hermetic storage bags during storage has been completed. Farm families periodically open their 100 kg storage bags to remove grain for consumption. The experiments measured the effects of grain moisture coupled with the frequency of bag opening on the efficacy of storage in bags for 3 and 6 months. Data is being analyzed.

Lessons Learned – Preliminary analysis shows that an oxygen gradient forms when the hermetic seal of the PICS bag is broken. Results also indicate that prolonged opening of PICS bags, containing maize above 15% moisture, will in time lead to poor quality grain.

(c) **Compare grain rewetting in storage and aflatoxin accumulation for hermetic storage and woven bags -** An experiment was conducted to compare aflatoxin accumulation in hermetic storage bags (PICS) and woven bags under two environmental conditions, in West Lafayette, IN and Marianna, AR. The 3-month storage experiment was replicated in both sites.

Lessons learned – Preliminary data analysis shows that prevention of *A. flavus* growth and aflatoxin accumulation in maize can be achieved by drying the grain to below 14% (aw < 0.70). At this moisture content, only the more xerophilic fungi will grow. Placing this dry grain in a hermetic bags (such as PICS) prevents rewetting, thus stops appreciable fungal growth. In a woven bag, rewetting occurs thus dramatically increased the growth of storage fungi. However, the increased moisture content was not enough in three months to impact *A. flavus* growth and aflatoxin accumulation. Testing longer storage time would require application of insecticides to manage insects that were destroying grains in the woven bags.

(5) Capacity Building: A Botany and Plant Pathology MS graduate student, Tim Tubbs, worked on the project. He is writing a manuscript for publications.

(6) Lessons Learned: see under individual activities.

(7) Presentations and Publications: none

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) **The Food Processing Training and Incubation Centre (FPTIC) at University of Eldoret, Kenya**. The renovation of a building donated by the University of Eldoret to house the new The Food Processing Training and Incubation Centre was completed. The Center will be used for training women and youth processors. It has mostly been outfitted, with moderate funds provided by the project and is almost ready and in minimal use. The extrusion equipment to process instant flours was shipped from the US in March 2016 and will be installed in July.

Lessons Learned: The group is in the midst of starting up an "incubation center" at University of Eldoret that has been done with minimal funds. The unit still needs additional equipment, and would function best with a skilled technical person managing it. Furthermore, the addition of an incubation center at the university presents other challenges, as well as some opportunities, that are different from a government research laboratory. Through the rather difficult renovation of an old building to house the incubation center, an interest has come forth from the university, and Prof. Mugalavai, to have a student course and perhaps in the future an option in the area of processing and entrepreneurship. If this is to happen, in addition to the university resources that may be made available, other modest financing opportunities will be needed.

(b) **Testing and selection of sorghum varieties for processing in Kenya**: Different varieties of sorghum were characterized according to their tannin levels using the bleach test (Table 1). Sorghum varieties from both research and the informal market with varying tannin levels were taste tested by both rural and urban respondents using a scale of 1- dislike very much and 5 -like very much). The ANOVA results of differences between means indicate that for both rural and urban respondents, low tannin and no tannin varieties scored higher means in acceptability, an indication that during further food processing, low and no-tannin sorghum varieties will be used. For appearance, both rural and urban consumers showed no preference between high and low/free tannin sorghums suggesting that the reddish color of high tannin types is not a discriminating factor in selection. The smell of the low/free tannin types was preferred by the rural consumers. The sorghum will further be composited with amaranth, cassava, and fortified with natural fortificants, which will be tested for expanded product lines.

Lessons Learned: While it was expected that low tannin or tannin-free sorghum types would be preferred in sorghum foods, some characteristics such as color of high tannin types were acceptable to consumers. Rural and urban consumers showed some differences in preferences, such as rural consumers preferred the smell of low or tannin-free types.

Table 1. ANOVA table of sensory characteristics of sorghum according to tannin levels.

	ANOVA	E1 High tannin Sorghum	E97 Low tannin Sorghum	MKT-RED High tannin Sorghum	SEREDO Low tannin Sorghum	T30b-1 No tannin Sorghum
Rural						
After taste	***	$3.5^{ab} \pm 0.2$	$3.0^{b} \pm 0.2$	$3.7^{a} \pm 0.2$	$3.1^{b} \pm 0.1$	$4.1^{b} \pm 0.1$
Appearance	NS	$4.1^{c} \pm 0.1$	$4.0^{bc} \pm 0.2$	$3.7^{c} \pm 0.2$	$4.0^{b} \pm 0.1$	$4.6^{a} \pm 0.1$
Flavor	NS	$2.9^{a} \pm 0.2$	$3.4^{b} \pm 0.1$	$3.7^{a} \pm 0.1$	$4.3^{b} \pm 0.1$	$4.5^{b} \pm 0.1$
Acceptability	***	$3.5^{ab} \pm 0.1$	$3.6^{ab} \pm 0.1$	$3.4^{a} \pm 0.2$	$4.1^{ab} \pm 0.1$	$4.4^{b} \pm 0.1$
Smell	***	$3.5^{ab} \pm 0.1$	$3.6^{b} \pm 0.1$	$3.6^{b} \pm 0.1$	$4.0^{ab} \pm 0. 1$	$4.5^{a} \pm 0.1$
Texture	***	$3.1^{a} \pm 0.1$	$3.6^{ab} \pm 0.1$	$3.5^{a} \pm 0.1$	$3.9^{ab} \pm 0.1$	$4.3^{b} \pm 01$
Urban						
After taste	*	$3.7^{ab} \pm 0.1$	$3.9^{b} \pm 0.1$	$3.4^{a} \pm 0.1$	$4.0^{b} \pm 0.1$	$4.0^{b} \pm 0.1$
Appearance	***	$4.4^{c} \pm 0.1$	$4.2^{bc} \pm 0.1$	$4.4^{c} \pm 0.1$	$4.0^{b} \pm 0.1$	$3.5^{a} \pm 0.1$
Flavor	***	$3.4^{a} \pm 0.1$	$3.9^{b} \pm 0.1$	$3.2^{a} \pm 0.2$	$4.1^{b} \pm 0.1$	$4.1^{b} \pm 0.1$
Acceptability	NS	$3.8^{ab} \pm 0.1$	$4.0^{b} \pm 0.1$	$3.6^{a} \pm 0.1$	$4.0^{ab} \pm 0.1$	$4.1^{b} \pm 0.1$
Smell	NS	$4.2^{ab} \pm 0.1$	$4.3^{b} \pm 0.1$	$4.4^{b} \pm 0.1$	$4.1^{ab} \pm 0.1$	$4.0^{a} \pm 0.0$
Texture	NS	$3.6^{a} \pm 0.1$	$3.9^{ab} \pm 0.1$	$3.8^{a} \pm 0.1$	$4.0^{ab} \pm 0.1$	$4.2^{b} \pm 0.1$

*** P-value < 0.001, * P-value < 0.05, NS-=not significant
Mean values with different letters significant.

(c) **A social study on cereals and legume flours consumption in Kenya.** The study was carried out at the Eldoret Municipal market, Kenya. The goal was to determine the composite flours most preferred by consumers. Millet, sorghum, amaranth, proso millet, pumpkin seed, cassava, maize, cowpea, soybean, groundnuts, and finger millet were purchased from the cereals and legume section of the market from randomly selected sellers (Figure 1). The raw grains were individually cleaned, sorted and milled into flours. Groundnuts, millet, sorghum, and soybean were roasted using traditional methods and milled individually. The flour products were packaged in clear plastic containers complete with ingredients labels. Consumers had free choice to buy the flour they desired to mix for composited flour. Consumers were also required to fill a form with information regarding their gender, nutritional education, if the product were for the whole family or specific family members, and any other recommendations. The sales were conducted by a woman trader at the market who had been trained on the basics of hygiene, packaging, and ingredient labeling of the products. Majority of the people who purchased the flour were women who had partial information on nutrition education. From the results, finger millet, sorghum, pumpkin seeds, amaranth grain and pearl millet were the most preferred cereal flours for composited flours. Cowpea flour was mainly used as a fortificant and thus was bought in smaller quantities. Cassava was also bought in small quantities and the respondents indicated that it helped in refining the cereal texture and also expanding it. The flours were mainly bought to make porridge for their households, particularly for children. A few men who bought the flour indicated that they needed it for health benefits. Most of the men chose to fortify the major cereal such as sorghum and millet with pumpkin seed flour and amaranth grain flour based on their knowledge of their nutrition benefits.

Lessons Learned: The market study showed that consumers generally had some nutritional knowledge of local foods. Buyers prefer to include millet, sorghum, pumpkin seeds, and amaranth in their composite flours. Cowpea flour is mainly used as a fortificants in smaller quantities.

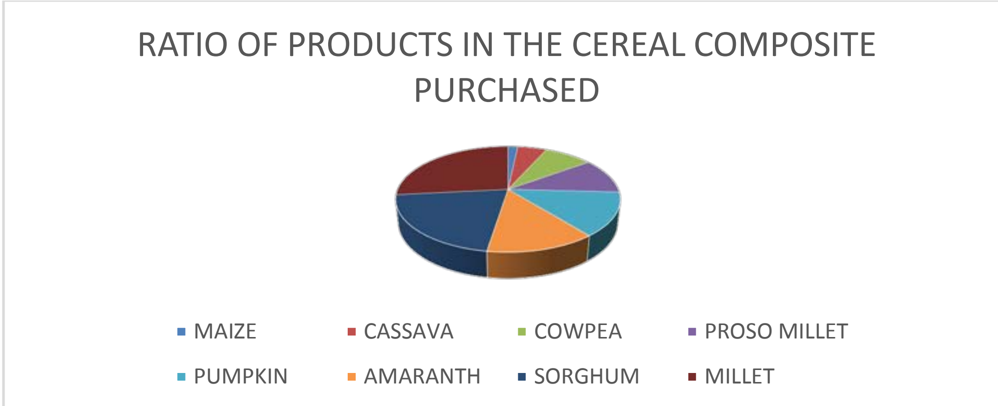

Figure 1. Ratio of products in the cereal composites purchased

(d) **Assessment of consumers' interest in instant food products in Senegal**

New low-cost extruders allow small enterprises to enter the market for processed cereal products, in particular instant, fortified and flavored mixes. To assess consumers' interest in these products, FPL conducted a consumer study in Touba, Senegal. The study was conducted by a team of researchers from CIMMYT, Purdue University, ITA/Senegal, and the University of Pretoria. This study used a combination of affective tests and experimental auctions with 200 consumers to evaluate four new products with conventional millet four as control: instant millet flour, instant millet flour with added mango and carrot extract, and the previous product with added micronutrients from either synthetic or natural origin (Figure 2). The products were coded using letters of the alphabet: A, B, C, D, and E (Figure 3). The results of the affective tests showed that consumers made little distinction between the five products for appearance, aroma, taste and overall appreciation (Figure 4). Similarly, during the experimental auctions without providing additional information on the products, there was no difference in willingness-to-pay (WTP) between them. However, after that information is provided, consumers were willing to pay a modest premium for instant flour, and a large premium for added mango and carrot extract and for added micronutrients, although not for micronutrients from natural sources. Income increases overall WTP, while education increases WTP for instant flour. The study concluded that there is a potential market for instant and fortified millet flour in Touba, but likely in the higher income and education groups.

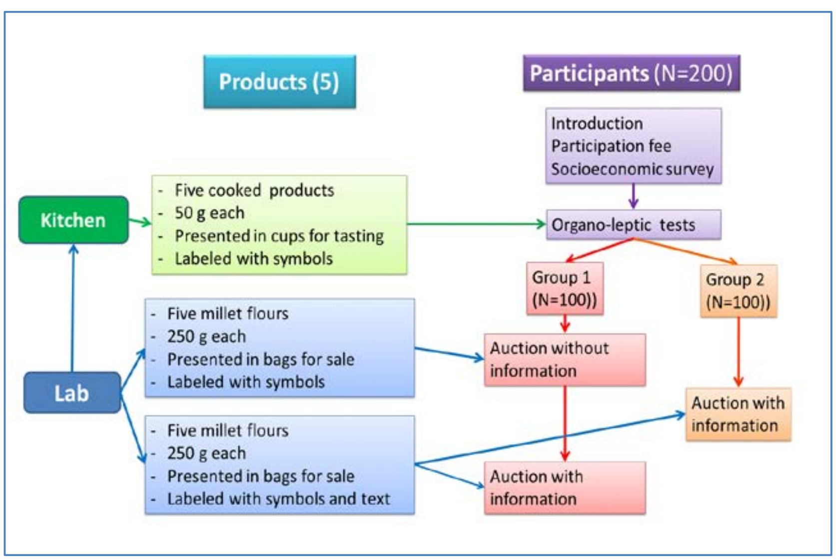

Figure 2. Study design of consumer preference test conducted in Touba, Senegal

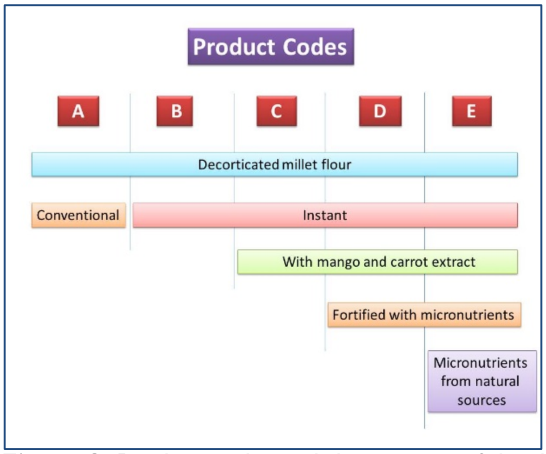

Figure 3. Product codes and the content of the different products.

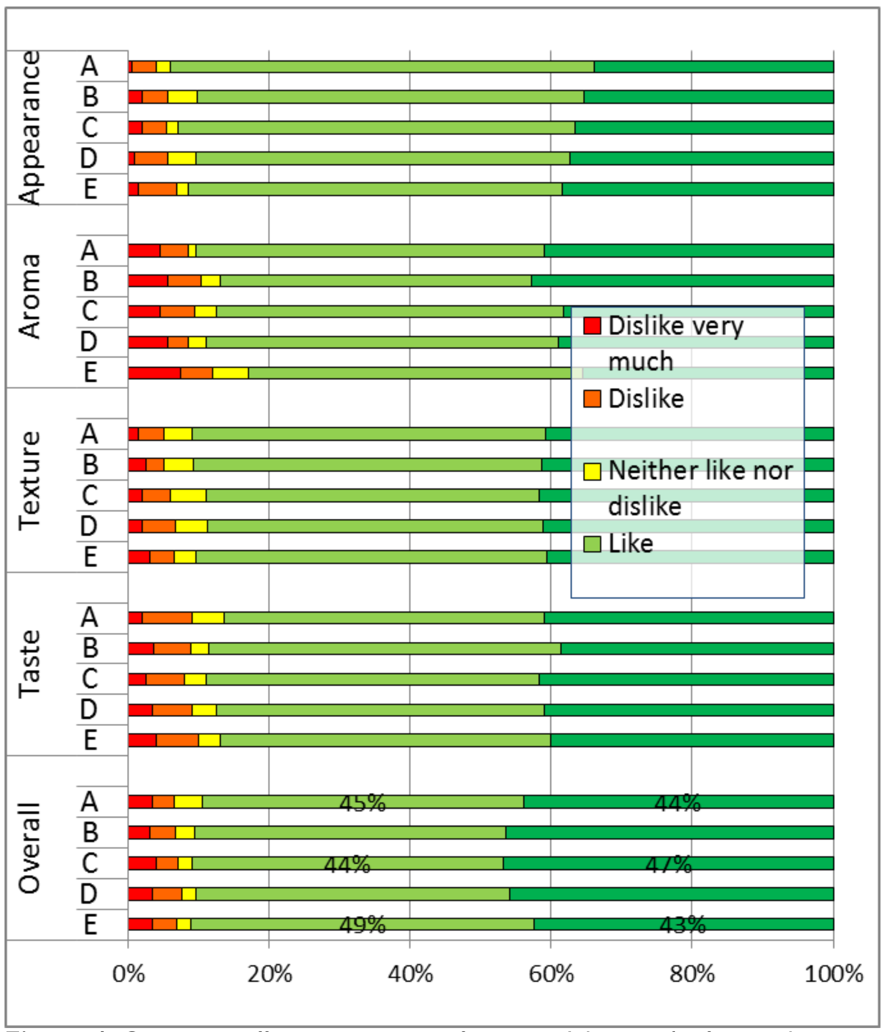

Figure 4. Consumer affective tests, on a five-point Likert scale, for attributes appearance, aroma, texture and taste, and overall appreciation.

Lessons Learned: This study showed that there is a willingness to pay for instant flour and further instant flour with nutrient fortification (synthetic and natural nutrients were the same). This study was done on a mid-lower economic group, and will be repeated in November 2016 (proposed) on higher level economic groups in Dakar.

(e) **Instant and micronutrient fortified food products in Senegal.** A major accomplishment of this period was processing of high quality instant millet flour and fortified products with added synthetic vitamin-mineral premix or one or more of baobab and hibiscus powders. Two students were trained to proficiency on the use of the extruder by Salif Sow (who was previously trained by Amudhan Ponrajan, Ph.D. engineering student from Purdue). Conditions were optimized to produce flour of high quality with fully gelatinized starch, and that were truly "instant". Porridges made by simple addition of water were comparable to those traditionally prepared by cooking. Microbial analysis conducted at ITA on the extruded flours showed zero coliform count, indicating their safety. Over 200 kg of instant decorticated millet flour was produced for use in the consumer preference studies in Touba. Instant flours were judged by the participants of the study to be equal to or better than the traditionally prepared porridge.

The ITA-INTSORMIL CRSP project previously had identified Mme. Mbacke as an entrepreneur processor to partner with outside of Dakar in the city of Touba. Assistance was provided to help her start a cereal processing company, that worked to improve the livelihoods of disadvantaged women in Touba and stretching to other regions of Senegal. On March 11, ITA and FPL officially transferred the extrusion technology to her processing unit "Touba Darou Salam" in the form of a large ceremony (~500 attendees). Speakers included the Mayor of Touba, ITA Director General Mamadou Amadou Seck, B. Hamaker representing FPL, the Minister of Industry and Mines Ali Ngouye Ndiaye, USAID/Senegal Deputy Mission Director Sharon Carter, and Mme. Astou Gaye Mbacke. Angela Records, from USAID Washington, also attended. This was an important event for the project and increased its visibility with the government and other interested in processing and entrepreneurship (Appendix A).

Lessons Learned: The project has now transferred the extruder technology with its instant flour capability to the processing unit Touba Darou Salam of Mme. Mbacke. A large ceremony to mark this transfer and what it could mean to Senegal for the processing and use of millet, as well as its nutritional fortification, was held on March 11 in Touba and has generated quite a good interest in the project and its possibilities of linking farmers to markets, stimulating rural entrepreneurism, and enhancing nutrition. The project is evaluating how to build on this momentum and opportunity.

(f) **Collaborative product development efforts for nutrient-dense cereal-based products at University of Pretoria, South Africa**

In support of the pearl millet product development in Senegal, Prof Riette de Kock and PhD student Mr. Isiguzoro Onyeoziri contributed to the design of a comprehensive study to evaluate the shelf-life of the dry pearl millet products. Because of the high lipid content of pearl millet, the products may be very prone to oxidative and even hydrolytic rancidity. They will identify the sensory attributes that can be used as predictors for the end of shelf-life using the "Survival Analysis" technique.

In support of the product development in Kenya, PhD student Mr Adeyemi Adeyanju (under the supervision of Prof Gyebi Duodu, Prof John Taylor and Dr Johanita Kruger) has commenced work to develop soured sorghum, amaranth and sorghum-amaranth composite porridges with enhanced protein quality, micronutrient bioaccessibility and health-promoting properties. Also, MSc student Mr John Lubaale (under the supervision of Profs Duodu and Taylor) has commenced work to study the effect of lactic fermentation on nutritional quality and health-promoting properties of finger millet gruel.

(5) Capacity Building:
   (a) Long-term training: All students are working to develop various products (fortified and non-fortified) and processes for improved nutrition for the targeting the FPL focus countries.
      (i) Purdue University - Pablo Cesar Torres-Aguilar (Ph.D. student, advisor, B. Hamaker) started in Fall 2014 (supported through Purdue cost-share), Hawi Debelo (Ph.D. student, advisor M. Ferruzzi) is supported on research funds only and started fall 2014, Emmanuel Ayua (Ph.D. student from Kenya, advisor B. Hamaker) started January 2016 of this reporting period and is supported in full by FPL. Cheikh Ndiaye (Ph.D. student from Senegal, advisor M. Ferruzzi) is supported in large part by the USAID ERA project, but also in part from FPL.
      (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). Eliasse Diémé (Ph.D. student, Cheikh Anta Diop University, Food Science and Nutrition) is supported. Abdourahmane Diop (M.S. student, University of Thiès, Agricultural Economics) is supported for his field research.
      (iii) University of Eldoret/Kenya - two Kenyan students (Rose Likoko, MSc. Nutrition University of Eldoret and Harriet Nyakecho, Ph.D. Gender, Pwani University) are on the FPL project.
      (iv) University of Pretoria
      Students involved in the FPL project: Isiguzoro Onyeoziri, Adeyemi Adeyanju, John Gwamba, and John Lubaale with variying levels of support.
   (b) Short-term training:
      (i) Prof. Riette de Kock and her team at University of Pretoria provided a 1 week (November 1-6, 2015) sensory and consumer testing training to 3 PIs from collaborating institutions in Kenya and Senegal: 1) Violet Mugalavai (University of Eldoret); and 2) Djibril Traore and Mamadou Sadji (ITA). They went through the six steps to Sensory Evaluation, application of the six steps to in-country project specific case studies; methods (questionnaire design); product selection, preparation and serving; panel (recruitment criteria), testing environment, and participated in training sessions for descriptive and consumer sensory testing of sorghum and maize based products. They were exposed to practical product testing situations both as panelists/consumers as well as researchers. Three types of sensory test methods were covered difference, descriptive and affective/hedonic, as well as basic requirements for test controls, test panels and testing environment. They also discussed methods of statistical analysis and the possible way forward for Kenya and Senegal sensory experiments.
      (ii) In December 2015, Prof. Gyebi Duodu of University of Pretoria trained four graduate students at Eldoret University, studying under Prof. Violet Mugalavai, on the use of the Bleach test to identify sorghum grains with a pigmented testa (Figure 3). This is one of five simple methods for determination of sorghum end-use quality developed at the University of Pretoria, which are being applied to facilitate supply of grain of the required quality for processing from small-holder farmers.
      (iii) ITA is working closely to build expertise and capacity at 3 processing enterprises: Touba Darou Salam directed by Mme. Mbacke, and in Dakar, FreeWork Services directed by Mme. Deme, and Maria Distribution directed by Mme. Diouf. Training has been provided directly to Touba Darou Salam through installation and training of the extruder that occurred in March 2016.

(6) Lessons Learned: see under individual activities.

(7) Presentations and Publications:
   (a) Food Processing Training Manual: developed by Prof Violet Mugalavai and is being edited by Prof. Augustino Onkware.
   (b) Report on the consumer experiment in Touba: “Measuring consumers’ interest in instant fortified millet products - a field experiment in Touba, Senegal” by De Groote et al. 2016 (paper submitted to the AAAE conference).

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) Potential solution to low levels of zinc. A potential solution to the problem of the low levels of zinc, in particular is to use iron and zinc biofortified pearl millet. Dhanashakti a biofortified variety developed by ICRISAT in India was found to have more than double the iron content and 40% higher zinc content than regular improved pearl millet (Table 2).

Table 2. Fe and Zn contents (mg/100 g, as is basis) of high and normal Fe and Zn pearl millet.

	Fe		Zn	
CULTIVAR	**Content**	**% contribution to RDA***	**Content**	**% contribution to RDA***
Dhanashakti	9.12 ± 0.18	19.5	4.79 ± 0.14	24.0
ICMB 92111	4.43 ± 0.11	9.5	3.40 ± 0.07	17.0

Means and standard deviation (n= 2), * - Percentage contribution that 15 g of pearl millet in a 30 g solids complementary porridge with food to food fortification (50% pearl millet) could make towards the iron (7 mg/day) and zinc (3 mg/day) RDA of infants aged 12-24 months.

Lessons learned: High levels of iron and zinc in the ICRISAT millet variety Dhanashakti have led the team to realize that this, or a similar, biofortified millet, if used in the whole grain form, would be an adequate starting millet material to provide the target range of micronutrients (~30% of recommended values) with further addition of locally sources nutrient-rich plant materials. We are in communication with ICRISAT-Niger, Sadore Centre and the ICRISAT-Mali group to explore a partnership on biofortified millet for potential use in instant fortified flours.

(b) **Impact of extrusion on quality attributes of instantized fruit/vegetable-cereal blends**

In Senegal, interest in leveraging native plants as food ingredients for alleviating micronutrient deficiencies has grown simultaneously with the desire for new convenient forms of traditional products. Extrusion offers a cost-effective path to generate high quality instant thin and thick porridges from traditional grains. The extent to which co-extrusion of cereals and nutrient-rich plant materials can be applied to generate new micronutrient dense blended fruit/vegetable-cereal products was explored in the work of this report period. To understand the impact of extrusion on quality attributes of instantized fruit/vegetable-cereal blends, millet (Senegalese Souna variety) was prepared as whole grain (WG) or decorticated (DC) (extraction rate of 70%). Powdered carrot (CRT), papaya (PAP) and mango (MAN) were combined with WG or DC millet (25:75 %) and adjusted to ~30% moisture prior to extrusion on a Technochem Mini-Extruder© (900rpm; Final Temp = 87.9-115 °C). Instantized products were assessed for quality attributes [color, water absorption and solubility index, pasting properties (RVA), as well as provitamin A and total carotenoids recovery (HPLC)]. Extruded products contained 6.2-74.4 and 4.4-6.9 µg/g dry weight of total and provitamin A carotenoids, respectively Figure 5. Carotenoid recovery ranged from 29.7-65.9% suggesting marginal to good stability to extrusion (Table 3). CRT blends provided highest carotenoid levels reaching 7442 ug/100g dry weight due to high starting material content. Extrusion of DC millet with CRT and PAP powders had greatest impact on final color increasing browning index and chroma values respectively from 30 and 15 (DC control) to 90 and 40 (DC-CRT) and 72 and 35 (DC-PAP) ($P<0.05$). Similar effects were observed in WG products. Water solubility and absorption indexes were significantly

(P<0.05) increased by inclusion of fruit/vegetable powders in both DC and WG products. Extrusion with fruit/vegetable powders altered physical properties of final porridges. Highest peak and final viscosities were observed in WG-CRT porridges (1517 and 2426 RVU) while MAN and PAP addition decreased viscosity. Peak and breakdown viscosities were lower in DC blends (864-1243.3 and 80.7-145 RVU) compared to DC control (2453.3 and 1978.7 RVU). These data suggest that production of extruded fruit/vegetable millet blends with reasonable recovery of provitamin A carotenoids is possible, however, the impact to physical and sensorial properties must be maintained or optimized.

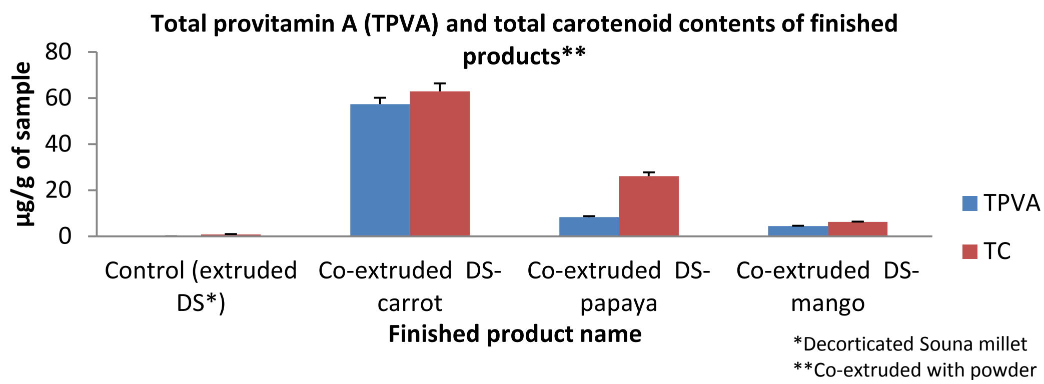

Figure 5. Total provitamin A carotenoids and total carotenoids of the final products (n=3, p<0.05).

Table 3. Recovery of provitamin A and total carotenoids in the final co-extruded with decorticated.

	Carotenoids in ug/g* (100% DW)	**Carotenoids in ug/g* (25% DW)**	**Carotenoids in ug/g* ext.**	**Carotenoids in ug/100g* ext.**	**Recovery**
					TPVA recovery
Carrot	482.4	121	57.3	5727.00	47.5
Papaya	50.1	13	8.3	825.00	65.9
Mango	59.4	15	4.4	440.00	29.7
					TC recovery
Carrot	516.2	129	62.84	6284.00	48.7
Papaya	164.7	45.3	26.07	2607.00	57.6
Mango	65.3	17.6	6.19	619.00	35.1

* Concentration factor of 2

(5) Capacity Building:
   (a) ITA - Maty Diop is supported through FPL for her PhD programs at Cheikh Anta Diop University in Dakar.
   (b) A Masters student John Gwamba (under the supervision of Prof. John Taylor and Dr. Johanita Kruger) investigated the processing technologies of grain decortication (dehulling), steeping/lactic fermentation and parboiling singly and in combination to determine whether any could selectively remove the phytate whilst retaining essential minerals, with the aim of improving mineral bioavailability. None of the treatments affected phytate:iron molar ratio, which remained high (15-18:1). Phytate:zinc ratio was reduced somewhat by decortication, from 31:1 to 26:1 and somewhat further by subsequent steeping/fermentation and parboiling to 21:1, but still remained very high.

Lessons learned: Co-extrusion of millet and nutrient-rich plant materials appears to be one possible path forward to making fortified instant flours, particularly since the extrusion process greatly reduces or eliminates microbial loads.

(6) Lessons Learned: see under individual activities

(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 Section B: Beam Interactions with Materials and Atoms, 363, 177-182.
  (b) Ortiz D, Rocheford T, Ferruzzi MG. Influence of Temperature and Humidity on the Stability of Carotenoids in Biofortified Maize (Zea mays L.) Genotypes during Controlled Postharvest Storage. J Agric Food Chem. 2016 Apr 6;64(13):2727-36.
  (c) Hawi Debelo, Cheikh Ndiaye, Bruce R Hamaker and Mario G Ferruzzi. Interactions between Native African Plant Materials Modify in vitro Bioaccessibility of Provitamin A Carotenoids from Blended Cereal Products. Presented at Experimental Biology 2016. San Diego, CA.
  (d) Darwin Ortiz, Torbert Rocheford and Mario G. Ferruzzi. Influence of temperature and humidity on the stability of carotenoids in biofortified maize genotypes. Presented at Experimental Biology 2016.

VI) HUMAN AND INSTITUTIONAL CAPACITY DEVELOPEMENT[6]

a) Short-term training

Trainee	**Purpose:**	**Home institution**	**Training institution or Mechanism**
Violet Mugalavai	Sensory and consumer testing training	University of Eldoret, Kenya	University of Pretoria
Djibril Traore	Sensory and consumer testing training	ITA, Senegal	University of Pretoria
Mamadou Sadji	Sensory and consumer testing training	ITA, Senegal	University of Pretoria
Madame Mbacke	Installation and training on extrusion technology	Touba Darou Salam Processing Facility	Touba Darou Salam Processing Facility
4 Graduate Students	Bleach test to identify sorghum grains with a pigmented testa by Prof. Gyebi Duodu of University of Pretoria	University of Eldoret, Kenya	University of Eldoret, Kenya

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.

[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.

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
Emmanuel Ayua	Male	Purdue University	PhD	Food Science	2019	Kenya	USA
Cheikh Ndiaye**	Male	Purdue University	PhD	Food Science	2018	Kenya	USA
Fallou Sarr	Male	Cheikh Anta Diop University	PhD	Food Science	2019	Senegal	Senegal
Maty Diop	Female	Cheikh Anta Diop University	PhD	Nutrition Science	2019	Senegal	Senegal
Eliasse Diémé	Male	Cheikh Anta Diop University	PhD	Food Science & Nutrition	2019	Senegal	Senegal
Abdourahmane Diop	Male	University of Thiès	MS	Agricultural Economics	2017	Senegal	Senegal
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
Isiguzoro Onyeoziri	Male	University of Pretoria	PhD	Food Science	2018	Nigeria	South Africa
Adeyemi Adeyanju	Male	University of Pretoria	PhD	Food Science	2017	Nigeria	South Africa
Renee van der Merwe	Female	University of Pretoria	MS	Nutrition	2017	South Africa	South Africa
John Lubaale**	Male	University of Pretoria	MS	Food Science	2017	Uganda	South Africa
John Gwamba**	Male	University of Pretoria	MS	Food Science	2016	Botswana	South Africa
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	2018	Ethiopia	USA
Ravindra Shrestha	Male	Purdue University	MS	Agricultural & Biological Engineering	2016	Nepal	USA

** Students were supported on research only

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 was shipped to the site in March 2016. The Incubation Center will be used to train food processors in Kenya.
   ii) Partners: University of Eldoret

VII) TECHNOLOGY TRANSFER AND SCALING PARTNERSHIPS

a) **Commercialization of solar drying technologies**: Ileleji is exploring options to commercialize the solar drying technologies through a start-up company he will be leading. He has been working with Purdue University Foundry, a university business incubator to develop a business and commercialization plan to make the technology available to small- and medium-holder farmers, with emphasis first in Senegal and Kenya. He visited with potential stakeholders and commercialization partners in Senegal and is also engaged with potential parts manufacturers for the solar dryer in Africa and China. He is working with the FPL Steering Committee to develop an IP management plan to address any conflict of interest between the start-up and the project. He is looking into applying for a USAID-DIV in collaboration with FPL and other stakeholders to pursue pilot-scale prototyping and testing in Kenya and Senegal.
b) Plan of Action: Training of women food processors in Senegal.
   i) Steps taken: ITA team has identified three women-led Dakar processing enterprises for capacity building for food technology dissemination and scale up across Senegal. 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 technology adoption and 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: instant foods (fortified and non-fortified) in the process of scaling in Senegal

VIII) ENVIRONMENTAL MANAGEMENT AND MITIGATION PLAN (EMMP)

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

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 two components of the project meet on a regular basis to discuss project updates, plan future activities and resolve project–related issues as follows: 1) drying and storage – monthly and 2) processing and nutrition – biweekly. 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.

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

a) The Corporative University College of Kenya, one of the collaborators on the drying and storage component of the FPL project failed to deliver on the portion of activities, even after being given several chances to do so. Purdue decided to terminate their sub-agreement. Kenya agricultural Research Organization (KALRO) will take over the activities with management oversite by CIMMYT-Kenya.
b) Dr. Corinne Alexander, a key PI to the project on impact assessment suddenly passed away in the month of January. Dr. Johnathan Bauchet, a faculty member in the Department of Consumer Sciences at Purdue joined the project to take over some of the impact assessment activities. (Biography: Jonathan Bauchet is an assistant professor in the Department of Consumer Science at Purdue University. His research interests are in international development, particularly focusing on the financial life of poor households in developing countries. He is also interested impact evaluation and its methodologies. His recent work examined the demand for life microinsurance among microfinance borrowers in Mexico, as well as the impact of an innovative anti-poverty program in Andhra Pradesh, India. He teaches courses on risk and insurance, and on consumer investment and savings decisions. Jonathan holds a PhD in Public Administration from New York University's Wagner School of Public Service, a M.A. in Sustainable International Development from Brandeis University, and a B.A. in Economics, Management and Law from Universite Pantheon Assas, Paris).

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 in the focus countries and other Feed the Future countries. 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].

Appendix A: Ceremony for Extruder technology transfer to Touba Darou Salam Processing Unit belonging Madame Mbacke: Speech by Bruce Hamaker, Feed the Future FPL project
Friday, March 11, 2016
Dear Minister of Industry and Mines Mr. Ali Ngouye Ndiaye, Deputy USAID Mission Director Sharon Carter, ITA Director General Dr. Mamadou Amadou Seck, Mme. Astou Gaye Mbacke, Dr. Angela Records from USAID Washington, and distinguished guests: It is my pleasure to be with you here today in Touba to officially transfer this extruder and the technology it represents to the Touba Darou Salam cereal processing unit. This will allow for the processing of millet and other grains to convenient and nutritious instant thick porridge (*lakh*) and thin porridge (*rouye*) products ready for the Senegalese market.
Just last week, we conducted in Touba a consumer test with 200 people showing willingness to pay a premium for instant and nutrient fortified products; the results were very encouraging. With these products, not only women will be freed from the tedious work of dehulling, milling and cooking for preparation of "lakh" or "rouye", but also this task will no longer be confined to them, because dads and children will be capable of preparing their own porridges by simply adding hot water to the enriched instant flour. More than 90% of Senegalese, adults and children, consume regularly these porridges. With the enrichment of these foods combined with their instant and convenient form, we expect a strong market demand.
We at Purdue University in the United States in collaboration with Institut de Technologie Alimentaire, Dakar, under the auspices of the USAID project Feed the Future Innovation Lab for Food Processing and Post-harvest Handling (FPL), have partnered with Mme. Mbacke and her food processing unit "Touba Darou Salam" because of her extensive experience and investment to help disadvantaged women in Senegal. Through our joint activities we expect to contribute to economic growth through entrepreneurism, provide better millet markets for local farmers, and promote enhanced nutritional products. This is the first time in the region that instant flour technology has been introduced to local populations.
Mme. Mbacke is a philanthropist and passionate individual for change. Her GIE and model of "credit mutual" to empower women works and has a country-wide impact. We view this partnership as a unique opportunity to rapidly and effectively disseminate advanced food processing and nutrition technologies.
Also, by placing this extruder in her charge, her processing unit will become an incubator for other women entrepreneurs. Technical support will be given through ITA and FPL. This model will be replicated throughout the 14 regions of Senegal. The project will take advantage of the local cereals produced in different regions, as well as fruits and nutrient-rich wild plants.
Finally, I wish to recognize that there is a history of support of USAID agricultural programs to ITA, as well as to Mme. Mbacke and other women entrepreneurs. For years we partnered with ITA through the INTSORMIL program, first through the direction of Dr. Ababacar N'Doye and now under the effective leadership of Dr. Mamadou Amadou Seck. Through INTSORMIL we introduced extrusion technology to ITA and through the USAID Education and Research in Agriculture (ERA) Programme we together began working on naturally fortified instant flour products. Today, the FPL project through ITA works with Mme. Mbacke, and is further supported by the Feed the Future Sorghum and Millet Innovation Lab (SMIL) project.
I again am very happy to be here and look forward to our continued work with Mme. Mbacke.

[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.


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