Empowering Smallholder Women Farmers in Senegal: Development of Bonbon Bouye Nutrition Bar

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Bonbon Bouye nutrition bar and packaging developed by the Montana State Food Product Development Lab (MSU FPDL).[1]

Photos courtesy of the MSU FPDL and Rebecca Soule, respectively

Bonbon Bouye is a nutrition bar (i.e., snack) developed for school-age children in Senegal. The Bonbon Bouye nutrition bar is rich in nutrients, such as protein, fiber, calcium, iron, vitamin C, and folate. The snack was formulated containing cowpea and baobab fruit indigenous to Africa and locally grown peanut and corn. Through focus groups and consumer sensory tests conducted with adults and children in Senegal, the Bonbon Bouye nutrition bar was designed targeting school-age Senegalese children's flavor and texture preferences.

The product development work was conducted between 2018 and 2020 by the Montana State University (MSU) Food Product Development Lab (FPDL) in collaboration with Bountifield International (a nonprofit organization) with input from Senegalese smallholder women farmers.

This project also provided the foundations to secure sponsorship from the African Development Bank (AfDB) to build a small manufacturing plant in Ndangane, Senegal where the smallholder women farmers will be able to produce Bonbon Bouye and other products.

Food Science in Action:

- ✓ Food Engineering
- ✓ Food Microbiology
- ✓ Food Processing
- ✓ Food Quality
- ✓ Food Safety
- ✓ Process Development
- ✓ Product Development
- ✓ Sensory Evaluation

Introduction

Recent estimates indicate that around 282 million people in Africa (approximately 20% of its population) face hunger with the majority (over 90%) residing in Sub-Saharan Africa (i.e., Central Africa, East Africa, West Africa, and Southern Africa).[2, 3] In West Africa (i.e., Benin, Burkina Faso, Cabo Verde, Côte d'Ivoire, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone, and Togo), between 2000 and 2020 the number of people suffering undernourishment (i.e., insufficient caloric intake) increased from 38 million to 59 million people.[3]

In addition to hunger, millions of people in West Africa suffer from micronutrient deficiencies and food insecurity (i.e., not having access to sufficient, nutritious, good quality food). From 2014 to 2019, West Africa experienced an increase in people experiencing moderate or severe food insecurity from 144 million to 208 million people.[3]

Despite significant improvements in reducing malnutrition to less than 20% (one of the lowest in Sub-Saharan Africa),[4] food insecurity and undernutrition remain critical challenges for Senegal. It has been reported that in Senegal, 17% of its population lack access to sufficient, safe, and nutritious food.[5]

On the other hand, certain plant-based foods indigenous to Africa (e.g., cowpea and baobab fruit) and crops locally grown in Senegal (e.g., peanut and corn) are rich in nutrients but are underutilized and could be included in solutions proposed to address malnutrition in Senegal.

Response

In 2018, Edwin Allan, an MSU graduate student led the development of a nutritious snack for West African school-age children via a partnership between the MSU Food Product Development Lab (FPDL), Bountifield International, and smallholder women farmers from the Kaffrine province in Senegal (Figures 1 and 2).[6,7,8] The FPDL is within the MSU College of Education, Health and Human Development, is led by its Director, Professor Wan-Yuan Kuo, and endeavors to "[develop] healthy and eco-friendly food products that honor Indigenous and local

Figure 1. *Allan (left) conducts a focus group with smallholder farmers in Senegal.*[7]

Photo courtesy of the MSU FPDL

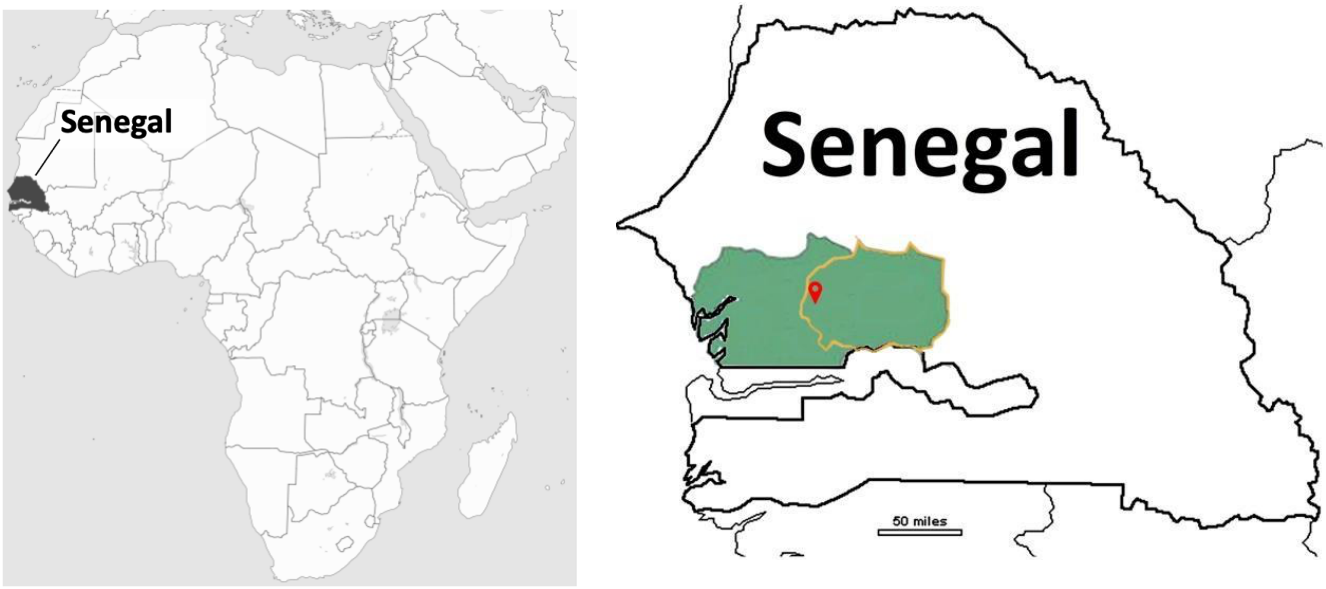

Figure 2. *Left - Senegal in Africa. Right - Senegal peanut basin (green), Kaffrine region (yellow outline) and plant construction site location (Ndangane).*[1,6,21,25]

communities and their foods through creative partnerships and innovations."[9]

Allan, a recent graduate of Nutrition and Food Science at the University of Ghana, had contacted Professor Kuo regarding his desire to pursue a master's degree in Sustainable Food Systems at MSU. Allan was motivated to find solutions for the substantial agricultural waste in West Africa resulting from lack of knowledge in food processing technologies and value-added product development.[10] In fall 2018, Professor Kuo welcomed Allan to the MSU FPDL, where she served as his thesis advisor and sponsored him in his research project — which became the basis for developing Bonbon Bouye.[11]

The Bonbon Bouye MSU FPDL project team also included undergraduate students Cullen Kinnare (Food and Nutrition), Emily Raber (Dietetics), Amber Clifton (Dietetics), Haley Darlinton (Chemical Engineering), Ed Shaw (Sustainable Food and Bioenergy Systems), and Olivia Schwintek (Sustainable Food and Bioenergy Systems).[8,11,12]

Collaborator Bountifield International, founded in 1981, is a nonprofit organization based in Minneapolis - St. Paul, Minnesota, USA, and focused on work in Sub-Saharan Africa. It aims to alleviate hunger and poverty by empowering rural communities through post-harvest processing mechanization, entrepreneurial development, sustainable agricultural practices, and fostering a resilient food system.[13] Locally, Aliou Ndiaye from Bountifield International served as the organization's Senegal Country Representative and played a vital role in coordinating the project in Senegal and connecting MSU researchers, local farmers, and local organizations.[10]

Central to Allan's research was the use of participatory action research (PAR). The PAR model recognizes the importance of engaging with the community stakeholders as active researchers, and crafting research designs rooted in their culture.[14] To achieve this, surveys and focus group discussions were carried out with Senegalese communities, and key project decisions were made together with the women farmers, as advocated by the PAR approach. These methods facilitated the identification of challenges and fostered dialogues with participants, leading to practical solutions.[14,15]

By applying the PAR model, it is hypothesized that the farmers and the community feel a sense of ownership and internal commitment to the research.[14] This process embeds the community's culture and food preferences into the product development process, generating co-created knowledge. Consequently, this approach enhances product acceptance and ensures continued production within the communities. Furthermore, the formulation of the product's ingredients and recipe are based on the

community's available resources and specifically target the identified dietary and health challenges faced by the community.[14,15] The use of the PAR research model led to developing a culturally acceptable product containing cowpea and baobab fruit indigenous to Africa and locally grown peanut and corn.[6,16]

This award-winning project was recognized for its positive potential impact in Senegal by empowering smallholder women farmers, reducing food imports, improving nutrition of school-age children, and reducing food waste. MSU students working on the project won first place in the 2020 Institute of Food Technologists' Developing Solutions for Developing Countries Competition and the Judges' Choice Award in the MSU venture pitch competition.[12,17,18]

Results

Product Development

From surveys and focus groups conducted by Allan and Professor Kuo in 2019 in the Diamal, Ndangane, Keur Serigne Djibel, and Ngouye Siwakh communities in Senegal, it was learned that cowpea and peanut harvests suffer losses due to insect damage, inadequate storage, and lack of effective post-harvest processing. It also led to the conclusion that development and commercialization of a culturally acceptable, nutritious food product could reduce cowpea and peanut post-harvest losses.[6,8]

In West Africa, consumption of commercial snack foods and drinks is popular with young children. A recent study indicated that 26% of children in Niger, 32% in Burkina Faso, 43% in Mali, and 45% in Côte d'Ivoire had consumed at least one commercial snack food or beverage in the prior 24 hours.[19] However, it is estimated that only 3% of the total value added to agricultural products corresponds to shelf-stable peanut products.[20] Thus, this gap presents an opportunity for developing nutritious peanut products for the local Senegal market using local ingredients to increase food security, nutrition, and revenue for smallholder peanut farmers.[16]

Because of similarities in flavor and texture to a local Senegalese peanut cake (i.e., Kungutu), focus groups participants selected Peanut Butter Baked Squares by Quaker™ as a reference product which helped the MSU FPDL technical team working in the development of the product and its preparation process. Input by the communities also helped in the selection of key ingredients that are available and acceptable in the region (i.e., cowpea flour, baobab fruit powder, peanut paste, and corn flour).[6,8]

Ingredients in the nutrition bar formulation were mainly added as a source of nutrients (cowpea, baobab fruit, peanut, and corn), flavor (cowpea, baobab fruit, peanut, sugar, and salt), texture (canola oil, baking powder, and acacia gum), and processing aid (water).

Softness and cohesiveness were identified by the focus groups of local women as important texture attributes for the acceptance of a baked product by local children.[21]

Acacia gum was used as a binder to increase cohesiveness and reduce hardness in the nutrition bar. Acacia gum was chosen among other common gums because the women farmers shared how they used to harvest gum from Acacia trees to make couscous for children, although currently they would have to purchase acacia gum from the market due to deforestation. The baobab fruit is rich in pectin and its content had to be limited to manage hardness.[16]

Peanut (*Arachis hypogaea*) is a legume with high levels of protein (24%), oil (50%), and fiber (8%) and contains all the essential amino acids.[22] In addition, peanut is an established cash crop in Senegal for the global market and its increased consumption has the potential to increase revenue for peanut farmers.[23]

Similar to other legumes, cowpea (*Vigna unguiculata*) has high contents of protein (22-32%) and carbohydrates (50-60%), but it is low in fat (1%). Compared to cereals, cowpea may have 2 to 4 times more protein, similar protein content as meats (18-25%), and it is also considered a good source of dietary fiber, minerals and B vitamins. However, as other legumes, it is low in the methionine and cystine essential amino acids.[24]

Corn (*Zea mays*) is an important food source worldwide. Whole grain corn flour contains

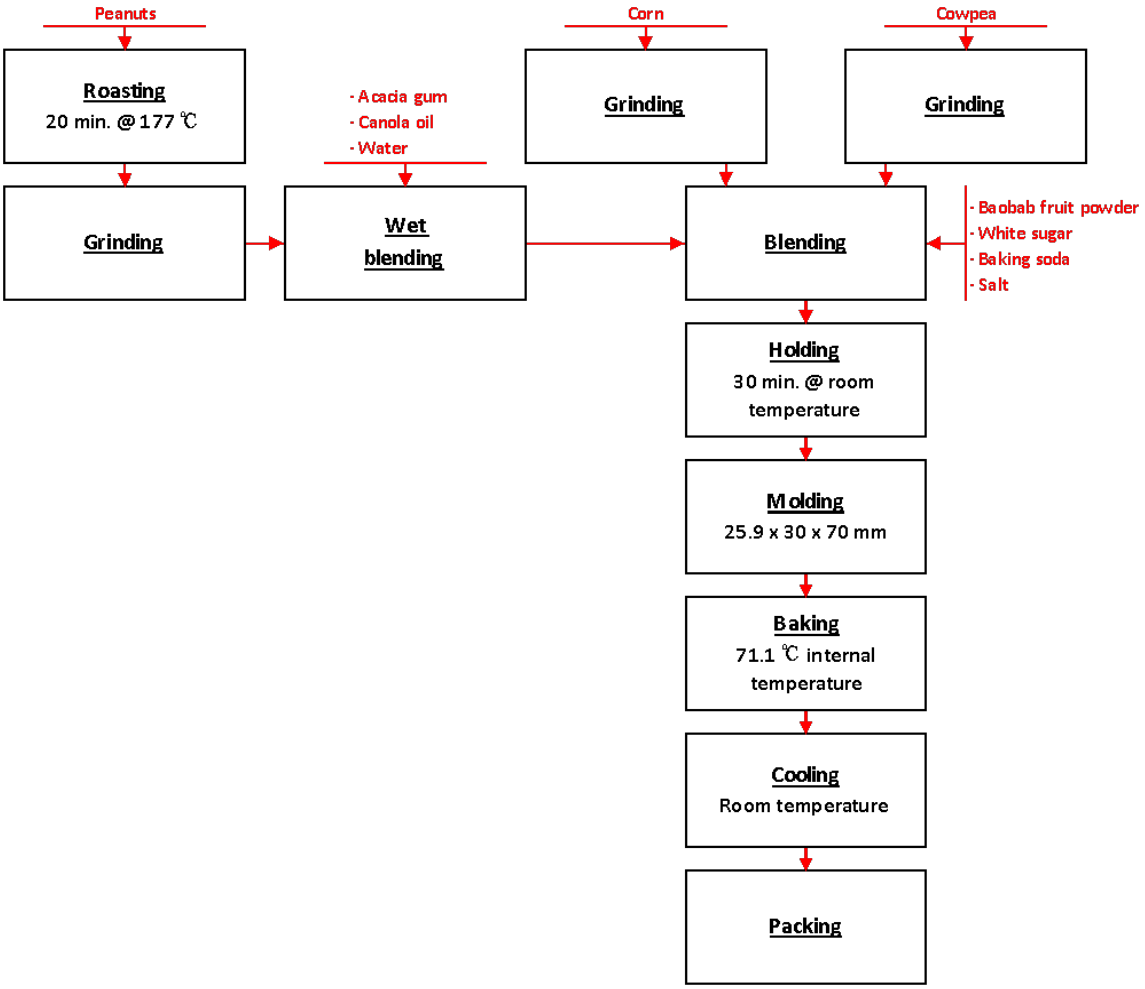

Figure 3. *General flow diagram for the preparation of Bonbon Bouye nutrition bar.*[6]

proteins (6.9%), lipids (3.9%), carbohydrates (77%), fiber, minerals, and vitamins. However, it is low in the lysine and tryptophan essential amino acids.[26]

Foods containing corn and cowpea flours, or other legumes, have been reported to provide protein of high quality because of their complementary amino acid composition. Corn protein is deficient in lysine and tryptophan but contains fair amounts of methionine and cystine, while cowpea and other legumes contain relatively high concentrations of lysine and tryptophan but are low in methionine and cystine.[27]

Baobab (*Adansonia digitata*) is a fruit tree species native to Sub-Saharan Africa, and its edible parts (leaves, seeds, and fruit) are mainly consumed by rural populations. Because of its high content of vitamins, minerals, and proteins, which are in low content in the cereal-dominated diets of Sub-Saharan Africa, adding baobab fruit powder to the nutrition bar helps to attain a more balanced nutrition.[28] Nevertheless, from input by the smallholder farmers focus groups, the amount of baobab fruit powder in a product needs to be optimized due to its sour taste.[21]

Process design included identification of the main unit operations (i.e., roasting, grinding, blending, molding, baking, cooling, and packing) (Figure 3) and HACCP analysis, i.e., Hazard Analysis (HA) and identification of Critical Control Points (CCP).[29]

The main food safety risks included aflatoxin contamination of peanuts from the growth of *Aspergillus flavus* and *Aspergillus parasiticus* during storage in warm and humid conditions, and microbial contamination during ingredient handling and processing.[29]

For peanuts grown and processed by the local community operating the plant, CCPs to prevent aflatoxin production were roasting to eliminate

molds (20 min. at 177 °C) and storage at favorable humidity and temperature conditions (Relative Humidity < 70%, 25-27 °C and peanut moisture < 7%).[29] Aflatoxin testing in peanuts was also identified as a CCP at the plant before processing is started.[1]

Baking (internal temperature of 71 °C) was identified as a CCP to control finished product microbial contamination during ingredient handling and processing.[29]

In 2020, Professor Kuo and Allan returned to Senegal to conduct consumer sensory acceptance tests of the nutrition bars (Figure 4).[16] Consumer sensory acceptance tests used a 9-point hedonic scale from "Dislike extremely" (1 point), "Neither like or dislike" (5 points) to "Like extremely" (9 points). Using response surface methodology, 12 formulations were tested first with adults (149 participants, 18 years old or above) and then, 3 of the formulations (varying in cowpea contents) were also tested with school-age children (121 participants, 8 to 12 years old).[6,16]

Contents of cowpea and corn flours and baobab fruit powder were varied among the 12 formulations. All other ingredient levels, i.e., peanut paste, water, sugar, canola oil, baking powder, acacia gum, and salt, as well as processing conditions were kept constant among all formulations.[6,16]

Consumer acceptance results indicated that the 3 products tested by school-age children were rated as "Like moderately" (9-point hedonic scale scores between 7.0 and 7.7). However, among adults only 2 products were rated "Like moderately" (9-point hedonic scales of 7.1 and 7.5).[6,16]

Statistical analysis returned an optimum formulation for sensory acceptance containing cowpea flour (24.9%), water (22.1%), sugar (17.3%), baobab fruit powder (9.95%), peanut paste (9.78%), canola oil (8.13%), corn flour (4.29%), baking powder (1.51%), acacia gum (1.17%), and table salt (0.9%).[6,16] The resulting optimal nutrition bar formulation can be an important source of nutrients critical for the growth of Senegalese school-age children.[6]

No further consumer sensory acceptance tests have been conducted on the optimum formulation; however, local collaborators in Senegal have been adjusting the bar making process to prolong the product shelf life.[11] So, it is likely that the formulation and the process may evolve and be improved over time which could impact the nutrient profile.

Allan earned his master's degree in May 2020, which concluded the MSU FPDL's research on the development of Bonbon Bouye in Senegal. However, the MSU FPDL continues its work in Senegal through several avenues described below. Although the partnership with Bountifield ended upon the completion of Allan's project, Ndiaye continued working independently with the MSU FPDL as its Senegal Program Coordinator.

Figure 4. *Consumer sensory acceptance tests were carried out with adults (left) and school-age children (right) in Senegal.[8,29]*

Photos courtesy of the MSU FPDL

Ndangane Food Factory

The African Development Bank (AfDB) has allocated funding to construct 100 food production factories throughout Senegal. In 2021-2022, a group of MSU Chemical Engineering students under the direction of Professor Paul Gannon designed plans for a potential factory in Ndangane where the women farmers could produce Bonbon Bouye and other products (Figure 2). The facility's design is human-centered and intends to address the needs of the women workers.[8] In addition to food processing areas, the plans included a prayer room, children's play area, office, classroom for training, and a community garden (Figure 5).[8,10]

In December 2021, on behalf of the MSU FPDL, Ndiaye met with AfDB representatives in Dakar, Senegal. Ndiaye highlighted the MSU FPDL's track record of working with smallholder farmers in Senegal, presented the factory blueprint designed by the MSU Chemical Engineering class, and advocated for the village of Ndangane to be considered as a location for one of the proposed factories. During the first half of 2022, AfDB officials approved the request and budgeted $60,000 for the final plant design, construction, equipment purchase, plant start up, and training. Construction of the plant began in January 2023 and at the time of writing (February 2024) commercial production of Bonbon Bouye nutrition bar is still pending (Figure 6).[10,12,25]

Lessons Learned

- The development of a new food product often involves a lengthy process and many iterations due to the absence of consumer input or its late inclusion towards the end of the development process. Developers of the Bonbon Bouye bar were able to create an acceptable new product in a relatively short time by working, receiving input, and co-developing directly with the local community (i.e., the Senegalese women farmers) on selecting local ingredients and community-feasible processing operations, and identifying important sensory properties.

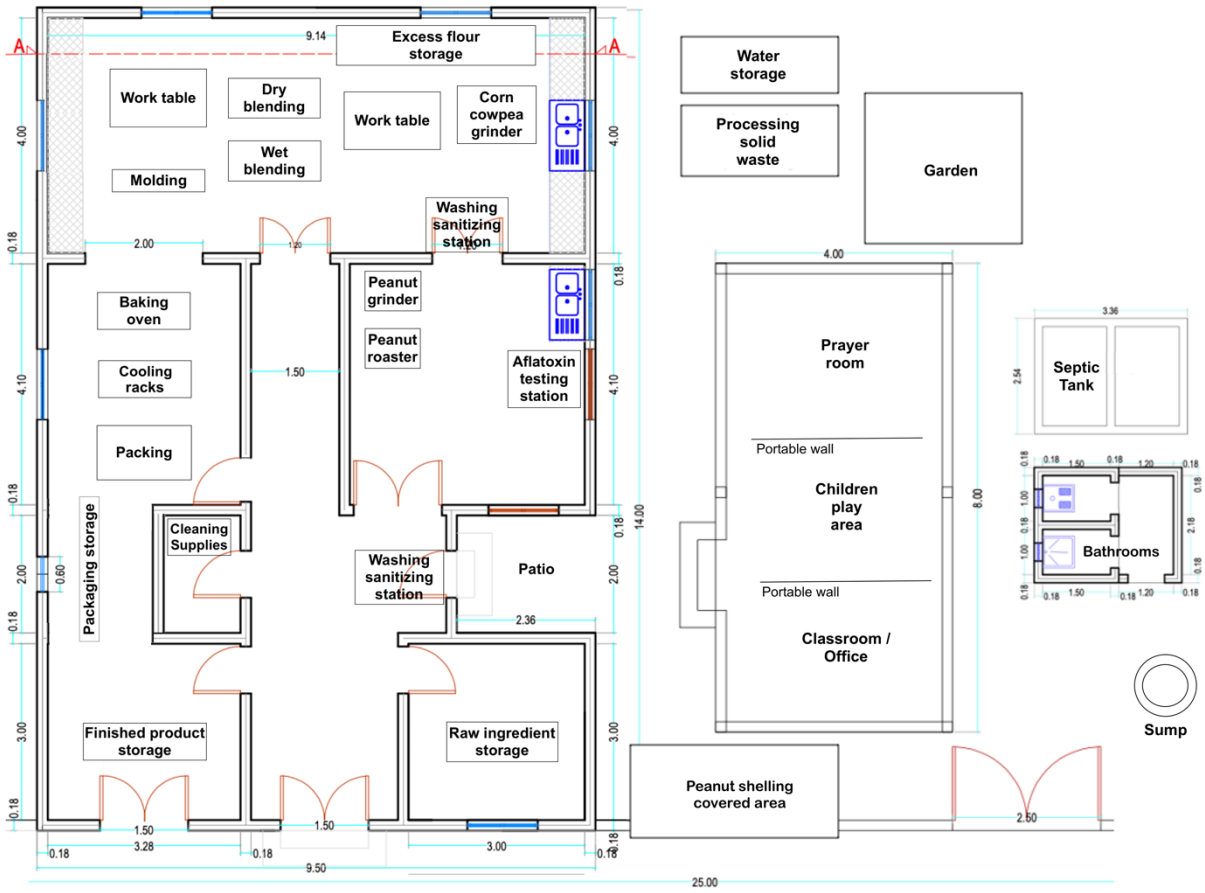

Figure 5. Bonbon Bouye plant floor plan (approx. 25 x 14 meters).[1]


Figure 6. *Pictures of the Bonbon Bouye plant site in Ndangane, Senegal at different stages of construction in January 2023, during visit by the MSU FPDL (left) and October 2023 (right).*[25]

Photos courtesy of MSU FPDL and Aliou Ndiaye, respectively

- The Bonbon Bouye bars were not developed in isolation. Cultural factors (e.g., the post-harvest role of the Senegalese women and call to prayer several times a day) were considered in the product development process and plant design. The whole community, from children, men, women to the tribal chief were involved and consulted during focus groups, product testing, training, and plant layout review.
- The MSU team could not have succeeded in implementing the Bonbon Bouye project without partnering with Bountifield International that already had a local presence, experience, and involvement in Senegal, or without the partnership with a sizable organization like the AfDB.

Next steps

- The manufacturing and commercialization of Bonbon Bouye in Senegal is now an AfDB-sponsored project. AfDB is leading the construction of the factory, purchase and installation of equipment, and training of the women farmers (e.g., business, accounting, quality, food safety, and sanitation). The MSU FPDL will continue being involved in the training of the women farmers in relation to food safety, manufacturing, and quality. However, as the women farmers will require thorough training in business and food manufacturing after the plant is built, the starting of sales and commercialization is of an uncertain time frame.[25]
- The MSU FPDL has secured funding from the Foundation for Food and Agriculture Research from January 2022 to December 2024 to explore development of new products for the Ndangane community in Senegal. The MSU FPDL is co-developing a nutritious fermented beverage (i.e., yogurt) that contains locally sourced sorghum, milk, and the indigenous baobab fruit.[8, 25] In January 2023, Professor Kuo traveled to Senegal with a new student research team to introduce the concept beverage and controlled fermentation techniques, plus engage the community in focus group discussions and Bonbon Bouye training baking trials with the women.[12]

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