How Using Biofortified Orange-Fleshed Sweet Potato as an Ingredient in Popular Ready-to-Eat Foods is Boosting Nutrition in sub-Saharan Africa

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Food Science in Action:

- ✓ Food Processing
- ✓ Product Development
- ✓ Ingredient Science
- ✓ Nutrition

Jean Pankuku inside her bakery and shop 20 kilometers off Malawi's second largest city, Blantyre. Her bakery focuses on commercializing nutritious and healthy foods using locally grown crops such as the orange-fleshed sweet potato.

Photo: V. Atakos (CIP-SSA)

The development of biofortified orange-fleshed sweet potato offered a solution to the vitamin A deficiency prevalent throughout sub-Saharan Africa that leads to blindness and an increased risk of death from infections. However, low consumer preference for this type of sweet potato due to its sensory attributes and image as a poor person's food prevented large-scale adoption of this nutritious crop. The International Potato Center found that by using a food science approach, the orange-fleshed sweet potato could be processed into a valuable ingredient for use in popular bakery products and other ready-to-eat foods to effectively deliver extra vitamin A to Kenyan and Rwandan consumers in an acceptable form.

Introduction

Sweet potato is a vitally important staple crop in much of sub-Saharan Africa with millions of tons produced each year. Its drought tolerance has made it particularly valuable as a food security crop compared to other less hardy regional staple crops such as maize. More than 80 kg per capita are consumed in countries where sweet potato is a primary staple crop (including Rwanda, Burundi, Uganda, and Malawi), with the most popular variety being the white-fleshed sweet potato (WFSP).[1]

In 1995, researchers became aware of the great potential of the less common, beta-carotene-rich, orange-fleshed sweet potato (OFSP) to be grown and utilized in sub-Saharan Africa to combat vitamin A deficiency.[1] In Africa, vitamin A deficiency has been declared a public health problem, with pregnant women and young children the most impacted.[2] Over 40% of children under five in sub-Saharan Africa have vitamin A deficiency.[3] Not only is vitamin A deficiency known to increase the risk of death from infections, it is also the leading cause of blindness in developing countries. Those living in remote areas may not be reached by traditional supplementation and fortification efforts, making

the availability of a local crop rich in beta-carotene (the precursor to vitamin A) particularly valuable. In addition, access to the seeds would allow them to grow their own supply of this nutritious crop.

This idea led to a series of coordinated efforts that included efficacy and effectiveness trials in children, scale-up analyses, and increased funding for the breeding and selection of high beta-carotene OFSP (a process known as biofortification).[1] Despite positive results, challenges remained in consumer acceptability. Not only was the drier, starchier texture of traditional WFSP preferred over OFSP, but sweet potato in general was perceived as a poor person's food.[1]

Response

In 2009, the International Potato Center (CIP), through investments from the Bill and Melinda Gates Foundation and other donors, funded the Sweetpotato Actions for Security and Health in Africa (SASHA) project to expand the access and uses of improved varieties of sweet potato such as OFSP. One goal was to diversify the uses of OFSP by incorporating it as an ingredient in popular, ready-to-eat foods. With this aim, product development work was done at CIP led by Dr. Tawanda Muzhingi of CIP and Mr. Antonio Magnaghi of Euro Ingredients Ltd. Kenya to try incorporating OFSP flour and puree into various food products.

Ultimately, the puree was found to be the most promising ingredient format for OFSP compared to flour because more could be used in baked goods economically. Higher usage levels lead to higher vitamin A concentration in the finished products, as well as higher OFSP demand, which supports OFSP farmers and strengthens the supply chain. CIP was able to successfully develop a process for producing OFSP puree with a 4-month shelf life using preservatives that would be economically viable for small-scale bakeries and informal sector or street vendors.

After successful product development using OFSP puree in bakery products at laboratory scale, CIP embarked to promote its application with local food manufacturers. Between 2010 and 2017, in partnership with the Rwanda Agricultural Board (RAB), local manufacturers such as Urwibutso Enterprises and young entrepreneurs in the Muhanga district received training on the benefits of using OFSP puree. These benefits included enhanced product nutrition, reduced product cost, and—when compared to OFSP flour—improved beta-carotene stability which results in higher vitamin A content after processing. The training also covered OFSP puree as a substitute for wheat flour to make products such as the popular golden power biscuits (cookies) and African donuts, known locally as mandazi.[4,5] CIP's training reached other countries, as well, including Ghana, Nigeria, and Mozambique, where bread is produced mostly by small and artisanal bakers.

From 2014 to 2015, CIP collaborated with Euro Ingredients Ltd. to perform consumer assessments of bread, buns, and cakes that used OFSP puree and approached Kenyan supermarket chain Tuskys, resulting in OFSP puree bread being marketed in six stores in Nairobi.[6] Other initiatives included a seminar, market survey, and studies to assess the acceptability of additional products utilizing OFSP puree, including agidi (corn jello) made with 30% OFSP puree in Nigeria's Kwara State, jam and non-alcoholic beverages made with OFSP in Abeokuta State of Nigeria, OFSP flour and puree-based complementary foods such as "Sweepolac" for nursing women in Ghana, and products for the VISTA project in Tanzania.[7]

Results

CIP's outreach helped raise awareness and identify key players to establish partnerships. Between 2015 and 2017, CIP facilitated collaborations in Kenya among about 3,000 local farmers (66% women) from Homa Bay, Migori, Kisumu, Siaya, Bungoma, and Busia counties; small scale processor Organi Ltd. in Kisumu; and supermarket chain Tuskys in Nairobi.[8] This effort resulted in the creation of a large-scale value-chain integration to produce vacuum-packed OFSP puree from unpeeled roots with 4 months of shelf life and no need of refrigeration for use in bakery products. As of June 2015, Organi Ltd. was producing 71,958 kg of puree over 15 months, while as of September 2016, Tuskys was selling more than 3,000 loaves of OFSP bread per day in 20 stores.[6]

The OFSP puree bread value-chain in Kenya has resulted in economic benefit for all players involved. OFSP root production by local farmers in three different sub-counties resulted in a profit of USD 655/ha and a 52% profit margin.[6] In 2016, after continuous improvement during OFSP puree processing, the operation achieved a monthly net profit margin of 18% when 10,500 kg/month of raw roots were received.[6] Regarding the manufacturing and sale of OFSP bakery products, the use of OFSP puree reduced the cost of producing bread and the need for added water and food color in the process. Furthermore, OFSP puree bread was selling for KES 55 (USD 0.52 in 2015) per 400-gram loaf which is KES 5 more than standard bread made from 100% white wheat flour.[6] This demonstrates both that consumers are willing to pay a slightly higher price for the added value and that OFSP bread represents a profitable opportunity for manufacturers. Other retailers including Naivas and Cleanshelf supermarkets also incorporated the use of OFSP in bread and buns in their stores.

> "I planted [OFSP] because of income and vitamin A as a food security, and even my babies—my children—love to eat it." — Olga Odhiambo Otieno, OFSP farmer for Organi Ltd.[9]
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> "It does help us in many ways, like food, and we've been selling them to get money for my school fee." — Beth Akinyu, Olga's daughter [9]

In the case of Rwanda, between 2014 and 2017, farmers producing OFSP puree within the CIP-promoted collaboration were able to sell their roots at RWF 20/kg above the average price of RWF 200-220 (USD 0.22-0.25 in 2019)/kg; 153.4 tons of OFSP roots were sold at a total value of USD 154,040.[10] This extra income allowed farmers to purchase essential goods and services such as livestock and access to government health insurance. Processors in Rwanda also benefited from utilizing OFSP puree when substituting wheat flour with OFSP; they were able to reduce their production cost per unit for bread, biscuits, and mandazi by 7%, 14%, and 15%, respectively.[10] This new supply chain also facilitated reduced gender segregation due to the high involvement of women.

Benefits of the work with OFSP can also be linked to consumers' nutrition. Between 2006 and 2009, it is estimated that OFSP flour had already reached 24,000 households in Uganda and Mozambique, increasing vitamin A intake among children and women, thus reducing the prevalence of low serum retinol by 9%.[11] Similarly in Rwanda, lab analysis has shown that a 30-gram slice of bread made with OFSP puree can provide about 50 Retinol Activity Equivalents (RAE) of beta-carotene, as well as increase its content of fiber, iron, and zinc.[12,13] Moreover, it was recently reported that substitution of wheat flour by OFSP puree in bread can lead to stable concentrations of beta-carotene and a longer shelf-life of bread products.[14]

The efforts around OFSP puree have shown scaling potential, not only at the industrial level, but also in household utilization. In Kenya, where the Scaling up Sweetpotato through Agriculture and Nutrition (SUSTAIN) initiative involved providing households with coupons to exchange for OFSP, up to 80% of the coupons were redeemed within a week in 2016 in comparison to 38% in 2014; it is estimated that OFSP is consumed at least twice a week during the production season.[12] Households are processing OFSP into flour or puree to substitute wheat flour in chapati, mandazi, jam, juice, cake, and several other homemade products.[15]

Lessons Learned

Both technical and non-technical factors (such as organizational, leadership, and institutional environment) were important to the successful outcome of these efforts.[16]

- While OFSP acceptability and adoption was originally limited, technical aspects such as training, food product development, and food processing to promote OFSP use in the form of puree accelerated and expanded its adoption.
- The application of OFSP puree as an ingredient in popular, ready-to-eat foods with reduced costs and improved shelf life proved to be an effective strategy to quickly build value-chains to scale and expand reach and impact.
- In addition to the essential role of food science and technology, certain non-technical factors were also key for the success of these efforts, including (a)

close collaboration between research, public, and private sectors, (b) training of local collaborators, (c) continuous education of consumers to promote demand, and (d) continuous and adaptive learning at all stages.

Next Steps

Lastly, while this article focuses on the progress made so far in Rwanda and Kenya, evidence of progress can also be found throughout other countries in the region. For instance, USAID's Feed the Future Initiative and CIP partnered with Zebra Farms in Mozambique and Universal Industries Ltd. in Malawi to commercialize products that include OFSP chips, biscuits, and juice.[17] Also in Malawi, CIP supported Tehilah Bakery and Value Addition Centre, a start-up led by Jean Pankuku, that now sells OFSP puree bread throughout the country.[18]

CIP has also partnered with BioInnovative Africa and social enterprise The Women's Bakery in a $750,000 project to further expand the application of OFSP puree not only in Rwanda but also in Uganda, Kenya, and Ethiopia.[19] Other countries in which CIP continues OFSP projects include South Africa (through SanBio, CSIR, and the University of Pretoria) and Burkina Faso (through Hystra's MERIEM project). Now, even in countries such as The Gambia where CIP has no presence, OFSP puree bread is making significant inroads in the bread market and improving the lives of those who grow it for a living.[20]

In addition to expanding OFSP applications, supporting research is also continuing. Some examples include the evaluation of food safety training and knowledge to improve microbial safety and quality within Kenya's OFSP value chain and collaboration with universities such as North Carolina State University and South Dakota State University to better understand beta-carotene retention and bioaccessibility through *in vitro* digestion of foods containing OFSP.[21,22,23]

Hence, we look forward to learning more from these and other on-going efforts in which food science and its professionals continue to play important roles to deliver relief and development globally.

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