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CHAPTER 9

VITAMIN A CASSAVA IN NIGERIA: CROP DEVELOPMENT AND DELIVERY

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ABSTRACT

Biofortified vitamin A "yellow" cassava can help address the adverse health effects of vitamin A deficiency. By 2016, HarvestPlus and its partners had successfully developed and delivered vitamin A cassava varieties to more than one million farming households in Nigeria and the Democratic Republic of Congo (DRC). HarvestPlus has established the proof of concept that vitamin A cassava varieties can be developed without compromising yield levels and that these varieties are widely accepted. The delivery program has shown that farmers are willing to grow vitamin A cassava varieties and consumers are willing to buy and eat vitamin A cassava products. This paper summarizes the country, nutritional and consumer background, the crop development and release of biofortified vitamin A cassava varieties in Nigeria, progress in monitoring and evaluation of results, and synthesizes lessons learned and future challenges.

Key words: Biofortification, Vitamin A Deficiency, Cassava, Vitamin A Cassava, Yellow Cassava

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INTRODUCTION

Cassava is the most widely eaten staple food in Nigeria. Roots are primarily white in color and contain no provitamin A. Vitamin A deficiency continues to be a significant public health problem in Nigeria, despite improving diets due to rising incomes and administration of vitamin A capsule and fortification programs over the past decade.

The first variety of provitamin A cassava was approved for release in Nigeria in late 2011, eight years after crop development activities were initiated in 2003 at the International Center for Tropical Agriculture (CIAT) and the International Institute of Tropical Agriculture (IITA) under funding from the HarvestPlus program. Five years after release and thirteen years after initial research activities, it is estimated that one million Nigerian farm households are growing “yellow” cassava varieties, which contain significant amounts of provitamin A even after processing. Yellow cassava now represents an additional source of vitamin A in Nigerian diets.

This chapter provides an overview of (i) the policy background and justification for developing, introducing, and scaling up use of provitamin A varieties in Nigeria, (ii) crop development activities, (iii) the strategy and experience-to-date with dissemination of biofortified varieties of cassava, and (iv) past and planned efforts to measure impact. The concluding section draws lessons learned and describes the steps that will need to be taken to integrate yellow cassava varieties into the Nigerian food system on a sustainable basis.

BACKGROUND AND JUSTIFICATION: PRE-RELEASE ACTIVITIES

During crop development and before the first varieties are released, it is necessary to develop evidence to demonstrate the viability and cost-effectiveness of biofortification and to use this information to convince policy makers to support the biofortification strategy.

Dietary Sources of Vitamin A, Prevalence of Vitamin A Deficiency, and Vitamin A Interventions[1]

Two forms of vitamin A are available in the human diet: preformed vitamin A (retinol) and provitamin A carotenoids. Preformed vitamin A is found in animal-source foods; provitamin A is found in some plant-source foods, and is metabolized by the body into retinol when consumed. The World Health Organization has established the Estimated Average Requirement (EAR) for vitamin A by age group. For children 4-6 years, this is 275 µg retinol; and for women, 500. Adequate vitamin A is important for healthy immune function; vitamin A deficiency leads to severe visual impairment and increased risk of illness and death from common infections.

Dietary sources Vitamin A is concentrated in relatively few foods. Although the richest sources of preformed vitamin A in the Nigerian diet are animal-based (for example, liver, dairy products, fish oils, and eggs), the most common sources of the nutrient are

[1] This section draws on the work of Ender [1].

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provitamin A carotenoids, including beta-carotene, from orange and yellow fruits and vegetables (pumpkin, yellow squash, carrots, yellow sweet potatoes, green leafy vegetables, mango, papaya, and other local carotene-rich fruits), some of which are highly seasonal in availability [1]. One significant source of vitamin A in the Nigerian diet is red palm oil, which has very high levels of vitamin A precursors (5720 µg retinol activity equivalent (µg RAE) units per 100 gm. of oil) [2].

Data on vitamin A intakes of individuals can be drawn from a 2006 UNICEF review of the Nigerian fortification program [3]. The investigators sampled 1,698 households in six States (Akwa Ibom, Lagos, Nasarawa, Oyo, Plateau and Kaduna), which under-represents the northern Sahelian part of the country. The results are given in Table 9.1.

Table 9.1 suggests that the youngest age group is not, in fact, the worst off with respect to meeting vitamin A nutrient requirements (that is, those who consume the least share, relative to daily requirements). That distinction is held by the preteens. The data also show that men are best able to meet their vitamin A needs. Unfortunately the “women” category was not disaggregated by physiological group and thus it is not possible to assess the level of risk of deficiency in lactating women (whose needs are the highest of all), but the average intake of women is clearly insufficient even for non-pregnant/non-lactating women. It is, however, clear from Table 9.1 that all groups assessed in this study had inadequate dietary vitamin A intake. The study did not assess vitamin A deficiency.

Vitamin A deficiency Unfortunately, there is no recent national data on vitamin A deficiency (VAD) in Nigeria. Based on the lack of systematic data on vitamin A status, dietary intake, program performance, and food consumption, it would appear that Nigeria is not adequately monitoring vitamin A deficiency.

The most recent national VAD study was conducted in 2001. The results showed that just under one-third of preschool children and one-fifth of pregnant women suffered from VAD at that time. Deficiencies in children were not remarkably different between urban and rural areas or among the agro-ecological zones used in that survey. Women’s status showed more variation. Vitamin A deficiency was less prevalent and exhibited far less regional variance than general undernutrition (stunting and wasting) in the same survey [4]. Due to seasonal variation in dietary intake and vitamin A stores in the body, inadequate dietary intake does not always result in clinical VAD.

Addressing vitamin A deficiency The main mechanisms for addressing vitamin A deficiency are improving diet through nutrition education (often focused on promoting breastfeeding and getting vitamin A-rich foods into the diets of very young children), semi-annual supplementation of children with mega-doses of vitamin A, and fortification of staple foods with vitamin A. All of these options are used in Nigeria, but few details exist on implementation or quantitative impact. The most recent Living Standards Measurement Survey estimates that on average only half (51%) of preschool children receive vitamin A supplements (37% of the poorest (wealth quintile) and up to 74% of the wealthiest quintile children) [5].

In the year 2000, Nigeria enacted laws requiring vitamin A fortification of all wheat flour, maize flour, edible vegetable oil, margarine and sugar with vitamin A (wheat flour was also to be fortified with iron and B vitamins). Sanusi and Akinyele found that consumption of fortified products (wheat and maize flour, sugar, and vegetable oil) was low (with few respondents even knowing about food fortification) and levels of vitamin A varied from 25-100% of the Standards Organization of Nigeria (SON) standard in oil to 50-80% in sugar and 50-80% in bread [3]. Studies in 2012 and 2013 have found widespread non-compliance with fortification standards [6, 7].

In addition to the mandatory fortification program, voluntary fortification is also ongoing. Nestlé is fortifying breakfast cereals and bouillon cubes, for instance. Ready-to-use therapeutic foods (RUTF) are also fortified. These highly nutritious foods are distributed through community-based management of acute malnutrition programs in food-insecure northern areas by UNICEF and non-governmental organizations (NGOs).

In this context, biofortification is a promising complementary intervention for Nigeria because it places the solution in the hands of farmers. Cassava is a widely-consumed staple food in Nigeria, and biofortified vitamin A cassava improves vitamin A intakes among those who consume it. Compared to supplements, vitamin A cassava provides a lower but more regular amount of vitamin A and reaches a wider variety of age groups. Compared to fortification, biofortification better reaches vulnerable households and those who produce the foods they consume. Continued engagement in crop development and strengthening the seed system, as well as a wide variety of advocacy and policy activities discussed below, are necessary for biofortification to be a sustainable intervention for addressing vitamin A deficiency.

Cassava Production and Consumption Patterns

Since cassava is a widely-consumed staple food in Nigeria, it was considered a promising vehicle for biofortification to increase vitamin A content and, therefore, dietary intake. Cassava production occurs predominantly in the southern rainforest savannah ecological zones (see Figure 9.1). Relatively small quantities are produced in northern Nigeria, although drought tolerant cassava varieties are being introduced into those areas as well [8]. The initiative to expand the range of cassava production to drier zones is supported by drought tolerance breeding initiatives at IITA and CIAT.

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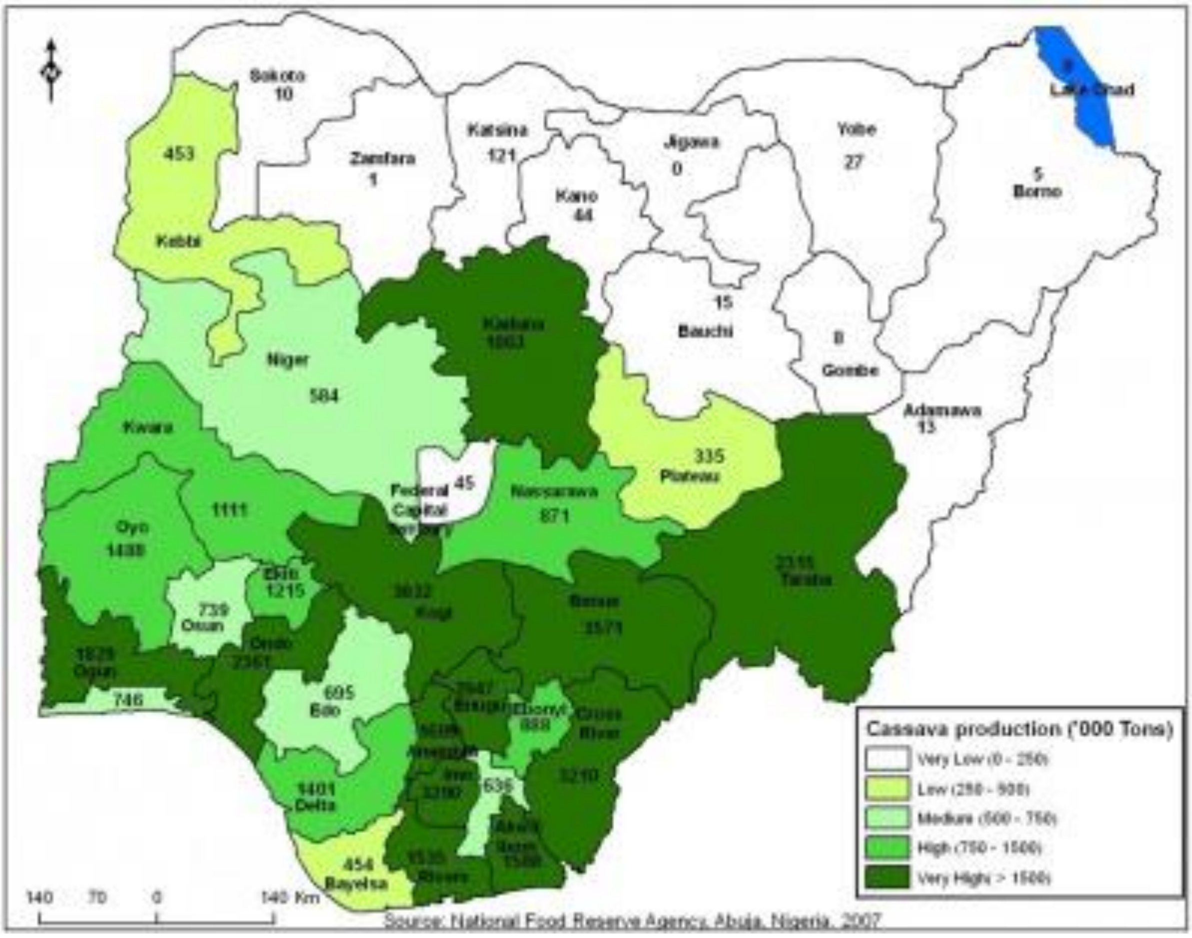

Source: National Food Reserve Agency [9]

Figure 9.1: Cassava Production by State in Nigeria, 2007

However, cassava consumption (see Figure 9.2) is relatively high countrywide, including some areas in the north. In most of these areas, cassava produced in the south is transported and sold through the private marketing system.

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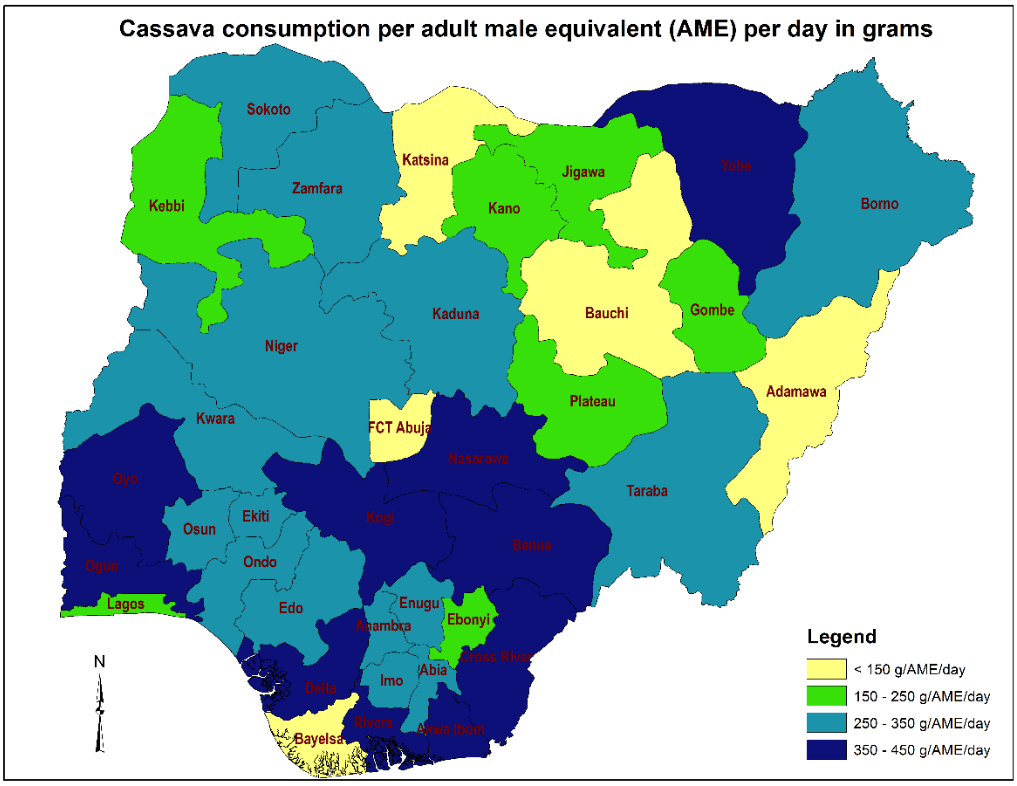

Source: HarvestPlus based on data from Nigeria 2010-2011 General Household Survey (GHS) [10]

Figure 9.2: Daily Cassava Consumption per Adult Male Equivalent (AME) (grams)

Setting Provitamin A Target Levels for Cassava Breeders and Establishing Nutritional Efficacy

The general methodological approach for setting target levels for plant breeders has been discussed in Chapter 1. As discussed, vitamin A target levels for plant breeders are based on age- and gender-specific nutrient requirements, daily consumption amounts of cassava and cassava products, nutrient retention after traditional storage, processing, and cooking, and the bioavailability of provitamin A in cassava, that is, the degree to which the human body can assimilate provitamin A from cassava and convert it to retinol.

Cassava intake Intakes were estimated through rural village surveys in cassava-growing areas in Nigeria. Cassava is typically eaten as gari, a grated and roasted form of cassava flour. Intakes in Table 9.2 are expressed in fresh weight cassava, as are the target levels for the plant breeders. Intakes were revised upward from initial assumptions based on the results of field surveys.

Provitamin A retention The degradation rate of carotenoids has been investigated and it was found that sun drying was more detrimental to the provitamin A levels (44-73% degradation) in cassava than shade (41%) or oven drying (10-45%) [11]. The most common cassava processing methods in developing countries (boiled, gari, fufu,

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fermented and unfermented flour) resulted in losses of beta-carotene ranging from 30% (boiled) to 70% (gari) [12]. Gari had the highest provitamin A degradation of the foods tested (60-90%). The degradation during storage reached levels as high as 80% after 1-4 months of storage and was highly dependent on the cassava variety.

Bioavailability Bioconversion studies have shown a 5:1 bioequivalence between beta-carotene and retinol, the form of vitamin A used by the body [13].

The original target level of +15 mg/kg of provitamin A was set to provide an estimated 50% of the EAR, based on assumptions for intakes of cassava, retention, and bioavailability, which were later revised as more precise data became available. Cassava intakes, when measured, were demonstrated to be much higher than originally assumed. Thus, provitamin A varieties that contain only +8 mg/kg, for example, will provide approximately 100% of EAR for non-pregnant, non-lactating women who consume 900 grams of cassava per day. As indicated later in this chapter, the first wave of released provitamin A cassava varieties contained 6-8 ppm total carotenoids, and the second wave contained up to 11 ppm. Later waves will contain higher levels of provitamin A.

Demonstrating Nutritional Efficacy and Consumer Acceptance

Efficacy trials An early efficacy study using yellow cassava, conducted in Eastern Kenya with children aged 5-13, showed a small but significant increase in serum retinol of +0.038 μmol/L ($P<0.05$) and in beta-carotene of +43.78 μmol/L ($P<0.05$) in the yellow cassava versus the control group [14]. The yellow cassava varieties in the study contained +6 ppm beta-carotene on average.

An efficacy trial with preschoolers aged 3-5 is currently being conducted in Osun State by Wageningen Agricultural University and Ibadan University. The yellow cassava varieties being used in this study contain +8 ppm provitamin A on average. The methodologies used and significance of efficacy trials for a range of biofortified crops are discussed in more detail in Chapter 2.

Consumer acceptance Since the pulp of commonly consumed conventional cassava varieties is white, successful introduction of yellow cassava depends on its acceptability and consumption by target populations in Nigeria.

In Nigeria, cassava is mainly consumed as gari. Preferences for gari differ across ethnocentric regions of the country. In the Igbo-dominated southeast, cassava flour is mixed with palm oil resulting in yellow gari, whereas the majority of the gari consumed in the Yoruba-dominated southwest is white. In both regions, however, it is possible to find gari in different shades of yellow in the local markets.

A consumer acceptance study conducted in 2011 in two Nigerian States revealed that, if delivered together with nutrition information, biofortified varieties were generally preferred both after sensory evaluation of taste, appearance and texture, and in terms of consumers' willingness to pay, elicited through an experimental auction technique [15].

Without nutrition information, variations occurred. The traditional palm oil mixed gari was preferred to that made from vitamin A cassava in Imo State, while gari made from a lighter colored vitamin A cassava variety was preferred in Oyo State where white gari is traditionally consumed.

Cost-Benefit Analysis

Ex ante cost/impact The *ex-ante* (before the intervention) impact analysis uses modelling tools and a 30 year time horizon, with pessimistic and optimistic assumptions about future coverage (adoption and consumption rates), costs (of breeding and delivery) and micronutrient content of yellow cassava.

- According to the ex-ante impact analysis conducted with the optimistic assumptions of 60% replacement of cassava with yellow cassava containing 15 ppm vitamin A, the vitamin A intake of target populations will increase by 94.6% by 2042. Additionally, the percentage of children under 5 suffering from vitamin A deficiency will fall from 29.5% in 2010 to 5.9% in 2042.
- According to a preliminary ex-ante impact analysis conducted with the assumption of 30% replacement of cassava with yellow cassava containing 8 ppm vitamin A, the cost per DALY (Disability Adjusted Life Year – measure of health benefit) saved is $1.01. According to the World Bank, interventions that cost less than $246 per DALY saved are highly cost-effective.
- In Nigeria, sugar fortification costs $50 per DALY saved, and supplementation costs $52 per DALY saved. Even though these interventions are also very cost-effective, biofortification is significantly less costly and has the potential to reach rural populations who may not have regular – if any -- access to fortified foods and supplements.

Biofortification priority index (BPI) The BPI prioritizes countries for vitamin A, iron, and zinc biofortification interventions based on their production and consumption of target crops and the rate of micronutrient deficiency among target population. Nigeria is a top priority for the introduction of vitamin A cassava among 78 countries in Africa, Asia, and Latin America and the Caribbean that are ranked for investment in vitamin A cassava.

Advocacy

Securing policy and financial support from national policymakers and other key stakeholders for biofortification activities is a key element of a successful scaling up strategy. Efforts should be initiated before release of biofortified varieties and should continue for several years after the first release of varieties.

Dr. Akinwunmi Adesina, who was the Minister of Agriculture until May 2015 and is now the President of the Africa Development Bank (AfDB), played a major role as a key supporter of biofortification in Nigeria. Similarly, Minister of Health Onyebuchi Chukwu made it possible for biofortification to be recognized in the health sector as a potent strategy to improve nutrition. The inclusion of biofortified foods in the Micronutrient Deficiency Control (MNDC) guideline, which was ratified by the Senate Committee on Health in 2014, gave additional political momentum to biofortification in Nigeria. The new guideline has been printed by the Federal Ministry of Health and circulated to health institutions in the country. Copies were also presented at the African Union Summit in Addis Ababa in 2014.

The continued participation of the public sector in seed multiplication (described in the following section) arises from the adoption of nutrition-sensitive agriculture at the national level and hence the inclusion of biofortification in the Agricultural Transformation Agenda by the Federal Ministry of Agriculture and Rural Development (FMARD). There have also been significant investments by the World Bank-funded West African Agricultural Productivity Project (WAAPP) in seed multiplication of vitamin A cassava in Nigeria. The public seed sector has continued to ensure that rural poor farmers have initial access to quality stems for planting and thereafter give stems to other farmers in return, making it a cost-efficient delivery system to meet the social responsibilities of the project.

BREEDING PROGRESS AND VARIETY RELEASES

Breeding to Date

During HarvestPlus Phase I (2003–2008), initial screening of germplasm accessions found ranges of 0-19 ppm provitamin A in existing cassava varieties. Studies on genotype-by-environment (GxE) interaction for carotenoid content did not result in drastic changes in the relative ranking of genotypes, and heritability of carotenoid content in cassava roots was found to be relatively high [16]. In Phase II (2009–2013), HarvestPlus and its partners developed analytical methods for cassava screening, demonstrating that spectrophotometric screening overestimated high-performance liquid chromatography (HPLC) values in yellow-fleshed cassava [17]. Rapid-cycling recurrent selection was used to shorten the normal breeding cycle from eight to 2-3 years for high carotenoid content [18]. Breeding programs for provitamin A cassava at the International Center for Tropical Agriculture (CIAT) and the International Institute of Tropical Agriculture (IITA) assumed full operational scale by 2011. The International Center for Tropical Agriculture (CIAT) generates high-provitamin A sources via rapid cycling in pre-breeding and provides in vitro clones and seed populations to IITA and the Nigerian National Root Crops Research Institute (NRCRI) and the Institut National pour l’Etude et la Recherche Agronomiques (INERA) in the Democratic Republic of Congo (DRC) for local adaptive breeding.

Three first-wave vitamin A cassava varieties with 6–8 ppm total carotenoid content were released in 2011 (see Table 9.3). Three second-wave varieties with up to 11 ppm were officially released in 2014. About 80% of cassava carotenoids are forms of provitamin A. In DRC, a variety developed by IITA under HarvestPlus and officially released as I011661 in 2008 was shown to contain 7 ppm provitamin A and is now under multiplication/distribution. Yellow cassava varieties have also been released in Ghana, Malawi and Sierra Leone. Regional trials are underway for fast-tracking release in other countries in West Africa that have similar agro-ecologies. Trial data is routinely uploaded to Cassavabase (www.cassavabase.org) to inform breeding efforts across Africa.

Regional Testing and Future Releases

More than 50 provitamin A varieties are now at different stages of evaluation to identify those that are agronomically competitive for third-wave release. The top five leads have more than 15 ppm (greater than 100% of target increment). These varieties will be put in tissue culture for international distribution, as IITA distributes elite provitamin A clones to numerous countries in the region. Local GxE testing of the deployed clones provides information on provitamin A levels and agronomic performance from multiple sites per country and allows high-precision identification of fast-track candidates and parents for breeding, as well as greater effectiveness in targeted breeding based on adaptive pattern. Vitamin A cassava varieties are being tested in 19 countries in Africa, as well as in Latin America and the Caribbean.

Capacity Building

Near-infrared reflectance spectroscopy (NIRS) was provided to IITA to accelerate and increase the quality and reliability of measuring and comparing Total Carotenoid Content (TCC) in breeding germplasm. In addition to NIRS, a portable device known as iCheck Carotene, used for measuring carotenoid levels, was introduced and has provided useful rapid field evaluation and selection of genotypes in the early breeding stages. The correlation between iCheck and spectrophotometer is high enough to produce acceptable data.

DELIVERY STRATEGIES AND RESULTS TO DATE

Delivery may be conceptualized and discussed as three broad sets of activities which to some extent are interdependent and must be implemented simultaneously: (i) cassava stem multiplication and extension to farmers, (ii) creating and building consumer demand, and (iii) connecting supply and demand through markets. The foundation of the successful introduction of yellow cassava in the Nigerian food system and its ultimate sustainability is consumer demand. However, a certain investment and momentum in the supply chain must be established initially before investing heavily in building consumer demand. Both the cassava supply chain and consumer demand are discussed here.

Scaling Up the Supply of Cassava Tubers

Cassava stem multiplication HarvestPlus employs two major channels (public and commercial) in the multiplication of vitamin A cassava in Nigeria. Generally, public multiplication programs funded by the government, development agencies, farmer and community based associations have social responsibilities aimed at alleviating poverty and food security gaps. Commercial multiplication programs, funded by private investors, aim at making profit. The former channel ensures horizontal access, where every farmer can access a small quantity of stems for planting. While the latter is more vertical and demand-driven, it ensures sufficient seed-stem supply for larger-scale production. Starting with the distribution of small free stem packs allows farmers to test the new biofortified varieties with minimal risk, and they can later link to commercial seed farms to purchase stems in larger quantities (see Figure 9.4).

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Stems are perishable and must be replanted within two weeks of harvesting. This dictates that multiplication must be located near the farms adopting the yellow cassava, and this is an impediment to development of private markets for stems. Starting with 100 bundles of stems (50 stems per bundle) of the three first-wave vitamin A cassava varieties in 2010, a decentralized, community-based seed production scheme was used to increase stem availability to 250,000 bundles by 2012. This demonstrated that the multiplication ratio in cassava can be increased from the conventional 1:5 to 1: >30 even in on-farm situations, using good agronomic practices.

In 2011, the biofortification crop delivery program started with stem multiplication in ten Local Government Areas (LGA) in each of the following four States; Oyo in the West, Imo in the East, Akwa Ibom in the South and Benue in the North. In 2012, the program expanded to six villages in each LGA making a total of 60 villages per State and 240 villages in the four targeted States. The program rolled out to 18 more States between 2013 and 2015, thus covering over 60% of all the States in the country and over 80% of the major cassava producing States even though the level of coverage differs from one State to the other.

The total land area under commercial stem multiplication and tuber production grew from 88 hectares in 2011 to 6,950 hectares in 2015 (
Figure 9.3). Stem multiplication by the public sector dominated the early years while commercial stem multiplication started very slowly in 2011 and picked up rapidly from 2014 onwards. Having "primed-the-pump" by initiating production of a substantial supply of provitamin A cassava, the expectation is that a burgeoning demand for yellow cassava (discussed below) will motivate future supplies. Commercial stem production is expected to account for over 90% of total stem supply by 2018.

In the commercial channel, seed investors multiply and supply stems to farmers on request. The selling price of stem bundles varies by region, and was lowest in the West (approx. $1 per bundle) and highest in the East (approx. $4) in 2014 and 2015. Sixty bundles are required to plant one hectare of cassava.

Over 1,000 extension agents and facilitators have been trained to train farmers and investors in Oyo, Benue, Akwa Ibom, and Imo States. Training focused on cost efficient multiplication, production and delivery systems, as well as group and cluster formation in the stem, processed food and marketing sectors.

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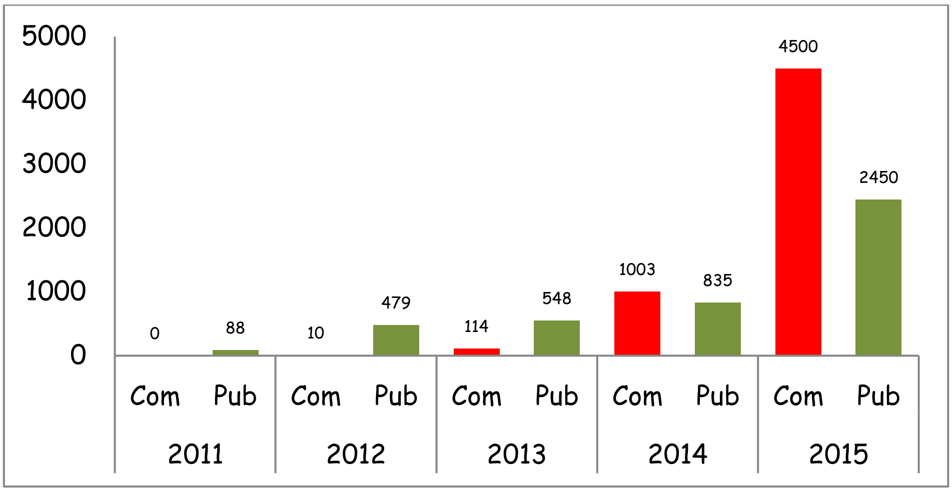

Source: HarvestPlus Nigeria [19]
Com: Commercial
Pub: Public

Figure 9.3: Trends in Number of Hectares Multiplied by Public and Commercial Sector Partners

Extension to farmers In Nigeria, large-scale delivery to farmers began in 2013, after multiplying stems for two consecutive years in 2011 and 2012. As of December 2015, HarvestPlus and its partners have cumulatively delivered over 2 million bundles of stems, resulting in over one million farming households planting vitamin A cassava [19]. Delivery channels have included direct distribution of free bundles of stems to smallholder farmers (Channel 1 in Figure 9.4), farmer to farmer distribution (Channel 2 in Figure 9.4 -- a formal “payback” program by initial recipients, plus further informal diffusion – Channels 3, 4, 5, and 12 in Figure 9.4), and direct marketing by commercial producers (Channel 8 in Figure 9.4). Based on these delivery assumptions, a 5-hectare cassava farm receiving 200 stems can be consuming yellow cassava all year round by Year 4, and produce substantial stems, tubers, and processed gari for sale.

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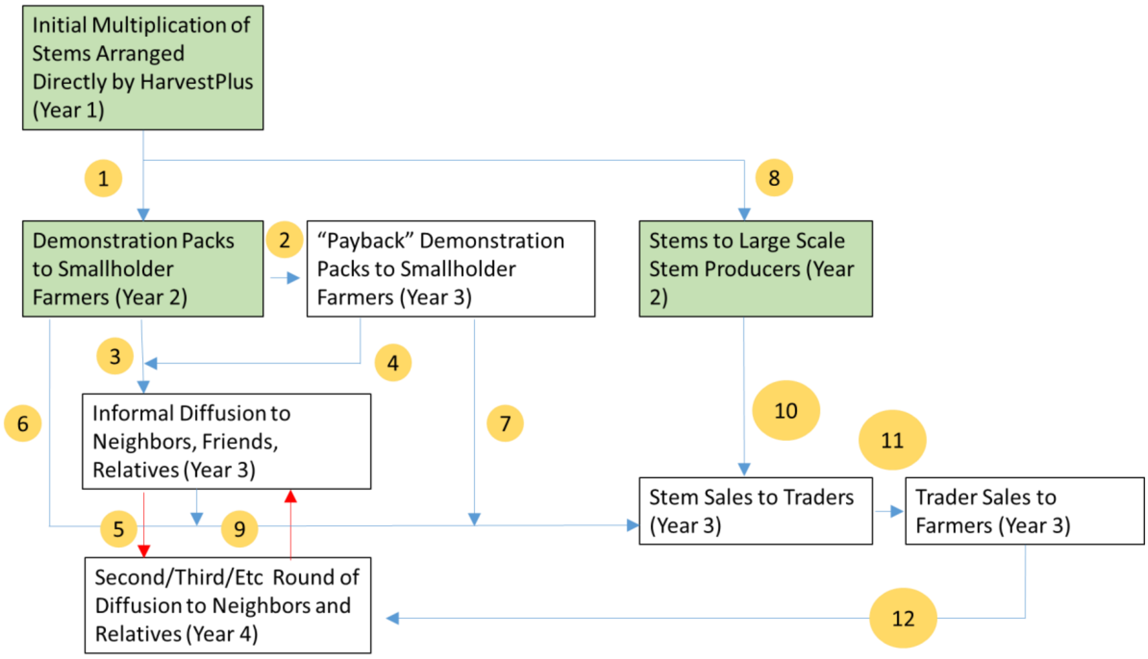

Figure 9.4: Cassava Stem Distribution, Diffusion, and Sales Flows

Differentiation in gender roles Culturally, there is gender specialization in cassava production and processing in Nigeria. While men dominate high energy activities like land clearing and soil tillage, women tend to dominate farm maintenance and food processing activities. Of the one million farmers planting vitamin A cassava in Nigeria, about 45% are women and 55% are men. Women dominate (75%) the food processing and marketing sector, while men dominate (95%) the commercial sale of cassava stems.

To increase the participation of women, HarvestPlus and its partners have deployed modified labor-saving farm tools, which help reduce the cost of production and increase production. For example, the barrow-cutter – a mechanical stem-cutting device attached to a wheelbarrow – was designed to reduce the cost of cutting stems from about $35 per hectare to less than $10 and at the same time help women transport over 250 kg of roots from farm to home, which is five-fold what they can traditionally carry on their heads. Similarly, the establishment of small-scale commercial farm services at the village level, focusing primarily on weed control using herbicides, is intended to reduce the drudgery of weeding, which accounts for over 50% of women's time on-farm [20].

Marketing

Some activities along the value chain, as shown in Figure 9.5, are necessary to ensure that effective demand can pull the supplies of yellow cassava from rural production to rural and urban markets.

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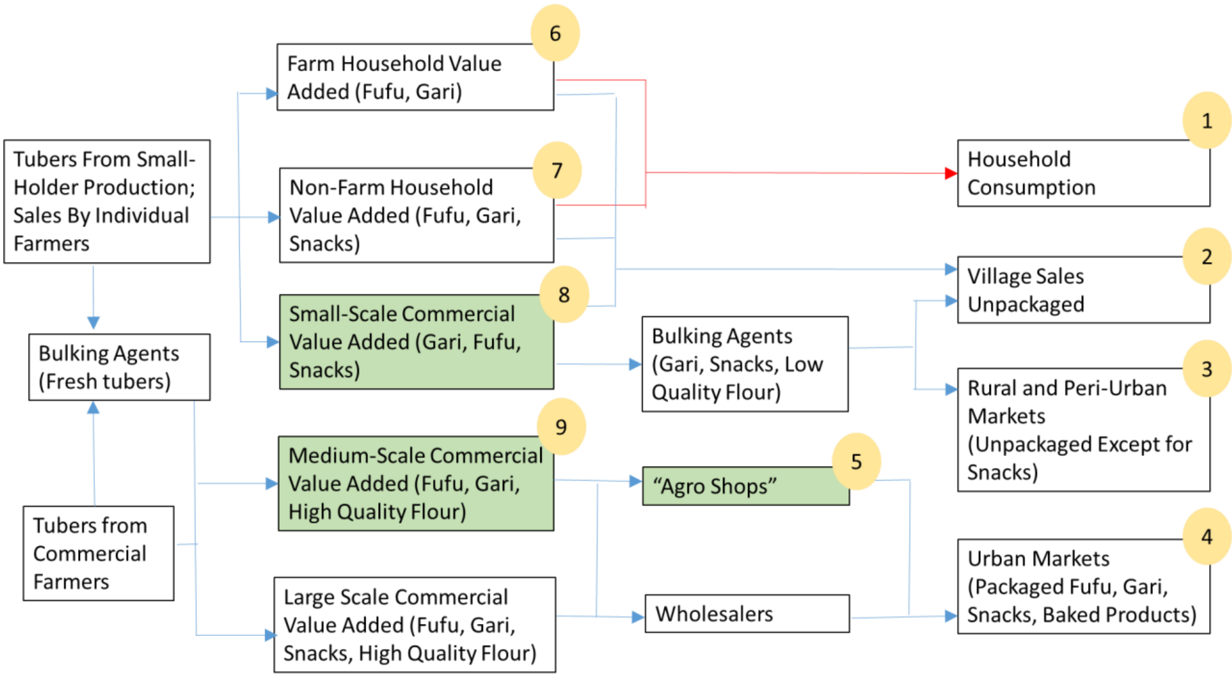

Figure 9.5: Value Chain Flows

Following the distribution of free seed packs and private sector engagement to supply stems in commercial quantities, HarvestPlus and its partners initiated systematic development of food market in 2014 to absorb production in excess of household food security needs. Nationally, for all cassava varieties, over 90% of the 53 million tons of fresh cassava roots harvested annually is processed into food, of which gari accounts for approximately 60%, while fufu and, to a lower extent, lafun, abacha, and flour, cumulatively account for more than 30% [21]. The industrial sector consumes less than 10% of total production. The high percentage of utilization for food products suggests that vitamin A cassava has immediate opportunity in the gari and fufu markets. The project, therefore, prioritized gari and fufu enterprises and emphasized two key areas: awareness creation and product development to strengthen their demand and supply. The project also built capacities for increased efficiency, quality control, and branding to improve the competitive ability of these products in the already saturated market.

Available data from vitamin A cassava investors suggest that gari is the most traded vitamin A cassava product, accounting for 58% of total sales in 2015. Fufu accounted for 30% of the total sales, followed by flour (12%), resulting from the high demand for vitamin A cassava-based snacks and confectioneries like queen cake, combo-bits, and combo-strips.

Household consumption is estimated to have accounted for more than 75% of all harvested roots. Many households are not yet producing commercially from the stem packs they received for trial. Such trials have provided justification for farmers to buy more stems to complement what they have, and increased commercialization is expected at the household level from 2016 onwards.

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The gross income in 2015 for medium- and small-scale investors in the vitamin A cassava value chain is tracked to be 265 million naira, equivalent to USD $1.3 million. The sales data show that gari has the highest gross sale of 135.5 million naira accounting for 52% of the income from vitamin A cassava sales. Flour, fufu and stems contributed 26%, 13% and 9%, respectively.

Product development and standardization In addition to conventional food products like gari and fufu, HarvestPlus has developed 20 additional food products for children and adults, targeted to both rural and urban consumers. A recipe book was produced, and 4,000 potential investors have been trained on processing vitamin A cassava into high quality gari, fufu, flour and confectionery. So far, 778 investors have invested in making vitamin A cassava products available in the market [19].

Distribution outlets The establishment of product distribution outlets by private investors, comprised of about 300 sales points across 10 States and supported with an online market, has facilitated consumer access to vitamin A cassava products in Nigeria. Investors in the vitamin A cassava processing sector have seized the opportunity of these sales outlets to market their products and this has catalyzed new investments and encouraged older investors to remain in production.

Creating Demand

Consumer marketing using print, television, and radio media were used extensively to communicate the importance of vitamin A cassava to consumers to create demand, and to investors to increase product supply. For example, in a single village in Oyo State, the number of women processing vitamin A cassava into gari increased from 5 in 2014 to 35 in 2016, following an increase in consumer demand for this product that resulted from a radio program 'Sagbedoro.' The radio program was broadcast for 13 weeks by the Federal Radio Corporation of Nigeria (FRCN) and focused on the importance of consuming more nutritious foods.

Movies broadcast on television. Africa's leading cable television (DSTV/Multichoice) is watched by viewers in 52 countries. In Nigeria alone, over 50% of the 180 million people have access to television. The engagement of movie stars in the entertainment industry was instrumental in the awareness creation efforts that have significantly increased the demand for more nutritious foods. The production of four movies debuted by Yellow Cassava (English) and the other three in major local languages - *Sunkani* (Hausa), *Dada Oni Paki* (Yoruba) and *Akpu Ebiyebi* (Ibo), made it possible to reach an estimated 35 million Nigerians through screenings in cinemas, universities and villages. Both Yellow Cassava and Dada Oni Paki won awards at the 2015 prestigious Africa Magic Viewer's Choice Award [22].

Radio and television reach Jingles were developed and translated into five local languages for creating awareness on radio and television prior to stem distribution. Overall, the frequency of jingle broadcast was higher for radio than for television (Figure 9.6) because radio has a wider reach and is a primary source of information for rural households. However, the estimated number of people reached was highest for television compared with other media channels. This is attributed to the broadcast of the award winning *Yellow Cassava* and *Dada Oni Paki* movies. Based on the data provided by the Federal Radio Corporation of Nigeria (FRCN) on number of listeners and Cable Television (DSTV/Multichoice) on number of viewers, it is estimated that over 50 million Nigerians have been informed.

Reach in villages It is estimated that in each of the villages where vitamin A cassava varieties are currently being multiplied, at least 50% of households have already received information on the importance of biofortification. Farmer to farmer information dissemination, field days, and radio jingles have all helped to increase awareness in non-target villages.

Nutritious Food Fair (NFF) The Nutritious Food Fair creates awareness and builds linkages among farmers, processors, marketers and consumers. The first NFF was held in November 2015 in Abuja and attended by over 3,000 participants. Over forty exhibitors displayed and sold their products related to biofortification. Several prominent government officials, Nollywood celebrities, and international visitors participated in various ways. The event was covered by ten media outlets.

Qualifying finalists from twenty high schools from various States in Nigeria participated in a national nutrition quiz competition. It is expected that the number of schools registering for this competition will increase each year. The venue of the NFF will be rotated annually with the government of Cross River State hosting the 2016 NFF.

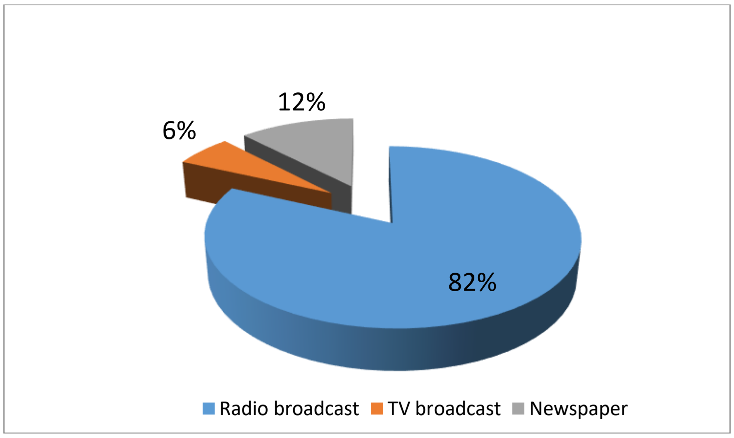

Figure 9.6: Frequency of Use of Different Media Channels for Communicating the Importance of Vitamin A Cassava in Nigeria

MONITORING AND MEASURING IMPACT

Progress in scaling up the supply and demand for provitamin A cassava is measured in three broad ways: regular monitoring of processes and outputs; annual collection of outcome indicators; and periodic impact assessment. Process, output and outcome indicators are collected through the Monitoring Learning and Action (MLA) system. The objectives of the MLA system are to: 1. contribute to and set the basis for accountability to management, donors and other stakeholders; 2. generate and share delivery progress data and results that feed into evidence supported operational decision making, business planning, communication and advocacy messaging. The MLA system captures data on stem sales, tuber production and marketing, which are used to advise the private sector on areas requiring improvement in terms of stem distribution to improve farmer access, as well as to inform tuber buyers on sources of roots. All data from the monitoring system is disaggregated to improve its usefulness for planning. Wherever necessary, data is disaggregated by gender, distribution channel, variety, and geographic region.

To further inform planning, a Nigeria vitamin A cassava forecasting model is currently being developed. The model will be used to estimate values for three impact indicators: percent of expected average requirement (EAR) delivered; change in prevalence of inadequate intake of target micronutrient in project intervention areas; and number of disability-adjusted life years (DALYs) averted. The forecasting model seeks to consistently model what has been achieved to date and to forecast future outcome and impact variables for medium-term strategies of country programs.

Impact Assessment Following five years of intensive delivery efforts to disseminate released varieties of provitamin A cassava to farm households in Nigeria, an impact assessment study will be conducted to understand the reach of these varieties. Since there are no formal seed systems for cassava planting materials (stems), the delivery channels used to deliver provitamin A cassava stems included public institutions, non-governmental organizations and the private sector. Cassava planting materials are often acquired through farmer-to-farmer diffusion. The impact assessment study will capture the adoption and diffusion rates in both direct delivery and expansion States. In the past, several improved cassava varieties have been introduced to farmers since the 1990s; however, their adoption rates are generally low [23], and the study will measure the degree to which yellow cassava delivery has been more successful.

Adoption could be hindered by several factors, such as poor management practices that may cause improved cassava production to result in yield levels that may not differ significantly from those of local varieties. Data obtained from the impact assessment study will shed light on to facilitators and constraints to adoption and diffusion of provitamin A cassava varieties. Yield differentials between farmers' fields and field trials, as well as the extent to which provitamin A cassava varieties are replacing traditional and other improved varieties on farmers' fields, will be assessed. Previous studies on the adoption of improved cassava varieties (in Nigeria and elsewhere) have not given adequate attention to gender considerations [24, 25], the impact assessment study will capture gender disaggregated data on adoption, diffusion, yield, use of provitamin A cassava outputs and decision making. The impact assessment study will be implemented in Nigeria beginning in late 2016.

CONCLUSIONS, LESSONS LEARNED, AND THE WAY FORWARD

Overall, the HarvestPlus breeding and delivery programs for Nigeria have demonstrated that large-scale agricultural delivery of new technologies is achievable within a few years of their introduction. The use of a multi-stakeholder platform that engages both public and private partners, using the former to create desired markets for the latter, has proven to be successful. With about one million farmers planting vitamin A cassava and 778 enterprises engaged in value addition and marketing, the number of Nigerians having access to more nutritious food is expected to continue increasing, based on trends observed between 2013 and 2015.

Lessons Learned

The Government of Nigeria has increasingly become nutrition conscious, and has supported the rapid adoption of biofortification to complement its supplementation and fortification efforts. This support has made it possible to integrate biofortification into major agriculture and health programs, particularly the Agricultural Transformation Agenda and the Micronutrient Nutrient Deficiency Control programs. Continuation of sensitizing the governments and policymakers will be essential to ongoing public support for biofortification programs.

Farmers and consumers in Nigeria have also become increasingly nutrition conscious, leading to the rapid integration of biofortification into food and dietary systems. The yellow color of the root and its processed products is seen as evidence of the presence of vitamin A and is liked by consumers. Yellow fufu has become a preference for fufu consumers in Akwa Ibom, while yellow gari (biofortified) is a growing preference for consumers in regions that traditionally consume white gari. Consumer demand creates an incentive for increasing cultivation of vitamin A cassava by farmers. To maintain and increase consumer demand, there is a need to continue communicating the importance of micronutrients in diets and develop new varieties with deeper yellow color.

Although the delivery of vitamin A cassava is designed to be market-led for sustainability, the initial distribution of free small seed packs was a successful promotional strategy to create market for these varieties. It has also proven to be an efficacious delivery strategy to reach vulnerable populations who typically do not have market access to improved seeds for planting. Many of the farmers who received and planted free stems liked the products and are now buying stems from commercial traders to complement what they have. In the case of biofortified cassava, distributing promotional free stem samples was a good marketing strategy to pique interest, particularly in rural populations.

Farmer-to-farmer seed distribution has also proven to be a cost effective and efficient delivery strategy, as it reduced delivery cost by almost 95% from $2 to less than $0.1 per household reached. There is need to continue to strengthen farmer-to-farmer distribution as a cost-effective channel to reach rural households with improved vitamin A cassava varieties.

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Commercial seed distribution has continued to spread seeds to locations not immediately targeted by the project, thus making it possible to expand into new areas without additional direct costs. Commercial seed distribution will ultimately sustain delivery efforts and should be strengthened by HarvestPlus through capacity building of farmers to multiply stems more efficiently and agri-input dealers to distribute stems at competitive prices.

Unlike cereals and legumes, cassava undergoes extensive processing before it becomes food after harvesting. Farmers who plant vitamin A cassava are interested in both food and increased income; there is, therefore, a need to develop the seed and food product value chains simultaneously.

The Nigerian population is quite heterogeneous, differing along social, cultural and geographic dimensions. In this regard, no single communication channel can provide information successfully to all people. HarvestPlus, therefore, engages a mix of channels, including the radio, television, print, and social media in creating awareness. Special communication tools like jingles, radio talk shows, movies, interviews, feature articles, information pamphlets, and Facebook, as well as road shows, agriculture shows and field days, have been used within the mixed channel concept. While this strategy has been successful in increasing demand, it is also costly and may be repetitive when applied to the same audience. Therefore, knowledge about the relative contribution of each channel within the mix has become very important to set cost-effective communication priorities. Research is underway to ensure that the most competitive channels are retained when rationalizing for increased cost efficiency.

Initial data collection in the delivery process has been greatly facilitated by the project's direct engagement in delivery activities. However, most of the strategies employed to reduce operational costs and sustain activities in the coming years, particularly farmer-to-farmer distribution and product sales, will progressively experience less direct involvement of the project. Increasingly, the collection of secondary data arising from initial investments has become more important than ever for more accurate impact measurement. Therefore, the development and deployment of monitoring and evaluation tools based on secondary and tertiary data will significantly improve progress assessment intelligence and strategic planning.

The Way Forward

Plant breeding will need to continue to produce high-yielding and competitive vitamin A cassava varieties that address current challenges in the value chain. Varieties with more than 15 ppm total carotenoid content and more than 30% dry matter content will revolutionize the vitamin A cassava sector in Nigeria. Breeding for root mealiness to improve cooking quality of freshly harvested vitamin A cassava roots will allow consumption without conventional processing, reducing nutrient loss and making more nutrients available to consumers. To facilitate fully integrating the provitamin A trait into national cassava breeding programs, HarvestPlus is working with the Ministry of Agriculture and the Variety Release Committee to ensure that micronutrient content becomes a criterion for releasing new varieties in Nigeria.

Increased participation of the private sector in stem production, processing and marketing should be strengthened by HarvestPlus and delivery partners for long term sustainability. Increased product diversification (products beyond gari and fufu) will broaden market opportunities and sustain private sector interest in the biofortified food sector. Efforts should, therefore, be intensified in the use of vitamin A cassava in weaning foods as well as validating vitamin A gari and fufu as low Glycemic Index foods. Different food-to-food fortification options including vitamin A cassava, cowpea, soybean and groundnut should be explored further, to improve the protein levels in foods that are targeted to infants and young children. The use of 'High Quality Flour' from vitamin A cassava in the production of pasta and baking of bread should be profiled nutritionally, and if justified, proceed towards commercialization.

There should be emphasis on increasing the number of marketing outlets to improve product distribution and access to consumers. Although medium scale food processors have started to distribute more nutritious vitamin A cassava foods in supermarkets and restaurants (vitamin A gari and fufu) in the large cities, there is a pressing need for investors to improve on packaging and branding of these products.

HarvestPlus will prioritize strengthening advocacy in a broader sense to ensure more effective integration of biofortification into national agriculture and health programs backed by policies. Bilateral and national funding will be needed to sustain the biofortification platform until 2018 when the private sector is expected to be fully active and dominant, ensuring future sustainability.

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Table 9.1: Vitamin A Intake in Individuals in 6 States of Nigeria, 2006

	Vitamin A intake (µg RAE/cap/day)	Vitamin A Estimated Average Requirements (EAR) µg EAR/cap/day	Intake as % EAR
Children 1-3 years	73.4	210	35
Children 4-8 years	71.9	275	26
Children 9-13 years	98.1	420 (female) 445 (male)	22-23
Men 14-70 years	348.5	630 (14 – 18 yrs)	55
		625 (19 – 70 yrs)	56
Women 14-70 years	266.2	485 (adolescent)	55
		530-550 (pregnant)	48-50
		885-900 (lactating)	30

RAE: Retinol Activity Equivalent; EAR: Estimated Average Requirement
Sources: Sanusi and Akinyele [3] EAR from: National Academy of Sciences, Institute of Medicine, Food and Nutrition Board, 2010.

Table 9.2: Breeding Target Level Calculation for Provitamin A Cassava

	Children 4-6 years	**Non-pregnant, non-lactating women**
Estimated Average Requirement (EAR) of absorbed retinol (micrograms per day)	275	500
Provitamin A target density (mg/kg or parts per million fresh weight)	+15	
Average daily cassava consumption (grams freshweight)	350	900
Provitamin A retention after processing (percent)	35%	
Provitamin A bioavailability (converts beta-carotene to retinol)	20%	
Percentage of the EAR provided by increased content of +15 ppm (full target)	133%	197%

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Table 9.3: Released Varieties of Vitamin A Cassava

Variety Name	Total Carotenoid Content (FW)*	Fresh Root Yield	Yield Relative to Check**	Dry Matter
Nigeria – Released in 2011 and 2014				
TMS 01/1371	+8 ppm	20.1 t/ha	87%	30.7%
TMS 01/1412	+7 ppm	29.8 t/ha	128%	30.1%
TMS 01/1368	+7 ppm	26.7 t/ha	115%	33.4%
TMS 07/0593	+11 ppm	21.5 t/ha	100%	34.6%
TMS 07/0539	+11 ppm	20.3 t/ha	94%	31.9%
TMS 07/0220	+11 ppm	23.1 t/ha	107%	32.7%
DRC – Released in 2008				
I011661	+9 ppm	34.9 t/ha	NA	30%

*Provitamin A content is approximately 80% of total carotenoid content (fresh weight – FW)

**National check TMS 30572; data for the 2011 releases (TMS 01/1371, TMS 01/1412 and TMS 01/1368) is from 2008/09 and 2009/10 multi-locational trials across 7 locations; data for the 2014 releases (TMS 07/0593, TMS 07/0539 and TMS 07/0220) is from 2011/12 and 2012/13 multi-locational trials across 8 locations.

NA: not applicable

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REFERENCES

1. **Ender G, Cooper P, McGuire J, Michaels G and R Welch** Case Study: Vitamin A-fortified Maize and Cassava in Nigeria. Unpublished report submitted to HarvestPlus, 2014.

2. **Stadlmayr B, Charrondiere UR, Enujiugha VN, Bayili RG, Fagbohoun EG, Samb B and B Burlingame** West African Food Composition Tables. FAO, Rome, 2012.

3. **Sanusi RA and IO Akinyele** Nigeria: Per Capita Consumption of Vitamin A-Fortified Wheat/Maize Flour, Sugar and Vegetable Oil. Unpublished report submitted to UNICEF, August 2006.

4. **Maziya-Dixon B, Akinyele IO, Oguntona EG, Nokoe S, Sansui RA and E Harris** Nigeria Food Consumption and Nutrition Survey 2001-2003 Summary. International Institute of Tropical Agriculture, Ibadan, 2004.

5. **Kuku-Shittu O, Mathiassen A, Wadhwa A, Myles L and A Ajibola** Comprehensive Food Security and Vulnerability Analysis Nigeria. IFPRI Discussion Paper 01275. International Food Policy Research Institute, Washington, DC, July 2013.

6. **Uchendu FN, Atinmo T and O Oyewole** Stability of Vitamin A in Selected Nigerian Bread Made From Commercial Fortified Wheat Flour. *International Journal of Applied Science and Technology*. 2012; **2(3)**: 93-98.

7. **Ogunmoyela OA, Adekoyeni O, Aminu OF and LO Umunna** A Critical Evaluation of Survey Results of Vitamin A and Fe Levels in the Mandatory Fortified Food Vehicles and Some Selected Processed Foods in Nigeria. *Nigerian Food Journal*. 2013; **31(2):** 52-62.

8. **Hassan S, Kuenobe CE, Jalloh A, Nelson CG and TS Thomas** Nigeria. **In:** Jalloh A, Nelson GC, Thomas TS, Zougmore R, and H. Roy-Maculey (Eds). West African Agriculture and Climate Change: A Comprehensive Analysis. Washington, DC: International Food Policy Research Institute, 2013: 259-290.

9. **Asante-Pok A** Analysis of Incentives and Disincentives for Cassava in Nigeria. Technical notes series, Monitoring African Food and Agricultural Policies, FAO, Rome, 2013.

10. **National Bureau of Statistics, Federal Ministry of Agriculture and Rural Development, and World Bank.** Living Standards Measurement—Integrated Surveys on Agriculture, General Household Survey Panel 2010/2011. Retrieved from: http://www.agrodep.org/dataset/nigeria-2010-20112012-2013-general-household-panel-survey-data Accessed 6 July 2016.

11. **De Moura FF, Miloff A and E Boy** Retention of provitamin A carotenoids in staple crops targeted for biofortification in Africa: cassava, maize and sweet potato. *Crit. Rev. Food Sci. Nutr.* 2015; **55**: 1246–1269.

12. **Chavez AL, Sanchez T, Ceballos H, Rodriguez-Amaya DB, Nestel P, Tohme J and M Ishitani** Retention of carotenoids in cassava roots submitted to different processing methods. *J. Sci. Food Agric.* 2007; **87**: 388–393.

13. **La Frano MR, Woodhouse LR, Burnett DJ and BJ Burri** Biofortified cassava increases β-carotene and vitamin A concentrations in the TAG-rich plasma layer of American women. *Br. J. Nutr.* 2013; **110**: 310–320.

14. **Talsma E, Brouwer I, Verhoef H, Mbera G, Mwangi A, Demir A, Maziya-Dixon B, Boy E, Zimmermann M and A Melse-Boonstra** Biofortified yellow cassava and vitamin A status of Kenyan children: a randomized controlled trial *American Journal of Clinical Nutrition* 2016; **103**: 258-267.

15. **Oparinde A, Banerji A, Birol E and P Ilona** Information and consumer willingness to pay for biofortified yellow cassava: evidence from experimental auctions in Nigeria. *Ag Econ.* 2016; 47(2): 215-233.

16. **Ssemakula G, Dixon AGO and B Maziya-Dixon** Stability of Total Carotenoid Concentration and Fresh Yield of Selected Yellow-Fleshed Cassava (*Manihot esculenta* Crantz). J. *Trop. Agric*. 2007; **45**: 14–20.

17. **Kimura M, Kobori CN, Rodriguez-Amaya DB and P Nestel** Screening and HPLC Methods for Carotenoids in Sweetpotato, Cassava and Maize for Plant Breeding Trials. *Food Chem.* 2007; **100**: 1734–1746.

18. **Ceballos H, Morante N, Sánchez T, Ortiz D, Aragón I, Chávez AL, Pizarro M, Calle F and D Dufour** Rapid Cycling Recurrent Selection for Increased Carotenoids Content in Cassava Roots. *Crop Sci.* 2013; **53**: 2342–2351.

19. **HarvestPlus-Nigeria.** Households Reached. Nigeria Database, 2015. Retrieved 8 June 2016 from: www.harvestplusng\data Accessed 6 July 2016.

20. **Ezedinma C, Udensi U, Okechukwu R, Ibana S, Akoroda M, Ilona P, Ogbe F, Sanni L, Lemchi J, Chikoye D, Okoro E and AGO Dixon** Cassava Weeds and Management in Nigeria. International Institute of Tropical Agriculture, Ibadan, 2007.

21. **Global Alliance for Improved Nutrition (GAIN).** Market Opportunity Analysis forNutrient – Rich cassava in Nigeria. GAIN, Geneva, 2014.

22. **DStv** Africa Magic Viewers Choice Award 2015 Nominees Announced. Dec 12, 2014. Retrieved 8 June 2016 from http://amvca2015-awards.dstv.com/

23. **Oparinde A, Abdoulaye T, Manyong V, Birol E, Asare-Marfo D, Kulakow P, and P Ilona** A Technical Review of Modern Cassava Technology Adoption in Nigeria (1985–2013): Trends, Challenges, and Opportunities. *HarvestPlus Working Paper* No. 23. International Food Policy Research Institute, Washington DC, 2016.

24. **Udensi UE, Tarawali G, Favour EU, Asumugha G, Ezedinma C, Okoye BC, Okarter C, Ilona P, Okechukwu R and A Dixon** Adoption of Selected Improved Cassava Varieties among Smallholder Farmers in South-Eastern Nigeria. *Journal of Food, Agriculture & Environment* 2011; **9(1):** 329–335.

25. **Alene AD, Abdoulaye T, Kulakow P and VM Manyong** Adoption of Improved Cassava Varieties in Southwestern Nigeria. Diffusion and Impact of Improved Varieties In Africa (DIIVA), Objective 2 Technical Report. International Institute of Tropical Agriculture, Malawi, October 2012.