

## Biofortification of Local Staples in Nigeria: Prospects and Problems

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### Abstract

Micronutrient deficiencies are common in most developing countries such as Nigeria. It most times results to health effects that range from mild to severe, and sometimes life-threatening. The most common micronutrient deficiencies include vitamin A, iron and zinc – with prevalence of 29.5%, 26%, and 20% respectively in children under five years. Commonly used interventions include nutrient supplementation, dietary diversification, commercial fortification, nutritional education and agricultural interventions. Some of these programmes are expensive with short term benefits. Biofortification of staples has been identified as a cost effective, sustainable means of delivery of micronutrients to the population. Biofortified crops formally released in Nigeria are provitamin A cassava, orange flesh sweet potato and yellow maize as well as quality protein maize. Research into biofortification of these and other staple crops are at various stages in different parts of the country. This paper reviews the extent of the work done so far, and recommends possible future expansion, scaling-up and application.

**Keywords:** Biofortification; Micronutrients; Cassava; Sweet potato; Maize; Sorghum

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### Introduction

Nigeria, the most populous country in the African continent and the seventh in the world [1] has an estimated population of 170,123,740 (2012 estimate), and an area of 923,768 square kilometers (356,667 square miles) that covers several agro-geographical zones. One of the most critical forms of malnutrition observed in Nigeria is micronutrient malnutrition, often referred to as hidden hunger. This results in poor immune system function, stunting, wasting, limited cognitive development and iron deficiency anemia [2,3]. The causes of micronutrient deficiency include suboptimal diets, consumption of poor quality staples, lack of consumption of fruits and vegetables, high cost of nutritious foods, poor processing due to ignorance concerning proper food handling procedures.

Micronutrient deficiencies contribute significantly to child mortality worldwide, and annual vitamin A and zinc deficiencies are estimated 600,000 and 400,000 deaths respectively [4]. It has been estimated that 25% of children under six years of age

in Nigeria suffer from vitamin A deficiency. This may result in poor growth, impaired vision, and impaired epithelial integrity [5,6]. Also, 47% of Nigerian women within the ages of 15 to 49 years suffer from iron deficiency, a main cause of anemia. Other effects of iron deficiency anemia include reduced levels of energy, physical activity and productivity, impaired mental development, weakening of the immune system. This eventually results to increased maternal and infant mortality [7]. Zinc deficiency is also common among rural communities with 20% of children under five, 28% of women and 43.8% of pregnant women showing symptoms of zinc deficiency [8] such as growth retardation, diarrhea, emotional disorders, weight loss, immune dysfunction and impaired wound healing [9].

These deficiencies account for 9% of global childhood disability adjusted life years, a term used by socio-economists to assess health impact. Deficiency of vitamin A by itself causes 964,000 Disability Adjusted Life Years (DALYs) in Nigeria [5]. Recent surveys in Nigeria showed that vitamin A dietary intake was inadequate in 83% of pre-school aged Nigerian children [10].

## Government strategies to address micronutrient malnutrition

A well-diversified diet is nature's own way of meeting the micronutrient needs of a population. However this might be currently unattainable in most households due to poverty and lack of education. Some farmers' families sell their micronutrient-rich harvested fruits and vegetables to buy cheaper staples. The biodiverse nature of Nigeria's food resources has not been well harnessed. Several species which have provided many micronutrients to the past generations are now extinct or unknown to the present generation. These include nuts, fruits and tubers like *Tertracarpidum conophorum*, *Coula edulis*, *Tertrupleura tetraptera*, several varieties of cocoyam, yam legumes and many others [11,12]. According to experts, for an individual to satisfy his or her overall nutrient needs from the diet, it must include at least 30 biologically distinct types of foods, with emphasis on plant foods [13]. The situation therefore calls for government intervention.

Several intervention strategies have been applied in Nigeria to address hidden hunger. These programs are usually sponsored and supervised by the government through the Federal Ministry of Health. They include nutrition education, delivery of targeted oral micronutrient supplements and mandatory fortification of some staple foods.

**Nutrition education:** This is carried out by nutrition/health officers and extension workers affiliated to hospitals and health centers in communities, as well as nutritionists and counsellors in schools. They teach the public on basic nutrition, importance of local food crops and their nutrient composition, proper processing methods for safety and nutrient retention and the need for dietary diversification. Their activities allow the public to be informed on any current issues of interest in health and nutrition. This is done through the mass media: Government sponsored radio/television programmes, news talk, drama, jingles and announcements. Hospitals/health centers, school activities, Community groups, women societies and non-governmental organizations.

Nutrition education is considered an efficient way of improving the nutritional status of the population [3]. However the extension workers and nutrition officers are not enough to reach the schools, hospitals and groups within the remote village.

**Micronutrient supplementation:** This is also enforced through government employed health workers, nurses and extension workers. These supplements are provided by the United Nations International Children's Emergency Fund (UNICEF) and they also supervise the deliveries [3].

It involves:

1. Delivery of doses of vitamin A supplements to pregnant and nursing mothers as part of the ante-natal and post-natal activities. This is presented in form of drops (Retinyl acetate or Retinyl palmitate) that provides 200,000 IU of vitamin A.

2. Delivery of vitamin A supplements in form of Vitamin A drops (200,000 IU) to infants every 6 months from birth until five years of age as part of the expanded programmer on immunization in Nigeria.
3. Iron and multivitamin supplements are also delivered to pregnant and nursing mothers at each ante-natal or post-natal visit.

These are very laudable activities and are targeted only at pregnant women, nursing mothers and infants below the age of five who are actually the most vulnerable. Benefits such as reduced maternal and infant mortality have been observed [3]. However, other women (especially those of child bearing age), adolescents, the aged and even the men also need the micronutrient supplementation. Another challenge in the use of micronutrient supplementation is that the program could cause toxicity in some infants since some may receive more than one high dose vitamin A supplement [3].

**Mandatory food fortification:** This is supervised/enforced through the National Agency for Food and Drug Administration and Control (NAFDAC) in order to ensure strict compliance by food processing companies. They also monitor the products through sales and distribution to ensure that the fortificant levels are maintained during the lifetime of the product. Food products that are mandatorily fortified in Nigeria are shown in **Table 1**. They include margarine, cooking vegetable oil, wheat flour, sugar and maize flour, which are fortified with vitamin A and salt which is fortified with iodine [14]. Compliance is generally enforced by the government through the activities of NAFDAC. These foods are readily available in shops and generally consumed by families in the urban areas (**Table 1**).

The challenge for fortification programs is that most people living in the rural communities may not consume enough of these mandatorily fortified foods. Therefore they are not able to obtain the required amount of the micronutrient. Also micronutrient levels may diminish during improper storage at high temperatures added to the losses experienced during processing and cooking at household level [15]. There is therefore the need for close monitoring to ensure compliance, throughout all the stages from production to consumption, which is time consuming, labor intensive and costly. Also because of the several approaches which sometimes may be combined for more effective micronutrient supply, it is necessary to monitor the status of the population to ensure effective delivery and to prevent overdose [3].

Both micronutrient supplementation and mandatory food fortification are very expensive ventures because they require massive financial input at the onset as well as continued funding through the period of delivery. Although fortification is less expensive and more cost effective than supplementation, both programs may sometimes be jeopardized by fluctuating political interest which is often the case in most developing countries such as Nigeria. Besides, the majority of the undernourished population lives in the rural communities who sometimes are beyond the reach of both intervention strategies.

**Table 1** Mandatorily fortified food products in Nigeria.

Product	Mandate	Nutrient	Level
Wheat Flour	Nigerian Industrial Standard : NIS 438:2000	Vitamin A	30 000 IU
		Thiamine	6.2 mg
		Niacin	49.5 mg
		Riboflavin	3.7 mg
		Iron	40.7 mg
Sunflower Oil	NIS 90:2000	Vitamin A	20 000 IU
Coconut Oil	NIS 387:2000		
Soya bean Oil	NIS 392:2000		
Rape seed Oil	NIS 394:2000		
Palm kernel	NIS 289:2000		
Oil Cotton	NIS 389:2000		
seed Oil	NIS 230:2000		
Palm Oil	NIS 391:2000		
Maize Oil	NIS 388:2000		
Groundnut Oil, Sesame Seed Oil	NIS 393:2000		
Sugar, refined white	NIS 90:2000	Vitamin A	25 000 IU
Sugar, refined brown	NIS 438:2000		
Margarine	NIS 243:2000	Vitamin A	26 000 – 33 000 IU
		Vitamin D	28 000 – 33 000 IU
Milled Maize Products	NIS 295:2000	Vitamin A	30 000 IU

## Biofortification in Nigeria

As part of the overall effort to minimize micronutrient deficiency, the Federal government of Nigeria in collaboration with some non-governmental agencies and international institutions has begun to supply the micronutrients lacking in the diet through biofortification of local staples. Biofortification has been defined as the enhancement of micronutrient levels of staple crops through conventional breeding or genetic engineering using transgenic methods [16]. The focus is on vitamin A, iron and zinc. These nutrients have been identified by World Health Organization (WHO) as the nutrients that are of immediate concern in Nigeria [17]. It is projected that biofortification of local staples will provide at least 30% of estimated average requirements (EAR) for iron, 25% for zinc and 50% for provitamin A [18].

Conventional breeding practices have been used in Nigeria for a long time to improve the characteristics of the crops such as yield, resistance to disease and early maturation. Such crops include rice, maize, cassava, wheat, sorghum, millet, banana, groundnut, sweet potato [19]. Some of the very early attempts on breeding to enhance nutrient density in Nigerian staples were by the International Center for Tropical Agriculture (CIAT) and International Institute of Tropical Agriculture (IITA) [20]. Selection of parents for the cassava breeding program was made on the basis of resistance to pest, low cyanide content, yellow root flesh and texture. Three seedling nurseries were established in 1990 at locations representing the semi humid (Ibadan), humid (Onne) and semi-arid (Kano) ecological zones. In 1991 a nursery was also established in Jos, a multi-altitude location in Nigeria.

The individuals selected were cloned and evaluated progressively following the IITA cassava scheme [21]. Also in 2001 the IITA in collaboration with Institute of Agricultural Research (IAR) Zaria developed and released the Quality Protein maize [22].

In 2004, the Bill and Melinda Gates Foundation (BMGF) announced 14 Grand Challenges in Global Health program, which focused on eradication of diseases in the developing world. The BioCassava Plus program was part of this program. The objective was to provide the complete minimum daily requirement for protein, iron, zinc, vitamin E and provitamin A in 500 gram meal for an adult and 250 gram meal for a child [21]. This project gave rise to one of the early attempts of biofortification in Nigeria which was tagged BioCassava Plus (BC+) initiated in 2005 [5].

The conventional breeding strategies applied led to the development of yellow cassava with increased  $\beta$ -carotene, shelf life and resistance to cassava mosaic disease. However iron and protein contents were not increased and cyanide level was not reduced. This was also confirmed by cassava breeders in the HarvestPlus program also funded by the BMGF. The transgenic approach seemed to be the only solution in attaining the complete biofortification objectives. The transgenic cassava biofortification produced cassava tubers with improved nutritional composition. The iron content of cassava increased four times (7.6 mg /100 g), vitamin A by ten (1500  $\mu$ g/100 g), root protein by four (10.4%). The cyanogen content was also reduced while reducing postharvest physiological deterioration and improving resistance to viruses [21]. Confined field trial was approved for the cassava in Nigeria in 2009 for the provitamin A and iron biofortified plants [21]. The

first set of GM events with at least twenty times more pro-vitamin A compared to wild type is in confined field evaluation at the National Root Crop Research Institute, Umudike in south eastern Nigeria. The outcome of this experience is yet to be made public, due to the fact that government approval has not been given for the release of the transgenic plants to farmers [10].

The research on biofortification (especially through conventional breeding) of staples in Nigeria and many other countries has advanced through the activities of HarvestPlus which was officially launched in 2004 [17]. The HarvestPlus program is the CGIAR's (Consultative Group on International Agricultural Research) Biofortification Challenge program primarily funded by the BMGF. Currently, the biofortification program in Nigeria has progressed substantially with the focus on three major staples [17] - cassava, sweet potato and maize and to a lesser extent on sorghum.

## Cassava

### Why cassava was selected?

Nigeria ranks the world's largest producer of cassava, producing about 54 million tons a year, 90% of which are used for food. Average consumption of cassava in Nigeria is 700 g/person/day. It is cultivated in all the agro-geographical zones of Nigeria and is well adapted to the different soil types and climatic conditions [22]. Most locally cultivated cassava varieties have white or cream colored flesh which contains very negligible amounts ( $\leq 120 \mu\text{g}/100 \text{g}$ ) of carotenoids [23].

### The journey so far

The provitamin A cassava varieties produced for Nigeria are the result from crossing of a yellow Brazilian type with high levels of beta-carotene and a white Nigerian variety which has virtually no carotene [24]. After screening thousands of seedlings each year for several years, and testing the promising varieties in 13 states of the country, the breeders and farmers chose 3 top varieties based on yield,  $\beta$ -carotene content, cooking characteristics and disease resistance, for the first launch in Nigeria, organized by the Nigeria's National Variety Release Committee in December 2011 [24]. Trials held in six locations - Umudike, Zaria, Ogoja, Nsukka, Mokwa, Otobi, all in Nigeria using the 3 varieties with average  $\beta$ -carotene content of  $1000 \mu\text{g}/100 \text{g}$  of fresh cassava [10].

The 3 vitamin A cassava varieties tagged 01/1371, 01/1368 and 01/1412 were released in 2011 in four states (Imo, Akwa-Ibom, Oyo and Benue) and later in 2012 were launched in Abia state. After further research, three other varieties were released (07/0593, 07/0220 and 07/0539) in 2014, with  $\beta$ -carotene contents ranging from 920 to  $1200 \mu\text{g}/100 \text{g}$  of fresh cassava [25].

Currently, 672 communities, 450,000 Nigerian households have received the vitamin A cassava stem cuttings. Also 1,299,998 cassava stems have been disseminated and 245 processing centers established [17]. The techniques applied include rapid multiplication technique, multiplication from back-up farms and house hold dissemination through farmer to farmer contact [25]. This is possible because the stems-cuts from harvested crops can

be used for fresh planting. Model villages have been established within the country with several points of sales for seedling and products. Eleven new provitamin A cassava varieties have also been selected for multisite trials in 10 states of Nigeria between 2014 and 2016 [17]. Nigeria works closely with 20 partners in four target states of Oyo, Benue, Imo and Akwa-Ibom and 22 expansion states to address challenges along the pro-vitamin A cassava value chain [26].

### Performance of provitamin A cassava in local products

Investigation by researchers revealed that the values for starch content, *gari* yield and dry matter content of the provitamin A cassava were 22-25%, 21-23% and 31-35% respectively. These values were within the same range as the popular traditional white varieties [27]. However other researchers have reported lower flour yield (12.9%) and starch yield (7.2%) for the  $\beta$ -carotene varieties in comparison with the white flesh varieties which had values for flour yield ranging from 23.0% to 27.02% and 12.3%-19.57% starch yield [28,29].

In addition, several product trials have been carried out with the provitamin A cassava at the pilot level. They include *gari*, cassava flour, *fufu*, *abacha* (fermented sliced cassava), high quality cassava flour (HQCF) used in composite flour for confectioneries, infant weaning food and edible starch [30].

About 56% and 36% of cassava produced in Nigeria are consumed as *gari* and *fufu* respectively. *Gari* and *fufu* show 30-40% and 82-100% provitamin A retention respectively after preparation [31]. *Gari* is a granulated product obtained through the process of grating, fermentation/gradual dewatering (for 2 days) and toasting. It is afterwards reconstituted into stiff dough by addition of hot water. *Fufu* is produced traditionally by steeping fresh cassava in water for several days until it softens, it is mashed and sieved with a coarse sieve. It is allowed to settle and is molded and cooked in boiling water before pounding to a smooth consistency with a mortar and pestle. Both products are consumed with local soups as staples [15,28].

Traditionally processed *fufu* has the strong characteristic fermented odor which sometimes is offensive to some people. The modern improved method was developed to produce an odourless *fufu*. This involves slicing the peeled cassava, soaking for 12 to 24 hours and drying (sometimes under the sun), after which it is ground to flour. The *fufu* is prepared when needed by reconstituting the cassava flour in water, cooking with continuous stirring until the desired consistency is produced [15,28].

The research [28] showed that the traditional method where only leaching occurred during the sieving of the retted cassava tubers produced less loss of  $\beta$ -carotene than the modern method that involved drying. Therefore the use of traditional method for the production of *fufu* from yellow root cassava varieties is recommended for maximum utilization of the nutrient in the provitamin A cassava varieties [28,29].

In another research [32], it was shown that the highest carotenoid retention (54.7-81.01%) was recorded for the oven dried cassava



chips, followed by the boiled (47.87-83.79%), fried (48.76-79.77%) and then lastly the sundried samples (32.86-56.40%). All the provitamin A cassava products showed high consumer acceptability (60-80%) as well as good  $\beta$ -carotene retention [25,33].

## Orange Fleshed Sweet Potato (OFSP)

### Why sweet potato was selected?

The annual production of sweet potatoes in Nigeria is 3.9 million metric tonnes making Nigeria the third largest producer in the world after China and Uganda [34]. Its short production cycle, adaptability in marginal soil and possibility of irrigation farming makes OFSP a cash crop that can be available all year round in Nigeria for household consumption, income generation and as industrial raw material [34].

Although the local sweet potato varieties contains very small amounts of provitamin A carotenoids (0-20  $\mu\text{g}/100\text{ g}$  fresh weight for the white and 274-437  $\mu\text{g}/100\text{ g}$  fresh weight for the cream coloured variety), the International Potato Centre (CIP) and National Agricultural Research Extension System (NARES) has produced OFSP that exceeds the target level of 3000  $\mu\text{g}/100\text{ g}$  fresh weight of OFSP. The OFSP varieties are also well adapted to local and agronomic condition [35]. The amount (g/day) of OFSP needed to supply 100% of the vitamin A requirement for people at risk for deficiency are 6-33 g/day for a 3 year old child, 68-381 g/day for a lactating woman. These are amounts that can easily be consumed in a day [36]. There is however no risk of over consumption of  $\beta$ -carotene because the conversion to vitamin A is based on body demand for the vitamin [36,37]. Unconverted carotene is stored in the fat tissues and the adrenal glands, not in the liver. In addition, carotenoids may also function as antioxidants protecting the body from the potentially damaging effects of various oxidizing agents [37].

### The journey so far

The distribution of OFSP in Nigeria is at different levels in different states. The International Potato Research Centre (CIP) is pioneering the work in collaboration with Agricultural and Rural Management Training Institute (ARMTI) Kwara State. The work involves the distribution of OFSP vines to farmers, providing access to its roots for consumption and commercialization, advancement of loans to farmers. To date, over 20,000 farming households have received bundles of the OFSP vines to plant which may also be replanted after harvest. However, since the potatoes are usually harvested at the beginning of the dry season the vines usually dry up before or after harvest due to the dry season. This makes replanting difficult for some farmers. Since 2012, there has been a growing awareness for OFSP to the point that cooperative groups have been formed [34].

The pilot phase in Kwara is meant to extend to other parts of the nation through the Federal Ministry of Agriculture, State miniseries of Agriculture, Federal Universities of Agriculture around its operational area as well as the efforts of the National Root Crop Research Institute, who are currently involved in OFSP

research [38]. Several states have been reached. In Osun state, there is a pilot phase of OFSP pottage in school feeding menu. Distribution of vines and progress monitoring are on in Ebonyi, Imo, Abia etc. This is part of the effort to reach the South eastern states of the country with the OFSP [38].

### Performance of OFSP in local products

The  $\beta$ -carotene content of OFSP ranges between 13200 to 19400  $\mu\text{g}/100\text{ g}$  fresh weight as against the white and cream varieties that contain 0-20 and 274-437  $\mu\text{g}/100\text{ g}$  fresh weight respectively [36]. Two cultivars of orange-fleshed sweet potato (centennial and CIP 440293) are being multiplied for distribution in South East and South-South as well as Osun, Kwara and Ondo States of Nigeria where investigation reveals high consumer acceptability of the OFSP [39].

Research [40] has shown that storage of the grated raw OFSP for 4 hours in a covered dish, at ambient tropical conditions did not produce any losses in the  $\beta$ -carotene content, however boiling of the OFSP for 30 minutes as is traditionally done before consumption gave a retention value of 70-80%. Also  $\beta$ -carotene retention of 80-98% for boiling/steaming, 30-70% for baking and 18-54% for frying have been reported by some authors [41]. All these are traditional cooking practices for sweet potatoes. In another work, it was observed that inclusion of OFSP flour in bread at 10% and its puree up to 30% were acceptable to consumers, and had a total carotenoid retention of 71.72% and 79.32% respectively [42].

Nutrient availability studies [43] showed that children who ate OFSP had a positive change in vitamin A liver reserves compared with those children eating white sweet potatoes, measured using the modified relative dose response test. Retention studies also showed that after cooking fresh OFSP containing 4085 to 22900  $\mu\text{g}$   $\beta$ -carotene/100 g, the fraction retained was 0.90 and the bioaccessible fraction was 0.25. Therefore the concentrations of bioaccessible  $\beta$ -carotenoid in OFSP ranged from 919 to 5152  $\mu\text{g}/100\text{ g}$  cooked weight [38]. The wide variation observed is a common occurrence among some agricultural materials as seen from the wide range of values for the raw samples.

## Maize Fortification In Nigeria

### Why maize was selected?

The largest maize producer in Africa is Nigeria, producing up to 8 million tonnes a year [44]. It is widely fed to weaning children with or without any protein supplement. About 30-40% of annual production is used as livestock feed [45]. Maize is consumed by millions of people throughout the country, eaten off the cob as boiled or roasted maize, whole grain or whole meal porridge. It can also be consumed as *ogi/akamu*, *tuwo*, etc. In *Ogi/akamu* preparation, the grain is soaked in water for 2 days (to allow microbial fermentation), it is milled and sieved using a muslim cloth. The filtrate is allowed to settle. The settled stock is reconstituted with water and cooked with continuous stirring into the maize gruel called *ogi/akamu*. *Tuwo* is prepared from dry milled dehulled maize. The maize flour is mixed with water

and cooked with continuous stirring to stiff dough, generally eaten with local soups [15].

There are already existing yellow maize varieties, so the provitamin A maize with a yellow colour will not be strange among consumers in Nigeria. The average consumption of maize in Nigeria is 300 g/capita/day. Therefore biofortification of maize at 1500 µg/100 g fresh weight will provide 50% of the estimated Vitamin A requirement [17].

### The journey so far

Maize breeding program for improved provitamin A in Nigeria was started by the International Maize research and wheat improvement center (CIMMYT), and IITA in collaboration with NARES in South Africa [43]. There are many varieties of maize that exhibit some provitamin A activity. These have been used to conventionally breed new varieties that will meet the target. The already existing common maize varieties in Nigeria, the white and the yellow maize contain 0 and 150 µg β-carotene /100 g fresh weight, respectively. The target has been set at 1500 µg β-carotene /100 g fresh weight for the biofortified maize as the amount needed to prevent vitamin A deficiency in areas where maize crop is a staple. To this date, only 57% of the target has been achieved (855 µg/100 g) which supplies about 25% of the daily vitamin A needs [46,47].

The hybrids, which are the first generation vitamin A-rich maize, were released on 4 July 2012 by the National Variety Release Committee of Nigeria as Ife maizehyb 3 and Ife maizehyb 4. The ceremony was done in Kaduna and Kano States. They are recognized as IITA hybrids A0905-28 and A0905-32, respectively [48]. The project was funded by HarvestPlus. The collaborating bodies include IITA, Institute of Agricultural research and training (IAR&T), University of Maiduguri and National Center for Genetic Resources and Breeding (NACGRAB), Institute of Agricultural Research (IAR) Zaria, University of Illinois and University of Wisconsin [49]. Since then these hybrids and other varieties of open pollinated maize varieties (Sammaz 38 and Sammaz 39 recognized as IITA synthetic PVASYN2 and PVASYN8) have been introduced into several states of the nation [49].

Quality protein maize (QPM) varieties have also been developed in Nigeria by IITA in collaboration with IAR and other Institutions. This hybrid, obtained by conventional breeding known as OBA 98 contains 15% protein and high levels of lysine and tryptophan. Reports [50] revealed that other varieties of QPM released in the country include three hybrid varieties (Mama-ba, Dada-ba and CIDA-ba) and five open pollinated (OP) varieties (Obatampa, EV8363, EV8766, Pool-18-SR and Pool-15-SR) which contain higher levels of protein, as well as lysine and tryptophan per 100 g protein. The varieties have been released since 2001 to Agricultural Development program (ADP) workers located in various states for proper dissemination to farmers [51]. However, multiplication, propagation, and utilization are still very low. The seeds are not yet available in the open market and the varieties are still unknown to the consumers due to poor dissemination and public awareness [50].

### Performance of biofortified maize in local products

Studies on performance of provitamin A maize in local food products have been scanty. Report by De Moura et al. [52] showed a 66-96% retention for maize porridge prepared from the yellow maize. Other researcher [35,37] report that consumption of the provitamin A maize is able to improve the vitamin A status of children

QPM contains higher protein levels 14-15% as against 8% contained in the traditional maize varieties. Apart from that, it contains the average of 4.0 g of lysine /100 g of protein, as against 2.96 g of lysine/100 g of protein for normal maize. Tryptophan content also increased from 0.61 g /100 g of protein for normal maize to 1.665 g/100 g of protein in the QPM. This shows that the QPM development was to increase the essential amino acid content of maize, particularly the lysine and tryptophan content [53]. QPM enhanced linear growth in weaning children by 19.3% and improved the resistance of the children common diseases such as diarrhea [53].

The benefits of replacing normal maize with QPM (*Obatampa* variety) in broiler diets was also investigated [54]. The results showed that final weight and weight gain of the broilers numerically increased linearly as percentage of QPM in the feed increased.

## Sorghum

### Why sorghum was selected?

Sorghum is Africa's second most important cereal and it provides the majority of daily calorie consumption for millions of residents. Sorghum is also one of the few crops that grow well in sub-Saharan conditions because it is drought and heat tolerant. Many people rely on sorghum as a staple food. However while sorghum provides a large amount of carbohydrates for local diets, it lacks a key nutrient, vitamin A. It also contains phytates that interferes with iron and zinc absorption. Biofortification through genetic engineering of sorghum can improve the availability of vitamin A and the absorption of iron and zinc [55]. Research shows that such biofortified sorghum could have the potential to contribute from 35 to 60 percent of the recommended daily allowance [RDA] of vitamin A for children in Africa [56].

### The journey so far

In one of the earliest attempts in 2009 [57], 164 landraces were collected from Niger and Northern Nigeria. Ten of them with the most intense endosperm colour were selected. These varieties represent a new genetic pool that will increase the genetic diversity in yellow endosperm sorghum in applied breeding programs. This is a major step in the biofortification program.

The African Biofortified Sorghum (ABS) Project began in 2005 as part of the Bill and Melinda Gates Grand Challenges program, which focused on biofortification of staple food crops in Africa to improve health through better nutrition. The ABS Project is developing a new biotech variety of sorghum that contains

$\beta$ -carotene through transgenic methods and has targeted Nigeria and Kenya as initial countries of introduction [58].

Three Successive Confined field trials (CFTs) were done between 2011 and 2013 in Zaria, Kaduna state, Nigeria. During this time the agronomic and nutritional characteristics of the biofortified sorghum varieties were investigated. Backcross for introgression of ABS nutritional traits into three elite varieties has also been done. Multi-location confined field trials are now being conducted in Kaduna, Zamfara and Kano States [10]. Elevated levels of provitamin A, iron and zinc have been achieved in the ABS using transgenic methods.

The project is implemented by IAR Zaria and NABDA. It is supported by Africa Harvest, Dupont, AATF, and BMGF [56]. However no genetically modified crop has received approval in Nigeria. So the next step is to get beyond the stage of confined field trials through abiding by the biosafety laws.

## Challenges in Biofortification of Local Staples in Nigeria

In spite of the progress so far made in the biofortification of staples in Nigeria, several challenges/problems are still faced in many areas.

### Dissemination/Distribution

Production and processing of staples in Nigeria is done by millions of independent small holder farmers and processors. Therefore dissemination of information and materials to each of them is a cumbersome process. Provision of cassava stem cutting also poses a peculiar problem because multiplication is limited to 20 per plant per year and the stem cuttings are highly perishable. The distribution of the stem cuttings requires the use of trucks and heavy duty manpower and equipment.

### Retention and bioavailability of nutrient

Storage of provitamin A maize, cassava and sweet potato flour for 4 months resulted to 20% retention of the nutrient [41]. The losses may be more severe with the traditional practice of displaying goods under the sun for sale in the market place. Several authors have reported differing levels of losses during processing and storage of the biofortified crops [18,59,60]. Studies on bioavailability of nutrients and efficacy trials are yet to be conducted in Nigeria. However, information from researchers elsewhere has shown the effectiveness of the biofortified crops in improving the nutrient status of the individuals [35,36,40].

### Consumer acceptability

There is reluctance among many Nigerian consumers towards the acceptance of biofortified foods since some may differ, in certain characteristics, from the acceptable traditional varieties. Some people have even shown concern that it undermines biodiversity [19]. Secondly, sweet potato is not commonly consumed in some areas and is relegated to the status of a secondary staple crop. The challenge therefore is to get producers and consumers to accept biofortified crops by properly educating them to know that biofortification is only complimentary to food biodiversity and not against it.

## Governmental registration

Registration of biofortified foods and their products is a challenge. This is because the trend is new and proper regulatory procedures have not yet been established to handle the registration. Also the possibilities of unintended long term consequences of growing/consumption of biofortified crops have not yet been properly investigated in Nigeria.

## The way forward

**Dissemination of information:** The different agencies involved in the distribution of the seedlings have adopted the use of community-based demand driven multiplication scheme. In this scheme, the farms are developed within communities by the extension officers and the farmers are reached more easily. It is expected that out of the 8 million farmers that grow improved cassava varieties, 6 million of them will be reached with the provitamin A cassava by 2018.

Informal and formal training sessions should be organized to teach them on the effective agronomic practices suitable for each agro-ecological zone in Nigeria. Efforts should also be made to improve the image of sweet potato, through processing, new food product development and by investing in sweet potato research and advocacy capacity.

The media/Film producing industry is currently involved in propagating the information on the use of biofortified staples in Nigeria. Nigeria has a thriving film industry – known as Nollywood – and in 2014 HarvestPlus collaborated with filmmakers to produce “The Yellow Cassava”, which was nominated for several awards. With more than 75 percent of Nigerians watching Nollywood movies, both in rural or urban areas, these movies have an important role to play in encouraging all Nigerians to grow and eat this nutritious cassava [61].

**Nutrient retention:** Efforts should be made to obtain information on the extent of nutrient losses for each variety, unit operation during processing, storage condition. Estimated food intakes as well as bioavailability of the nutrients are also needed to calculate bioconversion factors. This information will help to set accurate target levels for the biofortification of these staples.

**Efficacy trials:** Evidence that consumption of the biofortified crops and their products can improve vitamin status must be established for different population groups. The results of efficacy and effectiveness studies, as well as recent successes in delivery, provide evidence that biofortification is a promising strategy for combating hidden hunger [62]. However most of such studies were conducted outside Nigeria. HarvestPlus is currently conducting a randomized-controlled efficacy trial in Nigeria, to measure the impact of the consumption of biofortified yellow cassava on serum retinol levels among Nigerian Children under five years [52].

**Transgenic methods:** Research is on-going in the use of transgenic methods to increase the nutrient density of crops. It has been shown that the use of transgenic method is a faster way to reach the target concentration for the nutrients of interest. Right now, the BioCassava Plus program (which is to be completed in 2017),

has entered its Phase 2, which focuses on product improvement and delivery. The objectives include trait stacking (provitamin A and iron), human efficacy testing of biofortified cassava and passing regulatory approval in Nigeria [21]. However until now approval has not been granted to distribute genetically modified products in Nigeria [10]. Further research is needed in this area.

**Monitoring and evaluation of programs:** The implementation, monitoring and evaluation of the use of biofortified crops (through conventional breeding) as well as nutrition education programs in Nigeria are conducted by the Agricultural Development Project (ADP) in the various states of the Federation. This is a government parastatal under the State Ministries of Agriculture that supervises all Agricultural extension services.

However there is the need for closer participation from the food processing sector (to monitor changes during processing and storage), the health sector (to monitor bioavailability and efficacy), the private sector (for more funding), non-governmental agencies (for advocacy), international bodies etc. A lot of collaboration is needed to achieve the set objectives.

## Conclusion

Micronutrient deficiency in Nigeria is multifaceted and the causes are numerous. Therefore a multifaceted approach must be applied in combating the problem. Biofortification plays a very important role in addressing micronutrient deficiency. However it has to be applied in conjunction with the other relevant short term and long term intervention programs. When several staple crops have been effectively biofortified, they will all make their meaningful contribution to the biodiversity approach of the food basket if the right distribution networks are in place.

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The biofortified crops (through convention breeding) so far released in Nigeria are yellow flesh cassava, yellow maize, orange flesh sweet potato, all fortified with pro-vitamin A as well as the Quality protein maize fortified with protein and amino acids (lysine and tryptophan). Fortunately, the target levels for the biofortified staples will only provide a certain percentage of the RDA for the nutrient at the quantity the food is consumed (except for OFSP which is a secondary staple), so there is hardly any risk of hypervitaminosis, although effectiveness trials are necessary to measure the impact of these biofortified foods on vitamin A status and health. Besides, the different staples are consumed in different parts of the country and no population group consumes all the biofortified foods as staple at the same time.

Biofortification is cheap in its application, although the initial investment/technology for the research is quite heavy for developing countries such as Nigeria. The contributions and investments of several foreign agencies are highly recognized in this regard. In the words of the former Nigerian Minister of Agriculture [63,64], "Biofortification must be rigorously supported within the broader context of promoting a diversified and healthy food base for improved nutrition." and "the main focus now is to scale up biofortified crops to reach millions of households through institutional, regulatory and financial policy".

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