DEVELOPMENT

Vitamin A Cassava

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Target Micronutrient		Vitamin A	
Target Countries		Nigeria, Democratic Republic of Congo	
Baseline (parts per million, ppm)		0 ppm	
Target Increment		15 ppm	
Target Level in Crop		15 ppm	
Nutrition Factors		**Original Assumption**	**Measured/Revised[1]**
Cassava Consumption, grams/day (fresh weight)	Women	400 g/d	900 g/d
	Children	200 g/d	350 g/d
β-carotene Retention (%)		50%	21%
β -carotene Absorption (%)		8%	17%
Absorbed Vitamin A as % of EAR		50%	50%

Releases		
1st Wave	6–8 ppm (40–60% target increment)	Released: Nigeria, 2011; DRC 2008
2nd Wave	8–10 ppm (60–80% target increment)	Planned: Nigeria, 2014; DRC, 2015
3rd Wave	>15 ppm (>100% target increment)	Planned: 2016–18

Breeding to Date: During HarvestPlus Phase I (Discovery, 2003–2008), initial screening 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 of the relative ranking of genotypes, and heritability of carotenoid content in cassava roots is relatively high (1). Degradation rate of carotenoids was also investigated; sun drying was more detrimental to the provitamin A levels (27–56% retention) in cassava than shade (59%) or oven drying (55–91%). *Gari*, the most popular cassava dish consumed in West Africa, had the lowest provitamin A retention of the foods tested (10–30%). The retention of staple crops during storage reached levels as low as 20% after 1–4 months of storage and was highly dependent on genotype (2).

In Phase II (Development, 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 (3). Rapid-cycling recurrent selection was used to shorten the normal breeding cycle from 8 to 2–3 years for high carotenoid content (4). Breeding programs for provitamin A cassava at the International Center for Tropical (CIAT) and the International Institute of Tropical Agriculture (IITA) assumed full operational scale by 2011. 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 DRC for local adaptive breeding. Mainstreaming of the provitamin A trait is estimated at 50% of IITA's cassava breeding effort.

Three 1st-wave vitamin A cassava varieties with 6–8 ppm provitamin A were released in 2011. Five 2nd-wave varieties with up to 10 ppm are in the final stages of evaluation before official release in Nigeria. 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 in multiplication/distribution.

Future Releases: More than 50 provitamin A varieties are now at different stages of evaluation to identify those that are agronomically competitive for 3rd-wave release. The top 5 leads have up to 15 ppm (>100% of target increment). These varieties will be put in tissue culture for international distribution particularly targeting potential expansion countries. Some National Agricultural Research Systems (NARS) have started their own programs to release new varieties from past introductions; the most recent release developed by IITA is I06/1635 in Sierra Leone.

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 early breeding stages. The correlation between iCheck™ and spectrophotometer is high enough to produce acceptable data.

Regional Testing: 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.

Highlights:

- Three 1st-wave varieties were released in Nigeria in 2011; 2nd-wave varieties will be released in 2014.
- One 1st-wave variety was identified in DRC for multiplication and distribution; promising 2nd-wave varieties are in testing.
- Rapid-cycling recurrent selection has been implemented, and clones with up to 15 ppm provitamin A content are in the development pipeline.

Challenges:

- Dry matter content for provitamin A varieties is somewhat low compared to local preference and is a priority for improvement.
- Root mealiness or poundability, important in many African diets, is limited in current varieties and will be beneficial for provitamin A retention in cooking and development of weaning foods for children. This is also a breeding priority.

Released Varieties

Variety Name	Total Carotenoid Content (FW)*	Fresh Root Yield	Yield Relative to Check	Dry Matter
Nigeria – Released in 2011				
TMS 01/1371	7.8 ppm	20.1 t/ha	87%	30.7%
TMS 01/1412	7.4 ppm	29.8 t/ha	128%	30.1%
TMS 01/1368	6.9 ppm	26.7 t/ha	115%	33.4%
30572 (Control)	*0.9 ppm*	*23.2 t/ha*	*100%*	*37.1%*
DRC – Released in 2008				
I011661	9.4 ppm	34.9 t/ha	*NA*	30%
Butamu (Check)	*4.4 ppm*	*35.0 t/ha*	*NA*	*35%*

* Provitamin A content is approximately 80% of Total Carotenoid Content (fresh weight – FW)

Notes: Data from two years of multi-locational NCRP testing at 9 sites during 2008/09 and 2009/10 (Nigeria).

1. Ssemakula, G; Dixon, AGO; Maziya-Dixon, B. 2007. Stability of total carotenoid concentration and fresh yield of selected yellow-fleshed cassava (Manihot esculenta Crantz). *Journal of Tropical Agriculture* 45(1-2):14–20.
2. De Moura, F; Miloff, A; Boy, E. 2013. Retention of provitamin A carotenoids in staple crops targeted for biofortification in Africa: Cassava, maize and sweet potato. *Critical Reviews in Food Science and Nutrition*.
3. Kimura, M; et al. 2007. Screening and HPLC methods for carotenoids in sweetpotato, cassava and maize for plant breeding trials. *Food Chemistry* 100(4):1734–1746.
4. Ceballos, H; et al. 2013. Rapid cycling recurrent selection for increased carotenoids content in cassava roots. *Crop Science* 53(6):2342–2351.