Efficacy and Other Nutrition Evidence for Vitamin A Crops

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Some plant foods, e.g., carrots, mangos, and papaya, provide provitamin A carotenoids, a precursor of vitamin A. The bioavailability of the most common plant provitamin A (beta-carotene) varies widely in relation to the food crop, genotype, cooking method, individual genetic factors, and consumption of fat with the meal. Bioconversion of dietary beta-carotene to retinol across plant foods ranges from 3 to 28:1 by weight (1). Food carotenoid degradation displays exponential decay patterns during storage and varies with the food matrix, crop genotype, and form of storage. It increases directly with time and temperature during storage as well as with exposure to high temperature, light, acids, and oxygen during processing. Because the bioconversion of provitamin A carotenoids to vitamin A is homeostatically regulated, excess toxic accumulation of retinol is prevented.

Sweet Potato (*Ipomoea batatas*): Orange sweet potato (OSP) growing in Sub-Saharan Africa have high levels of beta-carotene (100–1600 µg retinol activity equivalent (RAE)/100 g fresh weight) and are well accepted by young children (2,3).

<u>Retention</u>: Boiling sweet potato for about 30 minutes retained 80–90% of beta-carotene (3) while steaming for the same amount of time resulted in 70–75% beta-carotene retention (4).

<u>Bioavailability</u>: A study in Bangladeshi men who consumed a high beta-carotene sweet potato reported a bioconversion of 13:1 bioequivalence between beta-carotene and retinol (5).

<u>Efficacy trials</u>: An efficacy study conducted in South Africa with 5–10-year-old children showed that the 3,4-didehydroretinol to retinol ratio (DR:R) was significantly greater in the OSP group than in a control white sweet potato group after 53 days of intervention (p=0.0203) (6). A smaller placebo-controlled randomized trial in Bangladesh with 14 adult men demonstrated that an additional 750 µg RAE/day as boiled canned OSP puree produced higher final serum retinol and beta-carotene concentrations (p<0.03) (7).

<u>Effectiveness</u>: The introduction and promotion of OSP assessed in Mozambique over four growing seasons demonstrated that serum retinol increased significantly at endline for children in the OSP intervention group (p<0.001) (8). The OSP intervention reached 24,000 households in Uganda and Mozambique from 2006–2009 with adoption rates of OSP greater than 60% above control communities (9). Introduction of OSP in rural Uganda resulted in increased vitamin A intakes among children and women and improved vitamin A status among children by decreasing the prevalence of low serum retinol (<1.05 mmol/L) by 9 percentage points (10).

Preliminary adjusted figures for the marginal cost per beneficiary were $5–8 and $6–10 in Uganda and Mozambique, respectively. Each DALY (disability-adjusted life year) saved would cost US$15–24 (11).

Cassava (*Manihot esculenta*): Cassava is an important food security crop for populations deriving sustenance from infertile soils. Total carotenoid content in cassava is 7.99 µg/g (range: 2.87–12.95 µg/g fresh weight), of which ~70% is beta-carotene (12).

<u>Retention</u>: The most common cassava processing methods in developing countries (i.e., boiled, *gari*, *fufu*, fermented and unfermented flour) resulted in losses of beta-carotene ranging from 30% (boiled) to 70% (*gari*) (12).

<u>Bioavailability</u>: Bioconversion studies have shown a 5:1 bioequivalence between beta-carotene and retinol (13).

<u>Efficacy trial</u>: An efficacy study conducted in Eastern Kenya with 5–13-year-old children showed an 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).

Maize (*Zea mays*): Maize provides an estimated 15% of the world's protein and 20% of the world's calories and is, therefore, considered a staple food for more than 200 million people (15).

<u>Retention</u>: A retention study was conducted in Zambia that showed provitamin A losses of 50% in 4 genotypes after 15 days of storage in ambient conditions, after which the provitamin A content stabilized for 6 months of storage (16). However, retention of 90–100% was observed with milled products, *nshima*, and porridge (16). Beta-carotene

degradation associated with traditional African household processing methods was approximately 25% for fermented and unfermented porridges (17).

Bioavailability: Bioconversion studies have shown a 3:1 (18) and 7:1 (19) bioequivalence between beta-carotene and retinol.

Efficacy trials: An efficacy study conducted in the Eastern province of Zambia with 5–7-year-old children showed that the total body stores of vitamin A in the children who were in the orange maize group increased significantly compared with those in the negative vitamin A control group; data were adjusted for infection (*unpublished*). Preliminary results suggest improvement of total body stores of vitamin A and visual adaptation to darkness even within a context of marginal-to-adequate baseline vitamin A status among study subjects. The beta-carotene in maize is an efficacious source of vitamin A when consumed as a staple crop.

Highlights:

- Nutrition studies have demonstrated that OSP is an efficacious intervention; promising results are available for efficacy of maize and cassava.

Challenges:

- The yellow/orange color of vitamin A crops may be a barrier to consumer acceptance in some cases. White maize is preferred over yellow/orange maize in Zambia; however, this is not the case with yellow cassava in Nigeria, where yellow *gari* (made yellow with red palm oil) can be found in the market.

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