

Yellow maize with high β -carotene is an effective source of vitamin A in healthy Zimbabwean men.

Muzhingi T, Gadaga TH, Siwela AH, Grusak MA, Russell RM, Tang G. *Am J Clin Nutr* 2011; 94: 510-519.

Introduction

In poor households of lower income countries, the major local staple food(s) often provide(s) more than half of the total dietary energy – and in some cases these staples may supply as much as 90% of the energy intake. In such situations, if the staple food is lacking in particular micronutrients (MNs), the consumers will have a high risk of inadequate MN intake and may suffer from related MN deficiencies. Recently, plant scientists have been addressing this problem by cross-breeding plant food cultivars that have a relatively high content of particular nutrients with locally cultivated varieties of the same foods with desirable agronomic traits. The purpose of these plant breeding activities is to develop phenotypes that combine both sets of preferred nutritional and agronomic characteristics. This process of plant breeding for high nutritional value, and related methods using genetic modification and other technologies to enhance the nutrient content of plant-source foods, have been described as “biofortification;” and efforts are proceeding to develop staple foods that are rich in vitamin A, iron, zinc, and/or other nutrients (Bouis, 2011; Nestel, 2006).

As new biofortified foods become available for introduction into the food supply, it is important for nutritionists to confirm that the increased amounts of nutrients that are present in these foods have adequate bioavailability when consumed by humans. The article selected for review in this month's edition of NNA describes the results of a study conducted among Zimbabwean men to evaluate vitamin A bioavailability from a yellow maize cultivar bred for its high β -carotene content. Thus, the study addressed a nutritional problem that concerns much of Africa and examined a food that is widely consumed in many countries in the region.

Once dietary carotenoids are absorbed by humans, β -carotene and other provitamin A carotenoids are converted to vitamin A, mostly in the enterocyte. The efficiency of carotenoid absorption and bioconversion to vitamin A depends on a number of dietary factors (Lietz 2010; Tanumihardjo, 2010; Tang, 2010), and is also affected by genetic factors (Leung, 2009) and, probably, the consumer's vitamin A status (Ribaya-Mercado 2000; Lietz 2010; Tanumihardjo, 2010).

Methods

The research project currently being reviewed was designed as a stable isotope tracer study to assess vitamin A bioavailability from an intrinsically labeled, yellow maize cultivar rich in β -carotene, compared with a reference dose of stable isotope-labeled retinol. For the intrinsic labeling, the yellow maize was grown in hydroponic tanks in a closed chamber, and the water in the tanks was labeled with the stable isotope deuterium (^2H). Thus, the maize plants synthesized β -carotene using the deuterated water, resulting in ^2H -enriched β -carotene with higher molecular weight in the mature maize kernels, which could then be traced in humans who consumed the labeled product. One week later, a separate

dose of ^{13}C - (stable isotope-) labeled retinyl acetate was given to the study participants as a reference dose of vitamin A bioavailability.

Eight healthy adult male Zimbabwean volunteers participated in the study. They consumed a single meal composed of ^2H -labeled maize porridge containing 300 g yellow maize (dry weight), 20 g butter and a capsule with 0.5 g corn oil. The reference dose of retinyl acetate was served in corn oil along with white maize porridge and butter one week later. Blood samples were drawn frequently following each test meal to measure ^2H - and ^{13}C -labeled retinol concentrations in plasma, as markers of absorption and bioconversion of β -carotene and retinyl acetate, respectively, to retinol. HPLC analyses of retinol and carotenoid compounds, and mass spectrometry analyses of isotope ratios of the isolated compounds were completed at the USDA Human Nutrition Research Center at Tufts University, USA. The relative bioavailability of β -carotene and other provitamin A carotenoids from the yellow maize was then calculated.

Results and Conclusions

The β -carotene isolated from the yellow maize was successfully labeled with ^2H , and the average molecular weight of the labeled compound was 546, compared with 537 for unlabeled β -carotene. Results of the analyses of blood samples from the study participants indicated that a small amount of intact labeled β -carotene from the test meal could be detected in all of the men, and all were able to convert the labeled β -carotene and retinyl acetate to retinol. The average conversion factor of β -carotene to retinol was 3.2 ± 1.5 by weight, indicating that 3.2 mg β -carotene and other provitamin A carotenoids provided by the yellow maize was equivalent to 1 mg retinol. The maize used in the study contained 1.2 mg all *trans*- β -carotene equivalents per serving of cooked porridge prepared from 300 g maize flour. Adults in Zimbabwe consume ~ 330 g maize/d (dry weight), so if they consumed this same amount of maize as the yellow maize used in the study, they would receive about 412 μg vitamin A activity from the maize, or approximately two-thirds of the FAO/WHO daily recommended intake for adult males.

Program and Policy Implications

Biofortification of staple foods with selected MNs offers an attractive strategy to enhance the nutritional quality of the diet, especially in settings where staple foods provide a very large proportion of dietary energy. In addition to yellow maize, several other food products have been developed and other existing products are being promoted to supply additional vitamin A, including orange fleshed sweet potato (OFSP), banana, cassava, and "Golden Rice" (Engelberger, 2003). If these products were to replace the unpigmented varieties of the respective foods that are currently being consumed, the biofortified cultivars could contribute substantially to vitamin A intake. However, this assumes that the β -carotene in these biofortified foods is successfully converted to retinol once consumed. Previous studies have found that OFSP enhances the vitamin A status of Bangladeshi adults (Haskell, 2004) and South African school children (van Jaarsveld, 2005), and that Golden Rice provides β -carotene that is successfully converted to vitamin A by US adults (Tang, 2009). Thus, there is a growing body of information to suggest that the β -carotene biofortified foods can be a good source of vitamin A. The current study suggests that yellow maize is another possible food source of vitamin A in areas where sizeable amounts of white maize are being consumed.

NNA Editors' Comments*

Biofortification presents an exciting new opportunity for collaboration between the agriculture and health sectors. The present study was a complex stable (non-radioactive) isotope tracer study involving plant scientists, nutritional biochemists, and clinical nutritionists, who focused primarily on the biological issue of β -carotene conversion to retinol. The project provides an excellent example of interdisciplinary research collaboration to address an important public health nutrition problem. Although the focus of the study was on the particular biological question of the bioconversion of provitamin A carotenoids to vitamin A, a number of other issues need to be considered before yellow maize can be considered a viable nutrition intervention strategy. In particular, farmer and consumer acceptability of yellow maize must be confirmed and/or promoted. Moreover, the existing production system for white maize would need to be converted to production of yellow maize, a process that will involve understanding local seed systems, recruiting relevant agricultural extension capacity, and conducting consumer education and behavior change interventions. With the continuous expansion of traditional vitamin A fortification programs in Africa, it is reassuring to note that bioconversion of β -carotene to retinol seems to be regulated by vitamin A status (Lietz 2010; Tanumihardjo, 2010). Thus, there is less risk of vitamin A toxicity occurring with β -carotene biofortification than might be the case with conventional retinol fortification of multiple food vehicles.

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*These comments have been added by the editorial team and are not part of the cited publication.



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