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EDITORIAL

A new era in plant metabolism research reveals a bright future for bio-fortification and human nutrition

The first three to four decades of the 20th century have been called the golden age of nutrition science, because most of the dietary requirements to keep us alive and healthy were mapped out during this period. The vitamins, minerals, amino acids, and fatty acids necessary to avoid the typical symptoms and diseases of deficiency were identified and characterized, and the amounts of these nutrients required on a daily basis to avoid deficiency were estimated. Although micronutrient deficiencies and particularly vitamin deficiencies continue to have profound effects on human health on populations throughout the developing world, the application of nutritional science together with the massive social and economic changes that occurred during the last century has led to the virtual eradication of the nutrient-deficiency diseases, at least in the developed world. Hence, the preoccupation of modern nutrition in the developed world has shifted to trying to understand and if possible to prevent diseases where diet is but one risk factor. The etiology of these diseases such as cancers, atherosclerosis, and diabetes as well as obesity is complex and multifactorial. They are certainly not the consequence of an isolated nutrient deficiency, but a role for diet in significantly influencing the risk of incidence has been clearly established.

A striking feature that has emerged from studying the epidemiology is that the consumption of fruits and vegetables decreases the frequency of some of the most prevalent diseases of the western world. It is clear that eating vegetables and fruits is strongly inversely correlated with the risk of developing both cancer and cardiovascular disease. The strength and consistency of the epidemiological findings, taken together with numerous data from experimental studies indicating potential beneficial effects, has led to the general dietary advice from governmental organizations to increase our intake of vegetables and fruits. However, such advice is rarely followed and, in general, people in many countries eat far less than the average recommended daily intake of 400 g of fruits and vegetables. Hence, the enhancement of micronutrient content in food crops by means of breeding and biotechnology (collectively called bio-fortification) is a major challenge not only in fighting deficiencies but also in ensuring that people are better protected against the killer diseases of the developed world. It is therefore timely and appropriate to consider the recent developments in plant nutriomics that underpin and compliment the governmental dietary advice to eat more fruits and vegetables.

In this Special Issue therefore, we have aimed at providing a comprehensive and up-to-date account of the technologies that are currently being employed to improve plant nutrient contents, together with the ways in which natural variation in crop plants might be exploited using marker-assisted breeding. This issue contains authoritative overviews on iron and zinc nutrition (Ghandilyan et al. 2006) and the production and biotechnological approaches to carotenoids (Botella-Pavia and Rodriguez-Conception 2006), pantothenate (Chakauya et al. 2006), and long-chain polyunsaturated fatty acids (Napier et al. 2006), as well as comprehensive accounts on current concepts of the biosynthesis of tocopherol (DellaPenna and Last 2006), ascorbate (Ishikawa et al. 2006), glutathione (Maughan and Foyer 2006), folate (Rébeillé et al. 2006), and vitamin B2 (Fischer and Bacher 2006). This volume further includes a consideration of molecular genetic approaches to resolve the current aspects of malnutrition relative to micronutrients (Lucca et al. 2006), as well as current approaches to crop bio-fortification, which should have significant impacts in developing countries where essential micronutrient deficiencies are still prevalent in populations.

The biosynthesis of vitamins A and E has been characterized in detail. In both cases, significant enhancement of their levels has been obtained by means of biotechnology. Golden rice was the first example of a vitamin bio-fortified crop. Because the first prototype was developed, alternative approaches have led to lines with an extremely high content of β-carotene, up to 23 fold higher than in the original rice line, undoubtedly opening the way toward controlling blindness and other vitamin A-related disorders (Lucca et al. 2006).

A significant leap in current knowledge has been made with regard to vitamin B9 (folates) in the past few years, particularly in our understanding of subcellular compartmentalization of the biosynthetic pathway and the importance of simultaneous 'tackling' of both branches in folate synthesis (Rébeillé et al. 2006). The pathway of vitamin B2 (riboflavin) synthesis has also been characterized in detail, and riboflavin synthase has been cloned from *Arabidopsis thaliana*, paving the road toward enhancement (Fischer and Bacher 2006). Genetic modification has furthermore allowed the enhancement of the levels of very long-chain polyunsaturated fatty acids, offering a sustainable alternative dietary source to fish oils (Napier et al. 2006).

In addition to vitamin A deficiency disorders, iron deficiency anemia affects huge population groups. Genetic improvement of rice through ferritin overexpression could double or even triple iron uptake in areas where rice is the staple food. This might be of considerable benefit to women in developing countries where iron uptake often is as low as 50% of the recommended daily allowance. This approach combined with enhanced iron bio-availability by a reduction of the anti-nutrient phytic acid or by raising the level of cysteine through enhancement of metallothionein could result in a strongly beneficial effect, although the latter remains to be proven (Lucca et al. 2006). Nevertheless, a detailed understanding of cellular homeostasis of iron and other mineral nutrients such as zinc is needed in order to further improve the effects of gene engineering approaches. In addition, interesting alleles of relevant genes are being identified by QTL analysis, which can used as advanced breeding tools to develop new varieties of crop species (Ghandilyan et al. 2006).

Taken together, this Special Issue provides a unique opportunity to the reader in offering a wealth of useful information on the innovative strategies that are currently being used to improve the content of vitamins, essential minerals, and antioxidants, as well as other key, non-essential nutrients that can have profound impacts on human health. Such approaches may be used to reduce micronutrient-related disorders, because bio-fortification of major food crops is a practical alternative and/or complementary solution to malnutrition in the developing world where poor infrastructure often renders other solutions unreachable for the poor who cannot afford to purchase high-quality micronutrient-supplemented processed food stuff. In addition, such approaches offer great benefits to the developed world, where bio-fortified foods may be attractive to the sophisticated consumer. In all cases, accompanying dietary advice should be simple to understand and easy to put into practice by the public.

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