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Editorial

Plant Metabolic Pathway manipulation: A New Hope to Combat Micronutrients Deficiency

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Micronutrients are vitamins and minerals which are required in small amounts but are necessary to ensure healthy physical and mental development. Vitamins are necessary for energy production, immune function, blood clotting and other functions. Meanwhile, minerals play an important role in growth, bone health, transmitting nerve pulses, maintain normal heart beats, insure immune system health, and several other processes. Essential micronutrients include iron, zinc, calcium, selenium, iodine, magnesium, and vitamins [1].

Micronutrient deficiencies form an important global health issue, by causing severe damage to human physically and intellectually in addition to increased risk of many serious diseases [2]. Unfortunately, the health impacts of micronutrient deficiency are not always acutely visible; it is therefore sometimes termed 'hidden hunger' [3]. According to The World Health Organization (WHO) more than two billion people (i.e. 1 in 3) suffer from micronutrient deficiency globally [4].

Biofortification is a type of micronutrients intervention that has potential to reach the rural poor effectively, this group of population are often at high risk of micronutrients deficiency. Biofortification is proved to play an important role in combating micronutrients deficiency, specially vitamins, by providing an economic and effective delivery of nutrients to population in need [2]. We should differentiate between food fortification which is simply exogenous adding of vitamins and minerals to foods and biofortification that means to enrich food plants including seeds, tubers, and leafy vegetables with vitamins through conventional breeding, biotechnology and/or agronomic approaches [5]. Many researches have been done in this field, leading to many successful examples. A number of biofortified crops have already been released worldwide [6,7] (Table 1).

By transgenic approach

Plant	Type of Biofortification	Country
Maize	Phytate degradation Lysine	China Australia, Canada, Japan, USA, Mexico, Taiwan, New Zealand
Soybean	Oleic acid	Australia, Canada, Japan, USA, Mexico, Taiwan, New Zealand, South Africa, South Korea, Philippines, Singapore
Canola	Phytate degradation	USA
Potato	Reduced amylase and increased amylopectin in starch granules.	USA, European Union
Cassava	Iron, Beta-carotene, Protein.	Nigeria
Flax	Essential amino acid	Canada, Colombia, USA

By breeding approach

Plant	Type of Biofortification	Country
Rice	Zinc and Iron	Bangladesh
Wheat	Zinc and iron Carotene Anthocyanins	India India China
Maize	Vitamin A Lysine and tryptophan	Zambia, Ghana, Nigeria India, China, Vietnam, South Africa, Ghana, Uganda, Peru, Brazil, Colombia
Sorghum	Iron	India, Nigeria
Pearl Millet	Iron	India, Niger
Beans	Iron and Zinc	Rwanda
Orange Sweet Potato	Vitamin A	Uganda, Zambia
Mango	Beta-Carotene	India
Grapes	Antioxidants	India
Cauliflower	Beta-carotene	India, USA

Table 1: *Biofortified edible plants released worldwide.*

In this article we will focus on the progress had done so far in the manipulation of the vitamin metabolism for developing vitamin-biofortified crops. Currently there are three strategies used to develop transgenic vitamin biofortified crops:

Over expressing the genes involved in biosynthesis

This strategy is used to biofortified food with vitamins A, B and C. Vitamin A exists in several forms known as retinoids. Human can synthesize retinal from the abundant provitamin A carotenoids present in fruits and vegetable such as orange, spinach, broccoli and sweet potato [8]. Plants produce four types of provitamin A carotenoids from phytoene [9]. The most commonly used gene for carotenoids biofortification is the genes encoding phytoene synthase alone or in combination with gene encoding phytoene desaturase. Phytoene synthase was applied to crops including canola, soybean, flax and potato [10,11]. Folates (vitamin B_9) include tetrahydrofolate and its derivatives. Folates are generally abundant in beet, legumes and dark-green leafy vegetables such as spinach. Production of folate-fortified crops depends on over expression of genes for dihydrofolate synthetase or GTP cyclohydrolase I, both enzymes are proposed to control a rate-determining step in folate biosynthesis in plant [12].

Silencing the genes involved in recycling

This strategy has been used to develop vitamin C (ascorbate) - biofortified crops. It has been carried out by knocking down the genes responsible for ascorbate recycling in the plant cell, such as monodehydroascorbate reductase (MDHAR) and dehydroascorbate reductase (DHAR). However, this strategy leads to less increase in vitamin C content in tomato, potato and maize compared to transgenic plants developed by overexpression of the genes involved in biosynthesis strategy [13,14].

Increasing the activity of the enzymes in different steps in the biosynthetic pathway.

This method has been successfully used in case of vitamin E. Vitamin E contains phenolic groups that easily oxidized to produce effective antioxidant derivatives that positively contribute to human health [15]. Most approaches to stimulate vitamin E levels in crops depend on increasing the activity of enzymes in each step in the biosynthetic pathway such as *p*- hydroxyphenylpyruvate dioxygenase, 2-methyl-6-phytyl-benzoquinol methyltransferase and tocopherol cyclase [16,17].

Generally, two criteria should be considered when selecting appropriate food crops for vitamin biofortification strategies: (1) the crop has to be widely used and of economic importance; (2) vitamin accumulation in the consumed part of the crop plant as well as its bioavailability to the consumers should not be restricted by any physiological or developmental limitations.

Biofortification based on crop breeding, targeted genetic manipulation, and/or the application of mineral fertilizers is a promising, efficient and cost-effective approach to improve vitamin status in populations suffering from nutrient deficiencies all over the world. While a lot of expectation has been laid on transgenic - based biofortification, still the number of the released biofortified cultivars is higher for breeding - based approach.

Manipulation of micronutrients metabolism in plant is still limited due to incomplete understanding of the regulation of the endogenous pathways, further studies are still required in this regard.

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