MOLECULAR BREEDING OF VEGETABLE CROPS FOR IMPROVED PROVITAMIN A CAROTENOID CONTENT

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Summary

Carotenoids play a crucial role in photosynthesis and they also are the ultimate source of vitamin A, which is essential for all animals. The carotenoid biosynthetic pathway in plants is complex, and the enzymes involved are often membrane-bound and/or not plentiful. These facts limit the ease of studying and manipulating this pathway to enhance the nutritional value of crop plants.

Yet this pathway has been extensively studied, and the genes involved were cloned and sequenced for many steps in the biosynthesis of carotenoids in several microbes, tomato, pepper and *Arabidopsis*. This knowledge provides a basis for altering the type and amount of nutritionally important carotenoids in vegetables. Application of this knowledge can have a significant impact in enhancing nutrient levels in vegetables.

1. Introduction

1.1. Biological Importance of Plant Carotenoids

Plant carotenoids are red, orange, and yellow lipid-soluble pigments found embedded in the membranes of chloroplasts and chromoplasts. Carotenoids play an essential role in the plant metabolism by allowing water molecules to be readily available as reductants for photosynthesis. The oxidation of water produces molecular oxygen, which can react with excited triplet state chlorophyll to form the reactive and cell-damaging singlet oxygen. Carotenoid pigments (associated with the reaction centers and antenna complexes) react with and efficiently quench singlet oxygen, triplet chlorophyll, and also superoxide anion radicals allowing the crucial conversion of light energy to chemical energy without any cellular damage. In addition to these antioxidant functions, carotenoids also play a series of other relevant functions in plant biology, such as (1) harvesting sunlight for the photosynthetic systems; (2) dissipating excess light energy absorbed by the antenna pigments; (3) serving as precursors for biosynthesis of the hormone abscisic acid; and (4) functioning as a color mechanism to guide pollinators to flowers as well as to attract agents of seed dispersal to fruits. Additional roles of carotenoids have been suggested including the stabilization of the plastid thylakoid membrane (e.g., zeaxanthin) and a structural function in the oligomerization of light harvesting complexes during photosynthetic apparatus assembly (e.g., lutein).

1.2. Nutritional Importance of Plant Carotenoids

The cleavage products of several dietary carotenoids, particularly β-carotene, fulfil essential requirements in human and animal nutrition (vitamin A), vision (retinal), and development (retinoic acid). Carotenoids also have additional benefits as food-coloring agents and apparently in prevention of some cancers. Vitamin A deficiency has been reported as the most common dietary problem affecting children worldwide (see *Global Importance of Vitamin A Deficiency in Humans and its Relationship to Malnutrition*). The top three natural sources of biologically active carotenes in the United States are vegetables (namely carrots, sweet potatoes, and tomatoes). Carotenoids with provitamin A potential are also found in other fruit vegetables (e.g., pepper, melons, watermelons, and *Cucurbita* species) and in several leafy vegetables (e.g., lettuce, spinach, and *Brassica* species). Field crops are, in general poor natural sources of dietary provitamin A carotenoids. Recent work with molecular manipulation of many carotenoid genes in transgenic rice indicates that this scenario may change in a near future.

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Biographical Sketches

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