Astaxanthin Rice, a new biofortified crop germplasm developed by multigene metabolic engineering

With the support by the National Natural Science Foundation of China, the research group directed by Professor Liu YaoGuang (刘耀光) at the State Key Laboratory for Conservation and Utilization of Subtropical Agro-Bioresources, College of Life Sciences, South China Agricultural University, recently reported the *de novo* biosynthesis of astaxanthin in rice endosperm in *Molecular Plant* (Zhu et al., 2018, https://doi.org/10.1016/j.molp.2018.09.007).

Genetic engineering of complex metabolic pathways and synthetic biology studies in plants require efficient vector tools for multigene assembly and plant transformation. Funded by the National Natural Science Foundation of China, Professor Liu's group previously developed a high-efficiency TransGene Stacking II (TGS II) vector system (Zhu et al., 2017). Using this system, they successfully stacked ten transgenes for anthocyanin biosynthesis in rice, and developed the first "Purple Endosperm Rice, or Zijingmi (紫晶米)", with high anthocyanin contents and antioxidant activity (Zhu et al., 2017, http://dx.doi.org/10.1016/j.molp.2017.05.008).

Carotenoids are essential phytonutrients for human health. Astaxanthin is a highly-valuable, red-orange ketocarotenoid with strong antioxidant activity, and is widely used in pharmaceutical, cosmetic and aquaculture industries. However, astaxanthin is not produced in almost all plants, and genetic engineering for astaxanthin biosynthesis in rice is difficult, because rice endosperm lacks expression of the enzymes for producing the carotenoid precursors of astaxanthin. In this study, Professor Liu's group used the TGS II system to successfully bioengineer the canthaxanthin (another ketocarotenoid) and astaxanthin biosynthesis in rice endosperm. By introducing two (*sZmPSY1*and *sPaCrtI*), three (*sZmPSY1*, *sPaCrtI* and *sCrBKT*) and four synthetic transgenes (*sZmPSY1*, *sPaCrtI*, *sCrBKT*, and *sHpBHY*), which encode phytoene synthase, phytoene desaturase, β-carotene ketolase, and β-carotene hydroxylase, respectively, they developed the yellow-grained β-carotene-enriched Golden Rice and two new orange-red-grained rice germplasms: Canthaxanthin Rice and Astaxanthin Rice, respectively. The Astaxanthin Rice, also called "Chijingmi (赤晶米)" in Chinese, is enriched with astaxanthin and has higher antioxidant activity.

This work also suggests that the engineered biosynthesis of other important diterpenoid substances (such as tanshinone and taxol) may be possible using rice endosperm as the bioreactor. This study promotes plant metabolic engineering and provides a remarkable reference for plant synthetic biology and crop biofortification.

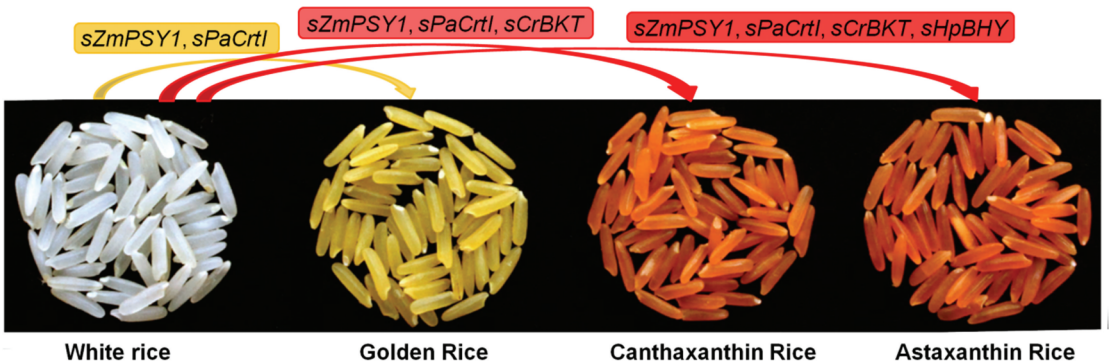

Figure *De novo* biosynthesis of β-carotene, canthaxanthin, and astaxanthin in rice endosperm by introducing and expressing two, three, and four synthetic transgenes, respectively.