Carotenogenesis in potato tubers

W.L. Morris, L. Ducreux, S. Millam, D. Stewart, D.W. Griffiths, C. Lacomme, H.V. Davies & M.A. Taylor

Plant carotenoids are 40-carbon isoprenoids with polyene chains that may contain up to 15 conjugated double bonds. In photosynthesis certain carotenoids have essential functions, acting as accessory pigments in light-harvesting and also as quenchers of triplet excited states in chlorophyll molecules, preventing free radical damage. Due to their bright distinct colours, carotenoids also function as animal attractants and are found in the chromoplasts of fruits and flowers. Plant-derived carotenoids are important in human health. All of the carotenoids that contain a β-ring (most notably β-carotene) can be converted to retinol and, thus are precursors of vitamin A. Additional health benefits of carotenoids are the subject of a growing area of research. For example, zeaxanthin (a relatively rare dietary carotenoid) in combination with lutein are essential components of the macular pigment of the eye and a low dietary intake of these carotenoids increases the risks of age-related macular degeneration. Lycopene, the major carotenoid found in tomato fruit, protects against prostate cancer.

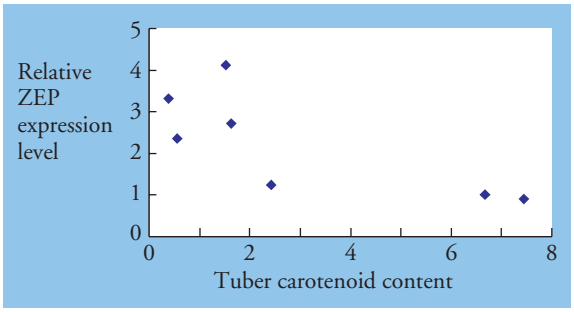

Figure 1 Quantitative real-time PCR reveals an inverse relationship between total tuber carotenoid content and the transcript level of the zeaxanthin epoxidase gene across a range of potato germplasm.

Over the past decade many of the genes encoding the enzymes of carotenogenesis have been cloned from plants. Transgenic manipulation of the carotenoid biochemical pathway has led to notable increases in the carotenoid content and the types of carotenoids produced in a range of crop plants most significantly rice, tomato and canola. Despite these successes however, there is still much to be learnt about the control of carotenoid content in crop plants. In potato germplasm for example, tuber flesh colour ranges from white to yellow to orange, depending on the tuber carotenoid content. The aim of our work at SCRI is to understand the molecular basis for this variation. We then wish to harness this knowledge and explore the limits of how much carotenoid can be produced in a potato tuber and the extent to which we can control the types of carotenoid that are produced. Longer-term we wish to be able to produce significant nutritional benefits in a major staple food.

Our approach has been to carry out a detailed comparison of carotenogenesis in a range of potato germplasm. Tuber carotenoid content is particularly high in a *S. phureja* accession (DB375\1). These tubers accumulate high levels of zeaxanthin and also contain significant levels of antheroxanthin, lutein and violaxanthin. We have demonstrated that tuber carotenoids accumulate during tuber development and the levels of carotenoids remain high during tuber maturation and are stable during six months of tuber storage at 4°C. During this storage phase however, there are changes in individual tuber carotenoid components possibly indicating carotenoid interconversions during storage. In parallel the transcript levels of 14 of the genes encoding carotenogenic activities have been profiled in a range of tuber germplasm during tuber development. Surprisingly we have discovered an inverse relationship between the zeaxanthin epoxidase transcript level and tuber carotenoid content. The molecular basis of this relationship is being pursued in collaboration with the Genome Dynamics Programme. A transgenic approach to manipulating tuber carotenoid content is also in progress. New protocols for the transformation of *S. phureja* have been developed. In collaboration with Cell-Cell Communication Programme we have been successful in developing a VIGS protocol for rapid determination of gene function in potato tubers and this is being used to determine the roles of the genes involved in potato carotenogenesis.