Popularizing description of the project results

Betalains are purple or yellow natural dyes present in plants (including red beet and *Mirabilis jalapa* flower) and fungi (fly agaric). One of the hitherto poorly known functions of these dyes is their photoprotective role (sunscreening). Implementation of the project allowed us to characterize the molecular mechanism occurring in betalains responsible for the ultrafast conversion of light to heat, which provides protection for biological systems. Act of photon absorption by betalain excites the dye to the singlet excited S_1 state. The dye in the S_1 state undergoes a very rapid change in the geometry transpiring over timescale significantly shorter than 1 billionth of a second, caused by the rotation around the double bonds C=N or C=C in the central molecular bridge. Changes in the geometry activates a fast nonradiative deactivation channel IC (internal conversion) leading the excited S_1 state to the electronic ground state S_0. The appearing excess of vibrational energy is dissipated as heat. An important parameter is a local viscosity hindering the change in the dye geometry, and causing deceleration of the decay of excited S_1 state. Detailed studies for several betalains (purple betanin and yellow dyes: indicaxanthin, vulgaxanthin I and miraxanthin V), using stationary and time-resolved methods of optical spectroscopy were completed. The research project was also devoted to the construction and testing photovoltaic cells sensitized with betalains (DSSC, dye-sensitized solar cells). The desired high performance of the primary electron injection process to titanium oxide (TiO_2) is limited by a competitive process of the S_1 state deactivation through non-radiative IC.

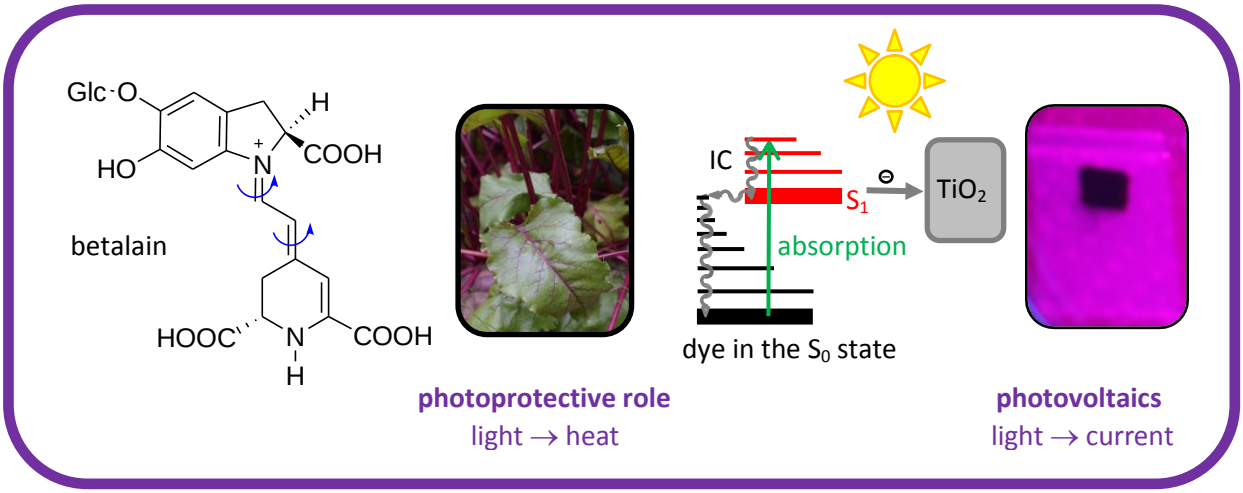

Figure 1. Betalains natural dyes exhibit a rapid (10^{11} s^{-1}) radiationless internal conversion IC as the main the S_1 excited state deactivation channel. IC plays a photoprotective role in biological systems, on the other hand, IC reduces the operating efficiency of the photovoltaic cells.

Betalains, besides their important biological functions in plants and fungi, are already commercially used as colorants in the food industry (10% of the market) and cosmetics. The dyes are known for the lack of toxicity and health benefits. The realized research project explains the mechanism of the sunscreening process in betalains at molecular level and reveals the detrimental photoinduced processes in betalain-based DSSC. The harvested knowledge opens up new possibilities for commercial use of betalains.