Abstract

Spectroscopic and structural studies of molecular organization of the pigment-protein complex LHCII in lipid environment

It is widely known that oxygen photosynthesis is one of the most important biochemical process on Earth. In the reaction of photosynthesis, energy of electromagnetic radiation is converted into energy of chemical bonds, which can be used by all living organisms. Moreover, the process of photosynthesis releases molecular oxygen into the atmosphere.

Photosynthetic pigment-protein complexes operate with exceptionally high quantum yield. In recent years, the view that not only primary processes of photoconversion are essential for high efficiency of photosynthesis, but also regulatory processes which adjust the number of excitations in rapidly changing light condition to the current energy demand of the photosynthetic apparatus, was established. Over the last decade, the processes of fast and reversible regulation, that are manifested by fluorescence quenching of dyes bound in photosynthetic complex, attracted particular attention. These phenomena are called non-photochemical quenching (NPQ). Several molecular mechanisms of action NPQ have been proposed so far, these rely mainly upon steric changes within the LHCII complex, enabling excitonic interaction between the dye bound in the complex or belonging to adjacent complexes (Holt et al. 2005; Horton et al. 2005; Pascal et al. 2005; Avital et al. 2006). These mechanisms can be both mutually exclusive and coexist with each other. A common feature of all regulation mechanisms is their activation in response to relatively high (in relation to the saturation level of photosynthesis) light intensity and the reversibility of the quenching process.

In the present study the results of research of the impact of LHCII complex phosphorylation on molecular organization of the lipid-protein membrane and excess

excitation quenching in these membrane will be presented. In the study lipid multi bilayers formed with chloroplast lipids, modified with non-phosphorylated (isolated from dark-adapted spinach leaves) and phosphorylated (isolated from pre-illuminated spinach leaves) LHCII complex, were used. Obtained lipid-protein multibilayers were used as a simple model of the thylakoid membrane system, appropriately under optimal illumination and stress light conditions. The results indicate that both form of the complex formed aggregated structures, characterized by different spectroscopic properties. The study showed that the process of protein phosphorylation and their reorganization in thylakoid membranes constitute regulatory mechanism of grana formation from single lipid-protein bilayers. The LHCII phosphorylation facilitates formation of the aggregated structures, capable of quenching of excess excitation in the process of non-radiative dissipation of excitation energy. Based on the results of the research the model of thylakoid membrane under optimal lighting and stress light conditions have been developed.

Studies of the effects of phosphorylation and the presence of xanthophyll cycle dyes on the molecular organization LHCII led to the conclusion that both zeaxanthin and the negatively charged phosphate groups bound to the complex lead to monomerization of a trimeric structure of LHCII. Because the phosphorylation and xanthophyll cycle depends on light intensity, it has been postulated that the process of monomerization of the LHCII can be one of the mechanisms regulating the excitation "density" in antenna complex system. This hypothesis is supported by research of spectroscopic properties of the LHCII trimers and monomers, which showed that the trimeric form of the complex is characterized by high efficiency of the electronic excitation energy transfer and is perfectly adapted to act as an antenna in the photosynthetic apparatus. The monomeric form of the complex is characterized by a higher efficiency of excitation energy dissipation, and a lower efficiency of intermolecular energy transfer of the electronic excitation.

Under physiological conditions, the photosynthetic apparatus of plants is exposed to rapid and substantial changes in light intensity. Effective adaptation to these changes ensures high efficiency of photosynthesis and protects the photosynthetic apparatus from damage due to photooxidation. The increase in the number of incident quanta, at low light intensities, also requires the mechanisms, which task is to adjust the density of the excitations to the capacity of the photosynthetic apparatus. In the described studies the molecular mechanisms that function *in vivo* in low light conditions, based on the reconstruction of the thylakoid grana and partial weakening of excitation energy transfer in photosynthetic antenna system will be

presented. This newly observed mechanism may play an important role in regulating the density of excitations in a system of the antenna complex in the thylakoid membranes of chloroplasts, at low light intensity.

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