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Editorial Open Access

Unusual Properties and Functions of Plant Pyruvate, Orthophospate Dikinase

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Editorial

The pyruvate, orthophosphate dikinase (PPDK, EC 2.7.9.1), crucial plant enzyme in the process of concentrating CO2 for Calvin cycle, catalyzes phosphoenolpyruvate-regeneration phase of the C4 photosynthetic pathway [1]. However plants possess also non-photosynthetic isoform of PPDK, which functions are less understood, probably due to its low abundance [2]. In all plants, PPDK is located in both cytoplasmic and plastidic compartments [3]. PPDK catalyzes the reversible ATP- and Pi- dependent formation of phosphoenolpyruvate from pyruvate [4,5].

The abundance and localization of PPDK can be controlled by elements within the promoter [6,7], while the activity is in addition to Mg^{2+} and temperature regulated by unusual PPDK regulatory protein (RP). This protein caused light/dark reversible regulation of chloroplast localized PPDK, in both C3 and C4 plants [6,8]. Its exceptionality lies in at least 3 points: i) RP is bifunctional, catalyzing both PPDK phosphorylation (inactivation) in dark and dephosphorylation (reactivation) in light, whereas these reactions are generally catalyzes by 2 different groups of enzymes, protein kinases and phosphates, respectively ii) the use of ADP instead of ATP as its phosphoryl donor and iii) utilization of an Pi-dependent, PPi-forming phosphorolytic dephosphorylation mechanism rather than the simple hydrolysis, which is employed by most protein phosphatase [8].

The photosynthetic function of C4 PPDK in chloroplasts of mesophyll cells is obvious; on the contrary various functions are suggested for non-photosynthetic PPDK of C3 plants. The tissues with the highest PPDK content in C3 plants appear to be seeds and mid-veins of leaves [7]. It is thought that in maturing seeds cytosolic PPDK is involved in amino acids inter-conversions and regulation between starch and storage protein accumulation, whereas in mid-veins of C3 plants in the provision of phosphoenolpyruvate to shikimate pathway [6]. Cytosolic PPDK in leaves of *Arabidopsis thaliana* plays an important role in the remobilization of amino acids during natural leaf senescence and thus in increase of seeds weight and N-content [7].

Our studies showed that PPDK could be also involved in stress defense responses [9-13]. The both, abiotic stress caused by drought [10] and biotic stress induced by viral infection [9,11] significantly increased PPDK activity in leaves of C3 tobacco plants. We suppose that PPDK in cooperation with phosphoenolpyruvate carboxylase, NAD-malate dehydrogenase and NADP-malic enzyme could participate in the conversion of NADH to NADPH, even at the expanse of ATP. But NADPH is indispensable coenzyme of antioxidant enzymes, enzymes involved in nitrogen assimilation and important compound for biosyntheses e.g. fatty acids or osmotically active compounds. All these features are helpful in conditions of stress [14]. In addition, the reverse reaction catalyzed by PPDK yielding ATP and Pi represents an obvious bioenergetic advance during stressful periods when mitochondrial ATP production via oxidative phosphorylation and photosynthesis may be limited or when the demands on ATP due to biosynthetic reactions are enhanced (as in case of stress) [10,15].

We also found that the PPDK activity could be affected by plant hormones cytokinins [13]. The PPDK activity was generally stimulated in transgenic rooted tobacco plants overproducing cytokinins (Pssu-ipt transgenic plants) and Pssu-ipt transgenic grafted plants compared with the control tobacco plants. Interestingly, during potyviral infection the activity of PPDK in Pssu-ipt transgenic plants was not significantly increased or the increase of the activity was smaller and started later than in infected non-transgenic controls. The transgenic plants showed lower virus accumulation and therefore lesser demand for the synthesis of viral proteins. It seems that high endogenous cytokinins content affects susceptibility to Potato virus Y, strain NTN. Tobacco plants overproducing cytokinins probably established pre-infection barrier prior to the infection that helped suppress or slow down the virus accumulation and symptoms development [13].

The presence of xenobiotics in soil, which are taken up by plant roots, can also act as a stressor and affect the plant metabolism. The anticonvulsant drug carbamazepine is considered as an indicator of sewage water pollution. Its metabolite 10,11-carbamazepine caused a moderate increase of the PPDK activity in leaves of both C3 plant sunflower and C4 plant maize. The increase of PPDK activity was more pronounced in maize roots. The presence of xenobiotics affected the metabolism of root enzymes, maize willingly extracted 10,11-carbamazepine from the soil, thus could be the plant with the potential to remove this metabolite [12].

Also other authors find out the relations of PPDK to stress, e.g. abscisic acid, all types of water stress including drought caused by polyethylene glycol, salt, submergence, low-oxygen stress and cold markedly induce PPDK [16-18].

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