Design and analysis of a reference model of sugar phosphate metabolism

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Abstract

Sugar phosphate metabolism (SPM), including the Calvin-Benson (CB) cycle, is the primary, highly regulated pathway in C₃-plants producing starch and sucrose from CO₂ via sugar phosphates and sugar nucleotides [1]. Understanding the interplay between regulation and efficiency of SPM requires development of mathematical models which would explain the observed dynamics of metabolic transformations. Here, we address this question by casting the existing models of SPM into one reference framework which not only facilitates comparison of different models, but also allows for studying the consequences of the included allosteric regulations.

The importance of the SPM for the increase of plant biomass has already resulted in 15 models with various level of detail. The existing models can be categorized into three classes: (1) describing only the fixation of CO₂ by Rubisco, (2) covering the three phases of the CB cycle, and (3) including both CB and sucrose/starch synthesis. They are either described via algebraic, differential, or differential-algebraic equations. In addition, one group of models describe the steady-state of the pathway, while the other could be used to obtain the dynamics of the metabolic profiles.

However, any attempt to compare these models is hindered by the different type of kinetic describing the reactions (e.g., mass action, Michaelis-Menten (MM), MM-like, and special forms) and various treatments of the allosteric regulations (e.g., metabolite- or enzyme-limited). To remedy this problem, we transform the 15 models into convenience kinetics which is based on MM and allows for a generic description of allosteric regulations while using thermodynamically independent system parameters [2]. In addition, we use the this formulation to choose a reference model which best approximates dynamic experimentally measured metabolic profiles [3].

References