Oxygen Consumption by Germinating Seeds

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Problem description

The following problem has been posed at the SWI-2013 (Study Group Mathematics With Industry) by the Fytagoras B.V. (Leiden):

“Seed germination in most seeds depends on the availability of oxygen. Living seeds start respiration upon imbibitions and respiration accelerates at the moment the germination really commences. The availability of oxygen to the embryo in the seed depends on the oxygen concentration around the seed, the respiration rate of the cells (in the embryo) and oxygen transport through the seed towards the cells of the embryo. Especially the transport through the seed is still a black box.

The problem consists of the development of a mathematical model for the oxygen transport and consumption within the seed that fits to the current biological knowledge on these processes and the available highly detailed time-resolved oxygen consumption measurements for single seeds of which various samples will be made available to the study group team. The model should allow starting to interpret the observed data and characteristics in terms of the functioning of internal oxygen transport processes and overall seed properties or to provide hypotheses on these that may be validated in future research.”

Approach

The experimental curves of oxygen consumption by germinating seeds of different plant species provided by Fytagoras B.V. all have a very characteristic ‘sigma’ shape that indicates a universal underlying mechanism largely independent of the seed morphology. The goal of this BSc Project is to test the hypothesis that the respiration is governed by the logistic equation that seems to fit the experimental data perfectly.

The student has to consider several relevant biological and physical processes and find suitable approximations. These processes are: the replication of the mitochondria where the population doubles during the division time, the corresponding decrease of the oxygen level as a result of chemical reaction, the diffusion of oxygen through the cell membrane and its relation to the replication rate. Taken together these processes should lead to the logistic equation with biologically meaningful parameters that could be determined by fitting the analytical solution of the logistic equation to the available experimental data.