Determining the minimum temperature at which bacterial cells could grow

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Abstract

Microbial cells in activated sludge wastewater treatment system could grow at 16 ^{o}C in temperate climes, which suggests the tenacity in which life could subsist and grow at temperatures much below the optimal. Temperature controls enzyme kinetics by providing the necessary energy to overcome the activation energy barrier during product formation mediated by an enzyme. Generally, below the denaturation temperature, higher temperatures tend to drive faster enzymatic activities; thereby, resulting in better growth performance. But, what is the minimum temperature at which a bacterial cell could grow? This question could be accessed from the experimental perspective through progressive use of lower incubator temperature and concomitant observation of cell growth response. But, could we approach the problem from the theoretical perspective supported perhaps by simulation tools? What does it take to simulate enzymatic activities that support cell growth using a whole cell computational model? What are the biophysical and biochemical parameters needed to constraint the model? Using a bottom up approach, one could define a solution methodology through first selecting biochemical reactions that support cell growth and biomass formation. This represents the core set of metabolic reactions needed for a biophysical simulation of how temperature influence cell growth. Subsequently, the temperature dependent activity level of the enzymes could be added to the model. However, difficulty exists in obtaining accurate thermophysical properties of enzymes given the need to obtain accurate temperature-activity relationships through the experimental approach and the relative lack of theoretical predictions in this regard. Assuming that accurate or good approximations of the temperature-activity relationship of individual enzymes in the core metabolic set could be obtained, one could subsequently move towards using a systems approach to probe how prevailing temperature in the cell's external environment influence enzymatic activity and cell growth response. Noting that extracellular environment temperature does not necessarily imply the internal cellular milieu is at a similar temperature, the simulation runs could help address two important questions. First, what is the set of enzymes that could not function at a particular low temperature? Secondly, are there cross-interaction effects between different enzymes at a particular temperature? Answers to these questions also hold implications on how evolution has shaped the temperature dependence of different enzymes, particularly those in central carbon metabolism. With readouts from metabolites produced, the simulation models should be able to arrive at the minimum temperature that supports cell growth. This endeavour at modelling the growth response of cells to different temperatures could hopefully inform us of our gaps in understanding at the biophysical and thermodynamics level, and maybe help recalibrate our best models for the task.

Keywords: growth response, bacteria, temperature-activity relationship, whole cell simulation, systems approach, thermodynamics,

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Conflicts of interest

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