TECHNISCHE UNIVERSITÄT DRESDEN

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A structured growth model for hairy roots of beetroot (*Beta vulgaris*)

Modelling and simulation of growth processes in plant cell tissue cultures

Secondary metabolites produced by plant *in vitro* cultures such as *Betanin* (red-dye in beetroot) are nowadays in the main focus within the branch of White Biotechnology. Cells genetically altered using *Agrobacterium rhizogenes* form hairy roots which can be cultivated in hormone free media in modern bioreactors.

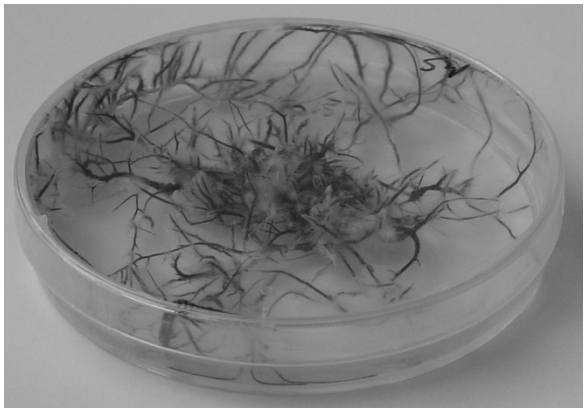


Fig. 1 Hairy roots of beetroot on agar-plate

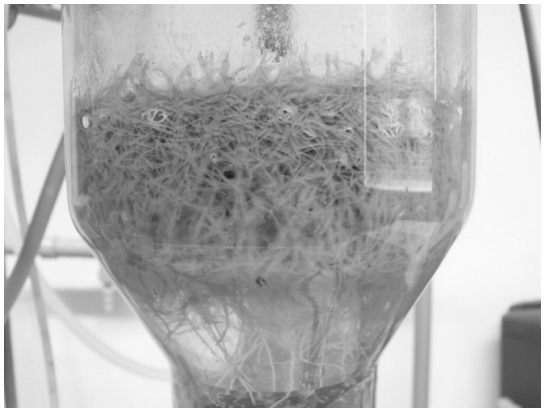


Fig. 2 Hairy root in bubble column bioreactor

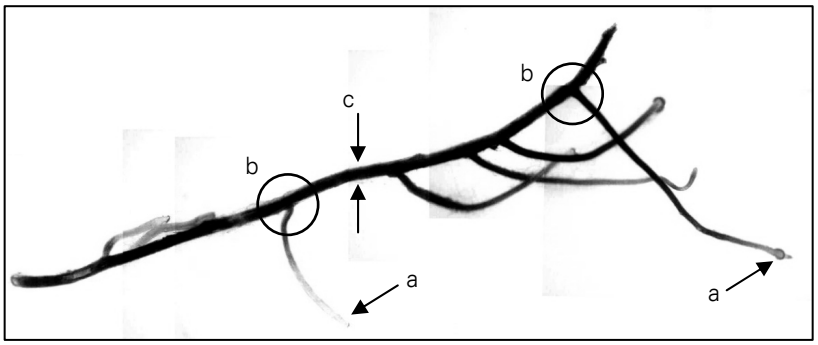
In order to improve the cultivation process (higher yield, shorter cultivation time) and the bioreactor design (bubble column and stirred reactors) a structured growth model with consequent simulations and visualization is necessary. While the growth of these tissue cultures on agar plates, in shaking flasks or bioreactors for industrial use has been heavily investigated experimentally only limited theoretical descriptions of the growth processes exist.

The gained knowledge can be used by other scientists to improve their cultivation protocols and to simulate growth of their own cultures by amending the parameters of the model.

Model construction

Hairy roots of beetroot (*Beta vulgaris*) have been chosen for modeling the growth morphology of hairy roots also with respect to the distribution of secondary metabolites such as the red dye *Betanin*. A matrix based approach is used for the proposed model which consists of a 2-dimensional model matrix for agar plates containing information about the condition of each cell forming the organ complex. Conditions are position, age, nutrient concentration inside the cell as well as concentration of secondary metabolites. A second matrix contains nutrient concentrations such as carbon source and oxygen in the media.

Parameters describing the growth dynamics of e.g. branching and tip movement have to be characterized systemically with appropriate experiments. Photos of *in vitro* cultures are treated with a semi-automatic picture recognition the measures distances and occurrences. Variation of experimental parameters and a sufficient number of experiments guarantee statistical significance.



a : elongation

b : branching

c : secondary thickening

Fig. 3 Hairy root complex prepared for automatic pattern recognition

Growth process simulation

The simulation process begins with a given start state of a small organ complex which is recalculated recursively for a defined time step. The growth processes involved such as elongation and branching through cell division as well as secondary thickening of already existing cells are described using differential equations. After each growth step the organ matrix and the nutrient matrix with the involved diffusion processes are calculated using partial differential equations (PDE). The newly formed matrices are used for the next calculation step.

Experimental comparison

Experimental results of cultivations of *B. vulgaris* are compared with the results of simulations.

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