agropolis fondation

3D virtual tomato fruit

3D Virtual fruit - Application for the control of fruit growth and quality

ABSTRACT

The architectural properties of a fruit, such as its size, shape, internal structure (number of carpels) and pattern of vasculature, are remarkably diverse among species and varieties and may have a significant impact on the distribution of water and carbon inside the fruit. The aim of the project was to investigate the effects of fruit architectural properties on fruit quality by means of a 3D functional-structural fruit model.
To construct this generic functional-structural fruit model, we developed a modelling pipeline in the OpenAlea platform that involves three steps: (a) creating a 3D volumetric mesh representation of the internal and external fruit structure, (b) generating a complex network of vasculature that is embedded within this mesh, and (c) integrating aspects of the fruit's function, such as water and carbon transport, with the fruit's structure. Magnetic Resonance Imaging data collected on a cherry tomato fruit were used as input for generating the internal and external fruit geometry (it is also possible to use polyhedral surfaces models from images of fruit slices to make models of fleshy fruit).
The model describes the late phase of fruit development when fruit growth is mostly due to cell expansion and it predicts the change in fresh weight and dry weight of the different tissues over time, as well as the sugar concentration heterogeneity within the pericarp tissue. This model is generic and unique since it allows generating a 3D volumetric representation of fruit architecture, including the external shape and internal structure. To generate the geometry of the large tissues, such as the pericarp, the reconstruction algorithm uses Delaunay refinement that produces high quality tetrahedral meshes from 3D image data, where each tetrahedron is labelled according to the part of the fruit tissue it represents. To generate the geometry of the vascular tissue, we used an algorithmic approach based on the assumption that vascular bundles are competing for space within the fruit. The transport of water and carbon through the vasculature is based on the hypothesis of osmotically driven bulk flow, where a hydrostatic pressure gradient (due to differences in local sugar concentrations) drives the flow of water and carbon between regions of sugar loading and unloading.
Finally, the 3D-model has been evaluated against experimental data on tomato and peach fruit.

Keywords : Plant, Ecophysio/architecture/phenotyping, Fruit quality, Growth, Model, Tomato

Year : 2008
Project number : 0803-027
Type of funding : AAP
Project type : AAP INRIA
Research units in the network :
Start date : 2009-01-01
End date : 2012-12-31
Flagship project : no

Project leader : Nadia Bertin Christophe Godin
Project leader's institution : INRA-INRAE
Project leader's RU : PSH AGAP

Budget allocated : 159242.93 €
Total budget allocated (including co-financing) : 218141 €
Funding : RTRA

PERSPECTIVES

Our perspectives are to apply the functional-structural model to analyse the impacts of fruit architectural properties on the distributions of water and carbohydrates within the fruit in relation to exogenous factors like temperature and humidity or nutrient supply. For instance it will be possible to investigate the role of asymmetric vascular structure and decreased density in some parts of the fruit on the occurrence of Blossom End Rot related to calcium deficiency in tomato fruit. In peach, we will investigate the role of micro-cracks occurring at the fruit surface during growth, on the distribution of sugars within the flesh.

At the moment, no mechanical constraints on the growth of the tissues have been taken into account. This should be done in frame of a new project entitled MECAFruit3D.
Another example is the role of the vascular patterns in tomato fruit (Solanum lycopersicum) in causing the calcium-deficiency disorder blossom end rot (BER), which is associated with reduced calcium transport to the apical end of the fruit via xylem vessels.
At the moment, no mechanical constraints on the growth of the tissues have been taken into account. This should be done in frame of a new project entitled MECAFruit3D.