INTERFACIAL MASS TRANSFER IN DEFORMABLE PLANT TISSUES

Lukas Eurich*, Arndt Wagner and Wolfgang Ehlers

Institute of Applied Mechanics, University of Stuttgart,
Pfaffenwaldring 7, 70569 Stuttgart, Germany
{Lukas.Eurich; Arndt.Wagner; Wolfgang.Ehlers}@mechbau.uni-stuttgart.de
www.mechbau.uni-stuttgart.de/ls2

Key Words: *Phase transitions, multiscale porosity, interfacial areas, Theory of Porous Media, coupled problems, plant biomechanics*

Plant tissues have developed several strategies to cope with multiple cycles of freezing and thawing events without being damaged. Understanding the involved strategies and mechanisms of plants exposed to frost conditions is of high interest, as they could potentially be used for the development of bio-inspired construction materials with optimised properties in terms of frost resistance, thermal isolation and guided water/moisture transport [1].

It has been frequently observed that ice formation in plant tissues occurs at species-specific and tissue-specific locations in the intercellular space, where freezing is not critical for the survivability of the plant. Inter- and intracellular water flows towards these preferred locations leading to a dehydration of the tissue cells, which prevents them from damage. For this water management, properties of the plant's microstructure are essential, which are arising from the anisotropic and inhomogeneous arrangement of the tissues cells [2].

Since the involved thermo-hydro-mechanical processes in plant tissues upon freezing and thawing cycles are strongly coupled, a modelling approach based on the Theory of Porous Media (TPM) is applied, which describes the multiphasic and multicomponent aggregate on the macroscale. In particular, a quaternary model is introduced with a solid skeleton (composed of the tissues cells) and two fluids in the intercellular space, namely, gaseous air and liquid water, which may turn into solid ice. The phase transition of the intercellular water occurs at a singular surface, which is characterised by a jump in physical quantities, such as the density [3]. The mass transfer can be formulated by using the energy jump at this interface leading to a thermodynamically consistent formulation. However, for the inclusion of the mass transfer into the respective mass balances, the surface-specific mass interaction needs to be transferred into a volume-specific quantity. Therefore, the consideration of the plant's pore-space geometry is crucial for the derivation of the liquid-solid interfacial areas, which depend on the volume fractions of the involved phases in the pore space. This contribution aims, in particular, to introduce a biologically motivated formulation for these interfacial areas. Furthermore, the pore water freezing leads also to the necessity to consider the compaction point in the material description, as the bulk material may undergo a transition from a porous to a non-porous material. Finally, the water management is taken into account by a Darcy law considering the partial saturation in the pore space and microstructural properties via spatially varying anisotropic permeability conditions.

REFERENCES

[1] L. Eurich, R. Schott, A. Wagner, A. Roth-Nebelsick and W. Ehlers, Proc. Appl. Math. Mech. **16**, 81-82 (2016).
[2] M. Mc Cully, M. Canny and C. Huang, Ann. Bot. **94**, 665-674 (2004).
[3] W. Ehlers & K. Häberle, Transp. Porous Med. **114**, 525-556 (2016).