Using synchrotron radiation-based X-ray microtomography (SRµCT) to analyze poplar wood grown under abiotic stress

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Softwood is a variform tissue complex composed of different cell types such as tracheids, fibres, vessels and parenchyma cells, that each fulfil specific tasks within the woody body of a tree. However, even within a tree genus wood structure can differ significantly due to either biotic or abiotic stress factors occurring during the growth season, or due to cultivar specific growth characteristics. Accordingly, reduced vessel size but increased vessel density has been detected in poplar wood grown under salt stress [1, 2, 3]. This is of special interest because the vessel system in broadleaf trees is responsible for water transport from roots to shoots and, hence, has significant impact on tree physiology.

In our investigations at DESY, we therefore applied SRµCT operated by HZG at the BW2 Beamline of the HASYLAB for characterization of small wood samples (Populus trichocarpa) grown under different saline conditions; thus we got a three-dimensional image of a small-scale sample, allowing in a non-destructive way to visualize size, volume, form and interconnectivity of the cells on a microstructural level. The samples were analysed using the photon energy of 9 keV. The effective pixel size in the data set is 3.26 µm. The total scan volume consists of 1536*1536*1023 voxel representing a volume of 5.0*5.0*3.3 mm³.

Using VGL StudioMAX as imaging software (Volume Graphics GmbH, Heidelberg, Germany), different cell types of the poplar wood sample could be visualized and emphasized. Particularly the water conducting vessels in the woody tissue represent the interconnectivity of water transporting vessel network in a 3D manner. Even though only a small section of the total sample volume is presented here, previous results of smaller vessel lumen areas in wood grown under salinity (Fig. 1, right) could be visually confirmed by the 3D image when compared to control samples (Fig. 1, left). Only a small section of the total sample volume is visualized.

Figure 1: SRµCT allows 3D analysis of a poplar wood sample. Different cell types can be visualized and emphasized. Interconnectivity of water transporting vessels (red) can be visualized over several millimetres in longitudinal direction. Vessel-interconnectivity appears to be reduced under salinity (right) compared to control wood (left). Only a small section of the total sample volume is visualized.
Also, the voxel data analysis leads to the impression that the vessel-grouping and interconnectivity was reduced under the influence of salt stress. In a second approach, we therefore focussed on further identification of this particular area of interest (Fig. 2).

Figure 2: SRμCT allows 3D analysis of vessel-fiber-interconnectivity within the cell wall material displayed in grey (left). Inversion of the cell wall material in favor of the lumen area reveals possible radial and tangential exchange points for water from the vessel lumina (VL) into fiber lumina (FL) or into parenchyma cells.

Especially when inverting the cell wall material in favour of the lumen-area of vessels and adjacent fibers, multiple contacts via pits emerge (Fig. 2, right), conveying a radial water network system in the stem. This is of special interest since such connections are a key factor for water availability of trees grown under environmental stress conditions because they allow water movement from fibers to transporting vessels.

In conclusion, as already pointed out in previous investigations [4], SRμCT is a great tool for visualization of connectivity and form of different cell types within a wood sample. Dependent on initial sample size, high resolution of the microstructure could be achievable. The technique is promising to calculate volumes, e.g. of water transported in vessels. Since it is possible to reconstruct the vessel network of a stem section, effects of wounding or other environmental stresses on the xylem structure in general, and particularly on the water transport system, can be detected and visualized in 3D by synchrotron radiation-based X-ray microtomography.

References