Rearrangement of Primary Cell Wall Polymers during Mechanical Stretch


Plant cells grow by the loosening of their primary cell walls and expanding from turgor. Therefore, characterization of how cell wall polymers respond to mechanical strain will aid our understanding of plant growth. This is also the foundation for the development of plant biomass-derived materials. The primary cell wall consists of semi-crystalline cellulose microfibrils embedded in a matrix of pectin and hemicellulose and is organized in a cross-lamellate structure. The interactions between these components play important roles in the mechanical properties of the wall. Onion outer epidermal peel, a model system for primary cell wall, was excised into 7 μm thick strips amenable for mechanical testing, microscopy, and X-ray scattering.

We have developed a method to stretch onion epidermal wall to various levels of strain and examine both reversible and irreversible structural change of wall polymer architecture. Atomic force microscopy revealed reversible reorientation and straightening of cellulose microfibrils in the innermost lamellae of onion epidermal wall. Cellulose microfibrils which were initially approximately oriented longitudinally are straightened and realigned towards the direction of the stretch, while microfibrils which were initially approximately oriented transversely became kinked. Small-angle X-ray scattering revealed overall reorientation of cellulose microfibrils, a part of which appear irreversible at high strains. A prominent scattering feature at high strains indicated that cellulose microfibrils packed together with a center-to-center spacing of 7.4 nm, which become absent after we partially removed the pectin matrix. We hypothesize that matrix polymers, most notably pectin, fill up this space and prevent the microfibrils from fully collapsing onto each other. In addition, wide-angle X-ray scattering showed extension of crystalline cellulose microfibrils upon high macroscale strain. Overall, these observations will shed light on the structure-mechanical property relationships of cell wall polymers and refine our models of cell wall microstructure.