MULTISCALE STRUCTURAL CHARACTERIZATION OF EPIDERMAL CELL WALLS DURING MECHANICAL STRETCH

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Abstract: Highly extensible epidermal cell walls limit cell growth and enable plants to comply with external loads such as wind and accumulated snow. Seeking to uncover the molecular mechanisms of wall's high extensibility and strength, we stretched onion epidermal walls uniaxially to various strains and characterized their structures from mesoscale to atomic scale. The rearranged wall structures were fixed by dehydration under tension and the reversibility of molecular rearrangement was examined by drying after relaxation following stretching. Upon deformation at high strain, epidermal walls extended longitudinally and shrank transversely. Atomic force microscopy revealed that cellulose microfibril movements at high strain depend on microfibril orientation. Longitudinally aligned microfibrils straightened out and became highly ordered, while transversely aligned microfibrils became curved and kinked. Small-angle X-ray scattering of walls at high strain revealed a 7.4 nm spacing aligned along the stretch direction, which we attribute to ~4 nm spacing between individual cellulose microfibrils. Furthermore, wide-angle X-ray scattering at high strain revealed widening of (004) lattice spacing and contraction of (200) lattice spacing in longitudinally aligned cellulose microfibrils, which implies longitudinal stretching of the cellulose crystal. These findings provide molecular insights into the wall's ability to bear more load beyond the yield point: aggregation of longitudinal microfibrils impedes microfibril sliding and enables further stretching of cellulose microfibrils to bear increased loads.