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## Multiscale NMR analysis of apple thermal denaturation

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Microstructure evolution of foods during cooking is difficult to assess because of the need of sensitive non destructive technique. To study such phenomena in apple, we undertook MRI, quantitative NMR and mechanical experiments at key temperatures of the cooking process (45, 50, 53, 60 and 70°C). MRI measurements were performed at 9.4 T with a 30mm diameter <sup>1</sup>H volume coil. We acquired 10 SE images at different TE (4.5 to 200ms), with a single echo per acquisition for preventing refocusing errors (TR=3000ms, voxel vol. 1mm<sup>3</sup> isotropic, duration 32min) to map T2 assuming a monoexponential decrease. NMR CPMG acquisitions, 90°x-[τ-180°y-τ-(echo)]<sub>n</sub>, were also carried out (τ=500μs and n=128). Data were fitted using non-negative least squares algorithm fed with a decomposition basis made of 200 T2 logarithmically-spaced from 1ms to 1000ms. In parallel, we performed puncture tests with a 2mm diameter flat end needle descending at 1mm/min until the strain reached 70%. Both T2 maps and quantitative NMR show a dramatic change in T2 values between raw and cooked parenchyma at a transition temperature of around 50°C. This change can be interpreted by the filling of pores after thermal permeabilization of the cell membranes. The effective T2 obtained by imaging is sensitive to internal magnetic field gradients, due to susceptibility differences (Van As et al., 1997). Then, this T2 is shorter than the CPMG's bulk T2 in the porous material (before 50°C) and it dramatically increases when the pores are filled. The resistance to a mechanical stress also displays a sharp decrease, for a slightly higher temperature of 53°C. This temperature shift supports the hypothesis of a complex thermal denaturation of the plasmalemma, first releasing vacuolar water before being structurally affected (Bourles et al., 2009). This work emphasizes the interest of multiscale relaxation studies for studying thermal denaturation of food products. CPMG allows resolving multiple T2 compartments in the whole sample whereas imaging is sensitive to heterogeneities.

### References

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