From in situ quantitative MRI to modeling the structural changes of meat during heating

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From *in-situ* quantitative MRI to modeling the structural changes of meat during heating

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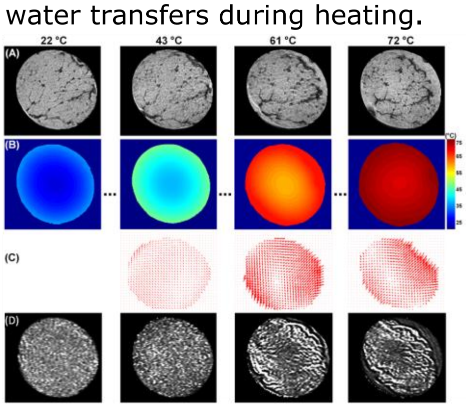
Modelling the effects of heating is vital to optimise the quality of cooked meats. The advantage of building a model on the basis of *in situ* measurements is that it relies on neither reductionist hypotheses by studying an intact sample at the scale of the food consumed, nor on simplified hypotheses by taking into account spatial variations in the sample. We present a novel MRI-compatible device that heats the meat sample via a fluid (20 to 75 °C) and a strategy based on dynamic images acquisition at 4.7T during heating and thermal numerical simulation that simultaneously maps deformation (1), proton density (PD) and temperature (2). The deformation field at temperature t_i was calculated from the geometrical transformation required to pass from the images showing muscle internal structural markers obtained at $t_{(i-1)}$ to that obtained at t_i (1). PD measurement consisted of two spin-echo acquisitions that differed only in their echo times. A fast MRI protocol was used (2) since a long TR was necessary to mitigate T_1 dependence. Also, experimental mapping of B_1 was preferred to numerical simulations in order to unbias PD maps (2, 3), since B_1 distribution depends on unknown and evolving factors. The figure shows: deformation fields (C) derived from T_2*-weighted images (A), temperature maps (B) and PD maps (D), at 4 temperatures. T_2*-weighted images show internal fiducial markers despite the loss of SNR with temperature. Temperature is almost radial and leads to the spatial variation of both deformation and PD. Deformation increases with temperature and accelerates over 58°C due to sarcoplasmic protein denaturation and collagen contraction. Water is then expelled to the exterior of the sample. Lines (C) and (D) show that the most deformed zones are those where PD is highest. The pressure in the muscle increases due to muscle contractions, causing water to transfer towards the exterior. Moreover, the temperature is higher at the superficial area of the sample, leading to the creation of interfascicular channels that can "trap" the migrating water. Finally average models were constructed from local information provided by maps. These models link deformation, proton density and temperature, and provide new information about the underlying mechanisms of meat deformation and water transfers during heating.



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