Real-time assessment of the internal porous structure of cereal materials under high-moisture conditions using 3D MRI and XRT

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Ingress of bulk water into porous cereal material causes hydration of the solid matrix accompanied by saturation and swelling of the material. Maintaining crispiness under high-moisture conditions for a certain time is an important feature in terms of consumer perception. Normally macroscopic techniques are used to evaluate crispiness, however these does not provide information about heterogeneity of internal structure changes.

Magnetic Resonance Imaging (MRI) which is ideally suited for non-invasive imaging of water as well as water mobilised tissue has found a broad range of applications in different areas, including more recently food science. Appropriate choice of the MRI measurement methods allows the real time visualisation of the effect of hydration in terms of rate and space distribution of structural changes. X-ray Tomography (XRT) on the other hand allows for high resolution 3D visualisation and characterisation (e.g. porosity assessment) of the non-hydrated material before and after certain durations of hydration.

The aim of this work was to use MRI to visualise and quantify in real-time the structural changes of the carbohydrate matrix (i.e. swelling) caused by ingress of water and correlate these with structural information from XRT. For this purpose both model and prototype food systems, comprising of phases with contrasting water activity (A_w) were used.

To accomplish this work, a RARE measurement method, adapted to the migration rate (time resolution 3.5 min. or better), was used to monitor water redistribution in prototype food systems (i.e. soup inclusions in water) at 25 °C and 60 °C. The obtained 3D images with submillimeter resolution allowed the visualisation of the time dependence of the spatial redistribution of moisture, which meant that quantification of the pace of water migration and the extent of matrix swelling could be assessed.

In order to understand more fully the role of different water transport mechanisms in carbohydrate matrix structure alteration, a model system composed of a hydrated gel phase (A_w > 0.9) in contact with an initially reasonably dry (A_w ~0.3) cereal based solid matrix with 3 different porosities, were monitored for 3 days. To properly assess the time dependence of the spatial distribution of the water ingress, the SPI measurement method was used, which allows the visualisation of low and high hydration regimes in various materials. Swelling of the carbohydrate matrix as well as progress of moisture migration through the gas phase were visualised, quantified and correlated with the structural information obtained from XRT measurements.

The obtained results demonstrate the potential of the application of the combined MRI/XRT approach to monitor the migration of moisture and accompanying structural changes related to hydration, within porous carbohydrate matrices. The measured migration rates for the model samples with different porosity can be used to predict water redistribution in multiple phase systems in a quantitative manner.

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