

The challenge to get MRI metabolic maps in fleshy fruit: tomato example

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Fruits are complex organs consisting in different tissues for which the development and metabolism are coordinated. In fleshy fruits, the properties of the different tissues change along fruit development including their microstructure, juiciness and biochemical composition. It is then critical to have a method providing spatial information about these properties non-destructively.

MRI is a tool of choice to non-invasively obtain an image. To obtain a metabolic map, two approaches can be used: magnetic resonance spectroscopic imaging (MRSI) or chemical exchange saturation transfer (CEST) MRI. We compare both methods in red-ripe tomato fruit as a model of fleshy fruit.

Materials and Methods

Moneymaker variety tomatoes were studied at red-ripe stage.

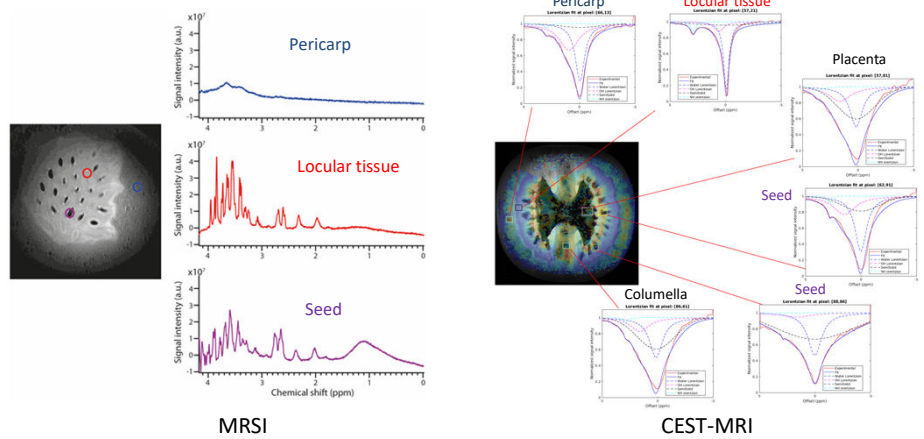
MRI acquisitions were performed on a 11.7-T Bruker Biospec equipped with a 72-mm circular polarizer coil and piloted by ParaVision 6.0.1. The MRSI acquisitions were performed with a semi-LASER volume selection and processed thanks to the software CSIapo [1]. Concerning the CEST acquisitions, first a WASSR experiment was performed to obtain a B_0 -map then the CEST contrasted image. The saturation conditions for the CEST acquisitions were a duration of 1 s at a power of 5 μ T and 51 offsets between - and + 5 ppm to obtain the so-called z-spectrum. Data were analyzed thanks to a home-made program written in MATLAB. For more details on the experimental conditions, see [2].

Results

1. MRSI vs CEST-MRI

The figure on the right demonstrates that the magnetic field inhomogeneity has deleterious effects on both MRSI and CEST-MRI. On MRSI, we can note significantly different NMR spectrum quality depending on the spatial position, while on CEST-MRI this is seen by the broadness of the water direct saturation signal centered at 0 ppm which differs according to the tissue.

While such quality variability is an issue for MRSI, it can be tackled in CEST-MRI by adjusting the z-spectrum on each voxel.



2. z-Spectra adjustments

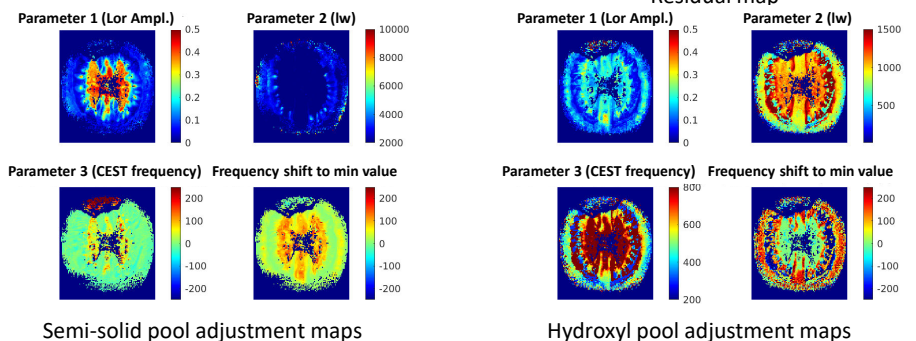
Adjustments were performed by considering a 4-pool model: water, hydroxyl and amino moieties as well as a semi-solid pool. This pool was mandatory to explain both the broadness of the central attenuation and the strong attenuation observed on some voxels at 5 ppm.

The water and metabolite pools were simulated using a Lorentzian shape (Eq. 1) while the semi-solid using a Gaussian one (Eq. 2) [3].

$$\text{Eq. 1: } A_i \left[\frac{1}{1 + \left(\frac{\omega - w_{ref,i}}{lw_i} \right)^2} \right]$$

$$\text{Eq. 2: } A_{SS} e^{-\ln(2) * \left(\frac{\omega - w_{ref,SS}}{lw_{SS}} \right)^2}$$

The maps show the quality of the adjustments. The residual map demonstrates a similar level of residual on all voxels. The 2 sets of 4 maps show the adjustment of the different parameters (parameters 1 to 3). The Lorentzian (or Gaussian) amplitude (parameter 1) is used to quantify the CEST effect.



Conclusions

We demonstrated the difficulty to perform metabolic MRI on tomatoes due to the variation of the magnetic field within the fruit. While this prohibits to run MRSI acquisitions, it can be tackled on CEST-MRI images by implementing an adjustment-based processing. Indeed, due to the change in the general exchange conditions, the simplest CEST analysis approaches (MTR_{asyM} , MTC_{mm}) cannot be used.

[1] Y. Le Fur, F. Nicoli, M. Guye, S. Confort-Gouny, P.J. Cozzone, F. Kober, Magn. Reson. Mat. Phys. Biol. Med. 23 (2010) 23-30.

[2] G. Pagés, C. Deborde, M. Lemaire-Chamley, A. Moing, J.-M. Bonny, Anal. Bioanal. Chem. 413 (2021) 1251-1257.

[3] R.M. Henkelman, X. Huang, Q.-S. Xiang, G.J. Stanisz, S.D. Swanson, M.J. Bronskill, Magn. Reson. Med. 29 (1993) 759-766.