Plants: A new application field for Chemical Exchange Saturation Transfer (CEST)

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Introduction: Chemical Shift Imaging (CSI) enables the *in vivo* detection of metabolites in living plant tissues (1). However, it can be challenging due to magnetic field inhomogeneities often occurring inside plants. Therefore, we applied Chemical Exchange Saturation Transfer (CEST) to plants (2). The CEST contrast arises from low-concentrated metabolites containing exchangeable protons. In this abstract we want to demonstrate the potential of CEST by showing exemplary results of measurements of barley and potatoes.

Methods: MR measurements were performed on a 9.4 T (barley grain) and 11.7 T (potato) MR scanner. We conducted CEST experiments in the range from ±5 ppm to detect the exchanging protons of the hydroxyl (at around 1 ppm) and the amino group (3 ppm). Even small saturations, such as a single block pulse of 200 ms duration and 2 µT amplitude, provided sufficient CEST contrast. For read-out a 2D spin echo sequence (RARE) was used. Before calculating the asymmetry spectra MRTasy, Z-spectra were B_0 corrected. CEST sugar (amino acid) maps were generated by integrating over the 1 ppm (3 ppm) peak in the asymmetry spectrum.

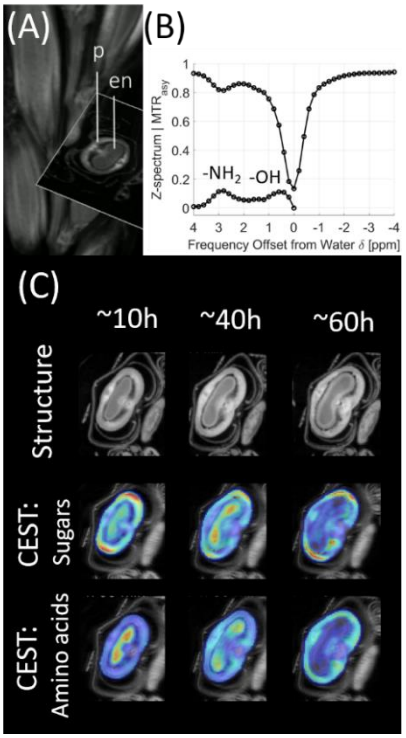

Fig. 1: (A) 3D images of a barley ear, showing position of the examined slice. p: pericarp, e: endosperm. (B) CEST spectrum from endosperm. (C) CEST-MTR$_{asy}$ maps during feeding of barley caryopsis.

Results and discussion: Both, sugars and amino acids, could be detected in the endosperm of barley grains by CEST (see Fig.1B). The endosperm of barley is shaped in two symmetrical wings, and the CEST spectra in these wings matched perfectly. Whereas in a separate CSI measurement (not shown) the NMR spectra varied due to T2* inhomogeneities. So, the decreased sensitivity to field inhomogeneities of CEST is an important advantage over CSI. In the following, the growing barley grain (attached to an intact ear) was monitored via CEST, showing the accumulation and decrease of sugar and amino acids (see Fig. 1C).

The applicability of CEST to much larger samples could be demonstrated: In our experiment with potato, CEST showed the distributions of sugars and amino acids within the tubers, whereby clear differences between varieties could be detected (Fig.2). So, it was shown that CEST is a versatile tool for the detection of sugars and amino acids in biological samples, whether small caryopses or larger sink organs. Monitoring dynamic growing processes is an interesting application where CEST-MRI provides new insight into the inner workings of intact plant tissues.

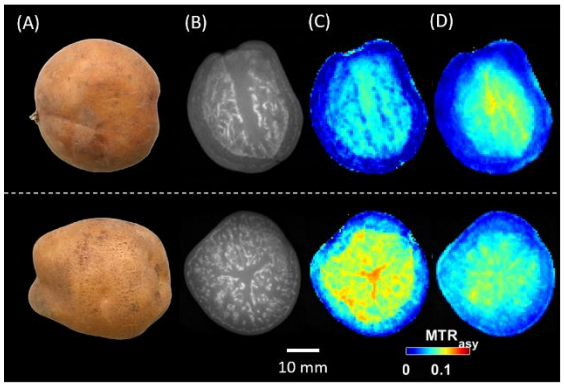

Fig. 2: CEST-MTRasy image for potato: (A) photograph of variety Ovalgelbe (top) and Flora (bottom), (B) structural MRI, (C) CEST-MTRasy image for sugars and (D) for amino acids.

Conclusion: We believe that CEST-MRI is a promising tool for plant examination and should be further explored in future research.

References: [1] Borisjuk et al., New Phytol. 238 (2023) 1775-1794. [2] Mayer et al., Sci.Adv.10, (2024) [3] Kim, et al.: Magn Reson Med (2009).