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Magnetic Resonance Imaging for short relaxation times applied to seed evaluation

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According to an analysis conducted by the Center for Advanced Studies in Applied Economics (Cepea) at ESALQ/USP, in partnership with the Confederation of Agriculture and Livestock of Brazil (CNA), the agricultural sector plays a crucial role in the Brazilian economy. In 2021, the Gross Domestic Product (GDP) of Brazilian agriculture experienced a growth of 8.36%. (1) This increase represents a significant share of 27.4% of the total Brazilian GDP. Furthermore, statistics collected by the Brazilian Association of Seeds and Seedlings (Abrasem) reveal that Brazil holds the top position in the global ranking of soybean seed production. The quality of seeds is a critical factor that significantly influences crop development and directly impacts productivity levels. Current seed evaluation methods, such as the tetrazolium test, the germination test and the utilization of X-ray images, still do not provide accurate and non-destructive identification of lesions in the early stages of the process. Therefore, Magnetic Resonance Imaging (MRI) has been proposed to evaluate seed injuries, allowing observing internal structures on a three-dimensional scale. While MRI is commonly used for imaging soft tissues, its application to hard tissues with low water content, such as bones, teeth, and seeds, remains challenging. In these cases, the water content is typically confined to a solid phase, i.e water interacting with biological tissue or confined in a porous system, which reduces its mobility and results in a relaxation profile with short or ultra-short relaxation times (i.e., T_2 0.1 - 10 ms). Producing images of samples with very short transverse relaxation time depends on the acquisition and encoding of the signal done very quickly after excitation and before the signal decay in the transverse plane. The challenge in this implementation lies in the existence of an intrinsic hardware delay time, also known as dead time, required to switch between the two operating modes of a radio frequency transmit/receive. (2) Some techniques were developed in an attempt to overcome these limitations and produce high-resolution images for samples with short transverse relaxation time, among them: Fast Low Angle Shot (FLASH), Zero Echo Time (ZTE), Ultra-short Echo Time (UTE) and Sweep imaging with Fourier transformation (SWIFT). Results obtained previously in (3) demonstrated that the transverse relaxation time of a healthy soybean seed falls within the range of 0.1 - 10 ms. Moreover, images of various seed types were obtained using FLASH, ZTE, and a modified variation of ZTE with the addition of a magnetization transfer pulse. This research project aims to investigate the application of MRI and image segmentation techniques for evaluating mechanical injuries and damage inflicted on seeds by insects during field or storage conditions. The approach to achieve this objective will involve utilizing various NMR methods and imaging segmentation techniques. Additionally, the implementation of these NMR methods will be carried out using two spectrometers: Bruker and the Digital Magnetic Spectrometer (DMRS) developed by Centro de Imagens e Espectroscopia por Ressonância Magnética (CIERMag).

Palavras-chave: Magnetic resonance. Short relaxation times. Seeds.

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