Accepted Manuscript

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PII:	S0260-8774(18)30092-X
DOI:	10.1016/j.jfoodeng.2018.03.002
Reference:	JFOE 9186
To appear in:	*Journal of Food Engineering*
Received Date:	21 September 2017
Revised Date:	02 March 2018
Accepted Date:	04 March 2018

Please cite this article as: M. Suchanek, Z. Olejniczak, Low field MRI study of the potato cell membrane electroporation by pulsed electric field, *Journal of Food Engineering* (2018), doi: 10.1016/j.jfoodeng.2018.03.002

Low field MRI study of the potato cell membrane electroporation by pulsed electric field

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Highlights

- Low field MRI method was proposed to study the electroporation in potato tissue caused by pulsed electric field.
- MRI contrast agent (CA) was applied during the imaging procedure to differentiate various tissues.
- The extent of the cell membrane electroporation in potato tubers was determined.
  The MRI results were confirmed by the conductivity measurements and compression tests.

Abstract

The effects of high voltage pulsed electric fields (PEF) applied to potato tubers were examined by the contrast enhanced, low field Magnetic Resonance Imaging (MRI). This is a non-destructive, and relatively inexpensive method that allows to monitor the spatial distribution of damages caused by the pulses and their evolution in time. The MRI results confirmed the irreversible damage of the potato tuber cell membranes caused by the PEF treatment, leading to non-selective flow of ions. The extent of electroporation was also evaluated by electrical conductivity measurements, as well as by compression tests and compared with the MRI. On the basis of these results, the PEF method can be optimized in applications aiming at the increase of the permeability of potato cell membranes.

Keywords: Pulsed electric fields, Electroporation, Low field MRI, Ion migration, Electrical breakdown

1. Introduction

The application of high voltage pulsed electric field (PEF) in the processing of plant-based food has been widely investigated in the last decades (Barbosa-Canovas et al., 2006), (Toepfl et al., 2014). New studies reporting the effects of PEF technique on various products of biological origin are still appearing (Barba et al., 2015). The technique has been mostly used for food preservation, due to its ability to deactivate spoilage and pathogenic microorganisms, like living bacteria, yeast and molds (Kethireddy et al., 2016), (Timmermans, et. al., 2016). The application of PEF as a pre-treatment step to improve the efficiency of some food processing was also reported. In particular, the extraction of intercellular components, like the oil extraction from the sunflower seeds (Shorstkii et al., 2017), or polyphenol extraction during the red wine vinification (Saldaña et al., 2017) were investigated. Finally, the PEF technique was used to improve the activity and stability of bioactive compounds and nutrients. After PEF stimulation, an enhanced release of bioactive compounds and consequently higher total antioxidant capacity (Buniowska et al., 2017), as well as an increased activity of the α-amylase enzyme and its conformational transitions (Tian et al., 2016) were observed.

The PEF is a food processing technology that applies short, high voltage pulses across a food material that is placed between two or more electrodes (Zhang et al. 1995). The pulses enhance the cell permeability by damaging the cell membrane and increasing the ion flow through it. For sufficiently high field strength, the membrane electroporation is irreversible, so its fundamental life functions cannot be restored, leading to a permanent loss of homeostasis (Angersbach et al., 2000). Potatoes have also been subjected to the PEF treatment. For example, the PEF method was used to support post processing, such