Electric field distribution and thermal effects in biological cells under PEF treatment

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Abstract-- In the electroporation process, pores can be generated in membranes of biological cells when the cells are stressed with an external electric field. The electroporation process has been studied for several decades, and is generally considered a non-thermal process. Electroporation can be used in multiple practical applications, such as genetic modification, targeted delivery of drugs, microbial inactivation, and the stimulation of bio-fuel production through PEF-induced lysis.

However, the interaction between the external electric field and bio-membranes is still not fully understood, and the effect of the electric field on the cell cytoplasm and cell membranes has not been widely studied. To address these gaps in the knowledge of the interaction between pulsed electric fields and microorganisms, a model of a single spherical cell stressed by an external electric field was developed using COMOSL Multiphysics. This cell model includes a nucleus, and as such may be used to represent eukaryotic microorganisms such as yeast and spherical algae.

Using this model, local heating effects in the cytoplasm and extracellular fluid were simulated. It was shown that the local temperature in the cytoplasm can be increased a few nanoseconds after application of the PEF impulse. Such local heating may damage the cell organelles in the cytoplasm. This model supports experimental findings which have demonstrated that ns-PEF impulses can damage the nucleus of a cell. A detailed investigation of the local heating effects and electric field distribution in the cytoplasm and cell nucleus will help to optimise the PEF treatment parameters for different practical applications.