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Studying the Variations of Complex Electrical Bio-Impedance of Plant Tissues During Boiling

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Abstract

Biological tissues show complex bioelectrical impedance which depends on the tissue compositions, tissue structure, tissue health and signal frequency. As the tissue composition, structure and health are significantly changed during boiling, there will be a significant change in tissue electrical properties in the boiled tissues. Therefore, impedance variation with tissue boiling can be correlated with the tissue health status and it can be suitably used for noninvasive assessment of tissue health either in food technology or in the medical treatment of a burnt patient. In this direction the impedance variation in banana stem tissues is studied in unboiled and boiled conditions and the responses of the complex bio-impedance are analyzed over a wide range of frequencies. Results demonstrate that the bioelectrical impedance of the plants tissues drastically reduce due to the boiling effect and the α-dispersion and β-dispersion in the bioimpedance found for unboiled tissue disappears in the boiled condition.

Keywords: electrical biompedance, plant tissue, banana stem tissue, electrical impedance spectroscopy (EIS), boiled tissue, Nyquist plot.

1. Introduction

Biological tissues contain the biological cells [1-2] which are composed of the intracellular fluids (ICF) containing nucleus and cytoplasm and surrounded by a cell envelops [3-5]. In animal cells [1-5], the cell organelles

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suspended in cytoplasm, are surrounded by a flexible cell envelop called the cell membrane whereas the plant cell compositions are covered by cells membranes and cell walls [1-5]. Envelop covered cells in animal and plant tissue are suspended in extracellular matrix [4, 6] made up of extracellular fluids (ECF). The cell organelles suspended in the cytoplasm produces an electrically conducting path the cell membranes, developed with a protein-lipid-protein layer [7-10], produce the capacitive paths to the electrical signal. Therefore, under an alternating electrical excitation, both the animal and plant tissues show a complex electrical bio-impedance [11-21] which depends on the tissue compositions and signal frequency [22-25]. As the physical property and electrical bioimpedance of a biological tissue varies with the change in tissue composition [26-30], the physiological changes [31-32], nutritional and metabolic disorders [33-35], illness and other diseases [36-41], the bulk electrical properties of tissues can be evaluated and utilized as for the noninvasive tissue characterization [42-46].

The vegetable tissues are the plant tissues which show a variable response over a wide band of frequencies due to their complex electrical bio-impedance [16, 47-52]. The frequency response of the vegetable tissue impedance depends on the tissue composition, tissue structure (or tissue anatomy) and the tissue health (physiology and pathology) [16, 47-52]. Therefore, the frequency response of the electrical bioimpedance of vegetables can provide their physiological properties which could be suitably used for noninvasive assessment of tissue health [16, 47-52]. As the biological tissue composition, structure and health all are significantly changed during boiling, there will be a significant variation in tissue impedance corresponding to the physiological and physiochemical changes occurred in the tissue interiors. The biological, biochemical and pathological studies can be applied to study the tissue properties in boiled or partially boiled tissues, but most of these methods are *in vitro* and invasive or destructive in nature. Therefore, a noninvasive, fast and low cost method is required to study the tissue health under boiling. Electrical Impedance Spectroscopy (EIS) [51-59], which is a well established impedance based material characterization technique in several fields of applied science, engineering and technology [47-52, 58-70], can be used in studying the impedance variation in biological tissues during boiling. EIS studies conducted on biological tissues during boiling will not only help us to study the food quality in food science and food technology but also it will help us to study the burnt tissue health during the medical treatment of burnt patients in hospitals and clinics. In this direction, EIS is studied on vegetable tissues in their un-boiled and boiled conditions and the frequency response of the complex bio-impedance are studied. Complex bioelectrical impedance (Z) and the phase angle of the bioelectrical impedance (θ) of the vegetable tissues are measured at different frequencies (ω) using an impedance analyzer before and after boiling and the variations of bioimpedance and phase angles are studied. The variations of the real part of impedance (R_Z), imaginary part of impedance (X_Z) and other impedance parameters are calculated from the Z and θ and the sample geometry. Nyquist plots and other impedance variation plots over frequency are studied and the variation of bioimpedance due to boiling is analyzed.

Nomenclature

Z	bioimpedance
R_z	real part of the bioimpedance
X_z	imaginary part of the bioimpedance
ω	angular frequency

2. Materials and Methods

2.1. Bioelectrical Impedance

Plant tissues are made up of the three dimensional array of cells (Fig. 1a) suspended in an extracellular matrix [1-2] (Fig. 1b). Plant cells are composed of intracellular fluids surrounded by a cell membrane and cell wall. Cell membrane has a complex structure of protein-lipid-protein (P-L-P) layer whereas the cell walls are made up of the cellulose and hemicellulose, pectin and in many cases lignin. The ICF and ECF of the plant tissues have more water and they produce a resistive path to an alternating electrical signal. But under an alternating electrical excitation, the cell membranes show some capacitive effect contributing to the capacitive reactance in their responses.