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Research Article

Influential Mechanism of the HPEF Parameters on the Dielectric Properties of Fresh Vegetables

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Abstract: The pretreatment of fresh vegetables with HPEF can improve lyophilized speed and reduce energy consumption, but when people study how to use fresh vegetables dielectric properties online to monitor the change of lyophilized water, they need to consider the impact of parameters of high voltage pulsed electric field on dielectric properties of fresh vegetables. Therefore, according to the author's many years of study and practical experience, this study first analyzes the dielectric properties of fresh vegetables and then develops the required equivalent circuit of this study; finally, it focuses on the impact of the mechanism of pulsed electric field parameters. The result of this study will provide a useful reference to the treatment of fresh vegetables with the HPEF.

Keywords: Dielectric properties, electric parameters, fresh vegetables, influential mechanism, the HPEF

INTRODUCTION

In recent years, domestic and foreign scholars have carried out a series of researches on pre-treatment applied to fresh vegetables with the consideration of the characteristics of HPEF. These researches are mainly: the sterilization the HPEF doing on fresh vegetables; the mechanism of pretreatment of fresh vegetables and the study of the impact on the physical properties and quality of fresh vegetables and the effects of the function on the fresh vegetables' cell structures as well as the influence of the electromagnetic characteristics (Rudan-Tasic *et al*., 2001). At the same time, they also have made a number of practical achievements on the process of the pretreatment of the HPEF or the controlling process of the parameters to be optimized on the fresh vegetables (Ma and Guo, 2013). The author makes a systematical research on the vacuum freeze-drying aspect on the pretreatment of the fresh vegetables with the HPEF and also does a reviewed analysis about the influential mechanism of the parameters on dielectric properties of fresh vegetables when they explore the freeze-drying as well as low-power technology and the optimization of the control parameters (Zhang and He, 2014).

MATERIALS AND METHODS

An analysis of the dielectric properties of fresh vegetables: The electrical property of fresh vegetables refers to conductivity, electrical penetration and dielectric properties under an applied electric field. Microscopically, fresh vegetables' tissues containing inorganic or organic ions have conductive properties; the membranes composed of lipid bilayer have dielectric properties. From a macro point of view, fresh vegetables can be used as non-homogeneous semiconductors or dielectrics. Dielectric properties refer to the response of bound charges (Charges only move in the range of molecular wires) in the biological molecules on the external electric field. The main parameters include: relative permittivity, the relative dielectric loss factor, dielectric loss tangent, the media equivalent impedance and the equivalent capacitance. The dielectric property is usually described by the complex relative permittivity (ε) and the mathematical expression is: $\varepsilon = \varepsilon' - \mathrm{j}\varepsilon''$.

In this calculation, $\mathrm{j} = (-1)^{0.5}$ and ε' is permittivity (Kristiawan *et al*., 2011), showing the ability of the material to receive charge and ε'' is the loss factor, representing the heating part absorbed and converted from energy in the electric field and determining the absorption and attenuation of the energy. The dielectric properties of fresh vegetables is very important as to test the heated conditions of the fresh vegetables in the HPEF and also have a strong correlation with the moisture content of materials with fresh vegetables, so when people study the HPEF in the freeze-drying of fresh vegetables, they need to focus on the understanding of the dielectric properties (Peyman and Gabriel, 2010).

Application of an equivalent circuit model: When analyzing the dielectric properties of the organism, the electrical model is the electrical system in parallel or in series of the equivalent resistance and the equivalent capacitance which is equivalent to the test sample under the set frequency in this study. Microscopically, people usually use the equivalent circuit model of individual

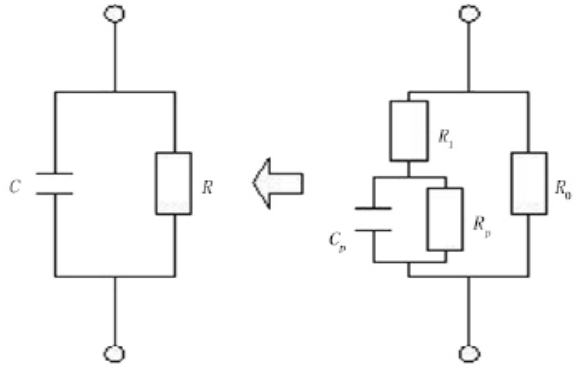

Fig. 1: Biological tissue equivalent circuit model

cells within the biological tissues (Zheng *et al*., 2011). When analyzing the macroscopic dielectric characteristics of fresh vegetables, people usually regard the alternating electric field of fresh vegetables as macro effective resistance of bioplasm as well as various liquid and a series or parallel capacitor equivalent circuit made up of macro effective capacitor of various liquids. The model of biological tissue equivalent circuit is shown in Fig. 1.

R_0 is the extracellular fluid equivalent resistance. R_p is the equivalent resistance of the cell wall and membrane. C_p is the equivalent capacitance of cell wall and cell membrane. R_1 is the equivalent resistance of intracellular fluid. If the dielectric properties of fresh vegetables are tested only in the need of measuring the equivalent capacitance and equivalent resistance of samples of fresh vegetables, you can get permittivity materials of the corresponding fresh vegetables after a simple conversion of the electric model (Guo, 2010).

RESULTS AND DISCUSSION

The influential mechanism of pulse voltage equivalent capacitance: After pretreatment of fresh vegetables with HPEF and under the function of the pulse voltage, charged particles of the fresh vegetables medium in an electric field move along the direction of electric field to produce a dipole, which is called polarization. When polarization occurs, polar molecules (such as water molecules, etc.) of fresh vegetables medium will form a directional polarization, namely from clutter arrangement to aligned arrangement and bound charges are generated in this process. And promise molecules of fresh vegetables' medium produce positive and negative induced charge in the dielectric surface. In this way, polarization of fresh vegetables media will produce inverted electric field, reduce the force acting on the two charges in the electric field and meanwhile exacerbate intensive collision between substances of fresh vegetables medium, thus impeding the movement of charge. Therefore, that polar molecules or polar molecules have failed to accumulate charges in the medium will result in a reduced ability to store charge media, which makes the equivalent capacitance of fresh vegetables declines and the dielectric permittivity decreases. What's more, that the polarization process inhibits charges moving causes the reduction of friction as well as collision between the polar molecules and charged particles around it and the produced heat. And even the heat produced in the process of the medium' moving by polar molecules cannot overcome the power brought by the inner blocking force of the medium, which makes the media's ability to store energy reduced and the equivalent capacitance decreases and at the same time, the equivalent capacitance of the medium will increase as the pulse voltage reduces.

The influential mechanism of pulse voltage equivalent impedance: Cell membrane is the initial site of the electromagnetic fields and cell function and all subsequent reactions are triggered by cell-mediated. The cell signaling systems in the cell membrane play an important role in mediating the electromagnetic field. Asami studied the influence of cell destruction on its dielectric characteristics and the results show that when the cell is destructed, dielectric relaxation phenomena will be produced, which means the cell membrane played a unique role in the maintenance of cell dielectric properties.

HPEF affects fresh vegetables and pulsed electric field generates a magnetic field. The alternative function of the electric field and the magnetic field increases the permeability of cell membrane and intensifies the shaking but weakens the film of the cell, therefore destroys the cell membrane. What's more, the impact of the HPEF on the permeability of cell membrane is affected by cell size, orientation and morphology. For intact cell of the fresh vegetables, two ends of its membrane will appear opposite free charge, which forms trans-membrane voltage. When a pulse voltage is applied to the cell, the charge accumulated at both ends of the cell membrane will increase the trans-membrane voltage so as to strengthen the squeezing action of gravity on the cell membrane of charge and make the cell membrane thinner. When the entire membrane potential (natural potential difference of fresh vegetables' cell membrane) reaches the limit, which makes the membrane becomes disordered and the membrane is damaged, so the pores are formed. At that time, the permeability of cell membranes increases, electrolyte leaks and electrical conductivity in the out material increases so that the cell impedance drops and the equivalent impedance media of fresh vegetables falls and the equivalent impedance of the fresh vegetables' tissue will increase as the pulse voltage decreases.

The influential mechanism of the pulse frequency equivalent capacitance: In order to maintain normal physiological function of the cell, there are some

potential differences inside and outside the cell membrane. Due to differences of the dielectric properties in the inside and outside of the cells and as the main point of the electromagnetic fields, the cell membrane equals to an electromagnetic field concentrator. The protein, polysaccharide molecules, lipids and other molecules is not charged in the slow flow, but ionizable groups in which present charge, which forms a dipole. When applying pulse frequency to fresh vegetables, charged particles within the cells will produce polarization effect and this process needs some time.

When the pulse frequency of the electric field applying to fresh vegetables is low enough, the dipole within the cells will orient according to the rotation of the electric field pulse without any hesitation, when polarization phenomenon will occur in most molecular within the cells and polarization rate increases as well as the equivalent capacitance becomes larger (Yali and Yuming, 2009). When the pulse frequency is greater than a critical value, it takes a long time for some polarization process as the pulse frequency increases and dipoles could not keep up with changes in the electric field pulse. This process will produce a time delay, which will consume the energy and therefore leads to the decrease of the equivalent capacitance. On the other hand, in the process that the electromagnetic field makes a dipole steer, various polar molecules in the medium of fresh vegetables undergoing rapid periodic movement. In this process, the polar molecules and its surrounding molecules collide and rub dramatically and the heat is generated. Wherein a portion of the heat is loss to overcome the inner viscous retarding force of the medium of the polar molecules and convert to energy, in which the relaxation loss occurs, leading to the energy storing in the fresh vegetables cells declines as well as the equivalent capacitance decreases and at the same time, equivalent capacitance of the fresh vegetables decreases as the pulse frequency increases.

The influential mechanism of pulse frequency equivalent impedance: In fresh vegetables' cells, the resistance of cell fluid is small with ionic conductivity. The membrane is composed of a large number of protein molecules and phospholipid bilayers, whose capacitance and resistance are relatively large and it is generally considered as highly non-conductive material.

When the outside electromagnetic field is applied to fresh vegetables, the polarization phenomenon of cell occurs and there will appear many tiny electric dipoles. When the pulse frequency is small, the electric dipole of fresh vegetables' cells does not change with the instantaneous movement of pulsed electric field but only to give a limited response, current cannot enter in the liquid of the cell through the cell membrane; if the higher pulse frequency is applied to the media and due to pulse frequency, the put points the unit time functioning on the gaps of cells increases and the electric dipole within the cells can keep up with the strength of polarization, which can move freely. On the other hand, the increasing of the pulse frequency damages the cell membrane and enhances the permeability so that the current can flow into the intracellular fluid through the cell membrane. Therefore, when pulsed electric field of the low frequency is added to the tissue of the fresh vegetables' cell, the current can only go through the extracellular fluid of cells. As the increase of pulse frequency and due to the current can not only go through the extracellular fluid, but also flow into Intracellular fluid through the cell membrane, the equivalent impedance of the whole fresh vegetables' tissue decreases.

CONCLUSION

When the pulsed electric field functioning on the fresh vegetables, electromagnetic parameters have some influence on the dielectric properties of fresh vegetables. The analysis of the influential mechanism can provide some foundation to the parameter optimization and monitoring of the process of the technology of the pretreatment the HEPF dealing with lyophilization of fresh vegetables, the on-line detection on the fresh vegetables of freeze-dried water based on dielectric properties of fresh vegetables and the knowledge about the laws of moisture migration and proliferation the electric field functioning on fresh vegetables' freeze-drying process and so on.

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