The effect of high voltage pulsed electric field on water molecular

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Abstract. In order to study the mechanism of high voltage pulsed electric field pre-treatment on the food drying technology. In this paper, water was treated with high pulse electric field (HPEF) in different frequency, and different voltage, then, the viscosity coefficient and the surface tension coefficient of the water were measured. The results showed that indicated that the viscosity coefficient and the surface tension coefficient of the treated water can be decreased, and while HPEF pre-treatment was applied for 22.5kV at a frequency of 50Hz and 70 Hz, the surface tension and the viscosity coefficient of the pre-treatment treatment were reduced 13.1% and 7.5%, respectively.

1. Introduction
Fresh fruits and vegetables have a moisture content ranging from 75 to 90%. They are highly heat sensitive and are apt to be highly perishable. Drying is defined as the reduction of moisture from the products and is an efficient and cheap method for the preservation of fruits and vegetables. Hot air drying is one of the most commonly used procedures in dried food with main disadvantages being prolonged duration and high energy consumption. Therefore it is necessary to explore low power consumption processing for hot air drying.

Dry pretreatment technology is utilized to treat food through some physical methods before drying it. Pretreatment can not only improve the quality of dried food but also increase drying rate and thus reduce energy consumption. For example, during the process of drying and dehydration for fruits and vegetables, ultrasound pretreatment certain intensity will enhance their drying rate and thus reduce the drying energy consumption [1-3].

In recent years, a novel pretreatment technique, high voltage pulsed electric field drying pretreatment technology has been developed only recently, Angers Bach et al. showed an increase in permeability of potato tissue by high intensity electrical field pulse treatment, which resulted in improved mass transfer during fluidized bed drying [4]. Ade-Omowaye et al. found that high voltage pulsed electric field pretreatment could increase the cell membrane permeability and improve the drying rate [5]. Gachovska found that pulsed electric field treatment could increase the drying rate of carrots and enhance the quality of dried carrots [6]. Electrically assisted drying would reduce the processing time, operating temperature, and energy consumption [7]. Other papers reported similar results that pulsed electric field pretreated samples could significantly improve the drying rate [8-9].

But, it is not a profoundly explored method of drying pretreatment, and, its mechanism has not been accurately determined, therefore, study the mechanisms of high voltage pulsed electric field pretreatment is one of the important theoretical basis for the technology industrialization application use.
Material drying is a process in which the free water penetrates and diffuses from material interior to exterior under the effects of differential concentrations and temperatures in and outside the material. In addition to differential concentrations and temperatures, the speed of material drying process, namely the drying rate, is also affected by the structure of hydronic itself. Generally, the liquid water is composed by single hydronic and hydronic cluster, hydronic combined by hydrogen bond (figure 1). Such cluster structure of water is the reason of its high viscosity, surface tension, melting point, boiling point and heat capacity. However, current analysis on liquid hydronic cluster structure only focuses on its viscosity and surface tension etc. Therefore, this thesis plans to identify the effect of high voltage pulse electric field on hydronic cluster structure by measuring the viscosity and surface tension of hydronic after it being processed by high voltage pulse electric field.

Figure 1. Schematic diagram of the structure of the water molecule

1. Needle electrodes  2. Sample  3. Chamber  4. grounded electrode  5. Thermometer  6. hygrometer  7. High voltage power  8. Voltage regulator

Figure 2. Schematic of the high pulse electric field experimental equipment.
2. Experimental procedure

2.1. Experimental equipment

Figure 2 shows a schematic diagram of the high pulse electric field setup developed for the experimental work. It consists of a vertically mounted electrode with multiple sharp pointed needles projected to a fixed horizontal grounded metallic plate on which the tap water to be pretreated is placed.

2.2. Experimental methods

The tap water were divided into 28 groups with similar weights. One was the control group and the others were experimental groups. The experimental groups were subjected to high-voltage pulsed electric field pretreatment with different voltage (18, 22.5, 27 kV), different frequency (50, 70, 90 Hz) and different time (2, 5, 8 min), respectively. Then, the Surface tension and Viscosity coefficient of all samples were measured.

2.3. Surface tension coefficient measurement

Align the transverse line on glass tube to the image in index mirror and scribed line in index mirror to ensure the spring bottom position is fixed, elongation of spring can be measured by the vernier (that is, the difference between the two readings before and after elongation).

According to Hooke’s law, within the elastic limit, elongation of the springs proportional to the applied force F, i.e., measure stiffness coefficient of spring k.

Hang U wire on small hook under the index bar, turn the lifting button, make three wires aligned, and record the Vernier initial value.

Immerge U wire into water in breaker, rotate screw under platform to lower down the platform slowly. Because of surface tension is applied on the wire, the horizontal scribed line on the index bar drops accordingly, to adjust the lifting button, make three wires aligned. Lower the platform a bit and repeat above adjustment, until the platform lowers a little, the wire comes out the liquid surface. Write down the meter ruler readings indicated by Vernier zero line, can get spring elongation, and then calculate the emerged surface tension coefficient.

\[
\sigma = \frac{k(s - s_0)}{2(l + d)} \tag{1}
\]

Where \(l\) and \(d\) are the width and diameter of the U wire (cm) \(\sigma\) is the surface tension coefficient.

2.4. Viscosity coefficient measurement

The water of the control group and experimental group were load in a glass cylinder of 1000 ml, respectively, and the measuring cylinder should be placed directly in the cylinder, so that the ball of wax would fall down the center line of the cylinder.

Measure the distance between the upper and lower line AB with a meter stick. The diameter \(d\) was measured by a helix micrometer.

Using a pair of tweezers to put the ball into the measuring cylinder, the ball is measured with a stopwatch to measure the constant velocity of the ball. The time \(t\) is required by the upper and lower scales of A and B, and the coefficient of the viscosity of the water is \(\eta\), which is the viscosity coefficient of the water.

\[
\eta = \frac{1}{18} \left( \rho - \rho_w \right) g \frac{d^2}{v^2} \tag{2}
\]

Where \(\rho\) and \(\rho_w\) are the density of water and the ball of wax (g cm\(^{-3}\)), and d is the diameter of the ball of wax (cm) sis.
2.5. Effect of high voltage pulsed electric field on the surface tension coefficient of tap water

The influence of high voltage pulsed electric field on the surface tension coefficient of tap water was shown in Figure 3-5, respectively. It can be seen from the graphs that the surface tension coefficient of tap water treated by high voltage pulsed electric field was lower than that of the control. Under a 27 kV at a frequency of 50 Hz for 5 min, the surface tension coefficient of treated tap water is 13.1% lower compared with that of the control group.

**Figure 3.** Effect of high voltage pulsed electric field on the surface tension coefficient of tap water

**Figure 4.** Effect of high voltage pulsed electric field on the surface tension coefficient of tap water.
**Figure 5.** Effect of high voltage pulsed electric field on the surface tension coefficient of tap water.

**Figure 6.** Effect of high voltage pulsed electric field on the viscosity coefficient of tap water.
2.6. Effect of high voltage pulsed electric field on the viscosity coefficient of tap water

Figure 6-8 show the results of the viscosity coefficient of tap water. According to the results, HPEF pretreatment can decrease the viscosity coefficient of tap water significantly. Under a 22.5kV voltage at

![Graph showing viscosity coefficient against voltage and pretreatment time.](image)

**Figure 7.** Effect of high voltage pulsed electric field on the viscosity coefficient of tap water.

![Graph showing viscosity coefficient against voltage.](image)

**Figure 8.** Effect of high voltage pulsed electric field on the viscosity coefficient of tap water.
a frequency of 70 Hz for 5min, the viscosity coefficient of pretreatments is 7.59% lower compared with that of the control group.

3. Conclusion
The the viscosity coefficient and the surface tension coefficient of the top water can be decreased by high-voltage pulsed electric fields pretreatment, and while high voltage pulsed electric field pretreatment was applied for 22.5kV at a frequency of 50Hz, the surface tension coefficient of the pretreatment treatment were reduced 13.1% and while high voltage pulsed electric field pretreatment was applied for 22.5kV at a frequency of 70Hz, the viscosity coefficient of pretreatments were reduced 7.5%, respectively.

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