

Electrohydrodynamic (edh) drying of ginger slices (*zingiber officinale*)

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Electrohydrodynamic (edh) drying of ginger slices (*zingiber officinale*)

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Abstract. Electrohydrodynamic (EHD) flow or ion wind of corona discharges has been generated utilizing pin-multi ring concentrated electrodes. The pin was made of stainless steel with a tip diameter of 0.018 mm. The multi-ring constructed electrodes by a metal material connected to each other and each ring has a diameter of 24 mm, 16 mm and 8 mm in the same width and thickness is 4 mm and 1 mm. EHD was generated by using a DC high voltage of 5 kV. Pin as an active electrode of corona discharge and multi-ring concentric electrodes as a collector and passive electrodes. The ion wind or EHD flow is produced through changes in voltage and distance between electrodes. The ionic wind generated system outputs through multi-ring concentric electrodes which will further dry the sample. A circle ginger slices as a sample with a diameter of 26 mm with a thickness of 2 mm. The drying is done at the distance between the fixed electrodes of 4 mm and the varied voltages are 1.2 kV, 1.4 kV, and 1.6 kV. The sample drying time varied 30 minutes, 60 minutes, 90 minutes, 120 minutes and 150 minutes. The result of drying the sample at a fixed voltage is obtained moisture of ginger slices decreased with increased drying time.

Keywords: Electrohydrodynamic flow, multi-ring concentric electrodes, moisture

1. Introduction

Ginger (*Zingiber officinale*) which has a slightly spicy flavor, flavorful and rhizome can be used as one of the traditional medicine ingredients. Ginger as pain drugs, cough, inflammation, gastrointestinal disorders and anti-cancer drugs [1]. Ginger as anti-cancer drugs through aromatherapy on chemotherapy-induced nausea and vomiting and health-related quality of life in women with breast cancer [2].

Drying is a very important process in the manufacture of ginger flour as medicine and food ingredients. Drying as sun drying, oven drying, vacuum-oven drying, and freeze drying [3] or heat pump dryer [4] consume high electrical power. Electrohydrodynamics (EHD) drying is one of the innovative active techniques that can improve the heat transfer with low power consumption. Electrohydrodynamics refers to the coupling between a high-voltage low-current electric field and the fluid field in a dielectric fluid medium [5]. EHD Drying research has been done to drying apple slices [6], drying mushroom slices [7], drying sea cucumber (*Stichopus japonicus*) [8].

In this study, the corona discharges are generated using pin-multi ring concentric configured electrodes, so that if the electrodes are in high voltage there will be a strong electric field between the



electrodes that will ionize the air around the active electrode. A corona discharge system using a pin-multi ring concentric electrode produces a velocity of EHD flow[9], ion mobility [10] and electricity efficiency [11] are greater than those produced by the corona discharges using a pin-ring electrode. The purpose of this study to applied EHD system on draining ginger slices and characterization of the physical properties of dried ginger slices. The effect of EHD flow on the ginger's drying rate, energy efficiency and shrinkage were evaluated from drying experiments.

2. Method

Ginger (*Zingiber officinale*) were purchased from local farmer market in Semarang, Indonesia, in July 2017 and then kept under the room temperature. The initial moisture content of ginger samples was in the range from 21,4 %. Before the cut, ginger peeled and then cut into slices with a circular shape with 2 mm thickness and diameter varied from 1-3 mm with 0.5 mm diameter interval.

2.1. Experimental apparatus

The main components of the corona discharge generator, yield of EHD flow, consist of pin electrodes and concentric multi-ring electrodes. Pin electrode is made of stainless steel with a pointed tip diameter of 0.14 mm. Concentric multi-ring electrodes consist of 3 Concentric Rings electrodes. The three concentric electrode rings have the same width and thickness of 2 mm each and the diameter of the ring electrode from the smallest of 8 mm, 16mm and 24 mm diameter respectively. Electrode pin and electrode of multi rings concentric as shown in FIG. 1

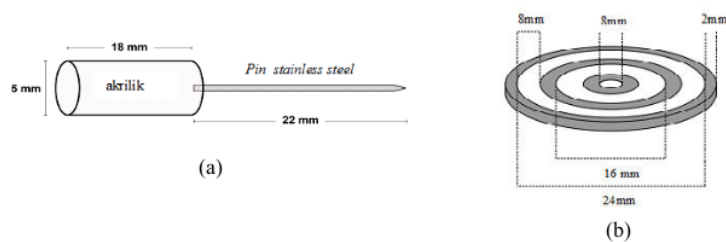


Fig.1. (a) Pin electrode and (b) Concentric multi-ring electrodes

The corona discharges yielded EHD flow was performed at the distance between the 6 mm electrodes and the DC high voltage of 3.4 kV. The voltage measurements are given to the corona discharge generating system through the high voltage probe voltage divider (SEW high voltage probe P20 P28) and the installed voltage can be determined using an oscilloscope (Good Will instrument, code number 5694495, Malaysia). The electric current after discharge was measured using a multimeter (Sanwa electronic instrument CD772 made by Tokyo). At the time of corona discharge, one of the radiation from the discharge in the form of EHD flow will flow from the pin electrode to the multi concentric ring electrode which will dry the ginger slices located on above the multi concentric ring electrode. The scheme of the experimental set-up of EHD drying of ginger slices is shown in Fig.2

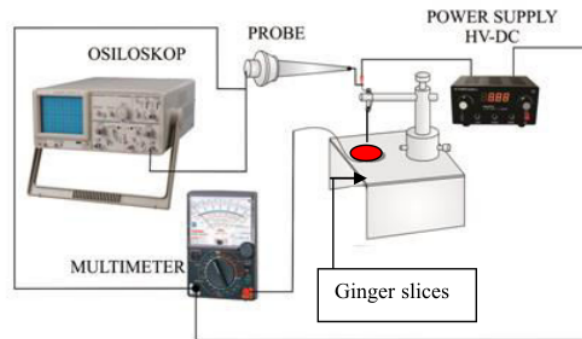


Fig.2. Experiment set-up of EHD system

2.2. Drying rate

The effect of EHD flow on the ginger's drying rate was evaluated from drying experiments at a temperature of 27°C. The discharge gap between pin electrode and multi-ring concentric was set constant at 6 mm. The diameter of ginger slices was 10-30 mm with diameter interval 5 mm. It was placed in the center of multi-ring concentric electrode. The mass of ginger slices was measured by weighing on the digital balance. It measurement before and after drying. Each slice of ginger is dried with a time of 300-1800 seconds with a time interval of 300 seconds. The drying rate (DR) of ginger slices was calculated using Eq. (1) and expressed as kg of water/kg dry matter. min

$$DR = \frac{m_1 - m_2}{t_2 - t_1} \quad (1)$$

where t_1 and t_2 are two different times (min) during drying; m_1 and m_2 are the mass (kg water/kg dry matter) of the ginger slices at time t_1 and t_2 , respectively (Dinani *et al.*, 2015).

2.3. Energy efficiency

Energy efficiency (η) of drying was calculated as specific energy consumption, or amount of energy needed to evaporate unit mass of water in kJ/kg (Martynenko *et al.*, 2016). Energy efficiency was determined from the supplied electric power (kW) and the drying rate (kg/s):

$$\eta = \frac{VI}{\Delta m} \Delta t \quad (2)$$

Where voltage, current I , and Δm was determined from the balance as a mass reduction for the time Δt .

2.4. Shrinkage

The heavy of both blanched and dried ginger slices of each drying treatment was measured by the mass method. Based on the measurements of the sample massa., heavy shrinkage was calculated using Eq (Nowacka *et al.*, 2012) :

$$S = \frac{m_1 - m_2}{m_1} \times 100 \quad (3)$$

Where S is the shrinkage of the ginger slices (%), m_1 is the mass of the blanched ginger slices before drying (kg), m_2 is the final mass of the ginger slices at the end of drying (kg) (Nowacka *et al.*, 2012).

3. Result and discussion

3.1. Current-voltage characteristics.

Current-voltage characteristics of the EHD flow generator utilizing pin-multi ring concentric electrode at the distance between the electrodes $d = 6$ mm as shown in Fig.3. The Current-voltage Curve with no ginger slices (I_{Non}) in red and with ginger slices on the pin multi-ring concentric electrode (I) green color. The diameter of ginger slices respectively $d = 6$ mm, 15 mm, 20 mm and 25 mm with the same thickness that is 20 mm

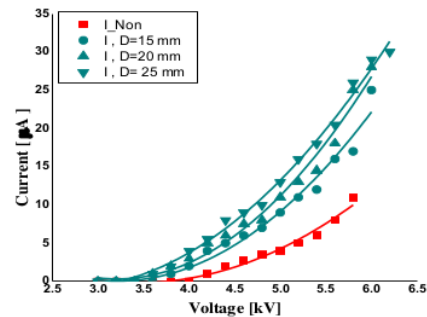


Figure 3. Current-voltage characteristics of the EHD flow generator

When the voltage is applied to the EHD flow generator, the air around the pin electrode will occur ionization. The result of this ionization (positive ion) will be rejected by positive electrode which then positive ion will move toward the passive electrode. The impact of positive ions with these passive electrodes reads as unipolar currents. When the given voltage gets bigger, then the positive ion production gets bigger so that the current value read on the amperemeter gets bigger.

Fig.2 shows that the rise of all current values is proportional to the voltage increase. The ion current with the sample on the multi-ring concentric electrode by the green color (I) is greater than the ion current without sample on the multi-ring concentric electrode by the red color (I_{Non}). It is because the ginger slice molecules placed in the electric field will be polarized into electric dipole moments that will produce an electric field has direction the same with the outer electric field so the total electric field increased. Samples with a diameter $D = 25$ mm result in an electric dipole moment greater than a sample with a diameter $D = 15$ mm. When the electric field is enlarged then the ionization process that occurs around the positive electrode will increase. Increasing the ionization process results in the production of positive ions that impinge more and more negative electrode, this is indicated by the greater the value of current that is read on the amperemeter,

3.2. Drying Rate

EHD Drying of ginger slices located above multi-ring concentric electrode is generated at a constant voltage $V = 4.3$ kV and the distance between fixed electrodes $d = 6$ mm. Drying rate (kg / s) of ginger slices function of the drying time (s) as shown in Fig. 4

Fig. 3. It showed that the drying rate (DR) for all samples decreased with time. Because the amount of the total water in the samples was limited and the mass of the water removed from the sample exposed to the electric field when the drying decreased. At the same time, the increase in the drying rate is proportional to the increase in the sample diameter. At drying time has reached 1500 s, the drying rate of the sample with diameter 1 cm, 1.5 cm and 2 cm is zero. However, for samples with diameter 2.5 cm and 3 cm drying rate not yet. It is because the outer loop of the sample with diameter 2.5 cm and 3 cm is not exposed to the electric field so the sample still contains enough water.

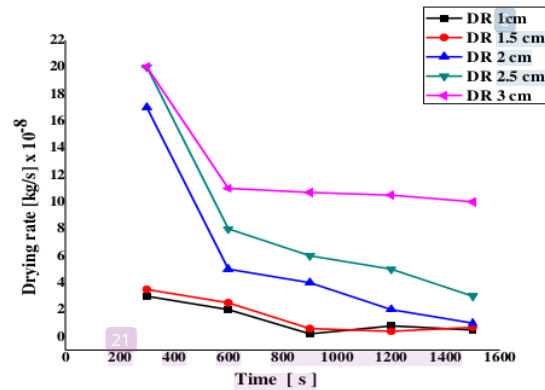


Fig 4. Drying rate of Ginger slices with diameter of 1, 1.5, 2,2.5 and 3 cm

3.3. Energy efficiency

Energy efficiency (η) of drying was calculated as the amount of energy needed to evaporate the mass of water unit in kJ / kg. Graph of energy efficiency as a function of the sample with diameter $D = 1\text{cm}, 1.5\text{ cm}, 2\text{ cm}, 2.5\text{ cm}$ and 3 cm and a thickness of 2 cm at a voltage $V = 4.3\text{ kV}$ and a distance $d = 6\text{ mm}$ electrodes and at drying time 600 seconds as in Fig.5. It shows the efficiency decreases as the sample diameter increases. This is due to the larger the diameter the greater the drying rate. This is in accordance with the formula (2) ie the energy efficiency is inversely proportional to the drying rate.

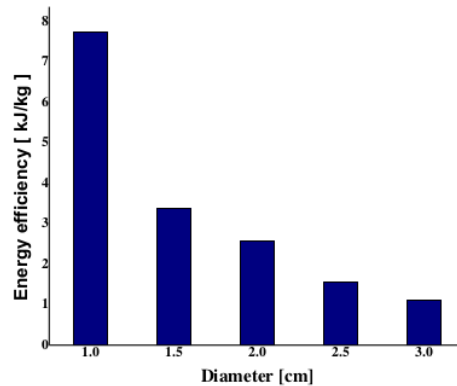


Fig 5. Efficiency Energy of Ginger slices at diameter varies.

3.4. Shrinkage

Shrinkage of materials during drying cannot be avoided because of the heating process and the discharge of water from the material. When water comes out of the material there is an imbalance between the pressure inside the material and outside the contraction material and triggers shrinkage, deformation and sometimes breaking or cracking of materials (Major & Sereno 2004). The graph of shrinkage (%) function of time [s] drying the sample with diameter $D = 1\text{ cm}, 1.5\text{ cm}, 2\text{ cm}, 2.5\text{ cm}$ and 3 cm and a thickness of 2 cm at a voltage $V = 4.3\text{ kV}$ and a distance $d = 6\text{ mm}$ electrodes as in Fig.6. It shrinkage of the sample increases with increasing drying time. This is due to the longer drying time, the more water coming out of the sample. The shrinkage on the drying of ginger slices with $D =$

3 cm was smallest. It due to on the ginger slice with $D = 3$ cm on the outer circumference of the slices no exposure to EHD flow.

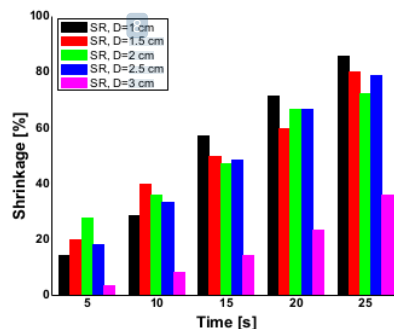


Fig 6. Shrinkage of Ginger slices at time varies.

4. Conclusion

The increase in current value (μA) of the EHD flow generator is proportional to the increase in voltage (kV). The current with a sample of ginger slices on a multi-ring concentric electrode is greater than the value of the no-sample current. Drying of ginger slices at the distance between electrodes remained $d = 6$ mm and voltage $V = 4.3$ kV resulted in the drying rate for all samples decreased with increased time. Drying rate for the constant time will increase as the sample diameter increases. The energy efficiency for the constant drying time will decrease as the sample diameter increases. Shrinkage of the sample will increase with increasing drying time.

Acknowledgements

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