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Ion wind drying with input power variation of the potato slices

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Abstract. The ion wind drying method has been used to dehydrate potato slices with a variation of electric power and a constant drying time of 30 minutes. Ion wind drying is generated by an electrohydrodynamic flow reactor using 10 x 10 pairs of pin electrodes and multi-ring concentric electrodes connected by a DC high voltage. The high electric field in space between electrode causes ionization of air at the atmosphere condition which is produced ion flow together with heat transfer, and radical ions which are used for drying. Power in the reactor during drying is influenced by the input voltage and the measured current obtained a minimum value of 10 Watt and a maximum value of 60 Watt. Ion wind drying in the sample slices found also the value of the level of drying, shrinkage, humidity, and energy consumption which increases with increasing power at the reactor.

1. Introduction

The consumption of potatoes (*Solanum tuberosum*) has increased in the last few years. Potato is a nutritious vegetable containing the highest levels of carbohydrate, and rich in minerals, protein. However, fresh potatoes will not be durable due to easily exposed to bacteria and mold [1]. Drying is one of the oldest and most effective methods for the preservation of potatoes by reducing water content and reducing microbial activity [2]. The drying process is one that is widely used in industry and it takes around 12-20% of the energy needed in the manufacturing industry [3].

Recent research has revealed that advanced drying technology can improve energy efficiency. It is like drying with the help of microwaves or ultrasonic [4], drying heat pumps [5], drying the refraction window [6] and drying high electric fields [7]. High electric field drying is also called EHD Drying [8], electric wind drying or Ionic wind drying [9]. An ionic wind or ionic wind is a stream coming from an ionized fluid produced by a strong electric field [10]. The ionic wind produced by the electrodes is charged with direct current (positive or negative) at a high enough voltage (in the kV range), while the applied voltage can be high, the current involved is usually very small (in the mA range), which makes the required power supply sufficient low [11].

Research on Ionic wind drying has been carried out by several researchers including Li et al (2006), Esehaghbeygi et al (2011), Bai et al (2013), Law (2014), Singh et al (2015), Dinani et al (2015) 2015 and Martynenko et al. (2016). Li (2006) has reported the results of ionic wind drying experiments for Okara cake with 3 needle and single plate electrodes [12]. Whereas Esehaghbeygi et al (2011) have conducted research on drying sliced tomatoes with multi-pin electrode electrodes at 10 kV voltage



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obtained the results of brightness and color do not change in addition to reduced water content [13]. Law (2014) has conducted research on drying with ionic wind flow because the ionization process with the results besides drying the sample also eliminates microorganisms during the drying process [14].

The objective of this study is to study the influence of the variation of the input power of the ionic wind drying on the physical characteristics of the potato slices dried. Another advantage of the ion wind drying system is that it can eliminate environmental microorganisms during the drying process [15]. Devices that use the ion wind from Plasma discharge from Corona also have many advantages including ion wind does not require moving parts and provides flexibility in channel form and is free from mechanical and acoustic vibration noise and can be operated at atmospheric pressure and room temperature [16].

2. Methods

2.1. Sample preparation

Potatoes (*Solanum Tuberosum*) are obtained at the Tembalang traditional market in the city of Semarang, Central Java, Indonesia. Potatoes that have been peeled are sliced with a thickness of 2 ± 0.5 mm, a diameter of $3 \text{ mm} \pm 0.5 \text{ mm}$, an initial mass of 18.95 grams, and humidity of 46.6%. Potato slices as a sample amounted to 5 slices as a test sample. The test sample was dried with ion wind for 30 minutes with voltage variations of 6 kV, 8 kV, 10 kV and 12 kV.

2.2. Experimental apparatus

Corona discharge generators which are yields ion wind have a major component consisting of 100 (10x10) pairs of is concentric three-ring electrode and electrode pins. Pin electrodes are made of a stainless steel sewing needle with a sharp tip diameter of 0.14 mm. The concentric three-ring electrode consists of 3 concentric ring electrodes. The three rings making up the electrodes have the same width and thickness of 2 mm each with 8 mm, 16 mm and 24 mm diameters, respectively. The measurement of the voltage which is applied to the corona discharge system through the High Voltage probe P20 (SEW P20 P28) and the installed power supply can be determined using an oscilloscope (Brand Goodwill instrument, code number 5694495, Malaysia). Electric current after corona discharge is measured using a multimeter (Sanwa electronic instrument CD772 made in Tokyo).

2.3. Experimental setup

The distance between the 4 mm electrodes was measured using a screw micrometer and DC high voltage is varied of 6 kV, 8 kV, 10 kV, and 12 kV. Corona discharge formed as a result of ionic wind flow flows from the pin electrode to the concentric three-ring electrode, then will dry the potato slices located on the acrylic plate and under the concentric three-ring electrode. The ion wind dryer circuit is shown in Figure 1

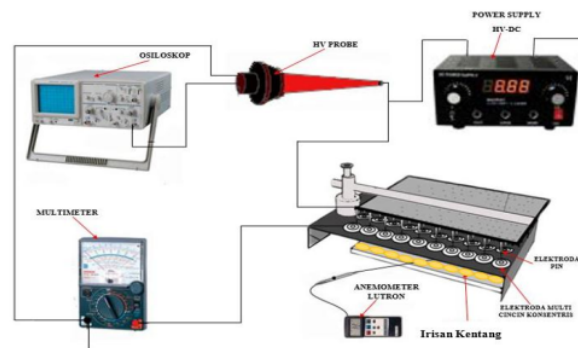


Figure 1 . A series of potato slices EHD dryers

2.4. Electric power

Electric power is the electrical energy consumed during the ion wind drying process at each voltage variation applied to the test sample expressed in equation (1) expressed as Watts.

$$P = V.I \quad (1)$$

P is the Power at EHD (Watt), V is the input voltage (kV), and I is the measured current (mA)[17].

2.5. Drying rate

Measurements of sliced potato mass were measured by digital weighing before and after carried out before and after drying within 30 minutes. The drying rate (DR) is calculated using Eq. (2) and stated as dB / minute.

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

Δm is the mass difference after and before drying (dB), Δt is the time difference after and before drying (minutes). Where, Δm is the mass difference after and before drying (dB), Δt is the time difference after and before drying (minutes)[18].

2.6. Shrinkage

Shrinkage on potato slices is affected by the condition of the initial water content in the sample (100%) at each mass difference the sliced sample is dried. There is can be calculated using equation (3) and expressed as (%).

$$SR = \frac{\Delta m}{m_0} \times 100\% \quad (3)$$

m_0 is the mass before drying (dB) [19].

2.7. Moisture content

The water content in potato slices was different after EHD drying, with an initial humidity of 46.6%. The water content in the sample slices can be calculated using equation (4)

$$SR = \frac{\Delta m}{m_0} \times 46,6\% \quad (4)$$

2.8. Energy efficiency

Energy efficiency is determined by the electric power supplied (kW) and the drying rate (kg / s) of the potato slices which can be calculated in equation (5) as (kJ/gr).

$$\eta = \frac{VI}{\Delta m} \times \Delta t \quad (5)$$

V is the input voltage (kV), and I is the output current (mA) [20].

3. Result and discussion

3.1. Power and current characteristics of the voltage function

Characterization of the drying of potato slices with ionic winds generated by a 10 x 10 pairs of multipin EHD ring concentrations obtained currents and voltages as a magnitude to obtain the magnitude of power (watts) according to Equation 1. which is implemented in the curve into Equation 1 in the curve in Figure 2.

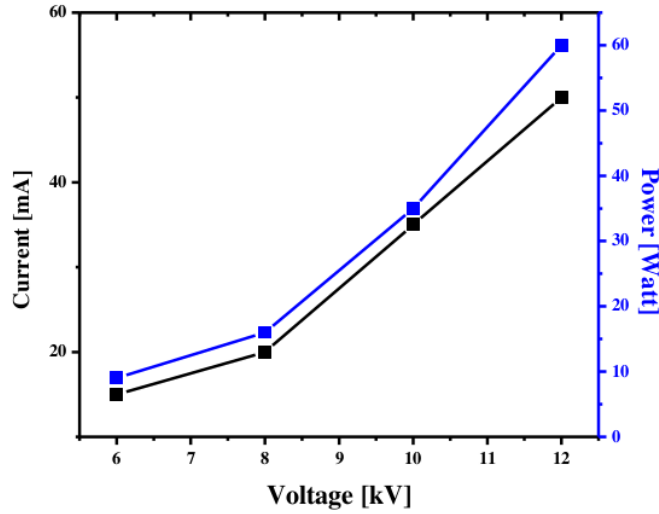


Figure 2. voltage – current – power

The curve in Figure 2. Shows that the current and power obtained increases with increasing input voltage. That is because the ionization process takes place more and more with increasing voltage is given [21] for 30 minutes. The process produces heat transfer [22], electric fields [23], ionic winds, and radical ions [24].

3.2. The drying rate and shrinkage of electric power 7

EHD drying on potato slices with voltage variations of 6 kV, 8 kV, 10 kV, and 12 kV and the distance between the two 4 mm electrodes for 30 minutes produces the same curve between the drying and shrinkage rates shown in Figure 3.

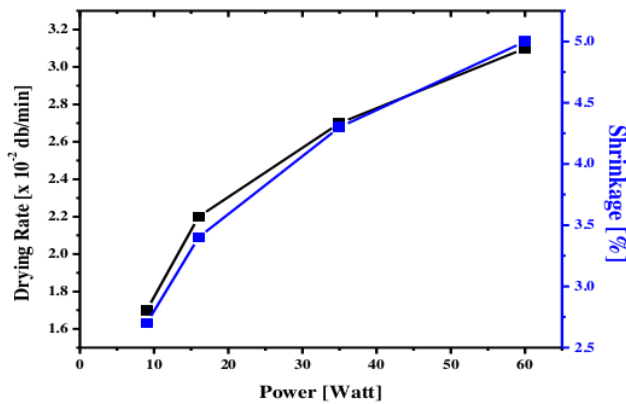


Figure 3. Power – DR -SR

In Figure 2. Shows the value of the drying rate and shrinkage increases with increasing power given. When the minimum power is 10 Watt, the drying rate value is 1.7×10^{-2} db / min and the shrinkage value is 2.7%, while when the maximum power is 60 watts, the drying rate value is 3.1×10^{-2} db / min and the shrinkage value is 5%. This is because the increasing ionization process results in the evaporation of the mass of water content in the potato slices getting faster and experiencing a reduction in mass [25] followed by damage to the cell wall which results in the potato slices shrinking [26]

3.3. The effect of electric power on moisture content and energy efficiency of sample

The 30-minute drying process at each given electric power variation will require energy efficiency and the percentage moisture content of the potato slices shown in Figure 4.

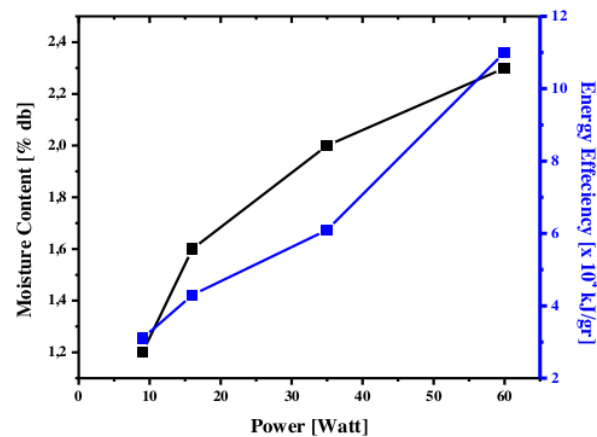


Figure 4. Power – MC –EF

Electrical power obtained from voltage variations and the measured electric current affect energy consumption during drying [28 , 42]. The electrical power obtained is also caused by the ionization between charge and ions in the atmosphere which is directly decreased the water content in the sample slices so that changes in humidity occur. When the minimum power is 10 Watt, the humidity value is 1.2% db and the energy efficiency value is 3.1×10^4 kJ / gram, while when the maximum power is 60 watts, the humidity value is 2.3% db and the energy efficiency on value is 11×10^4 kJ / gram.

4. Conclusion

The drying rate and shrinkage of the potato slices increase with increasing electric power used in the reactor. The moisture content in the potato slices during ionic wind drying is affected by mass transfer. The energy efficiency required at maximum power is 11×10^4 kJ / gram.

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