C14_Determination of ion wind velocity using the method of characteristics (MOC) and its application for drying of black turmeric (Curcuma aeruginosa Roxb) slices

by Ainie Khuriati

IOP Conf. Series: Journal of Physics: Conf. Series **1217** (2019) 012025 doi:10.1088/1742-6596/1217/1/012025

Determination of ion wind velocity using the method of characteristics (MOC) and its application for drying of black turmeric (*Curcuma aeruginosa Roxb*) slices.

Sumariyah[1], A Khuriati[1], E Fachriyah[2] and S H Pratiwi[1]

[1]Department of Physics, Faculty of Science and Mathematics, Diponegoro University Jl. Prof. Soedharto, SH, Tembalang, Semarang 50275, Indonesia
[2] Chemistry Department, Mathematics and Sciences Faculty, Diponegoro University, Jl. Prof. Soedharto, SH, Tembalang, Semarang 50275, Indonesia
E-mail: sumariyah.jaelani@gmail.com

Abstract. Ion wind drying also called corona wind drying in this study using a pin-multi ring concentric electrode. The purpose of the research is to determine the velocity of the ion wind by the characteristic of the method (MOC) and to apply it for drying the black turmeric *(Curcuma aeruginosa Roxb)*. In theory, the ion wind velocity is equal to the ion mobility multiplied by the electric field. In MOC, the ion mobility is obtained from the graph of the relationship between the electric corona discharge current and the applied high voltage. The ion wind produced by corona discharge has been drying of the black turmeric slices with an applied high voltage 4 kV, the gap electrode 6 mm and drying time 0-30 minutes with a 5 minute time interval. Sliced black turmeric was circle formed with a radius of 15 mm and a thickness of 2-8 mm with an interval of 2 mm thickness. According to the results obtained, a constant of comparing the ion wind velocity with the MOC.. Its value is around 102 which is hypotheses of the value of the relative permittivity the ion wind. The drying rate maximum of the black turmeric (*Curcuma aeruginosa Roxb*) slices occurs at the beginning of drying is after a 5 minute drying time. This characteristic for all the variations of the samples radius. This causes the moisture content of the black turmeric slices to drop drastically.

1. Introduction
Black turmeric (*Curcuma aeruginosa roxb*) is also called 'temu ring' in Java. It is one type of medicinal plant that is widespread in Southeast Asia including in Indonesia. It contains such us: flavonoids, saponins and bioactive compound curcumin [1]. The function of flavonoids as an anti-inflammatory can cure inflammation because these compounds have antibacterial, antiviral, antiseptic, antihistamine [2] effects. The curcumin can usage in food, cosmetic and pharmaceutical industries. The use of curcumin can be as anti-inflammatory, anti-bacterial, anti-carcinogenic, anti-fungal, antimicrobial agents [3]. Most of the black turmeric are sold in dried powder form. Various techniques have been used for drying of the rhizomes

Drying can be done by utilizing wind energy, solar thermal, and electrical energy. Drying electrical energy such as using microwave, ultrasound, heat pump drying and superheated drying, this drying has used 12% -15% of the total energy needs in the industry [4], so the development of the drying process is increasingly directed to the discovery of the drying method with increased energy efficiency.

Therefore, the aim of the research is to characterize the drying system which consumes quite low energy, namely ion wind drying and applying it to slices of black turmeric. Ion wind is generated using

IOP Conf. Series: Journal of Physics: Conf. Series **1217** (2019) 012025 doi:10.1088/1742-6596/1217/1/012025

a pair of electrodes whose sharp edges have different curvature and are subjected to DC high voltage sources. More pointed end electrodes are subjected to positive polarity and other electrodes are negative. The ion wind will flow in the direction of the electric field [5].

Ion wind drying uses high voltage sources [kV] or high electric field [V/m] but the current user is very low [μA] so the energy used is quite low. Another advantage of this drying system is that the drying results are more hygienic because corona discharge besides producing ion winds also produces ozone which is capable of killing microorganisms [6].

2. Materials and methods

2.1. Materials

The materials used in this report were black turmeric slices which were bought in the traditional market in Semarang city of Indonesia. The initial moisture content of black turmeric was measurement 36.4 %. Before being sliced in a circular shape, black tumeric is peeled first. The black turmeric slices have diameters 30 mm and its thickness varies from 2 mm - 8 mm with an interval of 2 mm thickness.

2.2.Experimental setup

Experiment setup of the ion wind drying and coupled equipment as shown in Figure 1. After the distance between electrodes d is set to 6 mm then the high voltage HV source is turned on with the pin electrodes having positive polarity and the multi-ring concentric electrodes having negative polarity, so that the corona formed is positive corona. The applied high voltage (*V*) was measured using a probe of a high-voltage (SEW *high voltage probe* P20 P28) varies from 0 volts to arc discharge with the voltage interval of 0.2 kV. At the time of corona discharge, one of the radiation from discharge corona in the form of ion wind will flow through the ring hole and then it radiating to the sample. The electric corona discharge current is measured using a microammeter (*Sanwa electronic instrument* CD772 made in Tokyo).

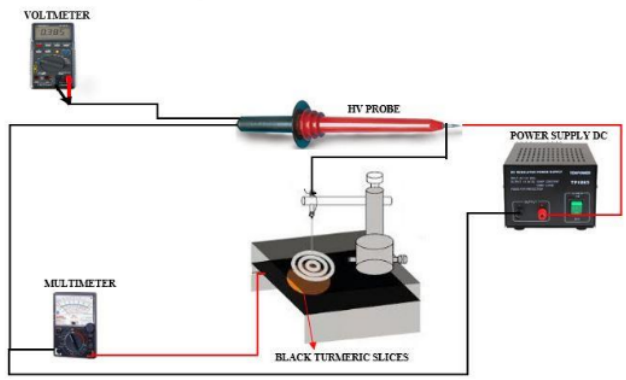

Figure 1. Experiment setup

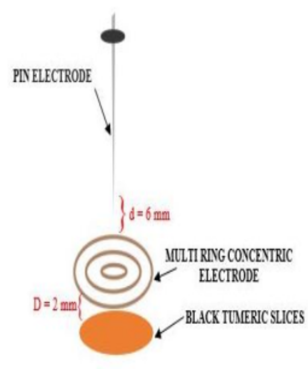

Figure 2. The sample position scheme from the electrode

In the drying process, black turmeric slices samples weighing 100 g which is on the glass plate was placed on the below of the multi-ring electrode by the distance 2 mm. At the time of corona discharge, one of the radiation from discharge corona in the form of ion wind will flow through the ring hole and then it radiating to the samples of black turmeric slices. The control sample was dried under the same conditions but without the ion wind treatment. The sample was dried with the constant applied voltage 3.4 kV while maintaining a 6 mm discharge gap, the time drying 0-30 minute and time interval 5 minute. The mass of the sample was weighed rapidly at regular intervals with an electronic balance (ARC120, Ohaus, USA) and used to calculate the moisture content of the sample.

IOP Conf. Series: Journal of Physics: Conf. Series **1217** (2019) 012025 doi:10.1088/1742-6596/1217/1/012025

3. Results and discussions

3.1. Determination of ion wind velocity using the method of characteristics (MOC)

In this study, the velocity of the ion wind was determined using a method of characteristic (MOC). Its method is utilizing current-voltage characteristics of the corona discharge system. In this study, the velocity of the ion wind was determined using a method of characteristic (MOC). Its method is utilizing corona current-voltage characteristics. Research using MOC such as the study to obtain the charge density distribution of positive corona discharge in gas in pin-plate geometry [7]. The other study, MOC to determine electric field distribution, electric potential, space charge density and EHD flow velocity produced by electric corona discharge in pin-plate and pin-grid configuration [8].

Preliminary experiments consisted of measuring the electric corona discharge current (μA) for different values of the positive applied high voltage from 1.4 to 4.4 kV with the voltage interval 0.2 kV and the electrode gap of 6 mm. The current-voltage relationship as shown in Figure 3.

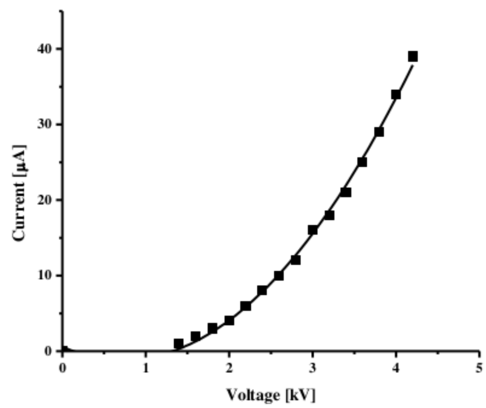

Figure 3. I-V characteristic

In Figure 3, it can be seen that the greater the voltage that is given the greater the current produced. The current value of *I* is proportional to the square of the value of *V* ($I \propto V^2$). This is in accordance with the equation:

$$I = \frac{2\mu\varepsilon_0 V^2}{d} \quad (1)$$

Or

$$I = CV^2 \quad (2)$$

Where *I* is the electric corona discharge current (ampere), *V* is the corona voltage (volt), μ is the ion mobility (m/Vs), is the permittivity of vacuum (F / m) and *d* is the distance between electrodes (m). From the characteristics of *I-V,* the value of constant *C* in the equation is obtained, so the equation of ion mobility:

$$C = \frac{2\mu\varepsilon_0}{d} \quad (3)$$

$$\mu = \frac{Cd}{2\varepsilon_0} \quad (4)$$

From equations (3) and (4) obtained the value of ion mobility $\mu = 13 \times 10^{-4}$ (m2 / Vs). The ion wind velocity is defined:

IOP Conf. Series: Journal of Physics: Conf. Series **1217** (2019) 012025 doi:10.1088/1742-6596/1217/1/012025

$$u = \mu . E \qquad (5)$$

Where E_{av} [V/m] is the average electric field intensity across the electrode gap. The average applied voltage V_{av} in this experiment 2.8 kV and the electrode gap $d = 6$ mm consequently $\mathbf{E}_{av} = 0{,}47\ 10^6$V/m. The ion wind speed by MOC according to equation (5) u = 6.07 10^2 ms-1. This value is far greater than the value of the direct measurement of wind velocity of 0.1 -10 ms^{-1} [7] with a comparable constant of about 100. This value is hypothesized as be the relative value of ion wind permittivity

3.2. Drying rate

Drying rate is a change in mass every time change. Graph drying rate of black turmeric slices as a function of drying time for thicknesses of 2 mm, 4 mm, 6 mm and 8 mm as shown in Figure 4.

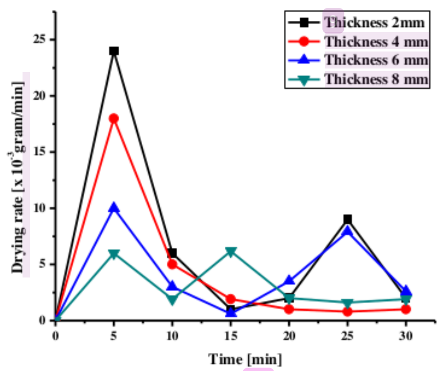

Figure 4. Drying rate as a function of the time

In Figure 3 it is shown that for all sample thicknesses, the maximum drying rate occurs at the beginning of drying time. It is according to the results of previous studies, namely the study of the ionic wind drying of wild ginger slices [9] and electrohydrodynamic (EHD) drying of ginger slices [10] for the variety of diameter value. This because occurs the transfer of a large portion of the mass from material to air in the form of water vapor drying occurs on the surface of the material. At the next, drying time 10 to 30 minutes the drying rate is relatively slow. This is because the movement of the diffusion of water from the material to the surface and the evaporation process on the material surface has been reduced. However, at a thickness of 2 mm, 5 mm and 8 mm the drying rate was decreased fluctuate.This is due to the lack of precision of the location of the tip of the pin electrode against the center of the sample surface.

3.3. Moisture content

The graph of moisture contents of black turmeric slices as a function of the drying time for thicknesses of 2 mm, 4 mm, 6 mm and 8 mm as shown in Figure 4.

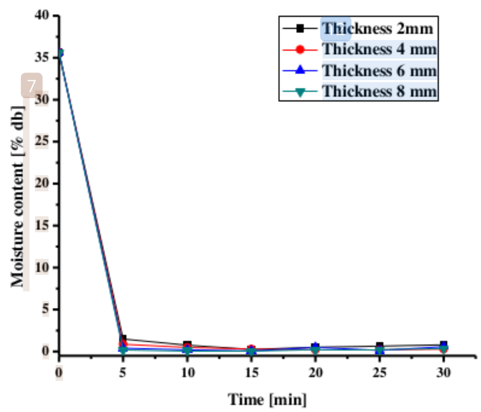

Figure 5. The moisture content of black turmeric slices as a function of time

In Figure 4 it can be seen that for all samples with varying thickness, moisture content in the first 5 minutes dropped drastically. The initial moisture content of 36.4% decreased to around 2.%. This is because at the same time the maximum drying rate has a very high mass transfer of water to air vapor so that moisture content decreases rapidly. This graph is in accordance with the graph in Dilip's writing about solid drying which divides moisture into 2 segments, namely the constant-rate drying period and the falling-rate period [11].

4. Conclusion

This paper has presented determined velocity of ion wind using a method of characteristic (MOC) and it was applicated to the drying of the black turmeric slices. The ion wind speed by MOC $\mathbf{u} = 6.07\ 102\ \mathrm{ms}^{-1}$. This value is far greater than the value of direct measurement of wind velocity of 0.1 -10 ms^{-1} with a comparable constant of about 100. This value is hypothesized as be the relative value of ion wind permittivity. The drying results, the maximum drying rate is obtained after drying for 5 minutes for all sample thicknesses. Conversely, the moisture contents of the sample after the first 5 minutes fell drastically from 36.4 percent to around 2 percent for all sample.

Acknowledgments

The authors would like to thank the University of Diponegoro who has approved this research so that it can be funded by the Directorate of Research and Community Service of the Ministry of Research, Technology and Higher Education according to the Letter of Assignment of Superior Research of Higher Education (PUPT) Number: 101-121/UN7.P4.3/PP/2018

References

[1] Alvika M S and Erba V C 2016 Cikta Morkoc H 1992 *J. Vac. Sci. Technol.* B 10 1237 *Konversi* **5** 17
[2] Mengying W, Yinghui M, Yuanyuan L, Yuan Z, Lihui M, Kexin Y, Zifeng P, Zhiqiang L, Zhongying L 2018 *Journal of Chramotography B* **1086** 1
[3] Li M, Grace Gar-Lee Y, Stephen K W T ,Kwok P F, Clara B-S L 2018 *Phytomedicine* **8**
[4] Moses J A, Tomas N, Alagusundaram K, Tiwari B K 2014 *Food Engineering Reviews* 2014 **6** 43
[5] Nur M, Azzulkha A H, Restiwijaya M, Muchlisin Z, Sumariyah 2014 *Advances in Physics Theories and Applications* **30**
[6] Khadre , M.A., A.E. Yousef, And J.-G. Kim, 2001 *Journal Of Food Science* **66** 9

[7] K. A damiak, P. Atten, 2004 *Journal of Electrostatics* **61** 85–98
[8] L. Zhao, K. Adamiak, 2005 *Journal of Electrostatics* **63** 337–350
[9] Sumariyah, Ainie Khuriati, Enny Fachriyah, 2018 *IOP Conf. Series: Journal of Physics: Conf. Series* **1025** (2018) 012016
[10] Sumariyah, Ainie Khuriati and, Enny Fachriyah, 2018 *IOP Conf. Series: Journal of Physics: Conf. Series* **1025** 012015 Conference 1
[11] M. Parikh, Dilip, 2015 *Chemical Engineering (New York- Mcgraw Hill Incorporated then Chemical Week Publishing Llc*) April 2014

C14_Determination of ion wind velocity using the method of characteristics (MOC) and its application for drying of black turmeric (Curcuma aeruginosa Roxb) slices

ORIGINALITY REPORT

12%	6%	8%	1%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	W Cao, Y Nishiyama, S Koide, Z.H Lu. "Drying Enhancement of Rough Rice by an Electric Field", Biosystems Engineering, 2004 Publication	2%
2	www.atlantis-press.com Internet Source	2%
3	telkomnika.uad.ac.id Internet Source	1%
4	Somayeh Taghian Dinani, Michel Havet. "The influence of voltage and air flow velocity of combined convective-electrohydrodynamic drying system on the kinetics andenergy consumption of mushroom slices", Journal of Cleaner Production, 2015 Publication	1%
5	www.bsn.go.id Internet Source	1%

6	Zhao, L.. "EHD flow in air produced by electric corona discharge in pin-plate configuration", Journal of Electrostatics, 200503 Publication	1 %
7	tel.archives-ouvertes.fr Internet Source	<1 %
8	www.semanticscholar.org Internet Source	<1 %
9	COMPEL: The International Journal for Computation and Mathematics in Electrical and Electronic Engineering, Volume 26, Issue 4 (2007-08-16) Publication	<1 %
10	Zhao, L.. "EHD gas flow in electrostatic levitation unit", Journal of Electrostatics, 200607 Publication	<1 %
11	A. K. Chaou, A. Mekhaldi, M. Teguar. "Elaboration of novel image processing algorithm for arcing discharges recognition on HV polluted insulator model", IEEE Transactions on Dielectrics and Electrical Insulation, 2015 Publication	<1 %
12	acikbilim.yok.gov.tr Internet Source	<1 %

13	www.worldscientific.com Internet Source	<1 %
14	International Journal of Structural Integrity, Volume 6, Issue 3 (2015) Publication	<1 %
15	Yiotis, A.. "A 2-D pore-network model of the drying of single-component liquids in porous media", Advances in Water Resources, 200102/03 Publication	<1 %
16	docplayer.net Internet Source	<1 %
17	A. Chelih, M. Bouadi, M. R. Bouazza, A. Safa, K. Yanallah, F. Pontiga. "Illustration of the dependence of the electrohydrodynamic force on the electrode configuration in a positive corona discharge", 2022 2nd International Conference on Advanced Electrical Engineering (ICAEE), 2022 Publication	<1 %

Exclude quotes	Off	Exclude matches	Off
Exclude bibliography	On		

C14_Determination of ion wind velocity using the method of characteristics (MOC) and its application for drying of black turmeric (Curcuma aeruginosa Roxb) slices

GRADEMARK REPORT

FINAL GRADE

/0

GENERAL COMMENTS

Instructor

PAGE 1

PAGE 2

PAGE 3

PAGE 4

PAGE 5

PAGE 6