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Time Estimation of Onion Leaf Drying

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Abstract

The main process of the onion post harvest treatment is drying proces. High moisture content of onion leaf and outer layer of onion must be reduced up to moisture content 12% or below (wet basis). This level keeps onion being still fresh. The conventional drying with direct sunlight still has been widely used because of the cheap process. However, this technique needs too long drying time as well as climate dependency. This research evaluated convective dryer for onion leaf drying. The mass transfer coefficient, and moisture diffusivity was estimated to predict effective drying time. Results show that the drying time was shorter as the temperature and air velocity increased. For example, at 60^{o}C and air velocity 0.5 m.s^{-1}, the drying time was about 19 hours. The drying time can be can be 5 hours shorter at higher air velocity. In addition, with increase of air velocity, the drying time can be also speeded up, significantly. Here, the air temperature must be kept at maximally 60^{o}C in order to avoid onion degradation. Therefore, the increase of air velocity is a good option to shorten drying time and retain the quality.

Keywords: *convective drying, diffusivity, moisture, quality, temperature*

Introduction

Onion, Allium cepa L., is known as one of the most impor-tant crops in many countries due to its functions as seasoning, food and for medical uses (Bonaccorsi et al., 2008). This special characteristic flavor (pung ency) or aroma, bio-logical compounds and medical functions are caused by their high organo-sulphur compounds (Mazza and LeMaguer, 1980; Corzo-Martínez et al., 2007). Onion production is the third highest in world vegetable produc-tion with the annual production capacity 47 million tonnes (Kumar et al, 2006). Brebes as one of the region in Central Java-Indonesia contribute about 170.000 tons. This activity involves around 30,000 ha lands and 100.000 farmers.

The main problems of onion stock is the post harvest treatment with drying process. Reducing water content to the desired level by drying process is one way to extend the shelf life of food product. The drying process must be designed with minimum substantial loss of flavor, taste, color and nutrients (Kumar dkk, 2006). Besides that, the other challenge in the food drying is the process must be operated efficiently. Conventional dryer with sunlight is really helpful in the aspect of simplicity and low energy cost. It has been used for long time in almost of all areas, such as farming, fishery, forestry, and herbal medicine. However, the dryer was incovenience because of climate dependency (Djaeni et al, 2013a). The conventional drying with direct sunlight depends on climate both the quality and continuity. In the claudy or rainy day, the drying cannot be well performed. As a result, the outer of onion layer has high moisture content. This can degrade the onion quality during storage as indicated in germination, smelty, bine growth, and decaying. Meanwhile, the oven dryer with fossil fuel combustion still deals with high energy consumption and onion quality degradation.

Regarding to this issue, the development of energy efficient dryer by exploring renewable energy such as biomass becomes more and more important.The drying process requires about 70% of total energy in post harvest treatment (Kudra, 2004; Djaeni et al, 2013a; Gilmour et al, 2004). In addition, most of industrial drying used the fossil fuel as energy source that was still in-efficient for energy usage. Currently, the energy efficiency of dryer ranged 30 – 60% which took 40 – 50% of total cost for the treatment. It means that the total energy introduced was about 1.5 – 3.0 times from real load. On the other hand, the modern drying technology has been widely developed with attractive result respecting to the product quality. However, the development of energy efficient dryer was scare. The fossil fuel consumption has been big issue since the feedstock is limited. Hence, the exploration of new renewable energy from biomass is attractive idea.

Recently, there have been more studies about the effect of drying parameters on moisture removal, expressed by kinetic models. They have been reported for different varieties of onion (Krokida et al., 2003; Sarsavadia et al.,

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1999; Sawhney et al., 1999; Kiranoudis et al., 1996; Yald ´yz and Ertek ´yn, 2001; Wang, 2002). However, there are some drying variables have significant effect on the drying kinetic, such as temperature and drying air velocity. This research evaluated convective dryer for onion drying after post-harvest process. The major was to dry the outer layer and leaf of onion up to moisture content of 12 - 16%. The mass transfer coefficient, and moisture diffusivity was calculated to predict effective drying time.

Materials and Methods

Materials

The local variety of onion from Brebes having initial moisture content around 85–90% was used for experimentation.

Experimental Set-Up

The onion drying was conducted in tray dryer. The aim was to dry the outer layer and leaf of onion up to moisture content of 15 - 20%. With dry outer layer and leaf, the inside part of onion can be kept fresh before used. Normally, the raw onion harvested from farm contained one third of leaf. Both parts contained 88 - 92% water. After drying, the average of moisture was desired at 80 - 85%.

Here, the onion drying was completed by zeolite put in the side of tray (Fig. 1). So, after removing water from product, the wet air was directly dehumidified by zeolite. The air temperature and humidity were measured by KW0600561, Krisbow®, Indonesia (noted as T-RH). The air velocity was measured with an anemometer KW0600562, Krisbow ®, Indonesia (Djaeni et al, 2013b).

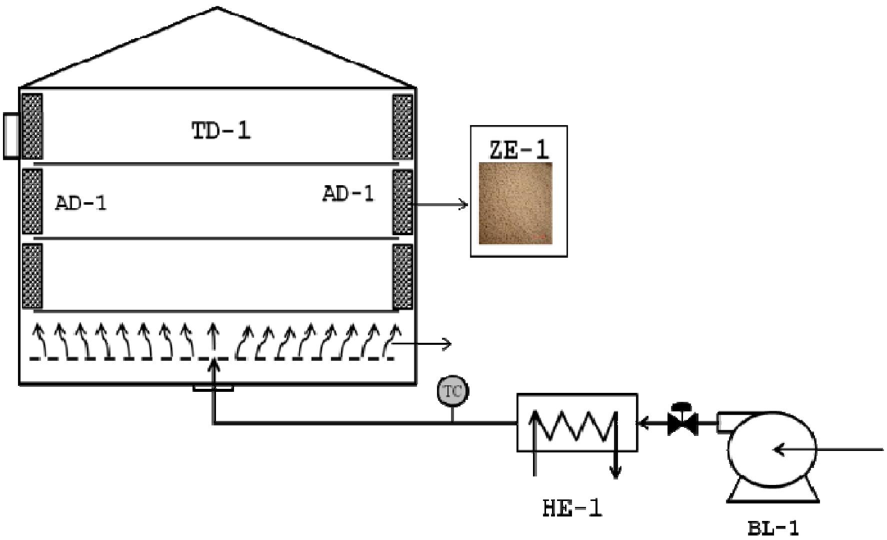

Fig. 1. Onion drying with zeolite (Note: TD-1: Tray Dryer, AD-1: Adsorber Box, ZE-1: zeolite, HE-1: Air Heater, BL-1: Blower. The tray dryer dimension was 0.6 x 0.4 x 0.6 m)

The ambient air was heated up to 50°C by electric heater. The air passed the dryer to dry 2 kg of onion. The mass of the sample was measured in every 1 h during drying process using a digital balance, measuring to an accuracy of 0.001 g. The digital balance was kept very close to the drying unit and the weight measurement process took about 10 s time. Experiments were stopped when the moisture content of the material up to desired level. The moisture content versus time was observed as input to find effective drying time. The effective drying time can be estimated based on the previous research (Djaeni et al, 2013b). The process was repeated for different air temperature.

Estimating Drying Time

The first theory of mass transfer in thin layer drying was described by Lewis (1921) based on Newton's law. The theory expressed as follows:

$$M_R = \frac{M - M_e}{M_0 - M_e} = exp(-kt) \qquad (1)$$

where: MR is the moisture ratio; M is the moisture content at time t and M_0 and Me, the initial and equilibrium moisture contents, respectively, on a dry basis; and k is mass transfer coefficient.
The value of k can be calculated by:

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$$k=\frac{ShD}{L} \quad (2)$$

The initial moisture content of the material was measured by drying in an oven at 105 °C for 24 h and expressed as kg water/kg dry solids which varied around 9.00 kg water/kg dry solids (AOAC, 1990).

The Diffusivity equation was developed by Crank (1975) can be used for various regularly shaped bodies such as rectangular, cylindrical and spherical products. For long drying period, this solution can be written in a logarithmic form as follows (Sun et al., 2007; Tutuncu & Labuza, 1996)

$$\ln M_R=\ln\frac{8}{\pi^2}-\frac{\pi^2 D_{eff} t}{4L_0^2} \quad (3)$$

where Deff is the effective diffusivity ($m^2.s^{-1}$); L_0 is the half thickness of slab (m). The form of Eq. (3) can be applicable for particles with slab geometry by assuming uniform initial moisture distribution. Diffusivities are typically determined by plotting experimental drying data in terms of ln MR versus drying time t in Eq. (3), because the plot demonstrates a straight line with the slope of (π^2 /Deff)/(4 L_0^2).

The relation between diffusivity and the drying mass transfer coefficient can be presented based on sherwood number (*Sh*) as follow:

$$Sh=2,0+0,55Re^{0,53}\ Sc^{1/3} \quad (4)$$

Schmidt and Reynold number can be calculated by:

$$Sc=\frac{v_a}{D} \quad (5)$$

$$Re=\frac{\rho_a L v_a}{\mu_a} \quad (6)$$

Where v_a is drying air velocity ($m.s^{-1}$), L is characteristic travelled length (m), μ is dynamic viscosity of air and ρ is density of air. By applying these equations, the value of drying time can be estimated by Lewis equation (Equation 1). (Nguyen, T.K., 2011; Takhar, P.S., 2011; Marinos-Kouris, D., and Maroulis, Z.B., 2006 ; Falabella, M. C., Suarez, C. and Viollaz, P. E., 1991)

Result and Discussion

The effect of operational temperature

The response of moisture content reduction as a function of time was illustrated in drying curve Fig. 2. In this experiment, the operational temperature of onion leaf was varied in the range of 40, 50, and 60°C. The result showed that the higher temperature give higher drying rate. In general, the water removal was affected by air temperature. Higher air temperature, higher water removal (Djaeni et al, 2013b). With higher temperature, the relative humidity of air was lower. Furthermore, the sensible heat of air for evaporating water was higher. It can enhance the driving force for mass transfer. Besides that, at higher temperature the drying process needed higher energy power which followed by larger driving force for heat transfer (Methakhup et al, 2005).

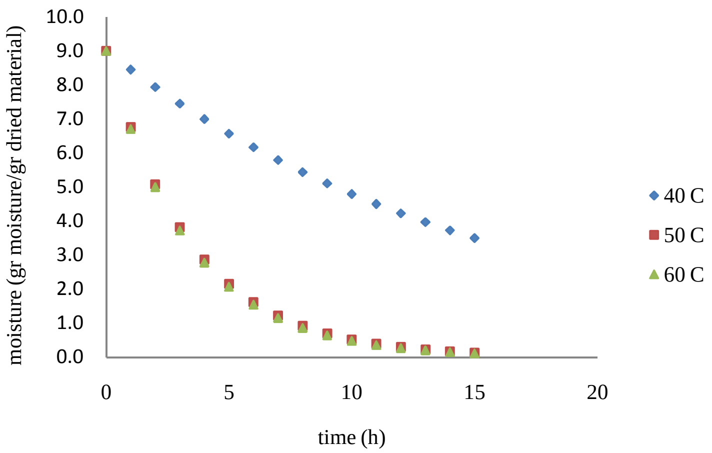

Fig.2. The response of moisture content in onion leaf versus time at different operational temperature for air velocity 0.5 $m.s^{-1}$

The initial moisture content of onion was very high 9 (gr moisture/gr dried material) or 90% wet basis. At initial, the drying rates were higher. It reduced gradually until the drying process completed. The high drying rate

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was caused by the higher moisture diffusion in the falling rate period. The decrease of drying rate was due to the more energy absorbed by the water at the product surface.

The water diffusivity, mass transfer coefficient and drying time were predicted using equation 1- 6. Firstly, the moisture diffusivity in onion leaf was estimated using Equation 3. After that, the constant of drying rate is calculated with Equation 2. The value of mass transfer coefficient used to estimate the drying time. The results were depicted in Table 1.

Regarding to the Table 1, at higher temperature, the diffusivity of moisture in onion leaf was higher. In general the values of D_{eff} for food materials dried using the conventional and solar drying methods in the range of 10^{-11}- 10^{-9} $m^2.s^{-1}$ for food materials dried using (Madamba, Driscoll, & Buckle, 1996). In this study, the moisture diffusivity was obtained in the range of 10^{-10} - 10^{-9} $m^2.s^{-1}$. The results show that the drying time was shorter as the higher temperature. At drying air temperature 40 ^oC the drying time was very low. It needed more than 80 h to remove the moisture content from 90% to 16 % wet basis. When the drying temperature increased to 60 ^oC, the drying time that needed to decrease water content until 12% wet basis can be speeded up to be 19 h.

Table 1. The value of water diffusivity, mass transfer coefficient and drying time in various operational air temperature for air velocity 0.5 m.s^{-1}

Temperature (^OC)	Diffusifity ($m^2.s^{-1}$)	k (s^{-1})	Drying time (h)	Moisture reduction (%wet basis)
40	5.274 x10^{-10}	1.7534 x10^{-5}	86	90-16
50	2.434 x10^{-9}	8.0925 x10^{-5}	23	90-13
60	2.596 x10^{-9}	8.3050 x10^{-5}	19	90-12

The effect of operational air velocity

Plots of moisture reduction with drying time at various operational air velocities were illustrated in Fig. 3. From the curve we can see that with increase of air velocity, the drying time can be also speeded up.

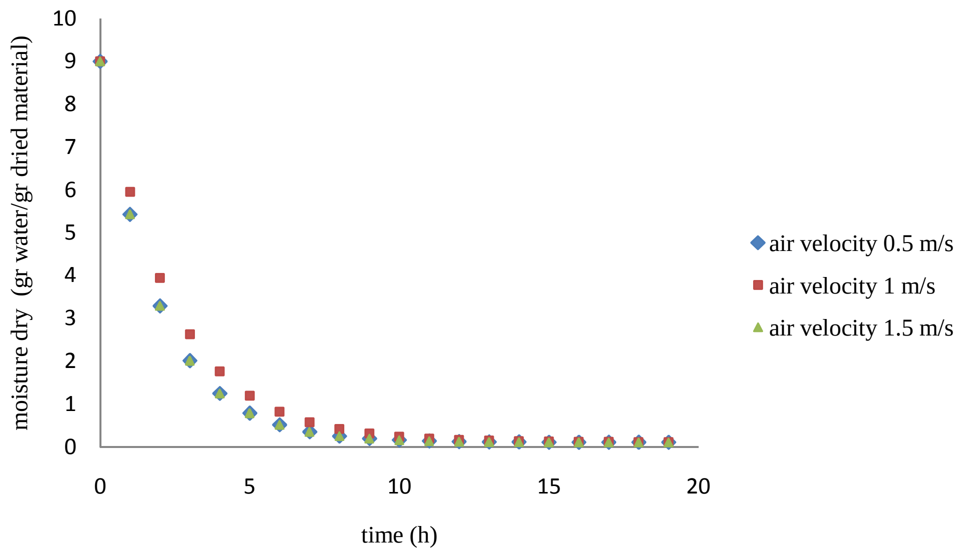

Fig.3. The response of moisture content in onion leaf versus time at different operational air velocity for air temperature 60^oC

The drying time at various air velocities were also estimated using equation above. The results were depicted in Table 2. The increase of air velocity enhanced the Sherwood number in which caused the constant of drying rate being higher. For example, the drying time can be accelerated 5 hours by increasing 2 fold operational drying air velocities to remove 78% water content. Hence, it can be noted that for heat sensitive products such as paddy, the increase of air velocity can be a potential option to speed up drying time instead of increasing operational temperature. This notification can also accommodate the previous recommendation pointed by Djaeni et al (2009).

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Table 2. The value of mass transfer coefficient and drying time in various operational air velocities for air tempeature 60 ^{0}C

Operational air velocities ($m.s^{-1}$)	k (s^{-1})	Drying time (hours)	Moisture reduction (%wet basis)
0.5	8.3050 x10^{-5}	19	90-12
1	1.1377 x10^{-4}	14	90-12
1.5	1.4258 x10^{-4}	11	90-12

Conclusion

The experiment was evaluated convective dryer for onion leaf drying at various drying air temperatures and air velocities. The results showed that parameter gave the positive effect on drying rate and drying time. The mass transfer coefficient, and moisture diffusivity was calculated to predict effective drying time. The works confirmed that the drying time was shorter as the temperature and air velocity increased. For example, at 60^{o}C and air velocity 0.5 $m.s^{-1}$, the drying time was about 19 h. Furthermore, the drying time can be accelerated 5 h by increasing 2 fold operational drying air velocities to remove 78% water. In addition, with increase of air velocity, the drying time can be also speeded up, significantly. Here, the air temperature must be kept at maximally 60^{o}C in order to avoid onion degradation. Therefore, the increase of air velocity is a good option to shorten drying time and retain the quality. The results can be a potential option for energy efficient dryer development.

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Lembar Tanya Jawab

Moderator : Jarot Raharjo (Pusat Teknologi Material, BPPT)

Notulen : Adi Ilcham (UPN "Veteran" Yogyakarta)

1.	Penanya	:	Nur Hidayati (Universitas Muhammadiyah Surakarta)
	Pertanyaan	:	Selain prediksi waktu, apakah nutrisi juga diuji?
	Jawaban	:	Setelah dikeringkan, dilakukan pengujian terhadap nutrisi bawang.
2.	Penanya	:	Sri Suhenry (UPN "Veteran" Yogyakarta)
	Pertanyaan	:	• Berapa kadar air minimum untuk bawang setelah dikeringkan? • Bagaimana kesimpulan proses dari penelitian ini?
	Jawaban	:	• Kadar air kurang dari 12%. Dengan kadar air tersebut mikroba tidak bisa tumbuh dan self life dapat diperpanjang. • Kesimpulan yang didapat adalah untuk suhu pengeringan 60^{o}C dan laju alir udara 0,5 m/det, waktu pengeringan dari kadar air 90% menjadi 12% diperlukan waktu 19 jam.