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Development and Performance Test of Vertical Bed Dryer for Drying of Corn Kernel

Juli Mrihardjono[1], Didik Ariwibowo[2], Sutrisno[3]

[1,2,3]Diponegoro University, Jl. Prof Sudharto, S.H. Tembalang Semarang Indonesia

ABSTRACT: This research aims to develop the design of vertical bed dryer which could dry corn kernel. The dryer characteristics has been investigated. The dryer design consists of three chambers which each in order to facilitate of inlet hot air dryer stream, corn kernel chamber, and outlet wet air. Each chamber was separated by perforated plate steel. Air flew by a blower and heated by 2 x 350 heaters. The research parameter was: (a) drying air temperature, varied 50-60 ^{o}C, (b) air velocity varied of 2-4 m/s, blower power (W), and moisture content, mc (%). The resuts shows that moisture content decreasing of 5 kg corn kernel from 20% to 10% took 24-26 minutes.

KEYWORDS: dryer, drying, vertical bed, corn kernel, moisture content

I. INTRODUCTION

Drying is a preservation process to reduce water activity by reducing water content, avoiding potential damage and contamination during long storage periods. The drying process must be able to improve hygienic conditions and product loss (Kaymak-Ertekin, 2002). Several drying methods have been developed such as microwave drying, hot-air drying, osmotic dehydration, spray drying, and vacuum impregnation. Another advantage of the food drying process is volume and weight reduction, which leads to storage and transportation costs (Okos et al., 1992).

Hygiene and cost-effective pathways in food preservation are important given the uncertainty of food supply. The introduction of dryers can improve the quality of dried products when compared to traditional drying methods such as sun drying. Therefore, a simulation model is needed for the design and operation of the dryer. Several researchers have developed simulation models for forced convection and natural convection drying systems proposed by Ratti and Mujumdar (1997). There have been many studies on the drying behavior of several fruits such as mushrooms, nuts, and pumpkin (Yaldiz and Ertekin, 20019) and chilies (Kaymak-Ertekin, 2002). However, some products from medicinal plants are sensitive to temperature, such as ginger, temulawak, kencur, turmeric, temureng and galangal.

One of the important agricultural commodities in Indonesia is corn. Safe storage for corn is at a moisture content (MC) of 14% -16% on a dry basis. In addition to food, corn is also used as animal feed. The problem with the quality of corn is the presence of aflatoxin, because aflatoxin is a toxic substance for humans and livestock. Normally, the MC of corn at harvest is in the range of 33-40% on a dry basis. At this MC level and humid weather conditions, Aspergillus flavus will infect corn kernels and then produce aflactoxin (Wongurai et al, 1992). Consequently, maize must be dried to 22-23% dry basis within 1-2 days (Prachayawarakorn et al, 1995).

In Indonesia, drying corn in the sun is no longer suitable due to the abundance of corn and it must be dried immediately for safe storage. Therefore, a mechanical dryer is needed as an alternative drying for corn kernels. There are several types of mechanical dryers such as fluidized bed dryers, rotary dryers, moving-bed dryers, and so on. The efficiency of these mechanical dryers differs due to differences in heat transfer and material characteristics. Fuidized bed dryer is widely applied in industry because it has several advantages compared to other types (Nonhebel and Moss, 1971), as follows:

1. The heat transfer rate is high, so the drying time is short and the size of the dryer is relatively small with a large capacity.
2. Bed condition isothermal, can produce relatively uniform product quality.

This advantage is achieved with a high air flow rate. With this fact, the thermal efficiency of the fluidized bed dryer is low (Giner and Calvelo, 1987). This is a consideration for dryer users in drying costs. Besides that, the use of the room or space footprint is also a concern. In general, bed dryers require a large footprint.

In order to improve thermal efficiency, optimization of bed height or thickness with respect to temperature and drying air rate needs to be investigated. Improvements to the vertical dryer design are also a path of exploration to increase drying capacity in a spatial footprint orientation. Therefore, a vertical bed dryer needs to be developed.

II. LITERATURE REVIEW

Drying or dehydration is a process of controlling heat from food products to evaporate a certain amount of water content. Drying is very important for a product for ease of transportation and to increase shelf life without losing quality. Drying includes a simultaneous process of heat transfer and mass transfer. The main parameters that control the drying rate are drying air temperature, air flow rate, air relative humidity (Sharad, 2013). These parameters are arranged in an equation or empirical relation. However, empirical relational literature on some agro products is not available and must be developed experimentally. In the drying process, hot air is generated and circulated over the material to be dried. The difference in water content between the core and the surface of the material creates a pressure gradient which becomes the driving force to remove water from the material.

Drying processes can be classified into three categories based on their operating pressure, namely: drying processes at atmospheric pressure, under vacuum pressure, and freeze drying. Freeze drying is a process of transferring water content by means of sublimation of the frozen material (Earle, 2004). Water transfer in vacuum drying is faster than at atmospheric pressure. The main limitation to vacuum and freeze drying is the need for a vacuum evacuation system resulting in high investment and operating costs. Other drawbacks of freeze drying are humidity control problems and the need for frozen storage space.

Drying technique at atmospheric pressure using hot air is the most economical technique. Among the drying techniques or methods with hot air is fluidized bed drying-¬FBD. FBD has advantages in the ease of controlling heat and mass transfer, uniform reduction of water content in a shorter time, and high drying rate (Kassem, 2011). FBD dryer increases efficiency because the material is covered with hot air which acts as drying air. An overview of the FBD dryer can be seen in Figure 1.

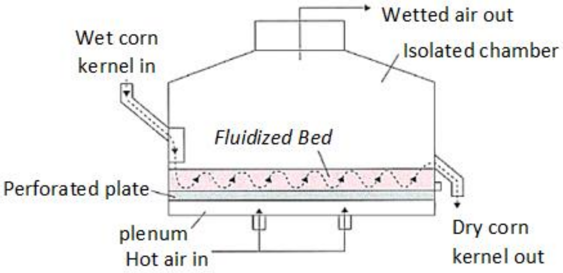

Figure 1. Fluidized bed dryer

These dryers can provide a uniform bed temperature throughout the drying period. However, air flow and the formation of hot spots can lead to variations in the humidity of the drying air and can cause product damage or quality non-uniformity. Products which are hygroscopic require special addition to be carried out in the FBD dryer.

The drying curve of a product represents the characteristics of the product against conditions of temperature, air velocity and pressure (Patil, 2012). A typical drying curve has three distinct periods, as shown in Figure 2.

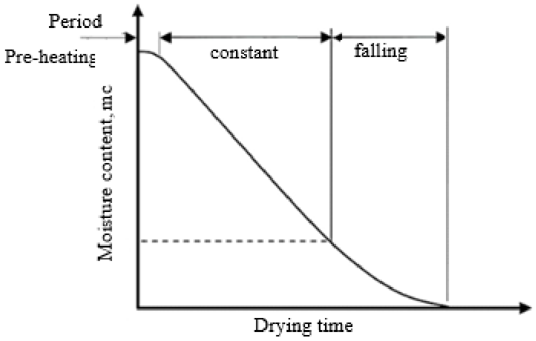

Figure 2. Drying curve

The initial period is when sensible heat is transferred to the wet material and then pre-heated. The second period is called the constant drying rate period. In this period, the free water content (free moisture) on the surface begins to evaporate and continues until all the water content has evaporated at the critical water content. The third period is called the falling rate period. The water content undergoes mass transfer by diffusion from the inside to the outside or surface and causes a driving force. Reduction of the moisture content of the wet material per unit time (drying rate) is a method for measuring dryer performance (Chen, 1989; Smirnov, 1989).

Sarker (2015) analyzed the energy efficiency and exergy of industrial-scale rice FBD dryers. The high operating temperature and high-water content of the material increase the specific energy consumption. Poor insulation also contributes to energy loss, resulting in only 31-37% exergy utilization and a large amount of energy wasted. Irigoyen (2016) tested the energy consumption of FBD dryers for soybean products, which confirmed that energy efficiency increased by 63%. Meanwhile, Ozahi and Demir (2015) reported that a lower ratio of normalized mass (mp/ma.▯t), in a pilot-scale FBD dryer, would reduce the drying efficiency of corn. Thus, normally energy efficiency on a pilot scale will be lower. Therefore, another dryer scheme needs to be made to compare the energy efficiency.

III. METHODOLOGY

Equipment in this research includes: vertical bed dryer prototype, thermometer, thermohygrometer, manometer, anemometer, and mc-meter. While the research material is in the form of corn kernels with an initial MC of around 23%.

A. Vertical Bed Dryer Prototype Design and Fabrication

The design of the vertical bed dryer prototype that will be made consists of the main components: vertical bed, fan, heater, and piping. The schematic of the tool can be seen in Figure 3. The vertical bed is in the form of a cylinder which consists of 3 (three) compartments in the form of annulus. Annulus-1 to facilitate the flow of drying air into the vertical bed, annulus-2 to place the corn kernels, and annulus-3 to facilitate the drying air to leave the vertical bed. Between the annulus is sealed with a wall made of perforated plate.

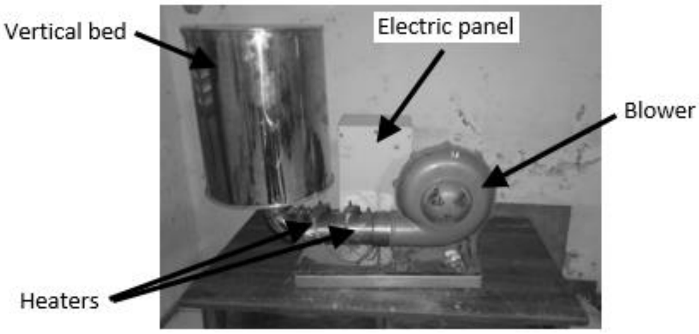

Figure 3. Drying curve

The dryer is equipped with instruments including:
i. Thermometer, to measure dry bulb temperature and wet bulb temperature.
ii. Manometer, to measure the pressure difference or pressure drop.
iii. Thermohygrometer, to measure the temperature and relative humidity of the air.
iv. Anemometer, to measure airspeed.
v. MC-meter, to measure the water content of corn kernels
vi. Infra-red thermometer, to measure the temperature of the drying wall.

The manometer, thermometer and thermohygrometer instruments are installed at the inlet and outlet of the vertical bed, while the anemometer is installed at the outlet bed.

B. Research Parameter

Title must be in 24 pt Regular font. Author name must be in 11 pt Regular font. Author affiliation must be in 10 pt Italic. Email address must be in 9 pt Courier Regular font.

Parameters in the research included air temperature, air velocity, air humidity, and corn seed bed thickness. These parameters are divided into dependent variables, independent variables, and the following fixed variables:

Independent variable:

a. Outlet air velocity (vud,out), which is varied at 2 m/s , 3 m/s , and 4 m/s.
b. The inlet air temperature (Tud,in), which is varied at 120 ^{o}C, 135 ^{o}C and 150 ^{o}C.

Dependent variable:

a. Relative humidity (RH) of outlet air (RH_{out})
b. Outlet air temperature ($T_{air,out}$)
c. Water content or final MC of corn kernels (final MC)
d. Fan Power (P_{fan})
e. Heater power (P_{heater})

Fixed variable:

a. The relative humidity (RH) of the inlet air (RH_{in}).
b. Radial bed thickness (H_{bed}) is set at 50 mm.

C. Research Procedure

After the prototype has been manufactured, testing is carried out with the following steps:

1. Inserting corn kernels into the annulus-2
2. Turn on the fan and heater
3. Set the fan speed, according to the specified independent variable
4. Set the inlet air temperature, according to the set independent variables
5. Adjust the damper to set the air fraction
6. Ensure that the anemometer reading on the outlet bed side is within the specified variable.
7. Make sure the thermometer reading does not change significantly

Data collection steps are carried out in 2 (two) stages including pre-research and main research. Data collection for pre-research is carried out as follows:

1. Run the vertical bed drying system until the indicated outlet temperature is stable
2. Record the time required to achieve these conditions and the test results are recorded in the observation table
3. The time recording results are described for the time interval for changing the temperature setting.

Furthermore, the main research data collection is carried out starting from the steady state so that the data taken is valid. The test data collection procedure is as follows:

1. Start
2. Set the temperature and airspeed as planned and wait for the system to settle down
3. Record the results of observations of measuring instruments such as air temperature and humidity, air speed, fan and heater power, RH, and mc corn kernels
4. Recording ends when mc corn has reached 14%

The data recording table can be seen in Table 1.

Table 1. Experimental data recording sheet

Set of independent variables set:

a. Outlet air velocity ($v_{air,out}$) : .... m/s
b. Inlet air temperature ($T_{air,in}$) : ..... ^{O}C
c. Recirculated air fraction (FR) : ....

Time, t (minute)	Air drying				Fan Power	Heater Power	mc
	Inlet condition		Outlet condition				
	$T_{air,in}$ (^{O}C)	$RH_{air,in}$ (%)	$T_{air,out}$ (^{O}C)	$RH_{air,out}$ (%)	(kW)	(kW)	(%)
0							
1							
2							
etc.							

D. Analysis

Experimental data are plotted in a graph of mc corn kernels versus time, for each set of independent variables defined. Then, the graphs are analyzed and compared, to find out the most efficient parameters. The efficient indicator is the specific energy consumption, which is the ratio between the energy required per kilogram of dry corn.

IV. RESULT AND DISCUSSION

Corn kernel is placed as a bed in the annulus drying chamber. Then the blower and heater are turned on. The drying temperature is set at 50 oC via the temperature controller setting. Every 2 (two) minutes the corn water content data is measured using a mc-meter until the water content reaches 10%. The results of drying shelled corn are presented in Figure 4.

Figure 4 shows that the trend of reducing the water content of shelled corn decreased sharply from the beginning of drying to the 8th minute. Then the trend is more gentle until the final water content is 9-10%. This trend is suspected because the water content outside the fiber diffuses more easily to reach the surface. then becomes saturated steam on the surface.

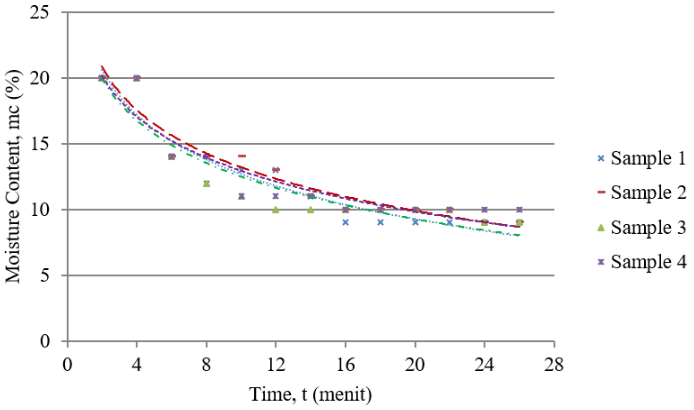

Figure 4. Corn drying curve

The process is continued by diffusion of water vapor into the hot air flow and advection also occurs so that the film layer of water vapor on the surface of the corn kernels is not saturated. The degree of saturation of the water vapor film layer on the surface becomes the driving force for diffusion outside the corn fiber.

The corn drying process is approached by a thin-layer drying mathematical model from Henderson-Pabis (in Lola, 2018). With this approach, the results of the mathematical model for each sample are presented in Table 2.

Table 2. R^2 value of Hendersen-Pabis model for each sample

Sample	Temperature (°C)	Henderson – Pabis Equation		
		A	k	R^2
Corn Kernel	50	4,924	0,8583	0,9022
		4,751	0,8625,	0,9276
		4,653	0,8293	0,8701
		4,489	0,8511	0,8795

The drying graphs of samples 1 to 2 show fitness with the Hendersen-Pabis model but with an average R^2 value close to 0.9. This low R^2 value is suspected because the thickness of the layer in this drying is 50 mm.

V. CONCLUSIONS

The conclusion from the results of research on drying corn with a vertical bed type dryer is that the characteristics of the developed vertical bed type corn dryer are similar to the characteristics of a horizontal bed type dryer, which is indicated by conformity to the Hendersen-Pabis equation. The suggestion from this research is the need for further research by completing data on various values of temperature variables and heating air velocity.

REFERENCES

1) Chen Peishi, Pei David CT, 1989. A mathematical model of drying processes. Int J Heat Mass Transf; 32:297–310.
2) Earle Richard L, Earle MD, 2004. Unit operations in food processing. New Zealand: Web Edition.
3) Kassem AS, Shokr AZ, Mahdy ARE, Aboukarima AM, Hamed EY, 2011. Comparison of drying characteristics of Thompson seedless grapes using combined microwave oven and hot air drying. J Saudi Soc Agric Sci; 10:33–40.
4) Lion, 2004,''Solar Energi Apllied For Heating And Drying'', Agricultural Journal, Energi System Engineering, Indian Istitute.
5) Lola Domnina B. Pestaño dkk. Mathematical Modeling of the Drying Kinetics of Thinly-Sliced Saba (Musa Balbasiana) Using Hot-Air Dryer, MATEC Web of Conferences 156, 02004 (2018)

6) Ozahi Emrah, Demir Hacimurat, 2015. Drying performance analysis of a batch type fluidized bed drying process for corn and unshelled pistachio nut regarding to energetic and exergetic efficiencies. Measurement; 60:85–96.
7) Phoungchandang, S, Saentaweesuk, S, 2011, Effect of two stage, tray and heat pump assisted-dehumidified drying on drying characteristics and qualities of dried ginger, Food and Bioproducts processing 89 hal 429-437, Elsevier.
8) Prachayawarakorn, S., Soponronnarit, S, Nathakaranakule, A. And Inchan, S., 1995. Controlling Aflaktoksin Contsmination in Maize Stored under Tropical Conditions, Proceedings of 17th ASEAN Technical Seminar on Grain Post-Harvest, Technology, Luut, Malaysia.
9) Patil RT, Dattatreya M Kadam, 2012. Handbook of food process design. 1st ed. UK.
10) Prasertsan S, Saen-saby P, Prateepchaikul G, Ngamsritrakul P., 1996. Effects of drying rate and ambient air conditions on the operating modes of heat pump dryer. In: Proceedings of the 10th international drying symposium; p. 529–34.
11) Sarker Md Sazzat Hossain, Ibrahim Mohd Nordin, Aziz Norashikin Abdul, Punan Mohd Salleh, 2015. Energy and exergy analysis of industrial fluidized bed drying of paddy. Energy 2015; 84:131–8.
12) Sharada S., 2013. Studies on effect of various operating parameters & foaming agents – drying of fruits and vegetables. Int J Mod Eng Res 2013; 3:1512–9.
13) Smirnov MS, Lysenko VI., 1989. Equations of drying curves. Int J Heat Mass Transf; 32:837–41.
14) Strumillo, C., 2006. Perspectives on development in drying. Drying Technol. 24, 1059e1068.
15) Torrez Irigoyen Ricardo M, Giner Sergio A., 2016. Drying, toasting of presoaked soybean in fluidized bed. Modeling, validation and simulation of operational variants for reducing energy consumption. J Food Eng 2016; 171:78–86.
16) Wongurai, A., Tsuruta, O. And Arai, K., 1992, Water Activity of Thai Maize and Growth of Aspegillus Flavus, Research Report of Maize Quality Improvement Resarch Centre Project, 7-9.