CHAPTER I
INTRODUCTION

1.1 Background

Drying is a process of evaporating liquid from wet raw materials by applying heat. Drying is an important operation in agricultural chemistry, biotechnology, food, polymers, ceramics, pharmaceuticals, pulp and paper, mineral processing, and wood processing industries. Drying various raw materials is necessary to facilitate handling of free-flowing solids, preservation and storage, reduction of transportation costs, achieving the desired product quality, and other purposes. In many processes, improper drying can cause permanent damage to product quality, rendering the product unsellable.

1.2 Problem Statement

Based on the background, a drying method was selected for the process of extracting water from solid materials. In this experiment, the operation of the equipment, drying time, and drying rate will be studied.

1.3 Practicum Objectives

1. To identify the effect of independent variables on the moisture content of the samples used.
2. To identify the effect of independent variables on the drying rate of the samples used.
3. To identify the correlation between drying time and moisture content.
4. To identify the correlation between moisture content and drying rate.
5. To understand how to read sorption isotherm curves.

1.4 Practicum Benefits

1. Students are able to identify the effect of independent variables on moisture content in the samples used.
2. Students are able to identify the effect of independent variables on the drying rate of the samples used.
3. Students are able to identify the correlation between drying time and moisture content.
4. Students are able to identify the correlation between moisture content and drying rate.

5. Students are able to understand how to read sorption isotherm curves.

CHAPTER II
LITERATURE REVIEW

2.1 Drying

Drying is the process of removing water or separating water in relatively small amounts from a material using heat energy. The result of the drying process is a dry material with a moisture content equivalent to the moisture content of normal equilibrium air or equivalent to a water activity value that is safe from microbiological, enzymatic, and chemical damage (Anton, 2011 in Risdianti et al., 2016). Physical changes that may occur include shrinkage, puffing, crystallization, and glass transition. In some cases, desired or undesired chemical or biochemical reactions may occur, leading to changes in color, texture, odor, or other properties of the solid product. In catalyst production, for example, drying conditions can result in significant differences.

Drying occurs through the evaporation of liquid by applying heat to wet raw materials. As mentioned before, heat may be provided by convection (direct drying), by conduction (contact or indirect drying), by radiation, or volumetrically by placing wet materials in a field of electromagnetic microwaves or radio frequencies. More than 85% of industrial drying is convective drying using hot air or direct combustion gas as the drying medium. Over 99% of applications involve water removal. All modes except dielectric (microwave and radio frequency) supply heat at the boundary of the drying object, so heat must diffuse into the solid primarily by conduction. The liquid must flow to the material boundary before being carried away by the carrier gas (or by vacuum application for non-convective drying).

Transportation of liquid vapor in solids can occur by one or more of the following mass transfer mechanisms:

- Liquid diffusion, if the solid is wet at a temperature below the boiling point of the liquid.
- Vapor diffusion, if the liquid evaporates in the material.
- Knudsen diffusion, if drying is carried out at very low temperatures and pressures, such as in freeze drying.
- Surface diffusion (possibly, though not proven).
- Hydrostatic pressure difference when the internal evaporation rate exceeds the rate of vapor transport through the solid to the environment.
- A combination of the above emchanism.

2.2 Drying rate

Based on the drying of wer solids under constant drying conditions. In the most common case, after an initial adjustment perio, the dry basis moisture content X decreases linearly with time as evaporation begins. This is followed by a non-linear decrease in X until, after a very long period, the solid reaches the equilibrium moisture content X* and the drying process stops. The free moisture content can be defined as:

$$Xf = (X - x^*) \tag{2.1}$$

he drying rate decreases to zero when Xf = 0

$$N = \left(\frac{Ms}{A}\right), \left(\frac{dX}{dT}\right) \text{atau } \left(\frac{Ms}{A}\right), \left(\frac{dXf}{dt}\right) \tag{2.2}$$

(Geankoplis, 1993)

Under constant drying conditions, N ($kg.m^{-2}.h^{-1}$) is the rate of water evaporation, A is the evaporation surface area (which may differ from the heat transfer surface area), and Ms is the mass of the dry solids. If A is unknown, the drying rate can be expressed in kg of water evaporated per hour.

The correlation between N vs X (Xf) s called the drying rate curve. This curve is obtained under constant drying conditions. It should be noted that under real conditions, dried materials are generally exposed to varying drying conditions (e.g., different solid–gas relative velocities). Therefore, a methodology must be developed to interpolate or utilize general drying rate data that displays the drying rate period.

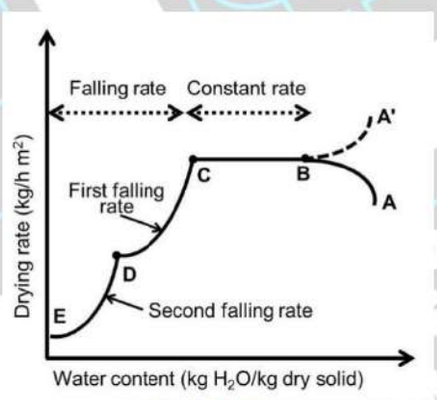

Figure 2.1 Batch curve under constant drying conditions

(da Silva *et al*., 2018)

The external drying rate curve is shown in Figure 2.1, where N=Nc=constant. The constant rate period is entirely governed by external heating and mass transfer in a water film on the evaporation surface. The drying period is not affected by the type of material being dried. Many foods and agricultural products, however, do not exhibit a constant rate period at

all, because the internal heat and mass transfer rates determine the rate at which moisture is exposed to the evaporation surface.

During the constant rate drying period, the drying rate is independent of moisture content. In this period, the material is wet enough to have a continuous film covering the entire surface, and the water behaves as if no solid material is present. If the solid is nonporous, the water removed during this period is mostly surface water. In porous solids, most water removed during the constant rate period comes from the interior of the solid. Evaporation from porous materials follows the same mechanism as evaporation from a wet-bulb thermometer, which is essentially constant rate drying. In the absence of radiation or conductive heat transfer through direct contact with a hot surface, the temperature of the solid during the constant rate period equals the air wet-bulb temperature.

In the constant rate period, the drying rate per unit area Rc can be reasonably estimated from correlations developed for evaporation from a free liquid surface. The calculation can be based on mass transfer equation 2.3 or heat transfer equation 2.4 as follows:

$$M_u = \frac{Mu \times Ky(yi-y) \times A}{(1-y)L} \quad (2.3)$$

$$m = \frac{hy(T-Ti)A}{Xi} \quad (2.4)$$

dimana:

m_u = evaporation area
A = surface area
hy = heat transfer coefficient
M_u = molecular weight of vapor
T = gas temperature
Ti = interface temperature
y = mole fraction
yi = mole fraction of vapor at the interface
Xi = latent heat at the temperature

When the air flows parallel to the solid surface, the heat transfer coefficient can be estimated dimensionally as:

$$hy = 0{,}0128\, G^{0,8} \quad (2.5)$$

dimana:

hy = heat transfer coefficient
G = mass velocity, lb/ft^2.jam

When the flow is perpendicular to the surface:

$$hy = 0\,37\,G^{0\,37} \quad (2,6)$$

the constant rate if mass transfer Rc is:

$$Rc = \frac{Mv}{A} = \frac{hy(T-Ti)}{\lambda} \quad (2.7)$$

(Geankoplis, 1993)

In most situations, as mentioned earlier, Ti can be assumed to be equal to the air wet-bulb temperature. If radiation from a hot environment and conduction from solid surfaces in contact with the material cannot be neglected, the interface temperature will be higher than the wet-bulb temperature, yi will increase, and the drying rate, according to Equation 2.3, will also increase. Methods for estimating these effects already exist.

2.3 Sorption Isoterm

A sorption isotherm curve represents the relationship between the moisture content (dry basis) of a material and the relative humidity or water activity at a specific temperature. The sorption isotherm curve is typically unique for each material. The parameter that indicates the amount of water present in a solid is the moisture content (X). The moisture content can be expressed in two forms. The first is the dry basis moisture content (X_{db}), which is the ratio of the weight of water to the weight of the dry solid:

$$X_{db} = \frac{\text{M water}}{\text{M dry solid}} \quad (2.8)$$

If the moisture content is expressed on a wet basis (X_{wb}), then:

$$X_{wb} = \frac{\text{M water}}{\text{M water} + \text{M dry solid}} \quad (2.9)$$

Hubungan antara X_{db} dan X_{wb} adalah:

$$X_{wb} = \frac{X_{db}}{1-X_{db}} \text{ atau } X_{db} = \frac{X_{wb}}{1-X_{wb}} \quad (2.10)$$

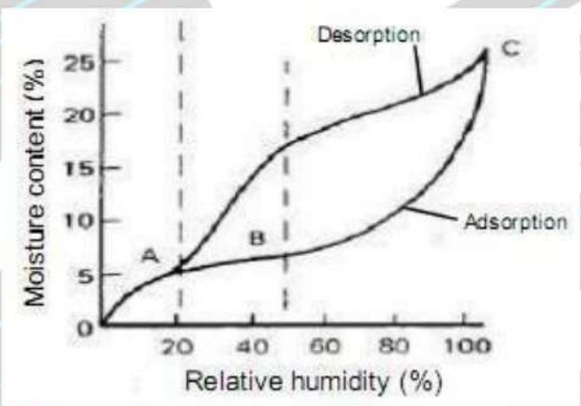

Figure 2.2 Sorption isotherm

(Andrade *et al*., 2011)

2.4 Rotary Dryer

A rotary dryer is a type of drying machine specifically used to dry various solid materials, usually in the form of powder or granules/particles. The solid material is fed into the inlet end and dried along the rotating tube/drum. The inclination of the tube and the fins inside the tube/drum cause the material to exit toward the outlet end. Rotary dryers are most suitable for drying materials that are not easily broken, heat-resistant, and require quick drying times (Zikri & Erlinawati, 2015).

The working principle of a rotary dryer is to use heat that is directly transferred to the material to be dried through a rotating drum. The heat source used comes from LPG gas that comes into contact with the surface of the drying drum. The heating temperature can be adjusted manually by regulating the gas coming out of the gas cylinder. The rotary system is used to ensure even drying (Tumbel, 2016).

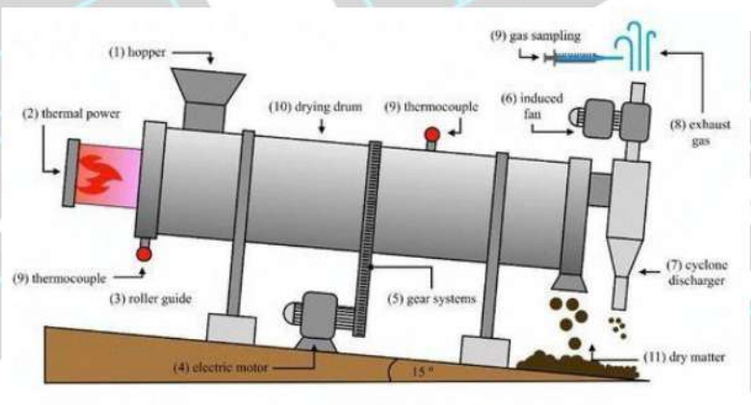

Figure 2.3 Rotary dryer

CHAPTER III
METHODOLOGY

3.1 Experimental Design

3.1.1 Drying Process Using a Rotary Dryer

3.1.2 Moisture Content Analysis

3.2 Materials and Equipment Used

3.2.1 Materials

1. Sample

3.2.2 Equipment

1. Rotary dryer
2. Oven
3. Scales
4. Thermometer
5. Porcelain Dish
6. Stopwatch
7. Chamber

3.3 Variable Determination

a. Dependent variable :

b. Independent variable :

c. Control variable :

3.4 Equipment Setup

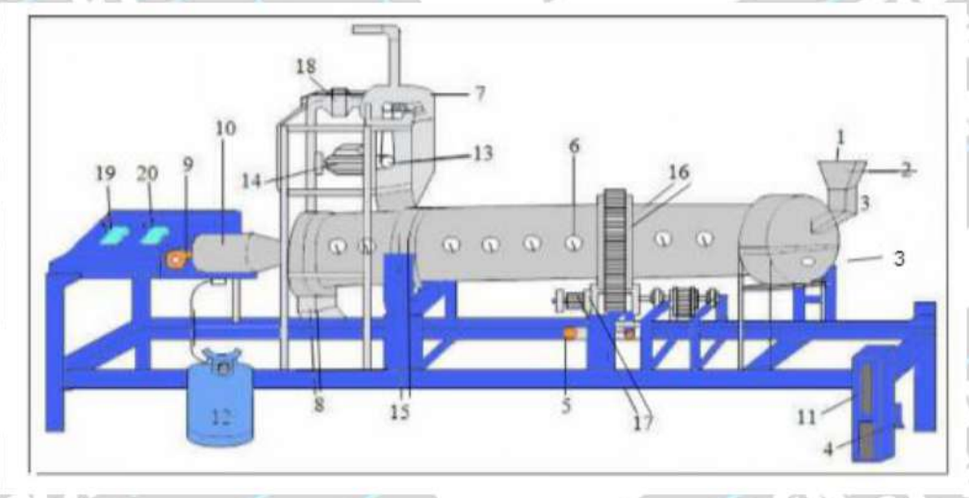

Figure 3.1 Rotary dryer

Component Description:

1. Hopper
2. Feed inlet
3. Feed hopper
4. Lifting jack
5. Motor with reducer
6. Thermometer
7. Cyclone
8. Product outlet
9. Dry air blower
10. Dry air inlet
11. Variable degree support
12. LPG tank
13. Roller
14. Suction blower motor
15. Riding ring
16. Pinion
17. Riding gear
18. Blower
19. Blower switch
20. Rotary shell drive switch

3.5 Practicum Procedure

Drying Process using a Rotary Dryer

1. Prepare the sample to be dried, weigh it according to the variable, then add 1000 mL of water to the sample and soak for 15 minutes.
2. Turn on the rotary dryer by connecting the power cable to the socket, then open the control panel box and switch it on.
3. Activate the equipment sequentially by switching on the switch motor blower, motor dryer and heater.
4. Set the rotary dryer variables according to the predetermined settings.
5. Insert the wet sample to be dried into the rotary dryer through the hopper.
6. Carry out the drying operation by weighing the sample to estimate the amount of water evaporated at 15-minute intervals for a total of 45 minutes.
7. After completion, analysis the experimental results and draw

conclusions.

Table 3.1 Experimental data format for drying process in rotary dryer

Time	Weight		
	Variable 1	Variable 2	Variable 3

Moisture Content Analysis

1. Weigh 20 grams of the wet sample to be analyzed before the drying process.
2. Place the sample into a porcelain dish, then put the dish along with the sample into an oven at 110°C until dry, and weigh it.
3. Calculate the difference between the initial and final weights to determine the moisture content.

Table 3.1 Experimental data format for moisture content analysis

Time	Weight

Table 3.2 Table format of the correlation between drying time (hour) and total moisture content (lb)

No	Drying time (hour)	Total moisture content (lb)

4. Create a table of drying time versus average mointure content at different drying rates.

Table 3.3 Table format of the correlation between drying time, mean moisture content, and drying rate"

No	Time	Average of moisture content (lb/lb)	Drying rate (lb/hour.ft^3)

5. Based on the processed data abovem plot a graph showing the correlation between drying rate and moisture content

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