Faculty of Engineering

DRYING OF FRUITS: EXPERIMENTAL AND KINETIC ANALYSIS

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Bachelor of Engineering with Honours

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DRYING OF FRUITS: EXPERIMENTAL AND KINETIC ANALYSIS

NUR SYAIDATUL AINN BINTI MOHIDI

A dissertation submitted in partial fulfillment

of the requirements for the degree of

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Dedicated to my beloved parents, who always bestow me sustainable motivations and encouragements

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ABSTRACT

Drying process is commonly used in preservation of agricultural product with different techniques such as oven drying, freeze drying, and solar drying. In this project, oven drying and solar drying techniques were used to dry banana, papaya and pineapple. Moisture content of samples was measured during drying in an oven at temperatures 65 to 85℃ and in a solar cabinet dryer. Empirical drying model was fitted into the experimental data. Experimental data shows that the moisture content decreases with time until equilibrium moisture content is reached. The final moisture content measured was from 0.34% to 0.49% for the fruit dried at temperature of 65℃ to 85℃. The difference in the final moisture contents measured indicates that the moisture removal for the drying fruits is governed by the internal structure. The drying time required to reach 30% final moisture content was 55 hours longer at low temperature at 65℃ compared with that measured for 85℃. A good fitting of drying models was found with standard errors of 0.964 to 16.55. The drying constants were estimated between 8.59 E-02 hr^{-1} to 1.53E-01hr^{-1} .

ABSTRAK

Proses pengeringan biasa digunakan dalam pemeliharaan produk pertanian dengan teknik yang berbeza seperti pengeringan ketuhar, pengeringan bekuan dan pengeringan solar. Dalam projek ini, teknik pengeringan ketuhar dan pengeringan solar digunakan untuk mengeringkan pisang, betik dan nenas. Kandungan kelembapan pada sampel dikira semasa pengeringan berlaku dalam ketuhar pada suhu 65 ke 85℃ dan di dalam pengering solar cabinet .Data daripada eksperimen menunjukkan kandungan kelembapan berkurang dengan masa sehingga kandungan kelembapan mencapai keseimbangan. Kandungan kelembapan akhir buah yang dikeringkan pada suhu 65℃ ke 85℃ adalah antara 0.34% ke 0.49%. Perbezaan dalam kandungan kelembapan akhir menunjukkan bahawa penyingkiran kelembapan buah yang dikeringkan dipengaruhi olek struktur dalaman buah.Tempoh pengeringan untuk kandungan kelembapan akhirmencapai 30% adalah 55 jam lebih lama pada suhu rendah 65℃ berbanding pada suhu 85℃. Model pengeringan yang paling sesuai dengan ralat piawai 0.964 ke 16.55.Ketetapan malar pengeringan dianggarkan antara 8.59 E-02 j^{-1}. ke 1.53E-01 j^{-1}.

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NOMENCLATURES

Ta	Absolute temperature
Ea	Activation energy
cm	Centimeter
Ha	Corrected humidity
℃	Degree celsius
ρ	Density
k_d	Drying constant
t	Drying time
X_e	Equilibrium moisture content
X_{Exp}	Experimental data of moisture content
R	Gas constant, 8.3144 J/mol.K
hr	Hour
Ho	Initial humidity
M_0	Initial moisture content
X_o	Initial moisture content
i	Initial time of drying
W_0	Initial weight of the sample
J/mol	Joule per mole

kPa	Kilo Pascal
kg	Kilogram
kJ/kg	Kilojoule per kilogram
$\dot{M}_{air}$	Mass flow rate
m_d	Mass of sample on dry basis
m_w	Mass of sample on wet basis
m	Meter
m^2	Meter square
m^2/s	Meter square per second
mt	Metric tonne
X	Moisture content
M_t	Moisture content of the sample at any time
X_t	Moisture content of the sample at each time
M_i	Moisture content of the sample at time *i*
X_d	Moisture content per unit of dry material
X_w	Moisture content per unit of wet material
A_0	Outlet area
X_{Pred}	Predicted data of moisture content
A	Pre-exponential factor
P	Pressure

P_w	Pressure at wet bulb temperature
Hs	Saturation humidity
P_s	Saturation vapor pressure
T	Temperature
V	Velocity
W_d	Weight of the dry solid
W_t	Weight of the sample at any time
W_w	Weight of the wet solid
wb	Wet basis

ABBREVIATIONS

DR	Drying rate
MC	Moisture content
MR	Moisture ratio
RH	Relative humidity

CHAPTER 1

INTRODUCTION

1.1 General Overview

Drying is a process to remove moisture from wet material which can be agricultural product, marine product, fabric product and others. Drying is one of the crucial processes to preserve food such as fruits and vegetables.

There are different techniques of drying that have been introduced. The conventional method is open sun drying that often used in drying of crop product for farmers. It is a method which the wet material is usually spread on a mat under the sun during hot days. This method is simple and cheap but it is not hygienic if it is used to dry food because contamination can occur and reduce the nutrient content of food. An improvement has been done with solar drying as another alternative. Solar drying technology is one of the simplest methods to preserve agricultural products and foods. Both of this method is dependent on the sunlight as energy source.

Malaysia is a warm climate country throughout the year and this is good for drying process. As the temperature is high during hot days, the rate of drying is faster. This type of climate makes solar drying method becomes more feasible. The energy comes from the sunlight for drying is free, meaning there is no emission of greenhouse gases which can reduce the pollution to environment.

Solar drying can be classified into direct, indirect and hybrid solar drying (Visavale, 2012). These dryers depend on the method of solar energy is collected and converted to thermal energy for drying purpose (Visavale, 2012). Direct solar dryer has the same principle as open drying method where the wet material are spread on the tray or mat and exposed to the sunlight. The wet material dried using this type of solar drying is covered with transparent cover such as plastic sheet. An example of direct solar dryer is solar cabinet dryer (Visavale, 2012). The solar cabinet can be built with plywood and consists of solar collector and shelves and the wet materials are dried on shelves inside the cabinet. The hot air enters the cabinet spread on the surface of wet material remove the moisture and flow out from the cabinet.

Direct solar drying has more advantages over open sun drying as its can protect fruits and vegetables from rains, dews and dusts (Visavale, 2012). It is simpler and cheaper to construct than the indirect dryer (Visavale, 2012). However, this type of drier has relatively slow overall drying rates (Visavale, 2012). The temperature for this technique of drying is uncontrollable and the effect of the condensation inside the drying chamber affects the drying rates of wet material.

Indirect solar dryer is another type of solar dryer which apply the same concept as direct dryer and different in term of heat transfer and vapor removal (Visavale, 2012). Heat transfer from the air to the surface of wet material is slower for indirect solar dryer and the rate of drying also lower compared to direct solar dryer. Agricultural product using this type of solar dryer has better quality over direct drying product. The product has better protection from insects, dust, and rain which maintain the product quality. This dryer can be operated at higher temperature with protection from direct radiation (Visavale, 2012). Disadvantage of indirect solar dryer is that it will incur larger maintenance costs than direct solar dryer due to the complexity in its construction (Visavale, 2012).

Hybrid solar dryers are the combination of direct and indirect type solar energy dryers features (Visavale, 2012). In this type of dryer, the heat supply comes from the direct solar radiation combined with air pre-heated in a solar collector heater. The quality of products varies according to the drying techniques used. For direct drying, the quality of product is usually lower than other technique because the product may be contaminated and the inconsistent temperature gives variation in the moisture content.The hybrid dryer is more efficient as it is a combination of direct and indirect drier which produces high quality of product.

1.2 Problem Statement

In tropical and subtropical countries, solar drying is one of the applicable methods for food preservation due to their hot climate with temperature recorded for tropical countries is 27℃ and subtropical countries are 23℃ (Fudholi et al, 2010) during day time. Different drying methods affect the quality of agricultural product such as fruits, vegetables and crops differently.

Sun light, the source of energy, comes during the day time only, meaning drying process occurred during hot days, and then stopped at night time when the temperature falls. Slow drying process occurred when the rain comes. The non-continuous drying in solar drying may affect the quality of the dried food. A continuous drying can be done using an oven. Although drying in an oven for a large volume of material can be expensive due to the electricity used, the drying temperature can be varied easily, meaning that the drying time can be controlled according to requirements.

The most effective drying method may be interpreted as those techniques that enhance the rate of drying and quality of the drying material. Different drying conditions affect the drying behavior differently, and it is important to study the drying kinetics of fruits dried using different condition because this study will identify the best approach of drying. Data on solar drying of fruits is affected by the climate change at the location where the fruits are dried, and study of drying kinetics for the climate in Kota Samarahan is limited.

Due to this reason, this project aims to study the drying behavior of fruits dried under Kota Samarahan climate, and results obtained were compared with the results obtained for drying under a controlled environment, an oven.

1.3 Objectives

The objectives of this project are

1. To design and fabricate a solar cabinet dryer
2. To investigate the factors that affect rate of drying
3. To compare the quality of dried product with different drying techniques
4. To analyze the drying kinetics of fruits and estimate the drying constant for different temperature and different fruits

A solar cabinet dryer made from plywood was designed and used in the project. The function of this solar cabinet dryer was to dry the dried material banana, papaya and pineapple.

The second objective was to investigate the factors that affect the rate of drying. The rate of drying was estimated based on the amount of moisture content per time. The moisture content of banana, papaya and pineapple was measured at different drying time.

The third objective was to compare the moisture content of dried product with different drying techniques. Drying was done in an oven at temperatures of 65-85°C and in a solar dryer. An empirical model was fitted onto the experimental data, and the drying constant for the fruits was estimated.

1.4 Project Scope

The investigation of drying kinetics was limited for banana, papaya and pineapple only. These fruits were dried using an oven at temperatures 65^{o}C to 85^{o}C, and in a solar cabinet dryer. Samples of ripe fruits were bought from Kota Samarahan and it is assumed that the variability in the properties of samples is insignificant. Variability in the moisture content may be due to the different location where the fruit was bought.