The Characteristic of Heat Pump Dehumidifier Drier in the Drying of Red Chili (*Capsium annum L*)

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Abstract — **Preservation of agricultural products have a very important to avoid the dropped of selling price when the harvest season arrives. Agricultural products are perishable because of high water content approximately 80 % which if the moisture content above 10% encourages proliferation of spoilage microorganisms in the material and cause the short shelf life. One way that has been done to preserve agricultural products such as red chili is dried using direct sunlight. Weakness of the sun drying can not reduce the water content to below 10% so spoilage microorganisms can live and breed, cause the short self life. Drying using Heat Pump Humidification Technology (HPD) is one solution to overcome the disadvantages of the direct sun drying. HPD can reduce the moisture content up to or below 10% will increase the self life and make easier to crush and to produce a chili powder. The purpose of this study to determine the appropriate mathematical model of the drying phenomena. The constant of the model equations are determined by Sum Square Error (SSE). Before being dried chilies dipped in hot water to remove the wax. PHD is used as an air dehumidifier that circulate in the dryer. Humidity difference causes the displacement of water from the chilies to dry air and lower the moisture content of chili. Moisture content of chili every 5 minutes is analyzed using gravimetric method. The results showed that the texture of the chili is very fragile with a moisture content of less than 10% and in the best conditions, the moisture content of chili is 6:35 wt%. From the research found that the appropriate model is Lewis model and the constant of the models obtained (k = 0.0056). Due to the moisture content of the product below 10 wt%, PHD can be considered as an agricultural product dryer.**

*K*eywords — **Chili, drying, heat pump, hpd**

I. INTRODUCTION

Drying of agricultural products intended to increase shelf life, reduce packaging, transportation expenses by reducing the weight and volume, improved appearance and more important is to maintain the original flavor and nutritional value. Conventional dryers require enormous amounts of energy for heating and removing the water. In order to reduce energy consumption, it is necessary to choose an efficient heating system. Heat pump provides an efficient technology and environmentally friendly due to low energy consumption (Fatouh, et al., 2006) The integration of heat pump and dryer known as heat pumps dryer or Heat Pump Dehumidifier (HPD). Heat pump evaporator can be used to air dehumidifier on the drying unit. Dehumidifier process of air can be achieved when the surface temperature of the evaporator is lower than the dew point temperature air at the evaporator inlet. Comparison of conventional dryers with PKD, that PKD has many advantages, including higher energy efficiency due to high coefficient of performance and a better quality product because it does not depend on ambient air conditions and easier control of drying conditions (Perera & Rahman, 1997;. Strommen et al, 2000). In addition, PKD has the ability to operate independently from the weather outside ambient conditions compared with the solar dryer (Jain, 2006). According of Phoungchandang and Saentaweesuk (2011), various types of products that have been dried in the drying experiments HPD, including biomaterials, sawn rubber, timber, bananas, basil, garlic, mango, ginger, composite food product, roasted red peppers , protein, lime leaves and white murberry. In this work presented red chilli (Capsicum annum L) drying by HPD. Red Chili is one of many horticultural crops in particular usefulness for domestic use, industry and medicine. On the outer skin of chili contains a layer of wax, can inhibit the evaporation of water contained. In general, red chili and spicy because they contain kapsaikin while the chili is dark red, yellow and not too spicy contain kapsatin. This chili is a seasonal crop, at harvest is abundant and cheap production in contrast to at no harvest the price rather expensive because demand continues to rise. Chili on the outer skin contains a layer of wax, can inhibit the evaporation of water contained. In general, red chili and spicy because they contain capsaikin while the fruit is dark red, yellow and not too spicy contain capsatin. Chili is generally harvested with high moisture content of fresh red chili easily because rot and mildew due to the activities of microorganisms contained. To make a long-lasting to be dried chili with low water content (10%) that microorganisms are not active anymore. Drying of the red chili peppers, temperature of drying should be not be too high because it will damage the chemical composition such as vitamin A and vitamin C found in chili peppers. The conventional solar drying of chili there are some obstacles that need large tracts of land and takes a relatively long time (16 days), so sometimes before it dries with perfect chili already decaying. This obstacle can be overcome by drying with HPD and the condition of the drying chamber can reach 21% humidity and a maximum temperature of 45^{o}C

TABLE 1
CHEMICAL COMPOSITION RED CHILI/DRY AND FRESH (100 GR OF CHILI)

Component	Fresh Chili	Dry Chili
Water (g)	90.9	10
Calorie (kal)	31	311
Protein (g)	1.0	15.9
Fat (g)	0.3	6.2
Carbohydrate (g)	7.3	61.8
Calcium (mg)	29	160
Phosphorus (mg)	24	370
Iron (mg)	0.5	2.3
Vitamin of A (iu)	470	576
Vitamin of C (mg)	18	50
Vitamin of B1 (mg)	0.05	0.4
b.d.d. (%)	83	85

Source of: Tjukup & Endang (2004)

II. MATHEMATICAL MODEL OF DRYING

Water content in the material expressed on a dry basis (dry basis) are:

$$x = \frac{\text{wet weight} - \text{dry weight}}{\text{dry weight}} = \frac{G_w - G_d}{G_d} \qquad \ldots(1)$$

The rate of drying or moisture loss of the material is assumed equal to the reduced moisture content of remaining

$$\frac{dx}{dt} = -k(x - x_e) \qquad \ldots(2)$$

when equation (2) integrated hence

$$\frac{x - x_e}{x_0 - x_e} = \exp\,(-k.t) \qquad \ldots(3)$$

Where xo is the initial moisture content, xe is the equilibrium moisture content in dynamis. Therefore, the equilibrium water content dynamis (xe) is very small compared with the water content (Qi-Long Shi, et al, 2008) then $\frac{x-x_e}{x_0-x_e}$ can be simplivied into $\frac{x}{x_0}$, and here inafter called the ratio of water content or moisture ratio (MR).

$$MR = \frac{x - x_e}{x_0 - x_e} = \frac{x}{x_0} = \exp\,(-k.t) \qquad \ldots(4)$$

$$MR = \exp\,(-k.t^n) \qquad \ldots(5)$$

Equation (4) is the basic mathematical models given by Lewis in the drying process. Equation (5) is a modification of equation (4) is presented by Page's in 1949, and the equation is often used in the drying of biomaterials. Henderson and Pabis (HP) using equation (6) to describe the falling drying period (Phoungchandang and Saentaweesuk, 2011).

$$MR = A.\exp\,(-k.t) \qquad \ldots(6)$$

Drying constant (k) related to temperature and Phoungchandang & Saentaweesuk (2011) using a model Archenius as follows:

$$k = a.\exp\left(-\frac{b}{T + 273.15}\right) \qquad \ldots(7)$$

A common performance indicators used to define the performance of PKD is the Specific moisture evaporation rate (SMER) (Chua, Chou, Ho, & Hawlader, 2002). This is defined as ratio of amount of water that evaporates and energy for drying.

$$SMER = \frac{\text{Amount of water that evaporates}}{\text{Energy for drying}} \left(\frac{kg}{kWh}\right) \qquad \ldots(8)$$

III. MATERIAL AND METHODS

Material to be dried is a large Red Lombok (Capsium annum L), previously washed and analyzed for initial water content, then to dry in full and sepated condition intactly and halved, some of bleaching and some of without bleaching (died with hot water) to dissolve wax in surface of chili. All four groups were then packed red chilies together in the drying chamber, with each sample weighted by a certain weight.

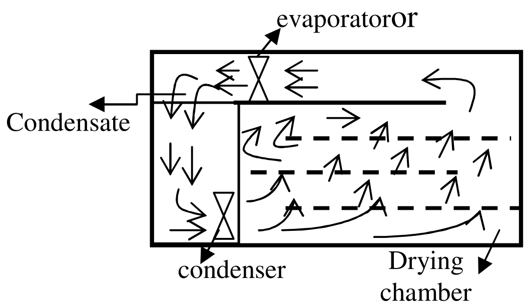

Fig.1. Scheme of heat pump dehumidifier (HPD) dryer system

Heat pumps are fitted with a closed air circulation (see Figure 1), which entered into the heat pump evaporator, the temperature dropped to below the dew point of water (T_{dew}) and water condensate removed from the system. The cold air is then used to cool the heat pump condenser, so that the air temperature rises, the water content has been reduced. Then air out of condenser is as the air with low relative humidity (dry air). Dry air after used of drying then sucked through the heat pump evaporator, thereby continuously.

At first chilies sorted in order to obtain a uniform ripeness, freshness and size. Chilies are washed with running water and then in the rain in, then weighed. Some of chili halved and some of intact and which halved each divided to become two shares, some of halved chili and some of intact chili be bleaching in hot water during maximum one minute. Each piece of chili put on a different drying rack and each sample weighed. Further, the rack inserted into the drying chamber and dried together. Data taken is the weight of each sample at a certain time interval until the moisture content below 10%., Temperature and humidity inside the drying chamber.

IV. RESULTS AND DISCUSSIONS

Relative humidity (RH) and temperature (T) air in the drying chamber is obtained from measurements of between 21 up to 30% and 41oC to 60oC, respectively. The initial data of drying were the sample weight at any drying time, then changed into the moisture content dry basis (x) according to equation (1). Results of the initial data processing is the moisture content against drying time can be seen in Figure 2.). The data are also presented with a comparison of the initial water content or moisture ratio (MR) of each drying time can be seen in Figure 3. Whereas photo of the dried chili can be seen in Figure 4. Drying results from each sample below the average level of 10%, ie the sample intact chilli reached 8.9608%, 8.2208% halved chili achieved, intact and halved in bleaching reached 7.9655% and 6.3552% respectively, with the same drying time. Bleaching samples with hot water can reach the lower levels because the layer of wax on the skin dissolved by hot water so as to accelerate the evaporation of water. Texture of the chili with water content (x) below 10% is very fragile and easy to make flour (mashed)

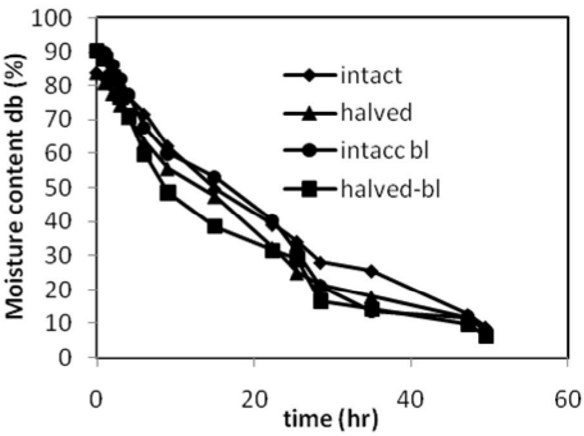

Fig 2. moisture content (%) VS drying time

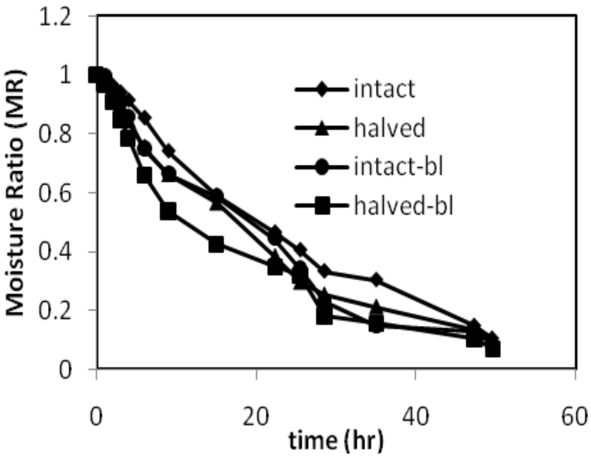

Fig 3. Moisture ratio (MR) VS drying time

Fig 4. Photo of dried chili result of the drying

Character of drying by HPD was tested by mathematical model equations by Lewis and Page, to get the drying constant (k) and the exponent of the time (t). Evaluation of k against Lewis equation using the method of the Golden Section, while Page and Pabis equation, use the Hooke Jeeves method, by minimizing the sum squared of errors (SSE) is the sum squared difference between MR data and the calculation of the equation. Evaluation results show the comparison between data and calculations of MR are not much different and minimum SSE is below 2% (Figure 5 & 6), the constants are obtained as shown in Table 2. Referring to the results of the evaluation with the minimization of the SSE under 2%, which means that the character of dried chili with HPD may be represented or satisfy the third equation (Lewis, Pabis, Page), but refers to the acquisition of a constant exponent (n) from the time the Page equation and the constant a in equation Pabis that the value the closer one and can be simplified so the equation of chili drying with HPD can be represented by a more modest or basic equation proposed by Lewis, with a constant drying between 0.04 to 0.055.

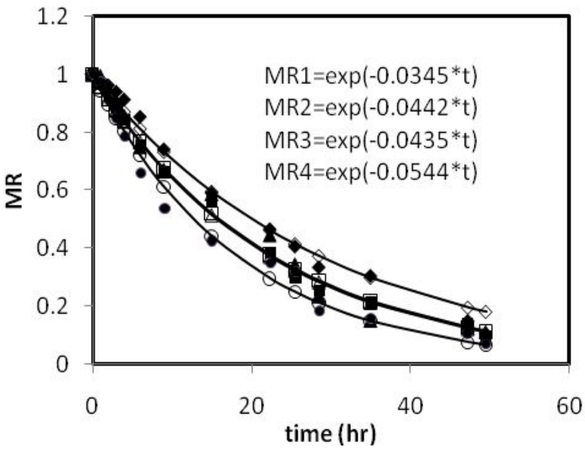

Fig.5 Moisture content (%) data and MR model equation (4) VS drying time.

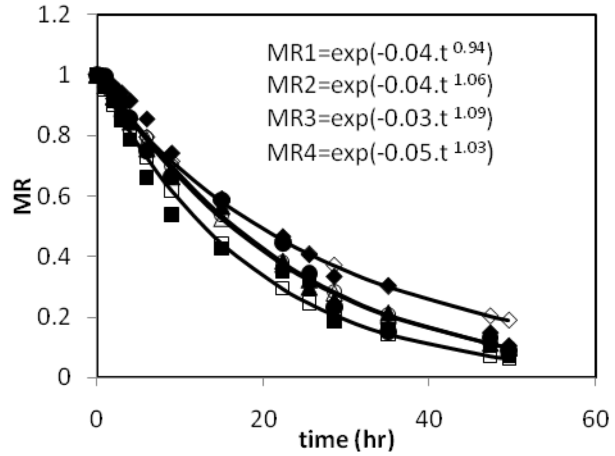

Fig 6.. Moisture ratio (MR) data and MR model equation (5) VS drying time

TABEL 2.
DRYING CONSTANT FROM LEWIS, PAGE DAN PABIS EQUATIONS

Characteristic of chili	MR=exp(-k.t) Lewis eq.	MR=exp(-k.t^n) Page eq.		MR=A.exp(-k.t) Pabis eq	
	k	k	n	a	k
Intact Chili	0.0345	0.04	0.94	1.06	0.04
Halved Chili	0.0442	0.04	1.06	1.01	0.04
Intact with bleaching	0.0435	0.03	1.09	1.03	0.04
Halved with bleaching	0.0544	0.05	1.03	0.99	0.05

This drying process following the drying curve falling (down), and the drying process rising very short, this is caused by relatih humidity (RH) is low so fast moisture absorption and moisture content in molecules chili evenly. This is consistent with the statement Minea (2010) that the water content in agricultural products is generally a water-free liquid in the cell cavities and as bound water contained in the cell wall structure.

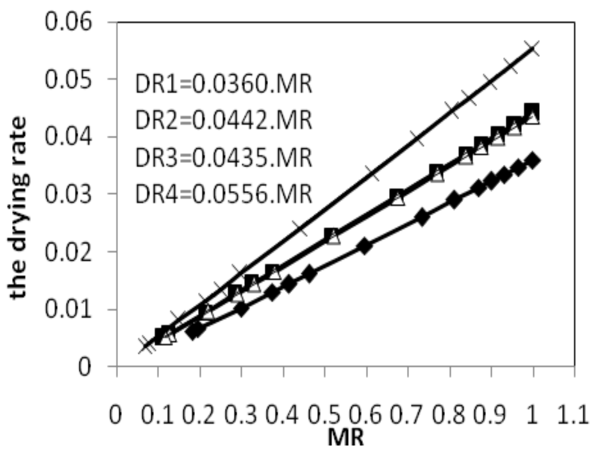

Fig 7. Drying rate (DR) VS Moisture Ratio (MR)

Drying rate is defined as decrease moisture content every time it is also equivalent to the decrease of MR at any time. Figure 7 shows that the drying rate is directly proportional or linear with moisture ratio and drying rate constants obtained from the sample intact chilli, halved, intact and halved with bleaching, are 0.036, 0.0442, 0.0435 and 0.0556 respectively. Treatment of chilli in bleaching can increase the rate of drying.

V. CONCLUSSION

Drying is influenced by surface area, the condition of dryer media and also treatment of dried material. In this study, drying of halved chilies faster and also with the bleaching treatment with hot water can accelerate the drying process. Drying by HPD improve air dried and the drying process is much faster and higher quality than traditional sun drying. Moisture content below 10%, ie the intact chilli, halved, intact and halved in bleahcing are 8.9608%, 8.2208%, 7.9655% and 6.3552% respectively, while the drying constant respectively are 0.0345; 0.0442; 0.0435 ; 0.0544 and the drying rate constant are 0036; 0.0442; 0.0435 and 0.0556. Textures of dried chilli results are very fragile and easily crushed into flour. The mathematical model of drying follows the standard equation by Lewis.

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