American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-6, Issue-12, pp-380-387
www.ajer.org
Research Paper Open Access

Observed YSD-UNIB12 Solar Drying Curve And Drying Time Prediction for White Pepper

Y. Yuwana[1], F. Effransa[2] and Marniza[3]
[1] *Agro-industrial Study Program, Department of Agricultural Technology, Faculty of Agriculture, University of Bengkulu, Indonesia*
[2]*Department of Agricultural Technology, Faculty of Agriculture, University of Bengkulu, Indonesia*
[3]*Department of Agricultural Technology, Faculty of Agriculture, University of Bengkulu, Indonesia*
Corresponding Author: Y. Yuwana

ABSTRACT: *Drying is a determinant process to produce high quality white pepper. This study explored the utilization of the YSD-UNIB solar dryer to produce dry white pepper grains, aiming to determine the model of the curve of the relationship between moisture content and drying time, to predict the drying time to complete the drying process with respect to the placement of grains on the racks and the thickness of the grains layer, and to describe the resulting grains by using the Indonesian National Standard of white pepper. The results of the experiments showed that the drying air temperature was 12.15°C higher than the ambient air temperature, and the drying air relative humidity was 35.66% lower than the ambient air relative humidity. The solar drying process was 2.17 h faster than the sun drying. The average drying time varied from 12.8 h to 10.0 h from the lower rack to the upper rack, and varying the thickness of the grains layer from 2 cm to 8 cm the average drying time increased 8.7 h to 14.4 h. The dry pepper grains produced by the solar drying was qualified for Grade II but by sorting the unfilled out grains to meet the threshold of less than 1%, the grains from the 2 cm and 4 cm thickness of the grains layers were qualified for Grade I. The suggestion was made to employ the thickness of the grains layers of 4 cm and 8 cm in drying the white pepper for the world markets and the domestic markets respectively.*

Keywords: *Drying curve, rack position, thickness, white pepper, YSD-UNIB12 solar dryer.*

Date of Submission: 18-12-2017 Date of acceptance: 03-01-2017

I. INTRODUCTION

Pepper (*Piper nigrum* Linn) is one of valuable commodities in Indonesia. Although the plant is not native origin, but it is widely cultivated by growers, especially in Sumatra, Borneo and Celebes islands. With total production of 82,167 tons in 2016 or estimated 82,964 tons in 2017 [1], Indonesian becomes the world second pepper producer and exporter after Vietnam. The plant produces pepper cherries for about 8-9 months after emerging flowers. The pepper cherries are usually harvested and then processed into white or black pepper, and white pepper is more valuable than the black one. To produce white pepper grains, the harvested cherries are fiber or plastic bagged and then submerged in water for about 7-14 days to make the flesh of the cherries spoilage in order to facilitate separating the grain from the flesh. Traditionally, the grain is sun dried, and it takes 3-5 days to obtain the dry grains of 13-14% moisture content. Alternatively the grain is mechanically dried using a drying machine. The machine usually operates in 50-60°C drying temperature and it takes about 15-16 hours to result the dry grains of about 12 % moisture content.

In terms of drying, sun drying is practicable, but it has some discrepancies, such as, space and labor intensives, time consuming, and risk of product damage, contamination and losses. On the other hand the mechanical drying is expensive. To solve these problems, solar dryers have been developed by researchers. According to the method of manipulating solar energy from the sun, the solar dryers may be distinguished as direct types [2], [3], [4], [5], indirect types [4], [6], [7], [8], and mixed types [9], [10].

In the last decade the Department of Agricultural Technology, Faculty of Agriculture, University of Bengkulu, Indonesia developed several types of solar dryer, including the YSD-UNIB12 solar dryer. This dryer has been tested to dry red pepper, mustard greens and cassava leaves [11], cassava [12], clothes [13], catfish [14].

In this research this solar dryer was modified in two aspects, i.e. its interior, the design and installation of the chimney, and was then introduced to dry the white pepper grains. The objectives of this research were to find the model of the curve of the observed moisture content in function of drying time, to predict the drying time to complete the drying process with respect to the placement of grains on racks and the thickness of the grains layer, and to describe the quality of the resulting dry pepper grains.

II. MATERIALS AND METHODS

2.1. Materials

Freshly harvest pepper cherries having yellow and red colors were prepared for the experiments. The cherries were put into a fiber bag and then submerged in a container filled with fresh water for 7 days in order to soften the flesh of the cherries. Along the submersion, the water was substituted regularly to keep the water clean and to avoid the cherries from contamination. After the submersion was completed, the cherries were pulped to produce the pepper grains. The pulping process was done in the water to protect the grains from oxidative browning. Before drying, the grains were sorted from the spoilage and insect attack grains.

2.2. Equipments

The YSD-UNIB solar dryer as shown schematically in Figure 1 was utilized for the experiments. The principle structure of the dryer was constructed from light steel slabs and completely covered with a transparent 14% UV plastic sheet, and the overall horizontal area of the dryer was 5 x 3 m^2. The drying chamber measured 2 x 3 x 1.95 m^3 and equipped with 10 racks arranged in 5 stories and a front door to facilitate the in-out movement

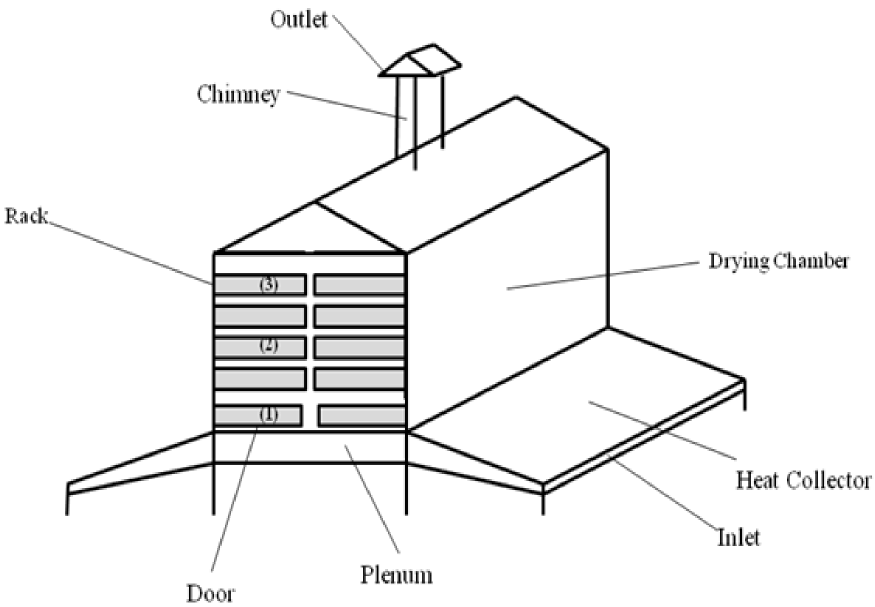

Figure 1. Schema of YSD-UNB solar dryer.

of the racks. Each rack measured about 2.95 x 0.95 x 0.25 m^3 and was made of nylon net framed with light steel slabs. The heat collector had 3 x 1.5 m^2 horizontal areas and was constructed from aluminum sheet. The surface of this sheet facing the sun was painted in black, whereas the back side of this sheet was sealed with plywood as a heat insulation. The slot of the inlet air was 0.15 m while the clearance of the upper end of the heat collector was 0.35 m and embedded with the plenum underneath the drying chamber. The roof of the drying chamber and the surface of the heat collector were inclined about 70% and 45% respectively. The frame of the chimney measured about 0.4 x 0.4 x 1.25 m^3 was made of steel slabs and installed in the center-top of the roof. The outlet air was placed on the upper side of the chimney to exhaust the humid air from the drying chamber.

The solar dryer worked as follows. The surface of the heat collector absorbed the solar energy as long as the sun struck the structure of the dryer and its temperature increased according to the intensity of incoming sun rays. The accumulated solar energy heated the fresh air entering from the inlet. The hot drying air entered the plenum and then passed through the racks containing the wet product to be dried. The drying chamber also accumulated the solar energy from the sun rays passing through the roof and the wall, and so added the solar energy content of the drying air. Due to the pressure gradient of the drying air in the lower end of the heat collector and in the chimney, the drying air continuously flowed from the inlet to the outlet. The moving drying air heated the product to evaporate its moisture content, and with the advancement of drying time the product moisture content continued to decrease reaching to a determined level as an indication that the drying process was completed.

The other important equipments employed in the experiments were digital thermo-hygrometers, a digital balance (accuracy of 0.1 g) and an oven. These equipments were utilized respectively to observe the temperature and the relative humidity of drying air and ambient air, to weigh the experimental pepper samples, to determine the dry pepper of the samples used for the moisture content calculation.

2.3. Experiments

The experimental samples were prepared with respect to the placement of grains on the racks, in three positions: lower (rack1, R1), middle (rack2, R2) and upper (rack3, R3) (see Figure 1), and the thicknesses of the grains layer : 2 cm (T1), 4 cm (T2), 6 cm (T3) and 8 cm (T4). As a comparison, the samples of the same thicknesses were sun dried. So every experimental run consisted of 16 samples to be dried, 12 samples for the solar dryer and 4 samples for the sun drying. The experimental samples were placed in baskets made of nylon net framed with strong wire, each basket measured about 20 x 20 x 10 cm^3. The experimental runs were carried out three times. The drying process was conducted every day from 9 AM to 4 PM until the samples of pepper grains were dried. The observation was made for the temperature and relative humidity of the drying air and ambient air, and the weight of the sample, with a time interval of one hour. The temperature and relative humidity of the drying air and ambient air were observed periodically by recording the scales of the thermo-hygrometers placed on rack1, rack3, rack3 and in a shading area out of the dryer, and then the representative drying temperature was the average of the first three measures whereas the fourth measure was adopted as the sun drying temperature. The samples were also weighted periodically along the drying process. By the end of the experimental runs, from each experimental run, a sample 100 g of the dry pepper grains was taken for the moisture content determination. The moisture content was calculated in wet basis by using Equation 1.

$$MC = \frac{W_w - W_d}{W_w} x100 \qquad (1)$$

where, MC = moisture content (%), W_w = wet weight of sample (kg), W_d = dry weight of sample (kg).

The observation data were averaged and then presented in the form of curves of temperature, relative humidity and moisture content in function of drying time. Using Microsoft Excel Package, the drying curves were modeled and a threshold of 12% moisture content adopted from INS 0004-2013 (Indonesian National Standard for White Pepper)[15] was employed to predict the drying time to produce the dry white pepper grains.

The quality parameters of resulting white pepper grains were described by using INS 0004-2013 as presented in Table 1. The color of the grains was described by using Munsell Color Chart. The insect contamination was observed by spreading the grains on a white paper sheet to find life or dead insects, and the results of the observation were reported. To determine the bulk density of grains, a breaker glass of 1000 ml was fulfilled with the grains, and the grains were then weighted with the digital balance, and finally, the bulk density was found by dividing the weight of the grains with the volume of the grains or the breaker glass, expressed in kg/m^3. The moisture content of the grains was determined from Equation 1. The unfilled out grains were separated by placing a sample of 100 g grains in 70% ethanol-water solution and the floated grains then were weighted and presented in the percentage of the sample weight. The foreign material and the black grains were visually separated from a sample of 100 g grains each and then were weighted. The values of these parameters

Table 1. Quality parameters of white pepper grains (ins 0004-2013)

No	Parameter	Unit	Quality Criteria	
			Grade I	Grade II
1	Color	-	Yellowish white	Gray-white or Brown-white
2	Insect contamination	-	Free from life/dead insects, free from grains attacked by insects	Free from life/dead insects, free from grains attacked by insects
3	Bulk density	g/l	Min. 600	Min. 600
4	Moisture content	%	Max. 13.00	Max. 14.00
5	Unfilled out grains	%	Max. 1.0	Max. 2.0
6	Foreign	%	Max. 1.0	Max. 2.0

	materials			
7	Black grains	%	Max. 1.0	Max. 2.0
8	Spoilage grains	%	Max. 1.0	Max. 2.0
9	Volatile oil	%	Presented according to tested result	Presented according to tested result

were also expressed in the percentages of the sample weights. A magnifying glass was utilized to inspect the spoilage grains in a sample of 100 g grains. The spoilage grains were weighted and expressed in the percentage of the sample weight. A sample of 100 g grains was utilized to determine the volatile oil content by employing the distillation method. The volume of resulting oil was presented in the form of ml per 100 g sample of grains (%).

III. RESULTS AND DISCUSSION

Figure 2 and 3 show, respectively the variations of the drying air and ambient temperature and the variations of the drying air and ambient air relative humidity along the drying processes. The experimental data also indicated that the averages drying air temperature and ambient air temperature were 43.90^{o}C and 31.75^{o}C, respectively, whereas the averages drying air relative humidity and ambient air relative humidity were 18.67% and 54.33%, respectively. In the other word, the dryer increased the drying air temperature of 12.15^{o}C higher than the ambient air temperature and decreased the drying air relative humidity of 35.66% lower than the ambient air relative humidity.

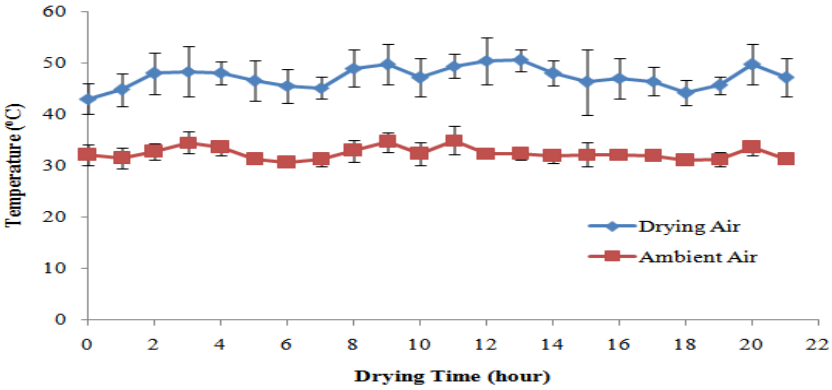

Figure 2. Drying air and ambient air temperatures during the drying process

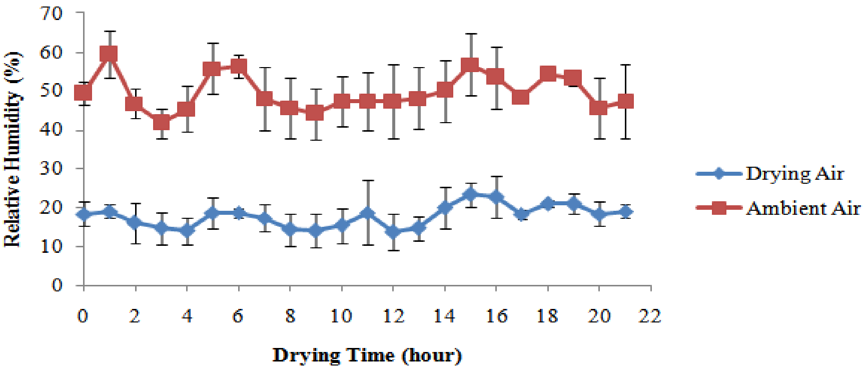

Figure 3. Drying air and ambient air relative humidity during the drying process

Figure 4, 5,6 and 7 present the curves of the relationship of grain moisture content and drying time, with respect to the rack position and the thickness of the grains layer for the solar drying, and with respect to the thickness of the grains layer for the sun drying.

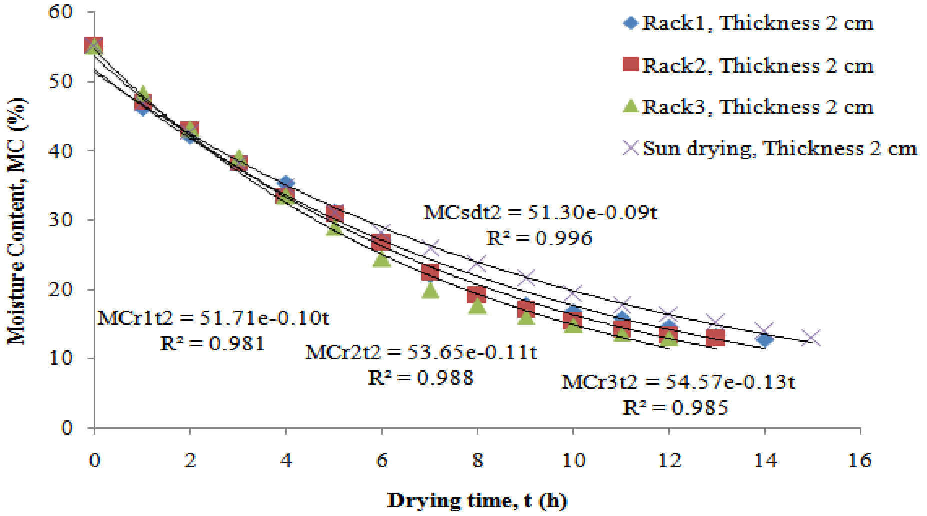

Figure 4. Curves of moisture content versus drying time for the 2 cm thickness of the grains layer

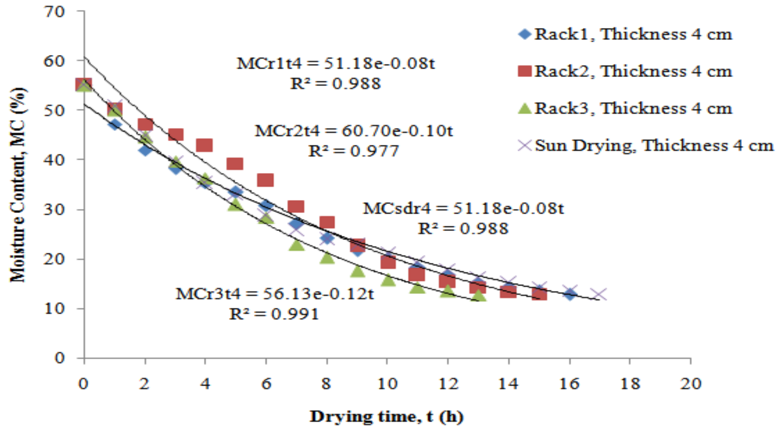

Figure 5. Curves of moisture content versus drying time for the 4 cm thickness of the grains layer

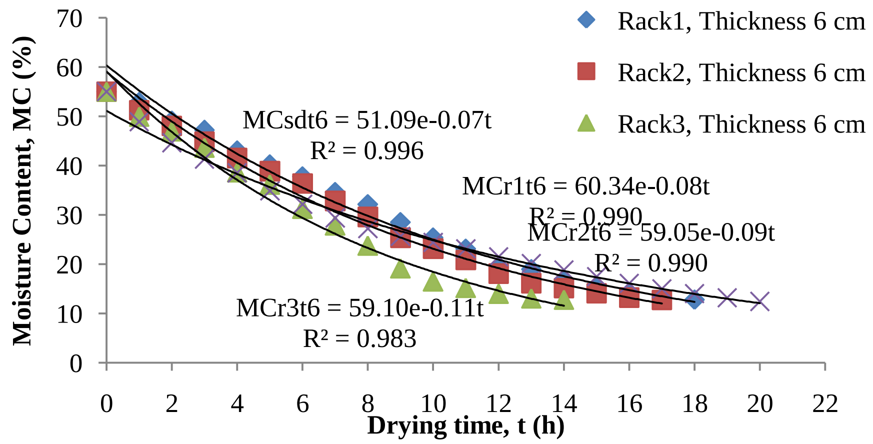

Figure 6. Curves of moisture content versus drying time for the 6 cm thickness of the grains layer

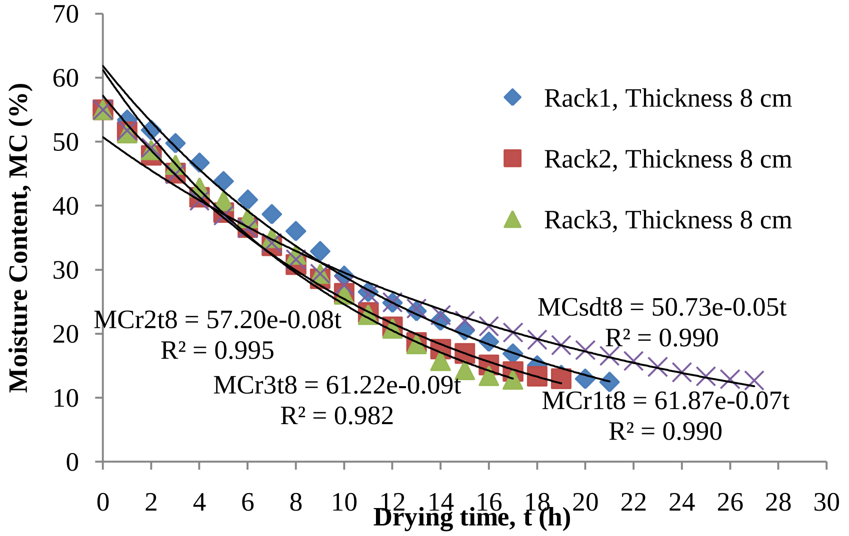

Figure 7. Curves of moisture content versus drying time for the 8 cm thickness of the grains layer

The figures indicated that the model of curves of the relationship of moisture content and drying time for both the solar drying and the sun drying was exponential. From these curves and utilizing the threshold of white pepper grain moisture content of 12%, the drying times to complete the drying process were calculated as shown in Table 2. Data in Table 2 indicated that, in general the solar drying was faster than the sun drying, the average solar drying time was 11.38 h compared to 13.55 h that of the sun drying. With respect to the placement of grains on the rack, the higher position of the rack was the shorter the drying time. The average drying time varied from 12.8 h to 10.0 h from the rack1 to the rack3. With respect to the thickness of the grains layer, the thicker of the grains layer needed a longer drying time for both the solar drying and the sun drying. In the case of solar drying, varying the thickness of the grains layer from 2 cm to 8 cm, the average drying time increased from 8.7 h to 14.4 h. Using the same variation range, the average sun drying time increased from 10.5 h to 18.6 h.

Table 2. Drying time to complete the drying process

Drying	Rack	Thickness of the grains layer (cm)	Drying Time (h)
Solar drying	1	2	9.5
	2		9.0
	3		7.7
Sun drying	-		10.5
Solar drying	1	4	11.7
	2		11.1
	3		8.6
Sun drying	-		11.7
	1	6	13.8
Solar drying	2		12.0
	3		9.8
Sun drying	-		13.4
Solar drying	1	8	16.1
	2		13.1
	3		14.0
Sun drying	-		18.6

The quality profile of the resulting dry white pepper grains is presented in Table 3. The grains from both the solar drying and the sun drying were met all the quality parameters for Grade II. If sorting was employed for unfilled out grains of the dry pepper to meet the threshold of less than 1%, the resulting grains from the solar drying of the 2 cm and 4 cm thicknesses of the grains layer were qualified for Grade I. Since Grade I white pepper and Grade II white pepper are usually for the world markets and the domestic markets respectively, this finding suggested that the solar drying with the 4 cm thickness of the grains layer might be employed to dry the grains for the world markets, whereas the solar drying with the 8 cm thickness of the grains layer could be utilized to dry the grains for the domestic markets.

Table 3. Profile of quality the resulting dry pepper grains

Quality Parameter of INS 0004-2013		Color	Insect contaminant	Bulk density (g/l)	Unfilled out grains (%)	Foreign materials (%)	Black grains (%)	Spoilage grains (%)	Moisture content (%)	Volatile oil content
Grade	I	Yellowish-white	Free from life/dead insects,	Min. 600	Max. 1.0	Max. 1.0	Max. 1.0	Max 1.0	Max. 13	%
	II	Grayish-white - Brownish-white	Free from life/dead insects	Min. 600	Max. 2.0	Max. 2.0	Max. 2.0	Max. 2.0	Max. 14	%
Samples										
R1 T1		Yellowish-white (5 Y 8/4)	-	612	1.33	0.56	0.57	0.98	12	
R1 T2		Yellowish-white (5 Y 8/4)	-	615	1.72	0.62	0.56	0.98	12	
R1 T3		Grayish-white (5Y8/2)	-	613	1.50	0.31	0.52	1.10	12	2.08
R1 T4		Brownish-white (5Y7/4)	-	617	1.75	0.42	0.77	1.17	12	
R2 T1		Yellowish-white (5 Y 8/4)	-	612	1.45	0.46	0.64	1.02	12	
R2 T2		Yellowish-white (5 Y 8/4)	-	615	1.32	0.56	0.62	1.04	12	
R2 T3		Grayish-white (5Y8/2)	-	616	1.51	0.31	0.66	1.18	12	2.05
R2 T4		Brownish-white (5Y7/4)	-	613	1.60	0.40	0.71	1.07	12	
R3 T1		Yellowish-white (5 Y 8/4)	-	615	1.52	0.34	0.48	0.98	12	
R3 T2		Yellowish-white (5 Y 8/4)	-	615	1.57	0.27	0.49	0.99	12	2.04
R3 T3		Grayish-white (5Y8/2)	-	613	1.61	0.33	0.61	1.10	12	
R3 T4		Grayish-white (5Y8/2)	-	617	1.55	0.52	0.63	1.05	12	
SDT1		Yellowish-white (5 Y 8/4)	-	611	1.72	0.62	0.61	1.08	12	
SDT2		Grayish-white (5Y8/2)	-	610	1.77	0.67	0.85	1.06	12	
SDT3		Brownish-white (5Y7/4)	-	611	1.71	0.72	0.72	1.10	12	2.01

SDT4	Brownish-white	-	609	1.75	0.78	0.70	1.10	12

Note : R = rack, T = thickness of the grains layer, SD = sun drying

IV. CONCLUSION

The curves of white pepper moisture content in function of drying time produced by the YSD-UNIB solar were exponential. The dryer was able to generate the drying air temperature of 12.15^{o}C higher than the ambient air temperature, and the drying air relative humidity of 35.66% lower than the ambient air relative humidity. The solar dryer completed the white pepper drying process in 2.17 h faster than the sun drying. The average drying time varied from 12.8 h to 10.0 h from the lower rack to the upper rack and varying the thickness of the grains layer from 2 cm to 8 cm, the average drying time increased from 8.7 h to 14.4 h. The dry pepper grains produced by the solar drying was qualified for Grade II but by sorting the unfilled out grains to meet the threshold of less than 1%, the grains from the 2 cm and 4 cm thicknesses of the grains layer were qualified for Grade I. For the world markets, the white pepper might be dried with the 4 cm thickness of the grains layer while for the domestic markets, the white pepper could be dried with the 8 cm thickness of the grains layer.

REFERENCES

[1]. Directorate General of Estate Crops, Ministry of Agriculture, Pepper. Estate Statistics of Indonesia, 2017.

[2]. S. Arun, S. Ayyappan, and V.V. Sreenarayanan, Experimental studies on drying characteristics of tomato in a solar tunnel green house dryer, IJRTE., 3(4), 2014, 32-37.

[3]. E.A. Almuhanna, Utilization of a solar greenhouse as a solar dryer for drying dates under the climatic conditions of the Eastern Province of Saudi Arabia, J. Agric. Sci. 4(3), 2012, 237-246.

[4]. S.S. Nandwani, Design construction and study of direct indirect natural circulation solar dryer in Costa Rica, ISIESCO Sci. Tech. Vision, 7(11), 2011, 43-47.

[5]. J.O. Olokor and F.M. Omojowo, Adaptation and improvement of a simple solar tent dryer to enhance fish drying, Nature and Science, 7(10), 2009,18-24.

[6]. P.C. Phadke, P.V. Walke, and V.M. Kriplani, A review on indirect solar dryers, ARPN J.Eng.Appl.Sci., 10(8), 2015, 3360-3371.

[7]. F. Sulaiman, N. Abdullah, and Z. Aliasak, Solar drying system for drying empty bunches, J. Phys.Sci., 24(1), 2013, 75-93.

[8]. J. Banout and P. Ehl, Using a double-pass solar drier for drying of bamboo shoots, J. Agr.& Rural Dev. Trop. Subtrop., 111(2), 2010, 119-127.

[9]. A. Azimi, T. Tavakoli, H.K. Beheshti, and A. Rahimia, Experimental study on eggplant drying by an indirect solar dryer and open sun drying, Iranica J. Energy & Environment, 3(4), 2012, 348-354.

[10]. A. Munir, U. Sultan, and M. Iqbal, Development and performance evaluation of a locally fabricated portable solar tunnel dryer for drying of fruits, vegetables and medicinal plants, Pak. J. Agri. Sci., 50(3), 2013, 493-498.

[11]. Y. Yuwana and E. Silvia, Utilization of YSD-UNIB12 solar dryer for red pepper, mustard greens, cassava leaf drying, Proceeding of National Seminar entitled "Sustanable Agriculture" Bengkulu, Indonesia, 2012, 145-152, (in Indonesian).

[12]. E. Silvia and Y. Yuwana, Performance of the YSD-UNIB12 solar dryer for cassava drying, Proceeding of National Seminar entitled "Sustanable Agriculture" Bengkulu, Indonesia, 2012, 263-270, (in Indonesian).

[13]. Y. Yuwana, B. Sidebang, and E. Silvia, Performance of the modified YSD-UNIB12 solar dryer for cloth materials, Journal of Agroindustri, 3(2), 2013, 98-104, (in Indonesian).

[14]. Y. Yuwana, R.N.B. Tarigan, and E. Silvia, 2017. Solar Drying Modes of Catfish (Clarias gariepinus), IJEI., 6(4), 2017, 06-12.

[15]. Indonesian Standardization Board (ISB), Indonesian National Standard, SNI 0004, 2013,White Pepper, ICS 1.67. 220.10, Spices.

Y. Yuwana1. "Observed Ysd-Unib Solar Drying Curve And Drying Time Prediction for White Pepper." American Journal of Engineering Research (AJER), vol. 06, no. 12, 2017, pp. 380-387.