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EFFECT OF BLANCHING AND DRYING PROCESS ANALYSIS OF CABYA FRUIT *(Piper retrofractrum Vahl.)* USING SOLAR DRYER

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ABSTRACT

One of the dried products is commonly used in Indonesia is cabya fruits (Piper retrofractum Vahl.). Cabya fruits are usually used as seasoning and folk medicine that have various benefits for health. A solar dryer is an option that can be used as one of post-harvest handling. Drying rate, mathematical modeling of drying curve, and physical characteristics as parameters to develop the drying process of cabya fruit using solar dryer has been studied. The effect of water blanching was also investigated. In this study, the final average moisture content of nontreatment and blanching cabya fruit were 9.34±0.56 and 9.70±1.1, respectively. Twelve thin layer models were used in this research. According to the criteria of statistical parameters which predicted with the greatest of R^2 value and the smallest of χ^2 and RMSE value, Midilli et al. was the most appropriate model to predict experimental data and describe the drying behavior of the cabya fruit, both nontreatment and blanching during drying in a solar dryer. Blanching well affected the drying process of cabya fruit. The cabya fruit with blanching increases the drying rate. The fruit with blanching pretreatment decreases moisture content faster than nontreatment cabya fruit. The equilibrium moisture content of blanching cabya fruit was achieved after 9.5 hours of the drying process, whereas nontreatment cabya fruit was achieved after 19 hours of drying. The cabya fruit with blanching pretreatment had less shrinkage than nontreatment cabya fruit.

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INTRODUCTION

Fresh fruits and vegetables are easily damaged (perishable) and have a short shelf life because of the high moisture content (70-75 %) (Orsat et al., 2006) and improperly handled. The damaged products cause a negative impression on the consumer. So, agricultural products require proper post-harvest handling. Drying is one of the practical processes for post-harvest handling. Drying has considerable benefits. Drying can reduce the moisture content of the product, which is safe for distribution and storage, decrease or inactivate microbial activity, avoid microbial augmentation, and gain financial worth (Betoret et al., 2016).

One of the dried products is commonly used in Indonesia is cabya fruits (*Piper retrofractum* Vahl.). Cabya fruits are usually used as seasoning and folk medicine that have various benefits for health. Farmers in Indonesia, especially around East Java and Madura as one of the primary producers. Cabya fruits were harvested by farmers in the red edible maturity. Drying with open sun drying is usually utilized by farmers to dry products of agriculture. Farmers need 4-7 days of drying with blanching pretreatment about 10-20 minutes. The drying process will be longer if conducted during the rainy season. So, the appropriate drying method is required to achieve effective and efficient post-harvest handling.

A solar dryer is an option that can be used as one of post-harvest handling. It has several advantages, i.e., solar dryer able to accelerate drying time than open sun drying, environmentally friendly, and also as a sustainable power source for farmers (Takahashi et al., 2018). Solar drying using a solar collector and photovoltaic module can absorb sunlight to make the drying process more maximal. The solar dryer has objectives to optimize the utilization of solar dryer, increase drying efficiency and improve the quality of drying products. As stated by Mardiyani that the best condition in the drying process is when the condition of the dryer in low relative humidity (10 %). The solar dryer was able to achieve low relative humidity (Mardiyani et al., 2019).

Some previous research still focused on biological studies and medical purposes such as analyze the influence of cabya fruit maturity on the content of product (Takahashi et al., 2018); physical analysis of cabya fruit and its piperine content (Tambunan et al., 2001); pharmacological such as dynamic content of antileishmanial from cabya fruit (Bodiwala et al., 2007); chemical content and antibacterial effects in the essential oil of cabya fruit (Jamal et al., 2013); but not in detail discussed drying process that may affect its content such as drying kinetics, mathematical modeling and physical analysis of products. These parameters are crucial parts of the drying technology process to obtain an optimal and efficient process, minimizing the quality reduction of cabya fruit and optimizing the development of cabya fruit products.

Blanching is one of the essential pretreatment before the drying process. The primary purpose of blanching is to inactivate enzymes, removing trapped air, and change the cell structure. Conducted to the previous research, blanching treatment increased the drying rate, shortened the drying time (Wang et al., 2021), and decreased the color changes of the dried samples(Wang et al., 2018).

The primary goals of this research were to analyze the process of drying, namely drying rate, mathematical modeling of drying curve, and physical characteristics as a parameter to develop the drying process of cabya fruit using a solar dryer. Then, the comparison of nontreatment and blanching treatment was also analyzed.

MATERIAL AND METHOD

Tools and Materials

Drying was conducted using a solar dryer (eco-friendly forced convective fixed bed dryer), was designed by Mardiyani (Mardiyani et al., 2019). The solar dryer comprises four parts, namely solar collector, drying column, photovoltaic panel, and blower. The most necessary part of the solar dryer is its collector. Solar collector converts its radiation to heat and transforms heat through fluid into a collector (Hematian et al., 2012). Besides, Accu (GS Astra GM5Z-3B 12 volt) was used as a power supply to drive the blower in the drying machine. The other tools used in this research were digital scales (Matrix-500), oven Memmert/UFE 550, hygrometer, water bath, stopwatch, and digital caliper ±0.01 mm.

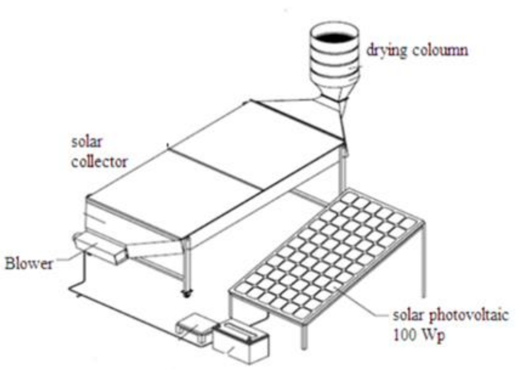

Figure 1. Design of Solar Dryer (Eco-Friendly Forced Convective Fixed Bed Dryer) (Mardiyani et al. 2019).

The cabya fruits (*Piper retrofractum* Vahl.) were obtained from farmers in Pasuruan, East Java Province. The average initial mass of each sample was 2.06±0.05 g with 68.02±0.51 % (wb) of average moisture content. The cabya fruits sorted based on the external color, i.e., orange maturity with L*a*b value was L*=31.76±2.08; a*=19.62±3.90; b*=37.21±0.79.

Drying Experiments

The drying process was conducted with two variations of pretreatment, namely nontreatment and blanching. Blanching was conducted using the water blanching method. The cabya fruits were soaked in hot water with ±70 °C of temperature for 3 minutes.

The cabya fruits were placed onto the drying column and dried with a solar dryer for a total of drying duration 24 hr (6 hr interval, started at 08.30 and continued till 14.30 at local time). The weight measurement of samples in the first two hours conducted every 15 minutes and in the next hours conducted every 30 minutes. The data was used to find the determination of moisture content alteration during the process of drying according to the standard gravimetric method on wet basis.

Drying Rate

The drying rate was calculated using Eq. (1) (Hawa et al., 2019).

$$DR = \frac{M_{t+\Delta t} - M_t}{\Delta t} \quad (1)$$

Mt and Mt+Δt were the moisture content at t and moisture content at t+Δt, respectively, and t was drying time. Then, the calculated drying rate presented graphically with drying time and moisture ratio for nontreatment and blanching.

Mathematical Modelling of Drying Curve

The moisture ratio of cabya fruit during the drying experiment was determined using Eq. (2) (Hawa et al., 2019).

$$MR = \frac{M_t - M_e}{M_o - M_e} \quad (2)$$

M_t, M_o, and M_e were the moisture content of the product at time *t*, initial moisture content of the product, and equilibrium moisture content of the product, respectively.

Twelve thin layer drying curve models were tested to choose the fittest model to describe the drying curve of cabya fruits. The models which are commonly used are listed in Table 1. Nonlinear regression analysis was performed by using Microsoft Excel 2016 to obtain the fittest constants for the respective model.

The fittest mathematical modeling in this research predicted according to the criteria of three statistical parameters, i.e., the greatest of the coefficient of determination (R^2) value and the smallest of root mean square error (*RMSE*) and reduced mean square of deviation (χ^2) value [10,11]. These parameters can be calculated with equation (3) and (4) as follows:

$$\chi^2 = \frac{\sum_{i=1}^{N}\left(MR_{ex,i} - MR_{pr,i}\right)^2}{N - np} \qquad (3)$$

$$RMSE = \left[\frac{1}{N}\sum_{i=1}^{N}(MR_{pr,i} - MR_{ex,i})^2\right]^{1/2} \qquad (4)$$

$MR_{ex,i}$ is the i-th experimentally observed moisture ratio, $MR_{pr,i}$ is the i-th predicted moisture ratio, N is the number of observations, and np is the number constants.

Physical Analysis

Physical characteristics observed in this research were shrinkage, which includes mass, length, width, and thickness of the cabya fruits. Twenty-five samples were used in the physical analysis. The initial condition (mass, length, width, and thickness) before drying was assumed at maximum condition (100 %). The shrinkage measurements were conducted every 3 hours until the end of the drying process using a digital caliper (±0.01 mm).

RESULT AND DISCUSSION

Drying Curve

The correlation among moisture content and drying time of nontreatment and blanching cabya fruits shown in Fig. 1. Blanching and nontreatment samples had negative correlation (-0.8898 and -0.7857). It shows that the moisture content was continuously reduced with increasing the drying time, as observed and expected by several other researchers (Akpinar et al., 2003; Akoy, 2014; Hawa et al., 2019). The water movement of the sample is getting slower until the equilibrium condition is reached. The equilibrium is reached when the weight loss less than 2 % (Hawa et al., 2014).

Table 1. Thin layer models to describe the drying curve of cabya fruits

No.	Model name	Model
1.	Newton	MR = exp($-kt$)
2.	Page	MR = exp($-kt^n$)
3.	Modified Page	MR = exp[$-(kt)^n$]
4.	Handerson-Pabis	MR = a exp($-kt$)^n
5.	Mod. Handerson-Pabis	MR = a exp($-kt$) + b exp($-gt$) + c exp($-ht$)
6.	Logarithmic	MR = a exp($-kt$) + c
7.	Midili *et al*	MR = a exp($-kt$) + bt
8.	Two-term	MR = a exp($-k_1t$) + b exp($-K_2t$)
9.	Two-term Exp.	MR = a exp($-k_0t$) + (1-a) exp($-K_1at$)
10.	Wang-Singh	MR = 1 + at +bt^2
11.	Diffusion Approach	MR = a exp($-kt$) + (1 - a) exp($-kbt$)
12.	Verma et.al.	MR = a exp(-kt) + (1-a) exp(-gt)

The final average moisture content of nontreatment and blanching cabya fruit were 9.34±0.56 and 9.70±1.1, respectively. According to the Badan Standarisasi Nasional, the maximal moisture content of simplicia as herbs is 10 %. The low moisture content can extend the shelf life of simplicia, because it can restrict the growth of microbial and chemical reactions (Amanto et al., 2015).

The fruit with blanching pretreatment decrease moisture content faster than nontreatment cabya fruit. The equilibrium moisture content was achieved after 9.5 hours of drying process by fruit with blanching pretreatment. The fruit with nontreatment began to gain the equilibrium moisture content at 19 hours after the drying process.

The pretreatment process is a notable parameter that influences the drying time. Pretreatment with blanching is the solution that more effective compared with nontreatment (Doymaz, 2009).

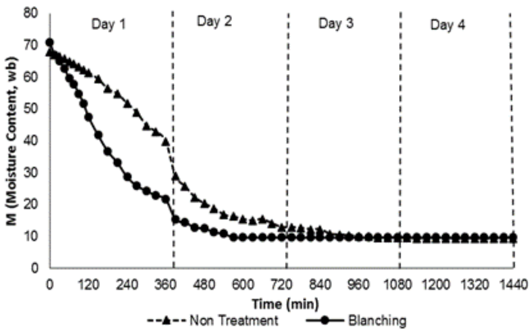

Figure 2. Moisture content and drying time of cabya fruit using solar drying

Drying Rate

In the drying process, the drying rate has essential meaning because it illustrates the speed of a drying process. In this research, the drying rate fluctuated, as shown in **Fig. 3.** The stage of the drying rate started with increasing the drying rate at the initial hour. The constant period occurred until the fourth hour of drying. This stage represents that unbound water is removed from the product. The first falling period began at the fourth hour until the sixth hour. This stage is reached when the drying rate begins to decrease. Afterward second falling period, which began when the surface completely dry. The second falling period takes much longer because the drying was slow.

The correlation of the drying rate of cabya fruit, both nontreatment and blanching, were shown in Fig. 2. Both blanching and nontreatment samples had a negative correlation (-0.50899 and -0.76094). It can be identified that the drying rate of cabya fruit was continuously decreased with increasing the drying time and decreasing the moisture content as expected and observed by several other researchers (Yaldiz, 2001; Toğrul and Pehlivan, 2002).

The cabya fruit with blanching increases the drying rate faster than nontreatment cabya fruit. The reasons why blanching able to accelerate the process of drying are internal water permeability increased because of the damage in the cell membranes by heat stress (Orikasa et al., 2018) internal, reciprocal to moisture dispersion is decreased by changes in the microstructure because of physical harm of the product (Watanabe et al., 2014), surface water permeability is improved because of diminished solidify of the sample surface (Orikasa et al., 2008).

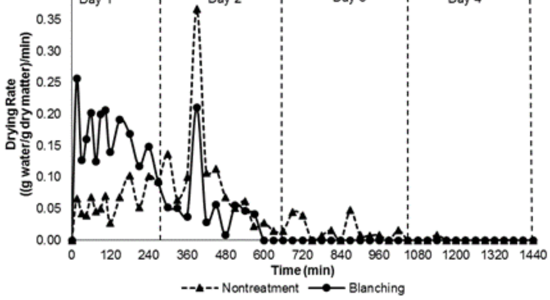

Fig. 3 Drying rate of nontreatment and blanching cabya fruit during solar drying

Mathematical Modelling of Drying Curve

Twelve thin-layer drying models (Newton, Page, Mod. Page, Handerson-Pabis, Logarithmic, Midilli, et al., Two-Term, Two-Term Exp, Mod. Henderson Pabis, Wang-Singh, Diffusion Approach, Verma, et al.) used in this research to describe the drying kinetics of nontreatment and blanching cabya fruit during solar drying. The results of drying models, model contants, and statistical parameters (R^2, χ^2, and RMSE) of nontreatment and blanching cabya fruit were shown in Table 2 and Table 3, respectively.

Table 2. Values of the model constant and statistical parameters of nontreatment cabya fruits

Model Name	Model Constant	R^2	*RMSE*	χ^2
Newton	k = 0.002624	0.96465	0.09667	0.00953
Page	k = 5.8246e^{-06}; n=2.0124398	0.99472	0.02853	0.00085
Modified Page	k =0.15032049 n = 2.01020184	0.99470	0.02853	0.00085
Henderson-Pabis	a = 1.163705; k = 0.003023	0.95915	0.07935	0.00654
Logarithmic	a = 1.224094; k = 0.002461; c = -0.08992	0.96520	0.06963	0.00514
Midilli et al.	a = 0.9698333; k = 1.8277e^{-06}; n=2.20139935; b = 8.0772e^{-06}	0.99510	0.02620	0.00074
Two-term	a = -9.5900711; k0 = 0.00667804; b = 10.5191949; k1 = 0.00583776	0.98997	0.03814	0.00157
Two-term Exp.	a = 0.00038628; k = 6.77763197	0.96467	0.09675	0.00973
Mod. Henderson-Pabis	a = 3.870147529; k = 0.001643642; b =-7.813725859; k1 =0.001516184; c =5.073276422; k2 = 0.001649167	0.96853	0.06624	0.00495
Wang-Singh	a = -0.0016147; b = 6.0526e^{-07}	0.94922	0.08422	0.00737
Diffusion approach	a = -16.1939; k = 0.0062; b = 0.9299	0.98872	0.04077	0.00176
Verma et al.	a = -13.9617937; k = 0.006266687; g = 0.00576251	0.98872	0.04078	0.00176

Table 3. Values of the model constant and statistical parameters of cabya fruits with blanching pretreatment

Model Name	Model Constant	R2	*RMSE*	χ^2
Newton	k = 0.00476	0.99162	0.03762	0.00144
Page	k = 0.000901; n=1.30479	0.99783	0.01493	0.00023
Modified Page	k =0.2781169; n = 1.30245	0.99782	0.01493	0.00023
Henderson-Pabis	a = 1.078714; k = 0.005155	0.99115	0.03116	0.00101
Logarithmic	a = 1.089159; k = 0.004875; c = -0.01957	0.99173	0.02821	0.00084
Midilli et al.	a = 0.97769415; k = 0.00068522; n=1.34910584; b = -2.601e^{-06}	0.99797	0.01399	0.00021
Two term	a = -5.7766823; k0 = 0.00312608; b = 6.83391343; k1 = 0.00336027		0.02313	0.00058
Two term Exp.	a = 0.00256967; k = 1.84778298	0.99456	0.03802	0.00150
Mod. Henderson-Pabis	a = 4.152179305; k = 0.002666046; b =-7.093872971; k1 =0.001697467; c =3.98595706; k2 = 0.001384217	0.99153	0.01932	0.00042
Wang-Singh	a = -0.0016147; b = 6.053e^{-07}	0.99612	0.18951	0.03732
Diffusion approach	a = -17.8229; k = 0.0029; b = 1.0256		0.02782	0.00082
Verma et al.	a = -7.52061276; k = 0.002880513; g =0.003052258	0.82850	0.02783	0.00082

According to the criteria of statistical parameters which predicted with the greatest value of R^2, and smallest value of RMSE and χ, the fittest model was Midili, et al. for nontreatment and blanching cabya fruit. For the thin layer solar drying of nontreatment cabya fruit, it was determined that R^2=0.99510, χ^2=0.00074, and RMSE=0.02620. The thin layer solar drying of cabya fruit with blanching, Midilli, et al. gave R^2=0.99797, χ^2=0.00021, and RMSE=0.01399.

The comparison of predicted values with observed values shown in Fig. 4. Based on the statistical parameters result, the graphic shows the close line, which indicates that Midilli et al. was the appropriate model to predict experimental data and describe the drying behavior of the cabya fruit, both nontreatment and blanching during drying with solar dryer. The Midilli et al. model was also suitable for some recent research. Satisfactorily describe the drying behavior of Cuminum cyminum in forced convection solar drying(A and M 2010), drying behavior of cashew in solar biomass hybrid dryer (Dhanushkodi et al., 2017), and drying behavior of red chili peppers and leech lime leaves in hot air drying (Waewsak et al., 2006).

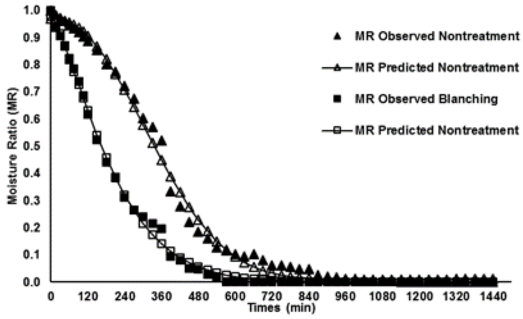

Fig. 4 The comparison of predicted values and observed values of nontreatment and blanching cabya fruit with Midilli et al. model

Physical Analysis

The physical characteristic is one of the ways to analyze the shrinkage of the product. The physical analyses of nontreatment and blanching cabya fruit during drying, including mass, length, width, and thickness, were determined and depicted in Table 4.

Table 4. Shrinkage of physical properties of nontreatment and blanching cabya fruits during the drying process

Sample	Characteristic	Time (h)								
		0	3	6	9	12	15	18	21	24
No Treatment	Mass	100 ± 0.00	72.05 ± 1.98	54.91± 2.50	43.76 ± 2.45	31.12± 2.45	25.63 ± 1.37	25.26 ± 1.49	24.77 ± 1.95	24.67 ± 1.98
	Length	100 ± 0.00	91.12 ± 1.24	82.26 ± 4.63	81.49 ± 1.32	75.38 ± 1.60	73.04 ± 1.43	72.85 ± 1.41	72.61 ± 1.15	71.95 ± 1.16
	Width	100 ± 0.00	85.45 ± 1.57	75.48 ± 2.26	73.25 ± 1.25	66.12 ± 1.64	65.60 ± 2.31	61.83 ± 1.07	60.87 ± 1.00	59.67 ± 0.94
	Thickness	100 ± 0.00	83.96 ± 3.26	72.19 ± 3.37	71.05 ± 2.92	62.63 ± 2.22	61.59 ± 2.06	58.07 ± 3.05	57.72 ± 2.22	55.36 ± 1.87
	Moisture content	68.02	56.35	39.89	16.88	12.89	10.53	9.59	9.34	9.34
Blanching	Mass	100 ± 0.00	48.36±3.71	40.30 ± 3.53	32.95 ± 1.66	32.54 ± 1.46	31.99 ± 1.49	31.97 ± 1.51	31.93 ± 1.48	31.84 ± 1.56
	Length	100 ± 0.00	83.31 ± 1.39	79.50 ± 1.72	76.09 ± 1.36	75.45 ± 2.04	74.99 ± 1.68	74.91 ± 1.80	74.14 ± 1.70	74.08 ± 2.00
	Width	100 ± 0.00	78.00 ± 3.40	75.13 ± 3.30	72.24 ± 4.55	71.62 ± 4.56	71.06 ± 4.50	70.70 ± 4.37	70.67 ± 3.62	69.39 ± 4.28
	Thickness	100 ± 0.00	72.31 ± 2.63	70.55 ± 3.80	70.23 ± 2.97	69.18 ± 1.83	67.86 ± 2.01	67.50 ± 1.96	67.21 ± 1.59	66.73 ± 1.69
	Moisture content	70.90	36.72	21.74	10.94	9.70	9.70	9.70	9.70	9.70

The initial condition of cabya fruit before the drying process was assumed at top condition (100 %). In general, physical characteristics alteration occurred quickly at the early stage of drying. Nontreatment cabya fruit reaches equilibrium after 15 hours of the drying process. The alteration of cabya fruit began balance at 9 hours of the drying process. The mass alteration of nontreatment cabya fruit was slower compared to cabya fruit with blanching.

The final physical characteristic (mass, length, width, and thickness) of nontreatment cabya fruit were 24.67 ± 1.98; 71.95 ± 1.16; 59.67 ± 0.94; 55.36 ± 1.87, respectively. The final mass, length, width, and thickness in cabya fruit with blanching were 31.84±1.56; 74.08±2.00; 69.39±4.28; 66.73±1.69, respectively.

The shrinkage of cabya fruit with blanching had less shrinkage than nontreatment cabya fruit. It can be concluded that blanching able to maintain the physical size of the product during drying.

The deformation and decrease in dimensions are caused by water loss and heating that cause pressure in the structure of the cellular. At the time when water is eliminated from the product, pressure imbalance is generated among the inside of the material and external pressure, which causes shrinkage of the product or collapse, deformation, and sometimes cracking of the product (Mayor and Sereno, 2004).

CONCLUSION

In this research, the final average moisture content of nontreatment and blanching cabya fruit were 9.34±0.56 and 9.70±1.1, respectively. Twelve thin layer models were used in this research. According to the criteria of statistical parameters which predicted with the greatest of R^2 value and the smallest of χ^2 and RMSE value, Midilli et al. was the most appropriate model to predict experimental data and describe the drying behavior of the cabya fruit, both nontreatment and blanching during drying in solar dryer.

Blanching process well affected the drying process of cabya fruit. The cabya fruit with blanching increases the drying rate. The fruit with blanching pretreatment decreases moisture content faster than nontreatment cabya fruit. The equilibrium moisture content of blanching cabya fruit was achieved after 9.5 hours of the drying process, whereas nontreatment cabya fruit was achieved after 19 hours of drying process. The cabya fruit with blanching treatment had less shrinkage than nontreatment cabya fruit.

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