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Modification of Indirect Solar Dryer for Simplicia Production

C W Purnomo[1,2] and S Indarti[1,3]

1 Agrotechnology Innovation Center (PIAT), Universitas Gadjah Mada, Berbah Sleman, Yogyakarta, Indonesia
2 Chemical Engineering Department, Univeristas Gadjah Mada, Jl Grafika no 2, Yogyakarta, Indonesia
3 Faculty of Agriculture, Universitas Gadjah Mada, Sleman, Yogyakarta, Indonesia
E-mail: chandra.purnomo@ugm.ac.id

Abstract. Simplicia is natural ingredient for herbal medicine that has been subjected to drying only. This study aims to develop an appropriate drying equipment to produce dried leaves of sambung nyawa (Gynura procumbens (Lour.) Merr.) or also called “longevity spinach”. Typical indirect solar drier was modified to be able to process more fresh leaves in order to speed up the production. The modification was done using double solar collector and wind powered ventilation. The double solar collector was applied in order to collect more solar energy for larger dimension of drying chamber, while the wind-ventilator was installed to provide forced convection of hot air flow inside the dryer. The drying kinetic including the drying constants were investigated using three common thin layer drying equations to model the drying behavior of the leaves. The moisture ratio (MR) depletion with respect to the drying time (t) of the leaves can be well represented by equation of $MR = 1.1732 \exp(-0.0993.t) - 0.1732 \exp(-17.3871.t)$.

1. Introduction

Solar dryer is a common technology to be used to preserve agriculture product. This dryer aims to replace the direct sun drying method in open environment which suffers from various drawbacks such as uneven moisture removal, loss of the crop and less hygienic [1]. In terms solar energy collection, in general there are two type of solar dryer which are direct and indirect solar dryer. The direct solar dryer is using transparent cover which allows solar energy to enter inside the drying chamber to dry up the materials while indirect dryer employs a solar energy collector outside the drying chamber which produce hot air that will flow passing the material inside the chamber. Direct dryer could have higher temperature inside the chamber especially when using natural air flow compared with indirect drying [2]. However, it may suffer from overheating of delicate materials like medicinal herbs. Indirect solar dryer is more favorable to be used for drying simplicial herbs due to ease of temperature and moisture control to avoid active ingredient such as essential oils deterioration [3].

Meanwhile in term of air flow system inside the dryer, there are two type which are natural and forced convection. The natural convection utilize the different air density due to the temperature different between hot air inside the drying chamber and cold air outside the dryer to create air circulation. Forced convection is suitable for large scale production for fast drying mechanism. However this type require electricity to run the blower or exhaust fan.

Despite the advantage of the solar dryer compared with direct sun dryer, the equipment is still gained not much attention to the ordinary farmers due to high investment cost and time consuming operation [4]. Thus the design of the dryer has to be continuously improved to minimize the drawbacks. A

typical indirect solar dryer has only one solar collector to be placed North or South direction for longer collection time of solar energy from morning until late afternoon. Typically, this solar dryer type only has a single drying chamber. In this study, indirect conventional solar heater was modified by additional of an extra solar collector in order to be able to enlarge the drying chamber. The solar collector is placed in the same direction of sun movement (East to West). The modification also provide a longer service time of the dryer throughout the day compared with a single solar collector dryer.
The other modification is by adding wind-ventilator on top of the chamber in order to create a negative air pressure to induce the air flow inside the dryer. Then, the modified dryer performance is evaluated by drying fresh longevity spinach leaves.

2. Experimental method

The leaves of longevity spinach (*gynura procumbens*) was freshly harvested and collected from Mangunan Region, Yogyakarta, Indonesia (7^{o}92'51"S and 110^{o}39'78"E). Before drying, the harvested leaves was spread on perforated stainless steel trays to form a single thin layer covering all the tray surface. Each tray was loaded with 0.22 kg of fresh leaves. Drying experiments were carried out using an indirect solar dryer with double collector which is constructed from stainless steel frames and walls as shown in Figure 1. The drying process were operated closer to the plantation site under forced convection by wind powered induced fan (ventilation). The experimental data were manually recorded every 2 h from 8 a.m. to 4 p.m. over three days and duplicated to obtain four data sets. The dryers were shut down during the night, and experimentation was resumed the next day at 8 a.m.

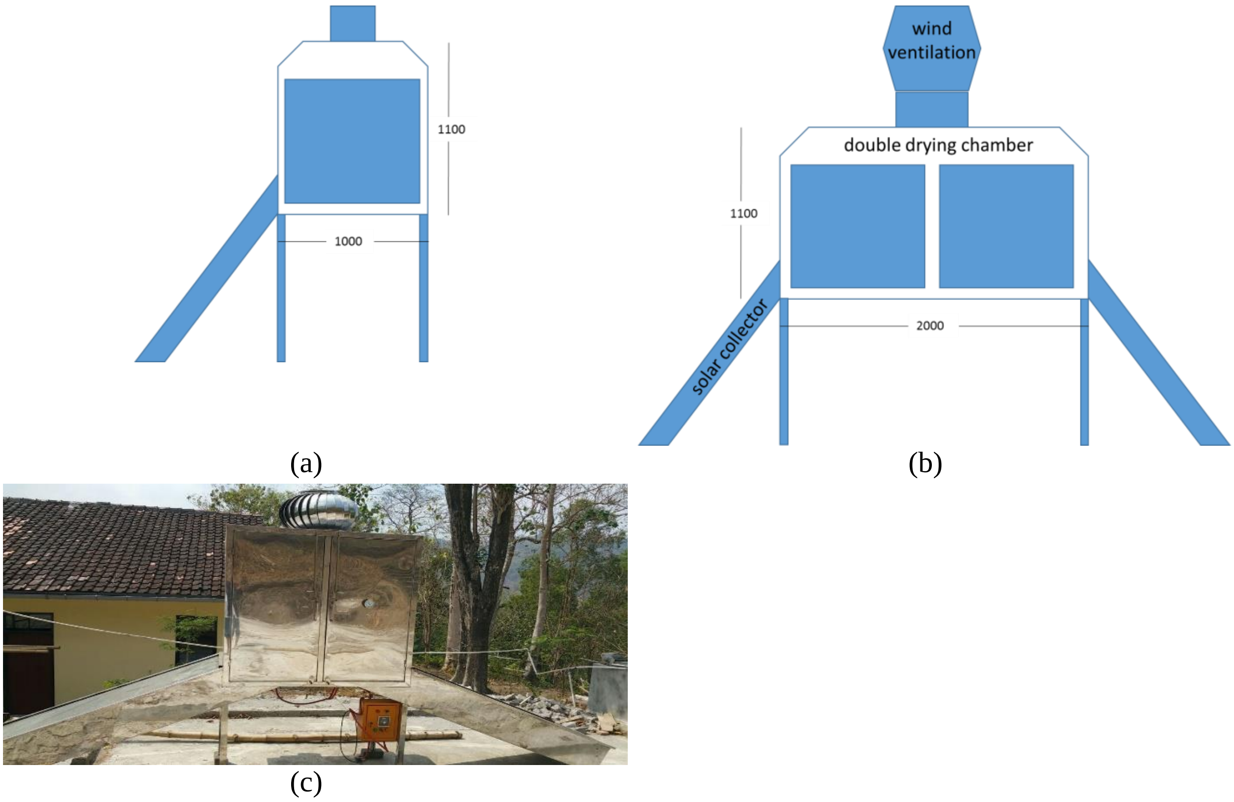

Figure 1. Typical indirect solar dryer: (a) conventional single collector dryer, (b) and (c) double collector dryer (in this study)

The drying calculation followed a previously reported work [2]. Moisture ratio (*MR*) was calculated using the following equation:

$$MR = \frac{M}{M_o} \quad (1)$$

where M, and M_o (kg water/kg solid) are the moisture content at a particular time, and initial moisture content respectively. The equilibrium moisture content can be omitted due to the continuous fluctuation of the relative humidity of the drying air during solar drying and the relatively small value compared to Mo and M. Three empirical models were used to fit the drying curves which are Newton, Henderson and Pabis, and Verma et al. [5] as shown in equation (2), (3) and (4) respectively. The data fitting was performed using MATLAB with minimum sum of square error (SSE) method.

$$MR = \exp(-kt) \quad (2)$$

$$MR = a\exp(-kt) \quad (3)$$

$$MR = a\exp(-kt) + (1-a)\exp(-gt) \quad (4)$$

Then, Fick's second law was solved analytically in order to evaluate the D_{eff} (effective diffusivity) by plotting experimental drying data in terms of *ln(MR)* versus drying time (t) to give a straight line with a slope (k_o) which D_{eff} can be calculated by equation (4) with L is the thickness of the dried material.

$$D_{eff} = 4\frac{k_o L^2}{\pi^2} \quad (5)$$

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3. Results and discussion

The internal temperature of drying chamber throughout a week is provided in Figure 2. The optimum temperature is about 42 ^{o}C at 12 p.m. while a large fluctuation is observed at 2 hours before and after the maximum temperature. Variety of cloud coverage and wind speed could be the cause of the temperature fluctuation inside the drying chamber. The temperature range is ideal for drying medicinal herb since a higher drying temperature can destroy active components inside the simplicia.

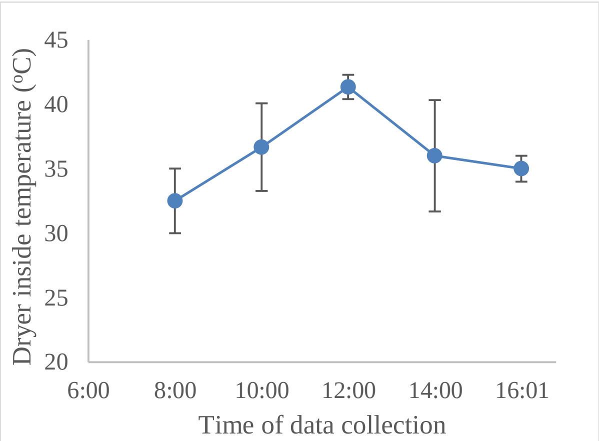

Figure 2. Temperature range in the drying chamber during data collection

The data fitting of drying curve is shown in Figure 3. The moisture was decreased rapidly during the beginning of the drying time due to the existence of surface water on the solids [6]. It can be visually observed that equation (3) fit the data better that the others. This also confirmed by the smallest SSE value by using this equation to fit the data. The obtained parameters and SSE values are listed for each equation in Table 1.

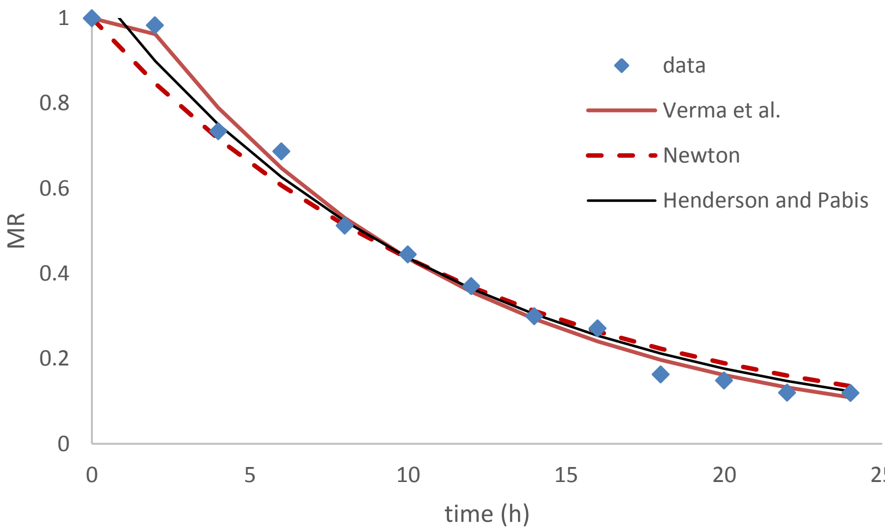

Figure 3. Data fitting plot with the model equations parameters obtained by Matlab

From Table 1, it is shown that the constants are quite close with the reference especially for the first two equation. The *k* values are slightly lower than the dryer of whole plant mints [2] but higher than stevia leave dryer [7]. This indicates that the rate of drying in this study is comparable to the literature which is promising since the dryer has no electric powered equipment for air circulation. This lower rate also could be due to the difference of the dried materials since the leaves of longevity spinach is thicker and larger than mint. Smaller leaves will have larger surface area than larger one which will accelerate the mass transfer of moisture during drying process. It is reflected by the value of effective diffusivity. The calculated D_{eff} of this study is 2.7×10^{-12} m^2s^{-1} which is smaller than the literature of 2.1×10^{-11} m^2s^{-1} [2]. The best fitted equation is Verma equation according to the lowest SSE value.

Table 1. The constants of the model equations of MR and SSE values

Model	Constants (this study)	SSE (this study)	Constants [2]	Constants [7]
Newton	*k* = 0.0832	0.0327	*k* = 0.1646	*k* = 0.0210
Henderson and Pabis	*a* = 1.0772; *k* = 0.0902	0.0214	*a* = 0.9718; *k* = 0.1575	*a* = 1.0117; *k* = 0.0212
Verna et al.	*a* = 1.1732; *k* = 0.0993; *g* = 17.3871	0.0082	*a* = 0.4357; *k* = 0.0693; *g* = 0.3215	*n.a.*

4. Conclusion

The new design of indirect dryer with two solar collector has shown an acceptable performance to be used for herb leaves dryer. The double collector provide enough drying air for larger drying chamber configuration that will also double the production rate of the simplicia. Verma equation is the most suitable model for representing the drying rate of the longevity leaves using the modified dryer.

5. References

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