Solar Drying System for Salted Silver Jewfish: Drying Models

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Solar Drying System for Salted Silver Jewfish: Drying Models

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Abstract

The present study aimed to investigate the drying models of salted silver jewfish in solar drying systems. A nonlinear regression method was used to fit different drying models, among which Page's model showed a better fit compared with Newton's and Henderson and Pabis's models. Findings indicated that Page's model is the best drying model for use in precisely predicting the drying behaviour of salted silver jewfish; it yielded the highest value of R^2 (0.9596) and the lowest mean bias error (0.0026) and root mean square error (0.0539). At the average drying temperature of 44 °C and relative air humidity of 28%, a 26 h drying time was required to reduce the moisture content of salted silver jewfish from 63.24% to 10%.

Keywords: *Solar energy, solar drying, drying kinetics, thin layer drying, drying curve*

1. Introduction

Malaysia is in the equatorial region, located between the North 1.30° North 6.60° longitude and Eastern 99.50° to latitude East 103.30°. The country usually receives an average solar radiation of 4000–5000 Wh/m^2. The average number of hours of sunshine received is 4–8 h. The average temperature is approximately 26 °C–32 °C. The technology of solar drying systems aims to reduce the drying time of wet ingredients by as much as 50% over conventional methods. The system generates a uniform moisture content of approximately 20%. The construction of a thermal chamber consists of several key components, such as a solar energy collector plate, a drying room and an air cycle system. The air cycle system then brings hot wind into the heating chamber for drying agricultural and marine products. This technology has the advantage of continuous drying and operation. During the drying process, the chamber interior always remains at a temperature of 40 °C–60 °C [1-3].

The drying process of agricultural and marine products in Malaysia currently uses the traditional direct drying method, which directly uses sunlight. The sun has been providing energy for billions of years. Solar energy, the solar radiation that reaches the earth, is a primary energy potential in the world's energy supply during the day and also a major source of energy that produces heat or thermal energy. Therefore, the number of various technologies based on solar energy has been growing rapidly to replace conventional

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energy. One such solar energy technology is solar-assisted drying, an environmentally friendly alternative. This solar drying system was developed to address the demand for drying systems that are easy to use, highly efficient, low-cost and require low power. The most common method is the use of a platform or drying padding. Burning coal, petroleum gas and rubber wood is also used for drying agricultural products, such as rice, cocoa and tobacco. However, the direct drying method has the following drawbacks: (i) it requires large spaces or surface areas; (ii) materials are easily dried and contaminated because they are left unattended; (iii) the drying time is relatively long and depends on weather conditions and environments. Unpolluted materials are also susceptible to microorganisms and substances, which can damage material quality. Thus, solar drying systems have been studied and developed in Malaysia as an alternative to the traditional method [4-7].

Various studies on the drying kinetics and models 26 vegetables, agricultural fruits and marine products have been published recently. Gupta et al. [8] studied the drying kinetics of brown seaweed with different temperatures and con1uded that the drying model for brown seaweed can be accurately predicted using Henderson and Pabis's model, the logarithmi11nodel and Newton's model. The present study was conducted to select the best drying model for describing the drying behaviour of salted silver jewfish in solar drying systems.

2. Materials and Methods

The main raw material used for the preparation of the sample in this study was the Malaysian silver jewfish (*Johniussoldado*); the total mass was 296.85 g, and the fish were obtained from the local market in Kajang, Malaysia. The selection of fish was based on availability in a large group, low cost and high economy. Impurities were removed from the fish by washing before the samples were provided to ensure quality of the raw material and avoid the breeding of microorganisms. The purified fish then underwent digging and drying.

In this study, the method used was dry salting with crystalline salt. The fish were processed with salt and then layered. Each layer of fish was stripped of salt. The preparation of crystalline salt should be in accordance with the mass of the fish. The amounts of salt to be prepared for large, medium and small fish are typically approximately 20%–30%, 15%–20% and 5%, respectively, of the mass of the fish. Digging was conducted for 4 h. The fish were cleaned again with water after digging to ensure that no residual salt was left in the fish, which could affect the drying process. The fish were dried in a solar drying system at the Green Energy Technology Innovation Park, UniversitiKebangsaan Malaysia (UKM), as shown in Fig22. The solar drying system is of the active dryer indirect type. The system comprises a double-pass solar air heater with fins, auxiliary heater, blower and drying chamber. Four so10 air heaters are set with a total area of 11.52 m^2. The drying chamber measures 4.8 m long, 1 m wide and 0.6 m high.

The mass decrease in the sample was manually recorded for a period of 30 min. Drying was considered completed when the final mass of the sample became constant. Wet and dry basis contents were obtained on the basis of the shrinkage of the sample mass.

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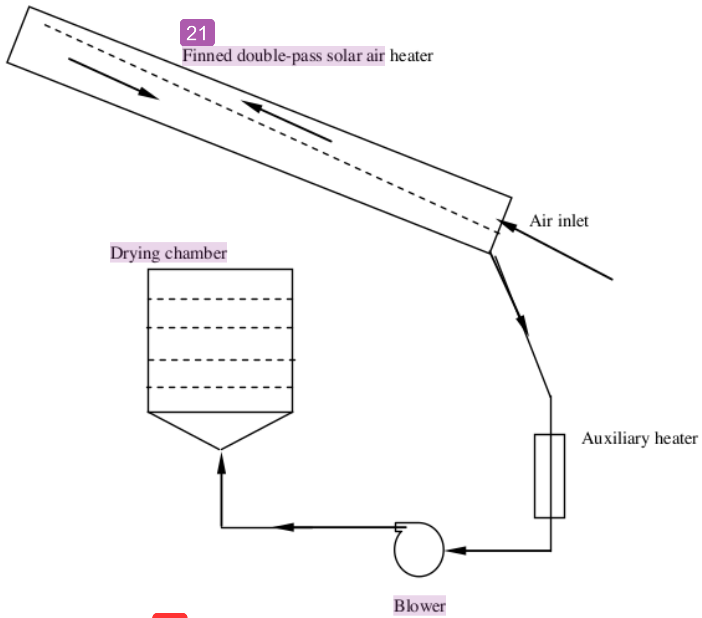

Figure 1.Schematic of the Solar Drying System

Drying was conducted from 09:00 AM to 06:00 PM to achieve the desired final mass and achieve a moisture content of 10%. The moisture ratio (MR) was calculated by Eq. (1), and the salted silver jewfish drying data were fitted by three drying models, as shown in Table 1.

$$MR = \frac{M - M_e}{M_0 - M_e} \qquad (1)$$

where M_0 is the initial moisture content and Me is the equilibrium moisture content. The values of the mean bias error (MBE), root mean square error (RMSE) coefficient and determination (R^2) were used to calculate the accuracy of the drying model. The model that produced the lowest RMSE and the highest R^2 to describe the drying curve was considered the best model [9-12]:

$$MBE = \frac{1}{N}\sum_{i=1}^{N}\left(MR_{pre,i} - MR_{\exp,i}\right)^2 \qquad (2)$$

$$RMSE = \left[\frac{1}{N}\sum_{i=1}^{N}\left(MR_{pre,i} - MR_{\exp,i}\right)^2\right]^{\frac{1}{2}} \qquad (3)$$

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Table 1.Drying Models

No.	Model name	Model
1	Newton	$MR = \exp(-kt)$
2	Page	$MR = \exp(-kt^n)$
3	Henderson and Pabis	$MR = a \exp(-kt)$

3. Results and Discussion

The drying curve test for salted silver jewfish was done in a solar drying system with an average temperature of 44 °C and a humidity of 28%. Mass change was recorded every 30 min until the mass reading became constant. After the drying test, a graph of the mass change of the sample against time was plotted to indicate the drying curve of the dried salted silver jewfish.

The results from the drying process showed that a time period of 26 h was required to reduce the moisture content from 63.24% to 10%. Raw data were analysed and recorded to determine the best model, which could be determined through R^2 and RMSE. The best drying model had the highest R^2 value and the lowest MBE and RMSE values. The model used in this study was different from thin-layer drying models. In these drying models, changes in moisture content with drying time calculated were plotted using the software Microsoft Excel. The drying model was fitted with the raw data. Figure 2 shows the exponential curves of Newton's model, which represent the correlation between the MRs and drying time. This figure demonstrates that *k* constant was 0.1078.

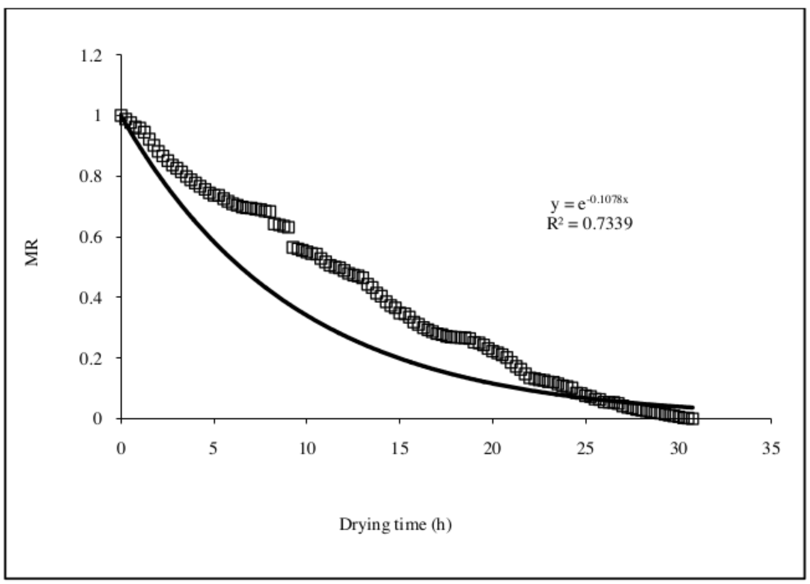

Figure 2.Newton model: MR vs. Drying Time

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Page's model can be expressed by

$$\ln(-\ln MR) = \ln k + n \ln t \quad (4)$$

Equation (4) is the correlation ln (−ln MR) with t, which is the curve of the logarithmic equation (Fig. 3). Figure 3 shows that n constant was 1.2621 and the obtained value for k constant was 0.0397.

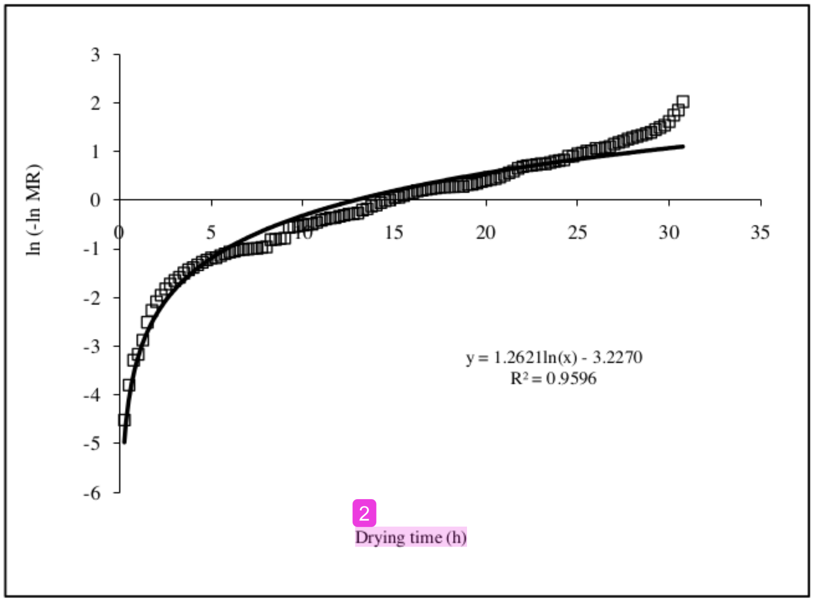

Figure 3.Page Model: ln (−ln MR) vs. Drying Time

Henderson and Pabis's model can be expressed by

$$\ln MR = -kt + \ln a \quad (5)$$

Equation (5) shows that a plot of ln MR versus drying time produced a straight line with intercept = ln a and slope = k. Graf ln MR versus t is shown in Fig. 4. k constant was 0.1414, and the obtained value of a constant was 1.9971. Table 2 shows a summary of the one-term thin-layer drying exponential models presented in the study, where the Page drying model has the highest value of R^2 (0.9596) and the lowest values of RMSE (0.0509) and MBE (0.0026) among all drying models.

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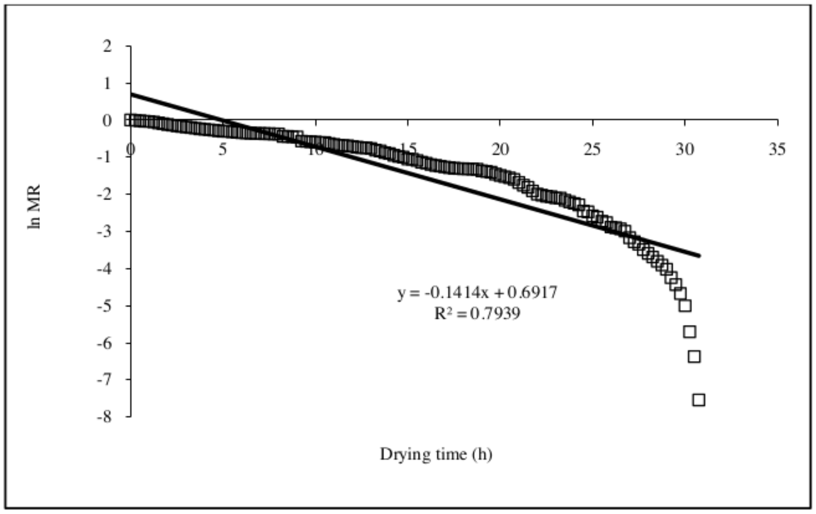

Figure 4.Henderson and PabisModel: ln MR vs. Drying Time

Table 2.Results of Thin-Layer Drying Model Analyses

Model	a	k	n	R^2	MBE	RMSE
Newton		0.1078		0.7339	0.0190	0.1377
Page		0.0397	1.2621	0.9596	0.0026	0.0509
Henderson and Pabis	1.9971	0.1414		0.7939	0.0701	0.2648

4. Conclusion

The drying process reduced the initial moisture content of 63% to a final moisture content of 10% within 3 days. The drying process occurred at an average temperature of approximately 44 °C and a mass flow rate of 0.07 kg/s. The result of the salted silver jewfish drying in the solar drying system showed that Page's model was the best model for jewfish drying; it produced the highest R^2 (0.9596) and the lowest MBE (0.0026) and RMSE (0.0509). Therefore, Page's model can be used to precisely predict the moisture content of dried salted silver jewfish in solar drying systems.

Acknowledgments

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References

[1] A. Fudholi , M.K.B.M. Ali, M. Mohammad, M.Y. Othman, M.H. Ruslan, K. Sopian, Solar drying technology: an overview. International Journal of Power Electronics and Drive Systems (IJPEDS) 9 (4) (2018), 1804-1813

[2] A. Fudholi, K. Sopian, B. Bakhtyar, M. Gabbasa, M.Y. Othman and M.H. Ruslan, Review of solar drying systems with air based solar collectors in Malaysia, Renewable and Sustainable Energy Review 51 (2015) 1191-1204.

[3] A. Fudholi, K. Sopian, M. Gabbasa, B. Bakhtyar, M. Yahya, M.H. Ruslan and S. Mat, Techno-economic of solar drying systems with water based solar collectors in Malaysia: a review, Renewable and Sustainable Energy Review 51 (2015) 809-820.
[4] A. Fudholi, K. Sopian, M.A. Alghoul, M.H. Ruslan and M.Y. Othman, Performances and improvement potential of solar drying system for palm oil fronds, Renewable Energy 78 (2015) 561-565.
[5] A. Fudholi, B. Bakhtyar, H. Saleh, M.H. Ruslan, M.Y. Othman and K. Sopian, Drying of salted silver jewfish in a hybrid solar drying system and under open sun: modeling and performance analyses. International Journal of Green Energy 13 (11) (2016): 1135-1144.
[6] A. Fudholi, K. Sopian, M.Y. Othman and M.H. Ruslan, Energy and exergy analyses of solar drying system for red seaweed, Energy and Buildings 68 (2014) 121-129.
[7] A. Fudholi, K. Sopian, M.H. Yazdi, M.H. Ruslan, M. Gabbasa and H.A. Kazem, Performance analysis of solar drying system for red chili, Solar Energy 99 (2014) 47-54.
[8] S. Gupta, S. Cox and N. Abu-Ghannam, Effect of different drying temperatures on the moisture and phytochemical constituents of edible Irish brown seaweed, LWT-Food Science and Technology 44 (2011) 1266-1272.
[9] A. Fudholi, M.Y. Othman, M.H. Ruslan and K. Sopian, Drying of Malaysian Capsicum annuum L. (red chili) dried by open and solar drying, International Journal of Photoenergy (2013) 1-9.
[10] M. Yahya, Performance analysis of solar assisted fluidized bed dryer integrated biomass furnace with and without heat pump for drying of paddy, International Journal of Photoenergy (2016) 1-17.
[11] M. Yahya, Design and performance evaluation of a solar assisted heat pump dryer integrated with biomass furnace for red chilli, International Journal of Photoenergy (2016) 1-14.
[12] M.Y. Othman, A. Fudholi, K. Sopian, M. H. Ruslan& M. Yahya. AnalisisKinetikPengeringanRumpaiLautGracilariacangiiMenggunakanSistemPengeringSuria (Drying Kinetics Analysis of Seaweed Gracilariacangii using Solar Drying System). SainsMalaysiana 41 (2) (2012) 245-252.

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