The Newton Model for Seaweed Drying: An Investigation of a Cabinet Dryer Using Biomass Energy

Nanang Apriandi*(1), Yusuf Dewantoro Herlambang(2), Ampala Khoryanton(3), Yanuar Mahfudz Safarudin(4), Zulhan Widya Baskara(5), Rani Raharjanti(6)

1,2,3,4 *Department of Mechanical Engineering, Politeknik Negeri Semarang*, Semarang, Indonesia

5 *Faculty of Mathematics and Natural Sciences, Universitas Mataram*, Nusa Tenggara Barat, Indonesia

6 *Department of Accounting, Politeknik Negeri Semarang*, Semarang, Indonesia

***Email address : **nanang.apriandi@polines.ac.id**

***Abstract*— This study investigates the viability of employing a cabinet-type dryer with a heat energy source derived from biomass combustion to dry Eucheuma sp. using Newton's model. In this investigation, seaweed was dried with air at a temperature of 55 °C. A reduction in water content of 8.1% was attained after six hours of drying. The data were analyzed and recorded to match the proposed drying mathematical model. The model feasibility test shows that, with a coefficient of determination (R^2) that is close to one and corrected at 0.9502, the Newton model can be used to predict the moisture content of dried seaweed after the drying process using a cabinet-type dryer with a source of heat energy from biomass combustion.**

Keywords*— Newton model, seaweed, drying, cabinet dryer, biomass.

I. Introduction

In Indonesia, there are tremendous development opportunities for the commodity seaweed. As of now, Indonesia exports dried seaweed to a number of nations, with Eucheuma seaweed predominating [1]. These nations include England, Japan, Australia, France, Germany, Chile, and Spain. Eucheuma seaweed is typically picked when it has a lot of water [2]. Drying is therefore essential to lower the water content. Special drying working conditions, one of which is a relatively high drying temperature, are required for some cases of drying materials with high moisture content [3].

For drying technology to accurately anticipate system performance, a mathematical model of the drying process must be established [4]. Another objective of mathematical modeling is to give the designers of appropriate dryers flexibility in selecting the best operating conditions for drying particular materials in order to optimize the drying process [5]. A specific drying mathematical model is typically constructed using the thin-layer drying technique. Thin-layer drying is a method in which all of the coating's components are exposed to airflow that has a consistent and uniform temperature and humidity [6]. The Newton model, commonly known as the Lewis model, is one of the mathematical models of thin-layer drying that is employed [7].

The thin-layer drying equation can be used to estimate the drying curve in general. To find the best control settings and ensure the final product's quality, it is essential to run drying simulations under various situations [8]. Numerous researchers have applied the Newton model to thin-layer drying for various agricultural products, including coconut chips [9], bilimbi or Averrhoa bilimbi [5], roselle [10], and lemongrass [11].

On the other hand, several other researchers used various dryer types and drying temperatures to study how Newton's model may be applied to the thin-layer drying of seaweed. In order to dry thin seaweed layers using a sun dryer with a drying temperature of 50 °C, Fudholi et al. [12] employed Newton's model. While this was going on, Fithriani et al. [2] used Newton's model to dry seaweed in a cabinet-type dryer that used an electric heater as its energy source, with temperature fluctuations of 40, 50, 60, and 70 °C. The findings of studies by [12] and [2] show that additional mathematical models will be feasible when the Newton model is applied to various dryer types and drying temperatures in the drying of seaweed.

Based on previous studies, the goal of this study was to determine whether it was possible to use the Newton model in a cabinet dryer that generated heat from biomass combustion to dry seaweed. In order to add references about the characteristics of the application of the Newton model for drying seaweed using various types of dryers and different drying temperatures, the findings of this study will subsequently be compared with the findings of research from [12] and [2].

II. Methods

In this work, a cabinet dryer that gets its heat energy from burning biomass in the form of coconut shells is used to dry Euchema sp. seaweed. The cabinet dryer includes a biomass combustion furnace, a drying chamber, an air circulation chimney, and a number of measurement devices, in addition to a heat storage device in the shape of an iron gram located in the plenum room. The drying temperature is measured using a type K thermocouple attached to the Autonics Temperature Indicator Series T4WM-N3NKCC. The dried material mass and drying time were measured using an analytical balance and a stopwatch, respectively. Figure 1 shows the schematic layout of the cabinet dryer used in this investigation.

A total of 50 grams of dried seaweed were examined in this investigation. Six hours of drying were completed, with 30-minute intervals used to collect data on changes in the dried seaweed mass. 55 °C is the typical drying temperature. The following analysis of seaweed drying data was performed using the Newton model given in Equation (1) and the water content ratio (MR), which is approximated by Equation (2) [13].

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$$MR = \exp(-k.t) \quad (1)$$

$$MR = \frac{MC_t - MC_e}{MC_o - MC_e} \quad (2)$$

Where:

MR = moisture ratio,
MC_t = moisture content of material dried at a specific time (%),
MC_o = initial moisture content of the dried material (%),
MC_e = equilibrium moisture content of the dried material (% dB),
k = drying rate constant,
t = time (minutes).

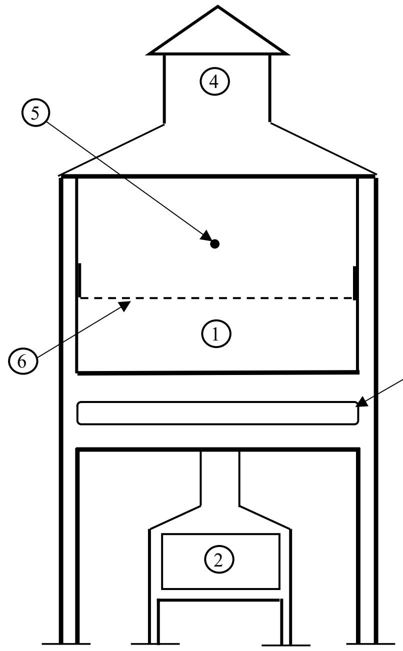

Fig. 1. Schematic of the cabinet dryer system with a biomass energy source: (1) drying chamber, (2) biomass combustion furnace, (3) heat storage, (4) air circulation chimney, (5) thermocouple, and (6) rack.

Two methods [14] can be used to determine the moisture content of materials that are drying at a given time: the moisture content on a wet basis is expressed in Equation (3), and the moisture content on a dry basis is expressed in Equation (4).

$$MC_{t-wb} = \frac{W_{tot} - W_t}{W_{tot}} \quad (3)$$

$$MC_{t-db} = \frac{W_{tot} - W_t}{W_{tot} - W_w} \quad (4)$$

Where:

$MC_{t\text{-}wb}$ = moisture content of a material on a wet basis, dried a specific time (%),
$MC_{t\text{-}db}$ = moisture content of a material on a dry basis, dried a specific time (%),
W_{tot} = total mass of dried material (gr),
W_t = mass of the material after drying at a specific time (gr),
W_w = mass of water contained in the dried material (gr).

The equilibrium moisture content is when no more water is released from the material to the environment during the drying process. Under these conditions, the mass of the material being dried is constant. Meanwhile, the value of the coefficient of determination (R^2) is used to determine the feasibility of the drying model. If the R^2 value is close to one, the drying model is considered appropriate for forecasting the moisture content of dry matter following the drying process [9] [12] [15].

III. Results and Discussion

The initial moisture content of dried seaweed is 95%, while the equilibrium moisture level is 5% dB. The estimated water content in dry seaweed conditions, where there is no measurable mass change during the drying process, is used to determine the equilibrium moisture content. The moisture content of the seaweed dropped from 95% to 86.91% after six hours of drying at an average temperature of 55 °C. Using Microsoft Excel, drying data in the form of variations in moisture content versus drying time were modified in accordance with the suggested drying model. Figure 2 illustrates the application of Newton's model to experimental data. Another way to express Newton's model [Equation (1)] is as follows:

$$\ln MR = -k.t \quad (5)$$

$$y = a.x \quad (6)$$

$$a = k \quad (7)$$

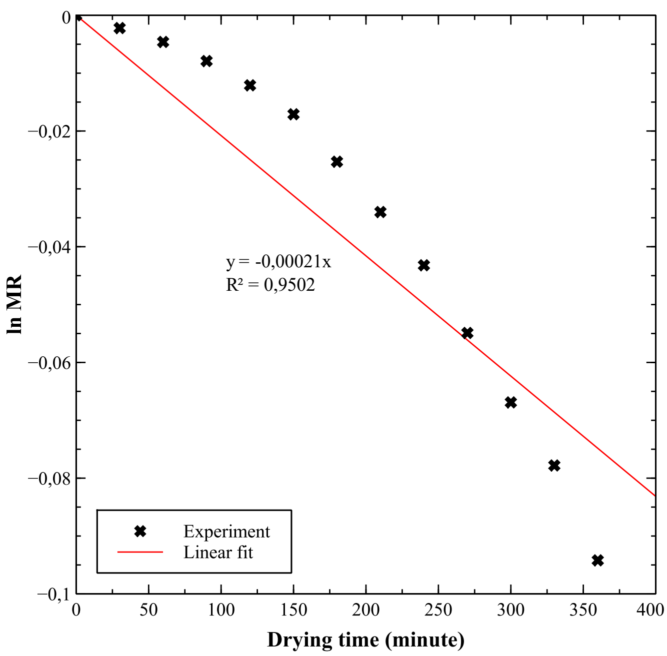

Fig. 1. Newton model: Plot of LnMR versus drying time

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The drying rate and the drying process are closely related. The size of the drying rate constant (k) can be calculated using the kinetic equation. Mathematically, the drying process can be viewed as kinetic [16]. Equation (5) illustrates the relationship between LnMR and drying time. The correlation graph plot generates a linear equation [Equation (6)], where "a" is the slope of the curve, which also indicates the value of k, with the relationship depicted in Equation (7).

With a corrected R^2 value of 0.9502, Figure 2 clearly displays the value of k at 0.0002. The Newton model can be used to forecast the moisture content of dried seaweed after drying using a cabinet dryer with a source of heat energy from biomass combustion, according to a value of R^2 that is close to one. The research findings for drying seaweed using the Newton model follow the same general pattern as earlier findings [2] and [12]. In earlier investigations, the Newton model was used to estimate the moisture content of seaweed during the drying process using a variety of dryer types and varying drying temperatures. Comparative inquiry results are shown in Table 1.

TABLE 1. COMPARATIVE INVESTIGATION RESULTS

No	Dryer Type	Operating Temperature (°C)	RH (%)	k	R^2	Equation	Refference
1	Solar dryer	50	43	0,4019	0,9033	ln MR = -4019t	[12]
2	Cabinet dryer: electric heater	40	40	0,0080	0,9500	ln MR = -0,008t	[2]
		50		0,0100	0,8710	ln MR = -0,01t	
		60		0,0120	0,9230	ln MR = -0,012t	
		70		0,0100	0,9210	ln MR = -0,01t	
3	Cabinet dryer: biomass	55	n.a	0,0002	0,9502	ln MR = -0,0002t	Current study

IV. Conclusion

According to the results of drying seaweed in a cabinet dryer powered by heat generated by biomass combustion, the Newton model is able to predict the moisture content of dried seaweed after drying. The coefficient of determination (R^2) is corrected to 0.9502 with a drying rate constant (k) of 0.0002, following the equation ln MR = -0.0002t.

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