Research Article

Experimental Investigation to Evaluate the Effective Moisture Diffusivity and Activation Energy of Cassava (*Manihot Esculenta*) under Convective Drying

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Abstract

Investigation of effective moisture diffusivity (D_{eff}) and activation energy (E_a) of cassava were conducted under convective drying at temperature and velocity of 60, 70, and 80 °C, and 1.0, 1.5, and 2.0 m/s, respectively. In the experiment, cassava was sliced into 3 mm-thickness and dried under given conditions until mass was saturated. D_{eff} and E_a were described by Fick's second law and Arrhenius-type equation, respectively. The experimental results indicated that the increase in D_{eff} was significantly affected by increasing the hot air temperature and velocity. The slope method was used to calculate average D_{eff}, and results were found to range from $3.83 \times 10^{-9} - 9.86 \times 10^{-9}$ m^2/s. The E_a was found to decrease with an increase in hot air velocity, ranging from 21.23–24.92 kJ/mol. Additionally, Moisture content (M_w) and Drying rate (DR) were also used to describe the drying kinetics. From the experimental results, M_w and DR decreased with an increase in drying time. DR increased with an increase in temperature and velocity, causing rapid decrease in M_w and drying time to reduce. The highest DR was found to be 0.55 g_{water}/min at a temperature of 80 °C and velocity of 2.0 m/s.

Keywords: Effective moisture diffusivity, Activation energy, Drying kinetics, Cassava, Convective drying

1 Introduction

Cassava (*Manihot esculenta*) is one of the most important economic crops of Thailand. It widely grows in northern, eastern, central, and northeastern regions since it can easily grow in extreme weather. Cassava products can be processed into many forms; food and non-food. Various kinds of industries involved in the production are established to support cassava cultivation, such as cassava chips, pellet, starch, and ethanol [1]. Chips or cassava sheet has the highest export volume, which equals to 38% of all cassava-based products. A report from the Office of Agricultural Economics indicates that the export volume of cassava chips in 2019 is 2,471.45 million USD (74,020 million Baht) [2]. To produce cassava chips, the raw material is chopped into small pieces and dried naturally on the ground to get dried cassava. A research study by Pornpraipech *et al.* [3] shows that factors of cassava plants, such as genetic differentiation, growing conditions, feeding, and harvesting process have different effects on the percentage of starch. Cassava varieties giving a high percentage of flour tend to dry more quickly. In addition, environmental conditions, season, sunlight, wind, moisture content, and thickness of cassava chips are also the external factors affecting the drying process. Olufayo and Ogunkunle [4] studied cassava drying with a solar dryer. The results showed drying in sunlight within high air humidity area, was not as effective as expected, leading to the raw material rotting and stinking. Although the demand for cassava chips is growing, supply from many countries is reducing, causing the price to increase. Design and selection of high efficient dryer will remove limitations of the solar drying process, leading to higher profit.

Drying is a common technique used to decrease the moisture content to a safe value and reduce the microbiological activity of moist materials [5]. There are many drying methods that can be adopted. Convective drying is usually used in the crop drying industry [6], [7]. During the drying process, heat and mass transfer mechanisms happen throughout, causing the effect on moisture transport phenomena within the material. Moisture diffusivity is considered to be an important variable in controlling the mass transfer in a material. In addition, it is useful for explaining moisture movement from the inside to the surface of the material [8]. It can be used to analyze the fundamental engineering concept of the drying process or to select of a suitable drying method. Also, it is found that prediction of mass transfer in crops preservation requires the moisture diffusion variable [9]. From related studies, effective moisture diffusivity (D_{eff}) has been used to describe all possible mechanisms of moisture diffusion within a material, a combination of liquid, vapor, and surface diffusion, capillary and hydrodynamic flow [10]. The physical structure and composition of the material may be changed during the drying process [11]. Since the theory of moisture diffusivity phenomena used to describe the moisture transport is highly complicated, experimental data is required to analyze these phenomena [12]. Thus, the thin-layer assumption and Fick's second law equation are widely deployed to analyze moisture diffusivity phenomena inside the material. Many researchers have studied D_{eff} of various types of crops using Fick's second law equation to describe the characteristics of the drying process. Depending on temperature, moisture content, and shape of material such as corn [13], carrot [14], onion [15], pomegranate [9], mango [16], pumpkin [17], apple [8], cassava flour [18], Sri Lanka's black pepper [19], banana chips [20] and carrot sliced [21] (Table 1). The results obtained from the studies found that D_{eff} increases with an increase in temperature and velocity, resulting in a higher drying rate and using less time to completion.

For sliced cassava drying, an analysis of the moisture diffusivity mechanism in terms of D_{eff} and E_a is likely to lack much data. Most research results are presented in the variable, moisture ratio, moisture content, and drying rate [22], [23]. Further studies are required to understand moisture diffusivity in the drying mechanism because both variables can be used to design and optimize the dryer with proper size [24] and desired heat amount on the larger drying scale [25]. The activation energy (E_a) can be used to analyze in order to find the amount of energy to initialize diffusion of a water molecule or to find the minimum energy to initialize the drying process. It is very beneficial for the cassava drying industry to analyze energy efficiency to reduce unnecessary energy consumption or recover waste energy from the drying process. The D_{eff} is the important variable used to develop a mathematical model for predicting moisture content which can only be calculated from the experimental result [26].

Table 1: Experimental results of D_{eff} in selected agri-product

Agri-product	Drying Condition	D_{eff} (m²/s)	E_a (kJ/mol)	References
Corn	Air temp. 55–75 °C	$9.5 \times 10^{-11} - 1.8 \times 10^{-10}$	29.56	[13]
Carrot	Air temp. 50–70 °C	$0.8 \times 10^{-9} - 9.3 \times 10^{-9}$	28.36	[14]
Onion	Air temp. 35–45 °C Infrared 300–500 W	$0.2 \times 10^{-10} - 1.5 \times 10^{-10}$	-	[15]
Pomegranate	microwave 25–95 W Pressure 25–195 mmHg	$5.2 \times 10^{-11} - 6.6 \times 10^{-11}$	-	[9]
Mango	Air temp. 45–60 °C Velocity 1.5–3.5 m/s	$4.9 \times 10^{-11} - 2.1 \times 10^{-10}$	10.49	[16]
Pumpkin	Air temp. 50–70 °C Velocity 1.0 m/s	$3.7 \times 10^{-8} - 7.1 \times 10^{-8}$	30.74	[17]
Apple	Air temp. 50–70 °C Velocity 1.0–1.2 m/s	$6.8 \times 10^{-10} - 1.3 \times 10^{-9}$	-	[8]
Cassava flour	Solar drying with Average temp. 60 °C	8.55×10^{-10}	-	[18]
Sri Lanka's black pepper	Air temp. 45–75 °C Velocity 1.60–2.37 m/s	$6.1 \times 10^{-11} - 2.0 \times 10^{-10}$	-	[19]
Banana chips	Air temp. 37–43 °C	$1.1 \times 10^{-10} - 1.6 \times 10^{-10}$	51.45	[20]
Carrot slice	Ultrasound and Infrared 900–1500 W	$8.1 \times 10^{-10} - 26.9 \times 10^{-10}$	-	[21]

Therefore, this research examines the effective moisture diffusivity (D_{eff}) and activation energy (E_a) of cassava during convective drying. This research will mainly focus on the effects of hot air temperature and velocity on D_{eff} and E_a. Besides, drying kinetics will be investigated in detail and presented in terms of moisture content (M_w) and drying rate (DR).

2 Materials and Methods

2.1 *Drying kinetics analysis*

2.1.1 Wet basis and dry basis moisture content

Wet basis and dry basis moisture content are calculated by Equations (1) and (2), which are the ratio of water to wet mass and water to dried mass in the material, respectively [26].

$$M_w = \frac{w-d}{w} \tag{1}$$

$$M_d = \frac{w-d}{d} \tag{2}$$

Where M_w is wet basis moisture content ($kg_{water}/kg_{wet,material}$), M_d is dry basis moisture content ($kg_{water}/kg_{dry,material}$), w is wet mass of material (kg) and d is dried mass of material (kg).

2.1.2 Moisture ratio

Moisture ratio is a figure used to describe the comparison between the rate of change of water amount of material and initial moisture at any given time during drying, calculated by Equation (3) [27].

$$MR = \frac{M_d - M_e}{M_0 - M_e} \tag{3}$$

Given that equilibrium moisture content is very low compared with initial moisture ($M_e << M_0$) and moisture content at any given time ($M_e << M_d$), and in order to consider moisture transfer of the entire drying process which almost completely eliminating moisture from cassava, the equilibrium moisture content is negligible and Equation (3) can be rewritten as Equation (4) [28].

$$MR = \frac{M_d}{M_0} \tag{4}$$

Where MR is moisture ratio (decimal), M_0 is initial moisture content ($kg_{water}/kg_{dry,material}$) and M_e is equilibrium moisture ($kg_{water}/kg_{dry,material}$).

2.1.3 Drying rate

The drying rate is calculated by Equation (5), which is the rate of water evaporation from material within a given time [29].

$$DR = \frac{\partial w}{\partial t} = \frac{w_t - w_{t-1}}{\Delta t} \tag{5}$$

Where DR is Drying rate (kg_{water}/min), w_t is the mass of treated material at any given time t (kg), d is the dried mass of material (kg), Δt = interval of data collection (min).

2.2 *Effective moisture diffusivity evaluation*

The drying process can be separated into 3 zones the initial zone, constant-rate zone, and falling-rate zone. Falling-rate zone dominates in the drying of most food materials [30]. In the falling-rate zone, the drying rate decreases with time. Friction forces in the material's pores transfer the moisture rate to control water movement from the inside to the surface of the material. Moisture transfer inside the material can be represented by effective moisture diffusivity (D_{eff}) [31]. Drying is a process of reducing moisture content through a complicated mechanism, namely diffusion. Solving these problems will be easier if the effect of temperature and pressure on fluids' properties are insignificant. Therefore, Fick's second law equation is deployed to describe water or moisture transfer inside materials being dried and to present the falling-rate zone as indicated in Equation (6) [32]. Furthermore, it is used in cases of sliced material (slab). The assumptions are as follows [16]:

1) Initial moisture content is uniformly distributed throughout the material.
2) Diffusion of moisture occurs uniformly through the material.
3) Friction of pores inside the material is negligible.
4) Shrinkage during drying is negligible.
5) Physical properties of fluids are constant.

From those assumptions, Equation (6) is manipulated to get Equation (7).

$$\frac{\partial M(r,t)}{\partial t} = \frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2 D_{eff}\frac{\partial M}{\partial t}\right) \quad (6)$$

$$MR = \frac{8}{\pi^2}\sum_{n=0}^{\infty}\frac{1}{(2n+1)^2}\exp\left(-\frac{\pi^2 D_{eff}(2n+1)^2}{4L^2}\right)t \quad (7)$$

Equation (7) is adopted by many researchers to calculate the D_{eff} of slab material [33]. Manipulating terms of series given that the drying process takes a very long time and drying rate is continuously decreased, terms 1, 2, 3, … can be neglected [6]. So, only the first term is left ($n = 0$).

$$MR = \frac{8}{\pi^2}\exp\left(-\frac{\pi^2 D_{eff}}{4L^2}\right)t \quad (8)$$

Equation (8) can be rewritten in logarithm, as in Equation (9).

$$\ln MR = \ln\frac{8}{\pi^2} - \frac{\pi^2 D_{eff}}{4L^2}t \quad (9)$$

From Equation (9), the relationship between ln *MR* and time of drying (t) is realized as a linear equation according to Equation (10). Linear regression analysis is used to find the equation and slope of the line ln *MR*–*t*. The slope of the graph can be used to calculate D_{eff} according to Equation (11), and D_{eff} derived from this equation is the average throughout the drying process at that given drying condition. The calculation of D_{eff} is called the "*slope method*" [23].

$$\ln MR = \left(-\frac{\pi^2 D_{eff}}{4L^2}\right)t + \ln\frac{8}{\pi^2} \quad (10)$$

$$Slope_{deff} = -\frac{D_{eff}\pi^2}{4L^2} \quad (11)$$

Where D_{eff} is Effective moisture diffusivity (m^2/s), L = Half of the material, thickness and t = Time of drying (s).

2.3 *Activation energy*

The activation energy (E_a) is the minimum energy required to initialize the diffusion effect, described by the Arrhenius-type equation. It shows the relationship between D_{eff} and air temperature (T), represented by

Figure 1: Diameter of sliced cassava.

Equation (12). [34]

$$D_{eff} = D_0\exp\left(-\frac{E_a}{RT}\right) \quad (12)$$

Equation (12) is rewritten to a logarithm form according to Equation (13) that is a linear equation form. E_a can be calculated from the slope of the graph between ln(D_{eff}) and $1/T$, as shown in Equation (14).

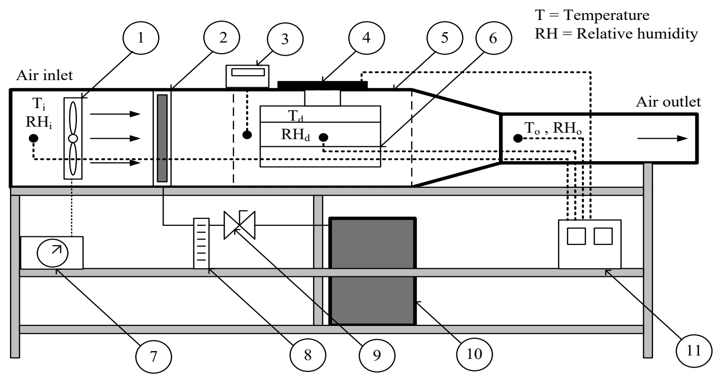
$$\ln D_{eff} = \ln D_0 - \left(\frac{E_a}{RT}\right) \quad (13)$$

$$Slope_{Ea} = -\left(\frac{E_a}{R}\right) \quad (14)$$

Where D_0 is the moisture diffusivity coefficient (m^2/s), E_a is the activation energy (kJ/mol), T is the air temperature (K), and R is the gas constant = 8.314 J/mol K.

2.4 *Preparation of sliced cassava samples*

In the preparation, cassava is used as samples selected from the same area of Nakhon Ratchasima, Thailand. Cassava samples used had an average diameter of 40 mm. The dirt and mud on the skin surface were washed and cleaned with fresh water. Then, the cassava was peeled and sliced into 3 mm thickness using a slicing machine and kept in sealed polyethylene bags at 5 ± 1 °C to ensure no additional moisture loss before the drying tests [35]. Initial moisture content was measured according to the house method based on AOAC 1990 standard [36], [37] in the Food Processing laboratory. The drying test was repeated 3 times for 10 samples. Measuring result revealed that the average initial moisture content of sliced cassava samples was 70 ± 2% w.b. The sliced cassava is shown in Figure 1.



1. Blower
2. Infrared gas burner
3. Digital hot wire anemometer
4. Load cell
5. Drying chamber
6. Drying tray
7. Power regulator
8. Gas flow meter
9. Pressure valve
10. LPG tank
11. Data logger

Figure 2: Schematic diagram of the dryer.

2.5 *Convective dryer*

A laboratory-scale convective dryer (hot air dryer) was constructed with a steel box and steel sheet coated with thermally insulated fiber-glass. The drying tray was made of stainless wire net to put the sample material and was hung on the load cell to measure its mass during the drying process. Hot air was blown into the drying chamber with a 55 W, 220–240 V blower. An infrared LPG burner was used as a heating energy source to generate hot air (Figure 4). Thermocouples K-type were installed inside the chamber to measure hot air temperature calibrated by adopting the Grant water bath method (Grant Instruments, Cambridge, UK) with ±0.5 °C (5–90 °C) of accuracy. A digital hot wire anemometer was also used to measure air velocity with an accuracy of ±2% from the factory. Load cells sensor was used to measure the mass of sliced cassava calibrated by the actual load with ±0.1 g (5–90 °C) accuracy and 0.01 kg resolution. All of the sensors were connected to a data logger (Graphtec model GL820) for recorded results. The schematic diagram of the dryer is shown in Figure 2.

2.6 *Drying procedures*

The sliced cassava samples were dried at drying conditions of temperature (T) of 60, 70, and 80 °C and the velocity (v) of 1.0, 1.5, and 2.0 m/s (Table 2). In each set of conditions, the operation was repeated 3 times. For the drying test, hot air temperature and velocity were adjusted under the designated condition. A 500 ± 5 g sliced cassava samples were put on the drying tray so that the cassava pieces would not overlap. The drying process continued until no further change was detected in the mass of the sliced cassava samples indicated with the load cell. The mass of the sliced cassava sample was recorded by the data logger every 30 seconds for further analysis.

Table 2: Drying conditions

Case	Drying Conditions		M_0 (% w.b.)	Mass of Sliced Cassava (g)
	T (°C)	v (m/s)		
1	60	1.0		
2	60	1.5		
3	60	2.0		
4	70	1.0		
5	70	1.5	70 ± 2	500 ± 5
6	70	2.0		
7	80	1.0		
8	80	1.5		
9	80	2.0		

* In each of drying condition was repeated 3 times.

3 Results and Discussion

3.1 *Drying kinetics*

The effect of temperature and air velocity on drying kinetics was conducted with different drying conditions, including hot air temperature of 60, 70, and 80 °C and velocity (v) of 1.0, 1.5, and 2.0 m/s. Drying

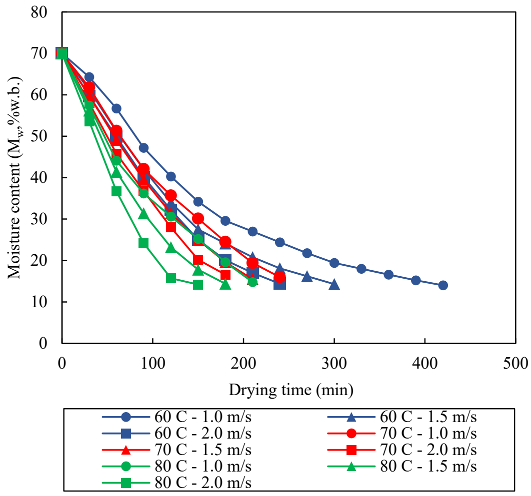


Figure 3: Relationship of M_w and t.

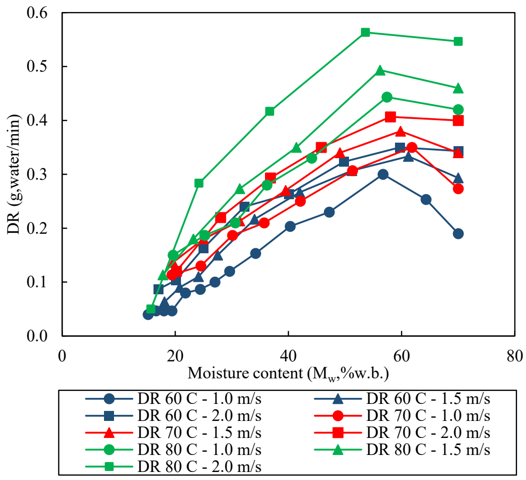


Figure 4: Relationship of DR and M_w.

kinetics was represented by a drying curve showing the relationship between moisture content (M_w) and drying time (t) (Figure 3) and between drying rate (DR) and moisture content (M_w) (Figure 4).

In Figures 3 and 4, DR and drying time range from 0.04–0.55 g_{water}/min and 150–415 min, respectively. M_w and DR decreased with an increase in the drying time. As temperature and hot air velocity increased, M_w rapidly decreased, causing DR to rise, decreasing the drying time. If the M_w of the samples is large, DR will be high. The experimental results are consistent with previous research studies, such as drying of rice [38], drying of okra [39], and drying of red chili [40]. This concludes that the drying rate as the hot air temperature rises. In this research, the maximum DR and minimum t are DR = 0.55 g_{water}/min and t = 150 min, respectively, where the hot air temperature is 80 °C, and the hot air velocity is 2.0 m/s.

According to the study of drying theory, the drying mechanisms can be categorized into 3 zones, which consist of the initial zone (drying rate increase), constant-rate zone (drying rate constant), and falling-rate zone (drying rate decrease) [41]. In this experiment, the initial zone was found in range from the drying start point to the maximum drying rate point of about 0–55 minutes at the beginning, and as the temperature and rate of hot air were increased, the time of this zone decreased. Meanwhile, the zone can be explained by the fact that in the initial zone, the temperature of the samples is lower than the temperature of the hot air, and the heat is transferred to the surface of the sample. This generates a significant energy, leading to water evaporation. As the temperature inside the sample increases, the moisture inside will appear on its surface and then evaporates and blows out by drying chamber with hot air flows through. As a result, the drying rate increases until the partial vapor pressure on the surface of the sample reaches saturation, after which the drying rate decreases immediately. Meanwhile, the constant-rate zone (constant drying rate) could not be observed similarly to the research by Mounir *et al.* [42], which explains that the constant-rate zone depends only on external factors such as air flow profile and shape of the samples.

Therefore, the experiments were mainly carried out in the falling-rate zone, similar to the above-mentioned studies, i.e., there is no occurrence of constant rate in Agri-product drying [43]. The falling-rate zone can be explained by the fact that the drying energy causes an increase in the temperature of the samples until it equals the temperature of the hot air. However, water evaporation from the samples continuously, while the moisture decreases, DR also decreases [44]. In this zone, the drying mechanism is determined by D_{eff}, which highly depends on air properties such as temperature, velocity, and moisture [45].

3.2 *Effective moisture diffusivity (D_{eff})*

In studying the effect of temperature and hot air velocity on effective moisture diffusivity (D_{eff}), the following

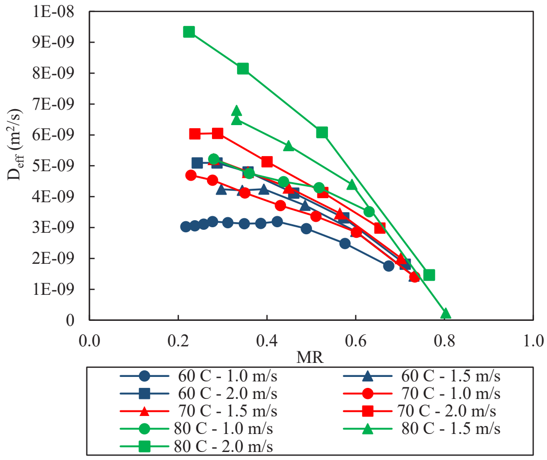


Figure 5: Relationship between D_{eff} and *MR*.

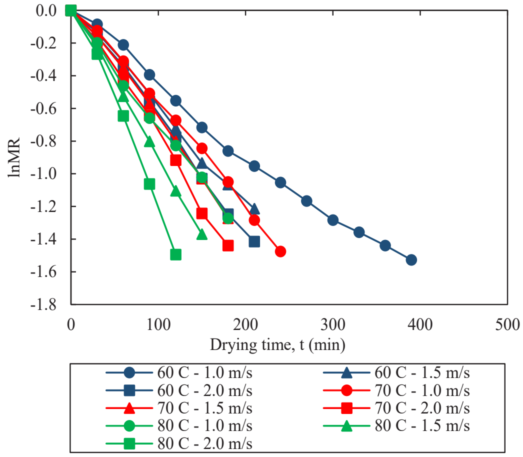


Figure 6: Relationship between lnMR and *t*.

drying conditions were selected: temperature of 60, 70, and 80 °C and velocity (v) of 1.0, 1.5, and 2.0 m/s. Analytical results derived from the relationship between D_{eff} and MR [Equation (11)] are represented in Figure 5.

The experimental result showed that D_{eff} increased with a decrease in *MR*. This can be explained to the effect that as *MR* decreases, the internal structure or pores inside the samples become larger, increasing the diffusion of moisture inside the samples [46]. Furthermore, in the initial zone of drying, the moisture content of the samples is high, causing the energy to be absorbed into the samples. Thus, as partial vapor pressure inside the samples and pores size increase, the moisture tends to be transferred easier, and D_{eff} is higher. To summarize, in the initial zone, moisture diffusion is the main driving mechanism of moisture from the samples. D_{eff} is a variable that can be used to analyze the behavior of the drying process [9]. The constant MR in various hot air temperature and velocity indicates that D_{eff} increases with the hot air temperature and velocity. The effect of temperature increasing is in line with previous researches. This can be explained in that as the drying temperature increases, the viscosity of water reduces, and then the molecular activation increases leading to an increase in the diffusion of water molecules inside the samples, and moisture diffusion increases [8], [47]. In addition, an increased D_{eff} resulting from an increased hot air velocity helps to accelerate the diffusion from the surface of the sample, as it is likewise with both potato drying [48] and Champignon mushroom drying [49]. In this research, the D_{eff} is higher than cassava flour drying with the solar dryer [18] and sliced cassava drying under ultrasound and infrared [21] as shown in Table 1.

Table 3: Calculated results of average D_{eff} for given temperature and velocity

Drying Condition	D_{eff} (m²/s)	R^2
60 °C – 1.0 m/s	3.83×10^{-9}	0.985
60 °C – 1.5 m/s	5.20×10^{-9}	0.995
60 °C – 2.0 m/s	6.39×10^{-9}	0.997
70 °C – 1.0 m/s	5.02×10^{-9}	0.997
70 °C – 1.5 m/s	6.57×10^{-9}	0.998
70 °C – 2.0 m/s	7.76×10^{-9}	0.995
80 °C – 1.0 m/s	6.39×10^{-9}	0.995
80 °C – 1.5 m/s	8.31×10^{-9}	0.998
80 °C – 2.0 m/s	9.86×10^{-9}	0.991

Furthermore, the result derived from slope method analysis [Equations (12) and (13)] used to calculate the average D_{eff} throughout the drying process at a given condition demonstrates the relationship between lnMR-t, as shown in Figure 6. Linear regression analysis gives the average D_{eff}, shown in Table 3, where the D_{eff} ranges from 3.83×10^{-9} – 9.86×10^{-9} m²/s. In previous research, D_{eff} ranges from 10^{-11} – 10^{-6} m²/s for drying food samples [50] and 10^{-11} – 10^{-9} m²/s for drying crops [51]. The D_{eff} of the samples selected is shown in Table 1.

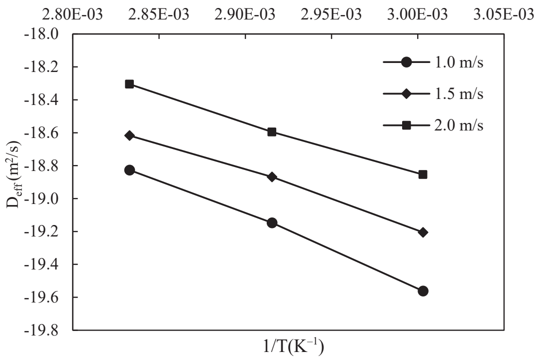


Figure 7: Relationship of lnD_{eff} and 1/T.

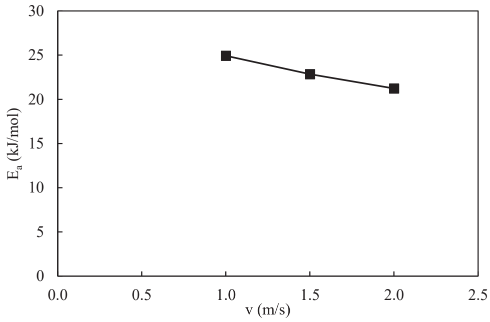


Figure 8: Relationship of E_a and *v*.

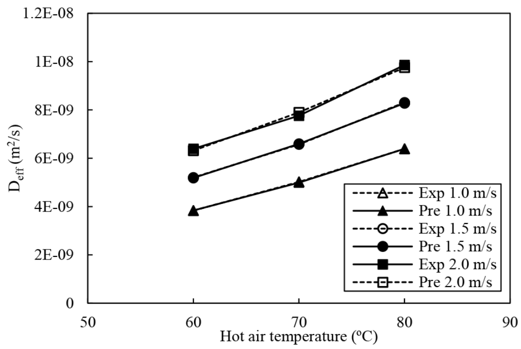


Figure 9: A comparison of D_{eff} from Arrhenius-type equation (Pre) and Slope method (Exp).

3.3 *Activation energy (E_a)*

Arrhenius-type equation, represented in Equation (14) and calculative result, shown in Table 3, can be used to draw a graph to demonstrate the relationship between ln(D_{eff}) and 1/T at an air velocity of 1.0, 1.5, and 2.0 m/s. The result in Figure 7 suggests that D_{eff} increases with an increase in the temperature and hot air velocity. These results are similar trending to those of Tunckal and Doymaz [20], Ragab *et al.* [23], and Jayatunga and Amarasingheb [43].

This can be explained by heat and mass transfer in that as the velocity of hot air increases, the heat, and mass transfer coefficients increase [52]. Heat can be transferred into the samples more easily, causing the activated water molecule to move faster. In addition, the high velocity of hot air draws up a large amount of moisture from the surface of the sample resulting in a decrease in activation energy (E_a). In previous researches, E_a of food samples ranges from 12.7–110 kJ/mol [53]. This research is in line with the research study of Mirzaee *et al.* [54], indicating that E_a of apricot ranges from 21.23–24.92 kJ/mol and Khanali *et al.* [55], indicating that E_a of rice ranges from 36.59–44.31 kJ/mol. These results show that E_a decreases as hot air velocity increases. In Figure 7, the graph is a straight line, so the slope of each line for each condition derived from regression analysis was used to calculate E_a according to Equation (14). The result shown in Figure 8 indicates that E_a decreased with an increase in hot air velocity. This experiment shows the E_a of 24.92, 22.85, and 21.23 kJ/mol at the velocity of 1.0, 1.5, and 2.0 m/s, respectively.

Furthermore, the Arrhenius-type equation can also be used to predict D_{eff} at any given temperature, as indicated in Table 4. A comparison between the experimental result derived from the slope method and the result by prediction with the Arrhenius-type equation is demonstrated in Figure 9. The predicted result is in close agreement with the experimental result with a high correlation, more than 0.995 of R^2.

Table 4: Arrhenius-type equation at given temperature

Hot Air Velocity	Arrhenius-type Equation
1.0 m/s	D_{eff} = 0.0000135 exp (−24.92/RT)
1.5 m/s	D_{eff} = 0.0000199 exp (−22.85/RT)
2.0 m/s	D_{eff} = 0.0000312 exp (−21.23/RT)

T = Hot air temperature (K)
R = Universal gas constant = 8.314 J/mol K

4 Conclusions

In this research, cassava slices were dried under convective drying, and adequate moisture diffusivity (D_{eff}), activation energy (E_a), and drying kinetics were investigated. The experimental result showed that D_{eff}

and E_a range from 3.83×10^{-9} – 9.86×10^{-9} m^2/s and 21.23–24.92 kJ/mol, respectively. The high D_{eff} can be accelerated moisture removal in the drying sample and reduce drying time. Hot air temperature, hot air velocity and moisture content influenced on D_{eff} under all drying conditions, and E_a was affected by hot air velocity. An analysis of drying kinetics shows that the mechanism of drying can be detected in the initial-rate and falling-rate zones only.

The estimated values of D_{eff} and E_a were in line with the moisture diffusion properties of agri-product and food products reported in the previous research. The experimental results can be applied to design and optimize the dryer and energy efficiency analysis. It would be very beneficial for the cassava drying industry to achieve optimum energy use. In addition, this investigation can be used as guidance for evaluating the D_{eff} and E_a of other agri-products with similar structures.

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