Moisture Sorption Isotherm Characteristics of Fermented Cassava Flour By Red Yeast Rice

M N Cahyanti¹, M N Alfiah¹, S Hartini¹

¹Chemistry Department, Science and Mathematics Faculty, Universitas Kristen Satya WacanaJl. Diponegoro 52-60 Salatiga, Indonesia

E-mail : margareta2486@gmail.com

Abstract. This study aims to study the characteristics of moisture sorption isotherm of fermented cassava flour by red yeast rice at various fitting models and to determine the best fit model. Samples were analyzed at 303K, 308K, and 313K and equilibrium relative humidity (ERH) from 10%-99% using the gravimetric method. The experimental data were fitted into five equations, e.g., Guggenheim-Anderson-de Boer (GAB), Henderson, Halsey, Oswin, and Chen-Clayton model. The best-fitting model was analyzed using Mean Relative Determination (MRD) analysis. The results showed that the GAB model was the best fitting model for 303K and 308K with MRD coefficient 1.98% and 3.11%. Henderson model was the best fit model for 313K with MRD coefficient 3.32%.

Keywords: moisture sorption isotherm, cassava flour, red yeast rice

1. Introduction

The moisture sorption isotherm curve is a curve that connects the equilibrium moisture content to the relative humidity of the environment at a given temperature. This curve is modeled with various mathematical models to determine the best model to further learn. The modeling curve can be used to study the moisture adsorption characteristics of the product. The modeling curve is also used to determine the shelf life of a product.

Previous research states that the GAB is the best model to explain the moisture adsorption by fermented cassava flour [1]. This research has a limitation because it uses only three models namely GAB, BET, and Caurie. Other research on sorption isotherms of moisture in cassava and its derivative products use another modeling.

Other studies [2] examined the isotherm of water sorption on instant cassava using BET, Oswin, Halsey, Henderson, Caurie, Chen-Clayton, and GAB models. The results show that Henderson model is the best model to explain the water absorption by instant cassava. Koua et al. use GAB, BET, Halsey, Oswin, Smith, Iglesias-Chirife, and Khun model to study moisture adsorption on cassava. Results demonstrated that the GAB model adequately predicted equilibrium moisture content of cassava for the range of temperatures and water activities studied [3]. Adebowale et al. use Bradley, Exponential, GAB, Iglesias-Chirife, and Oswin to research moisture adsorption on three different
varieties of cassava. However, the GAB model gave the best fit for sorption isotherm of tapioca from either the Odongbo or Okoiyawo varieties, while the exponential model was the best for that from TMS30572 variety [4].

The purpose of this research is to determine the characteristics of water sorption isotherm from fermented cassava flour using various modeling. The experimental data were fitted into five equations, e.g., Guggenheim-Anderson-de Boer (GAB), Henderson, Halsey, Oswin, and Chen-Clayton model.

2. Materials and Methods

The sample used in this research is fermented cassava with Angkak (Monascus purpureus). The chemicals used are seven types of salt used to regulate relative humidity (RH), i.e., NaOH, MgCl$_2$, K$_2$CO$_3$, Mg(NO$_3$)$_2$, KI, NaCl, KCl. Other chemicals used are distilled water. The tool used for this research is porcelain cup, chamber to determine sorption isotherm, moisture analyzer to measure moisture content, analytical balance, incubator, thermometer, hygrometer, drying cabinet and sieve for making flour.

2.1 Preparation of Fermented Cassava Flour [5]

Fresh cassava is cleaned from the skin then washed with running water. Cassava is steamed for approximately 60 minutes, then drained and cooled until cassava reaches room temperature. Cassava is cut and weighed as much as 1 kg then inoculated with Angkak with a concentration of 12%, then fermented for three days at room temperature. Fermented cassava is heated at a temperature of 55˚C to dry. After that, the fermentation is milled and sieved with mesh sieve 61.

2.2 Preparation of Chamber [6]

The saturated salt solution is prepared using NaOH, MgCl$_2$, K$_2$CO$_3$, Mg(NO$_3$)$_2$, KI, NaCl, KCl. The salt is weighed with a certain mass and then put into a beaker glass that contains warm water temperatures of approximately 50˚C and stirred until dissolved. If the salt is entirely soluble, the salt is added bit by bit until the salt does not dissolve. 50 ml of saturated salt solution is inserted in a chamber. The solution is allowed to stand for about seven days to obtain a constant RH.

2.3 Measurement of Moisture Content of Equilibrium [7]

5.00 grams of each sample is stored in a chamber with a specific RH. The chamber is stored at a temperature of 30˚C, 35˚C, and 40˚C. Weight sampling is done daily for seven days until steady state is reached. If the sample has molded before seven days then weighing can be stopped. Please follow these instructions as carefully as possible, so all articles within a conference have the same style to the title page. This paragraph follows a section title so it should not be indented.

2.4 Mathematical Modelling

Mathematical models used to study isotherm moisture sorption include the Guggenheim-Anderson-de Boer (GAB) model, Henderson, Halsey, Oswin, and Chen-Clayton. Each line equation for each model can be seen in Table 1.

2.5 Model Accuracy Test

The statistical validity of each model is determined using the MRD (Mean Relative Deviation) statistic parameter with the following equation:

$$\text{MRD} = 100 \times \frac{1}{n} \sum_{i=1}^{n} \frac{|M_i - M_{pi}|}{M_i}$$

MRD: Mean Relative Determination (%)

n: Number of observations

M$_i$: Experimental values of the equilibrium moisture content

M$_{pi}$: Predicted values of the equilibrium moisture content
Table 1. Models Used and Their Equations

| Model       | Equation                                                                 |
|-------------|---------------------------------------------------------------------------|
| GAB         | $M = \frac{M_mCK_{aw}}{(1 - K_{aw})(1 - K_{aw} + CK_{aw})}$               |
| Henderson   | $\ln M = \frac{1}{B} \ln(-\ln(1 - a_{w})) + \frac{1}{B} \ln \frac{1}{AT}$ |
| Halsey      | $\ln M = \ln A_1 - A_2 \ln(-\ln a_{w})$                                 |
| Oswin       | $\ln M = \ln P_1 + P_2 \ln\left(\frac{a_{w}}{1 - a_{w}}\right)$         |
| Chen-Clayton| $\ln\left(\ln\left(\frac{1}{a_{w}}\right)\right) = \ln P_1 - P_2 M$    |

3. Results and Discussion

The relative humidity (RH), water activity ($a_w$) and equilibrium moisture content (M) on the fermented cassava flour are shown in Table 2. Moisture sorption isotherm curves connecting the water activity with equilibrium moisture content are shown in Figure 1.

Table 2. Relative Humidity (RH), Water Activity ($a_w$) dan Equilibrium Moisture Content (M) at 30°C, 35°C, and 40°C

| Salt        | RH (°C) | $a_w$ (%) | M (%) | RH (°C) | $a_w$ (%) | M (%) | RH (°C) | $a_w$ (%) | M (%) |
|-------------|---------|-----------|-------|---------|-----------|-------|---------|-----------|-------|
| NaOH        | 11      | 0.11      | 2.55  | 10      | 0.10      | 2.37  | 10      | 0.10      | 2.14  |
| MgCl₂       | 38      | 0.38      | 6.57  | 38      | 0.38      | 6.09  | 31      | 0.31      | 4.88  |
| K₂CO₃       | 49      | 0.49      | 8.88  | 49      | 0.49      | 8.43  | 38      | 0.38      | 6.62  |
| Mg(NO₃)₂    | 66      | 0.66      | 13.08 | 65      | 0.65      | 10.88 | 48      | 0.48      | 8.57  |
| KI          | 79      | 0.79      | 18.54 | 79      | 0.79      | 16.85 | 64      | 0.64      | 12.23 |
| NaCl        | 88      | 0.88      | 24.35 | 88      | 0.88      | 22.52 | 74      | 0.74      | 15.28 |
| KCl         | 99      | 0.99      | 39.59 | 99      | 0.99      | 35.49 | 81      | 0.81      | 17.22 |
Table 2. shows the effect of RH and temperature on the moisture content of fermented cassava starch equilibrium. At high RH the equilibrium moisture content tends to be high as well. This phenomenon is due to the higher RH, the more water vapor in the environment around the fermented cassava flour that interacts with the powder. The higher the storage temperature, the lower the moisture content. This phenomenon is because the rising temperatures cause the water molecules to be active and increase their energy levels, so they become less stable and tend to release the bonds with flour [8]. This result is following previous research that examined the equilibrium moisture content of cassava composite flour and red bead tree seed [9]. The moisture sorption isotherm curve is S-shaped so that the process of moisture absorption on the fermented cassava flour is included in type II.

The moisture sorption isotherm curve is modeled with various mathematical models. The moisture sorption isotherm curve of fermented cassava flour of GAB, Henderson, Halsey, Oswin and Chen-Clayton models can be seen in Figures 2, 3, 4, 5, and 6.

![Figure 1. Moisture Sorption Isotherm Curve of Fermented Cassava](image)

![Figure 2. Moisture Sorption Isotherm Curve of Fermented Cassava Flour for GAB Model](image)
Figure 3. Moisture Sorption Isotherm Curve of Fermented Cassava Flour for Henderson Model

Figure 4. Moisture Sorption Isotherm Curve of Fermented Cassava Flour for Halsey Model
The equation of the lines of each model for each temperature is used to determine the predicted values of the equilibrium moisture content used for the calculation of MRD to assess the accuracy of the model. Table 3 shows the MRD values for each model for each temperature.

Table 3. The MRD Values for Each Model for Each Temperature

| Models         | MRD (%) |
|----------------|---------|
|                | 30°C    | 35°C    | 40°C    |
| GAB            | 1.98    | 3.11    | 4.36    |
| Henderson      | 5.61    | 6.67    | 3.32    |
| Halsey         | 32.00   | 28.39   | 12.97   |
| Oswin          | 21.61   | 17.82   | 6.29    |
| Chen-Clayton   | 12.26   | 14.83   | 10.97   |
Based on Table 3, GAB model has the smallest MRD values at 30°C and 35°C and Henderson at 40°C. The GAB model of GAB at 40 °C is still below 5% indicating that the GAB model can be used to explain the phenomena of adsorption of water in fermented cassava flour. The results of this study are in line with previous studies on the isotherm of water sorption of various types of flour. The research of sesame flour at three temperatures using five models (modified Oswin, modified Halsey, modified Chung-Pfost, modified Henderson and GAB) states that the GAB model is the best model for describing water absorption in sesame flour [10]. Research on moisture sorption isotherm fufu and tapioca at temperatures using eight models (Bradley, BET, Oswin, Smith, Halsey, Henderson, GAB, and Chung-Pfost) state that GAB is the best model to describe water adsorption of fufu and tapioca flour [11].

4. Conclusion
The best mathematical model describes the phenomenon of water adsorption of cassava flour fermented at temperatures 30°C and 35°C is GAB and Henderson models at 40 °C

References
[1] Alfiah MN, Hartini S and Cahyanti MN 2017 Alchemy 29 40.
[2] Wijaya IMAS, Fitriani PPE, Gunam IBW and Wrasiati LP 2016. International Conference on Agricultural and Food Engineering (Kuala Lumpur – UPM).
[3] Koua BK, Koffi PME, Gbaha P and Toure S 2014 J Food Sci Technol 1711 23.
[4] Adebowale AR, Sanni L, Awonorin S, Daniel I and Kuye A 2007 International Journal of Food Science and Technology 448 52.
[5] Lakahina O, Saputri YLID and Hartanto BD 2015 Mocaf Merah - Pangan Kaya Antioksidan Berbasis Kearifan Lokal. Salatiga: Unpublished.
[6] Hayati R, Abdullah A, Ayob MK and Soekarto ST.2004 Jurnal Teknologi dan Industri Pangan. 207 13.
[7] Aini N, Prihananto V and Wijonarko G 2014 Agritech 50 5.
[8] Chowdhury MMI, Huda MD, Hosain MA and Hassan MS 2006 Journal of Food Engineering 462 7.
[9] Cahyanti MN, and Pattiserlihun A 2017 Seminar Nasional Kimia dan Pendidikan Kimia IX (Solo: UNS).
[10] Menkov ND and Durakova AG 2007 Food Technol Biotechnol. 96 100.
[11] Sanni LO, Atere C and Kuye A 1997 Journal of Food Engineering 203 12