Sorption isotherm modeling of “gaplek” flour fortified by protein from red bead tree flour

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ABSTRACT

The objective of the study is to determine the characteristic of moisture sorption isotherm from “gaplek” flour fortified with protein from red bead tree flour using various modeling and being observed from the monolayer moisture content and its absorption types. This research used 5 salt solutions and storage temperature of 298K, 308K, and 318K. The models used were Brunauer-Emmet-Teller (BET), Guggenheim-Anderson-de Boer (GAB) and Caurie model. The monolayer moisture content was around 5.07 – 8.53% db. kb value of GAB model was around 0.5941-0.6252. c value of GAB model was around 16.0588-23.4111. C value of BET was around 32.7241-306.5000. Whereas the c value in Caurie model was around 1.1419-1.2769. The equilibrium and monolayer moisture content on ‘gaplek” flour fortified with protein from red bead tree flour was decreasing as the temperature going up. GAB constant value indicated that the process of moisture absorption on the “gaplek” flour fortified with protein from red bead tree flour categorized in type II.

Keywords: BET, Caurie, GAB, gaplek, isotherm, red bead tree

1. Introduction

“Gaplek” flour is local flour intended to be consumed which is modifiable. One of the modifications which can be done is by enriching the protein by adding red bead tree flour. Flour which comes from the result of drainage such as tapioca can be easily damaged because, after the process of draining, the flour reabsorbs water from its surrounding (Suprapti, 2005). The correlation of substance’s moisture content and relative humidity of its surrounding in the same temperature can be illustrated in a curve called moisture sorption isotherm curve (Adawiah & Soekarto, 2010). To describe this curve, there have been a lot of models developed such as Guggenheim Anderson de Boer (GAB), Brunauer–Emmet–Teller (BET) dan Caurie. Based on the above background, the objective of the study can be drawn as follows: to determine the water sorption isotherm characteristics of “gaplek” flour fortified with protein from red bead tree flour by using several modeling.
2. Materials and Methods

2.1 Materials

The materials used were cassava and red bead tree originally from Salatiga, fermentation yeast, aqua dest, NaOH, MgCl$_2$, K$_2$CO$_3$, Mg(NO$_3$)$_2$, KI, NaCl, and KCl. The tools used were drying cabinet, grinder, 61 mesh strainer, incubator, sorption container, and moisture analyzer Ohaus BM 25.

2.2 Methodology

The flour was made based on the previous research conducted by Maidawati (2011). The cassava was peeled and then washed. Next, cassava was cut into small pieces and dumped for one night in a 10% salt solution. The next day, cassava was dried using drying cabinet at a temperature of 50°C for two days.

The red bead tree was washed and damped for a night. Then, it was boiled until the skin opened (more or less 2 hours). The crust and cuticle were thrown. Next, it was dried in a drying cabinet for two days in a temperature of 50°C. After it is dried entirely, it was ground using a grinder.

“Gaplek” was steamed for 30 minutes and then cooled. After cooled down, “gaplek” was added 13.16% (w/w) red bead tree flour as the source of protein. It was then inoculated using fermentation yeast as much as 5% (w/w) and fermented for 40.12 hours. Fortified “gaplek” was dried in a drying cabinet for two days in a temperature of 50°C. It was then ground and strained using 61 mesh strainers.

The measurement of equilibrium moisture content was done based on the method by Budijanto et al. (2010) which had been modifying the type of salt and the storage temperature. This research used 5 kinds of saturated salt such as NaOH, K$_2$CO$_3$, Mg(NO$_3$)$_2$, KI, and NaCl. It was done to form certain RH and storage temperature of 298K, 308K, and 318K.

The models used in this research were Brunauer-Emmet-Teller (BET), Guggenheim-Anderson-de Boer (GAB) and Caurie. The equation for each model can be seen in Table 1.

Monolayer moisture content can be determined from the equilibrium sorption isotherm data by fitting BET, GAB, and Caurie model. Estimates of monolayer moisture content are related to the stability of food products physically and chemically. Determination of monolayer moisture content can be used to calculate the surface area of solid from food product using BET and GAB model based on Eq. 1.

\[
\text{Surface area of solid} = m_0 \times 35.53
\]  

Monolayer moisture content in Caurie model and Caurie constant can be used to determine the properties of sorbed water such as number of adsorbed monolayer (Eq. (2)), bound water content (Eq. (3)), density of adsorbed water in the monolayer (Eq. (4)), and surface area of adsorption (Eq. (5)).

\[
\text{Number of adsorbed monolayer} = \frac{m_0}{c}
\]  
\[
\text{Bound water content} = m_0 \times \text{Number of adsorbed monolayer}
\]  
\[
\text{Density of adsorbed water in the monolayer} = \frac{m_0}{c}
\]  
\[
\text{Surface area of adsorption} = \frac{m_0}{c \times \text{diameter of a water molecule} \times 10^{10}}
\]

One may produces some steps on the method. This is the style used in this paper.
Table 1. Equation  of GAB, BET, and Caurie model.

<table>
<thead>
<tr>
<th>Model</th>
<th>Equation</th>
<th>Description</th>
</tr>
</thead>
</table>
| GAB   | \[ m = \frac{m_0 k_b c a_w}{(1 - k_b a_w)(1 - k_b a_w + c k_b a_w)} \] | \[ a_w : \text{ water activity} \]
\[ m : \text{ equilibrium moisture content (} \% \text{ db)} \]
\[ m_0 : \text{ monolayer moisture content(} \% \text{ db)} \]
\[ c \text{ and } k_b : \text{ constant} \]
| BET   | \[ a_w (1 - a_w)^m = \frac{1}{m_0 c} + \frac{c - 1}{m_0 c} a_w \] | \[ a_w : \text{ water activity} \]
\[ m : \text{ equilibrium moisture content (} \% \text{ db)} \]
\[ m_0 : \text{ monolayer moisture content (} \% \text{ db)} \]
\[ c : \text{ constant} \]
| Caurie| \[ \ln \left( \frac{1}{m} \right) = -\ln(C m_0) + \frac{2C}{m_0} \ln \left( \frac{1 - a_w}{a_w} \right) \] | \[ m : \text{ equilibrium moisture content (} \% \text{ db)} \]
\[ C : \text{ Caurie Constant} \]
\[ m_0 : \text{ monolayer moisture content (} \% \text{ db)} \]
\[ a_w : \text{ water activity} \]

3. Results and Discussion

The moisture content when it was an equilibrium between samples and surrounding is called equilibrium moisture content. The equilibrium moisture content of "gaplek" flour fortified with protein from red bead tree flour can be seen in Table 2.

Table 2. Relative Humidity (RH), Water activity (\(a_w\)) and Equilibrium moisture content \((m)\) at the temperature of 298K, 308K, and 318K **.

<table>
<thead>
<tr>
<th>Temperature</th>
<th>298K</th>
<th>308K</th>
<th>318K</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salt</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NaOH</td>
<td>12</td>
<td>0.12</td>
<td>5.82</td>
</tr>
<tr>
<td>K&lt;sub&gt;2&lt;/sub&gt;CO&lt;sub&gt;3&lt;/sub&gt;</td>
<td>46</td>
<td>0.46</td>
<td>10.52</td>
</tr>
<tr>
<td>Mg(NO&lt;sub&gt;3&lt;/sub&gt;)&lt;sub&gt;2&lt;/sub&gt;</td>
<td>55</td>
<td>0.55</td>
<td>11.54</td>
</tr>
<tr>
<td>KI</td>
<td>76</td>
<td>0.76</td>
<td>14.73</td>
</tr>
<tr>
<td>NaCl</td>
<td>82</td>
<td>0.82</td>
<td>16.51</td>
</tr>
</tbody>
</table>

*): averaged result of 4 times repetitions

The data of equilibrium moisture content and water activity was then applied in the GAB, BET, and Caurie equations to get description about absorption process on the sample. The valuable constants from GAB, BET, and Caurie equations were shown on Table 3.

Table 3. GAB, BET, and Caurie constants on several storage temperatures.

<table>
<thead>
<tr>
<th>Model</th>
<th>GAB</th>
<th>BET</th>
<th>Caurie</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>(m_0)</td>
<td>(c)</td>
<td>(k_b)</td>
</tr>
<tr>
<td>Temperature</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>298K</td>
<td>8.23</td>
<td>23.4111</td>
<td>0.6252</td>
</tr>
<tr>
<td>308K</td>
<td>8.19</td>
<td>16.0588</td>
<td>0.6035</td>
</tr>
<tr>
<td>318K</td>
<td>7.37</td>
<td>21.7496</td>
<td>0.5941</td>
</tr>
</tbody>
</table>

Equilibrium moisture content and monolayer moisture content tended to decrease when the temperature rose. It was because the temperature increase caused the water molecule to become active and increased its energy level. As a result, it became unstable and tended to release its
bonding with flour substances (Chowdhury et al., 2006). It was precisely correlated with the previous research about the equilibrium moisture content of dry merunggai leaves in several temperatures (Sobolawe et al., 2017) and the research about water sorption isotherm on dry mung beans (Chowdhury et al., 2006).

Monolayer moisture content was around 5.07–8.53% db. This result was higher than cassava starch flour which was modified with red rice yeast fermentation that was around 4.86–6.91% db. (Alfiah et al., 2017). The monolayer moisture content changed as the composition changed as well. Commonly, monolayer moisture content of starchy food supply in GAB model was around 3.2–16.3% (Lomauro et al., 1985). Monolayer moisture content on "gaplek" flour fortified with the protein from red bead tree flour has shown that its GAB model was higher than BET model and almost the same with Caurie model. It was in line with the research by Alfiah et al. (2017).

Constant (c) on GAB and BET models were connected to absorption heat in monolayer area. BET constants were related to absorption heat in accordance with an algorithm in a monolayer area. Whereas in accordance to algorithm BET constants were related to chemical potential differences of the water molecule in a form of pure liquid in a monolayer area. GAB constants were related to variation in the energy value in the monolayer area and the layers above (Erbaş et al., 2016). BET constants score tended to be higher than the score of GAB constants. It was the same with the research of Koua et al. (2014) which used samples from dry cassava. The score of constants on Caurie model was related to the water density which was absorbed on the monolayer (Dalgiç et al., 2012). Then, it could be used to count the adsorption surface area on the adsorbent. It did not depend on the temperature. It was in line with the research by Rakshit et al. (2014) and Dalgiç et al. (2012).

The \( k_b \) constant was a constant related to absorption heat in the multilayer area (Basu et al., 2006). The \( k_b \) score was around 0.5941–0.6252. This score was similar to the \( k_b \) score in the research by Sanni et al. (1997) about tapioca that was around of 0.528–0.6201.

The \( k_b \) score was around 0.5941–0.6252, while the c score was around 16.0588–23.4111. Those two constants indicated that sorption isotherm on “gaplek” flour fortified by protein from red bead tree flour was following isotherm type II. Blahovec (2004) said that if \( 0<k<1 \) and \( c>2 \), the sorption isotherm followed type II. Type II had a graphic about the relation of \( a_w \) and \( m \) which is similar to letter S.

Once the monolayer moisture content was known, the solid surface area of the samples could be determined. The solid surface based on GAB and BET model for each temperature shown on Table 4.

<table>
<thead>
<tr>
<th>Model</th>
<th>GAB</th>
<th>BET</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td></td>
<td></td>
</tr>
<tr>
<td>303K</td>
<td>290.5881</td>
<td>191.9521</td>
</tr>
<tr>
<td>308K</td>
<td>289.0894</td>
<td>185.9852</td>
</tr>
<tr>
<td>313K</td>
<td>260.1782</td>
<td>179.0969</td>
</tr>
</tbody>
</table>

Monolayer moisture content in Caurie model and Caurie constant can be used to determine the properties of sorbed water. The properties of sorbed water based on Caurie model shown on Table 5.
Table 5. The Properties of Sorbed Water Based on Caurie Model

<table>
<thead>
<tr>
<th>Constant</th>
<th>m₀</th>
<th>C</th>
<th>N</th>
<th>Density</th>
<th>Surface area of Adsorption</th>
<th>Bound water</th>
</tr>
</thead>
<tbody>
<tr>
<td>303K</td>
<td>8.53</td>
<td>1.2530</td>
<td>6.805036</td>
<td>1.2530</td>
<td>182.4406</td>
<td>58.02618</td>
</tr>
<tr>
<td>308K</td>
<td>7.59</td>
<td>1.2769</td>
<td>5.945303</td>
<td>1.2769</td>
<td>159.3915</td>
<td>45.13474</td>
</tr>
<tr>
<td>313K</td>
<td>7.88</td>
<td>1.1419</td>
<td>6.903693</td>
<td>1.1419</td>
<td>185.0856</td>
<td>54.42561</td>
</tr>
</tbody>
</table>

A larger surface area means a large number of exposed polar groups. It’s led to increased water absorption. Table 4 shows the higher the temperature, the lower absorption surface area. The highest density is achieved at the highest temperature. The decrease of density of the sorbed water could be explain by the fact that the number of active polar groups decrease as result of cross linking and interaction of protein, polyphenols or sugar at higher temperature (Červenka, 2008). The increase in density of the sorbed water could be explain at higher temperatures the rate of chemical reactions at the multimolar phase and capillary water condensation in region III also increased which may have led to the increased in solubilization of sugars present in considerable amounts in food. This intermingling of the sugars with the water molecules may have caused an increase in the density of the sorbed water as adding sugar or salt to water increases in its density (Koua et al., 2014).

4. Conclusion and Remarks

The levels of equilibrium water content and monolayer water content on "gaplek" flour fortified with protein from red bead tree flour were decreasing as the temperature increases. The monolayer moisture contents on GAB model and Caurie were the same, whereas it was lower on BET model. The score of c constant on BET model was higher than GAB model. In the future case, it can be used to count the absorption surface area on the adsorbent. The score of Caurie constant did not depend on temperature. The constant tended to increase as the temperature rose. The score of GAB constant indicated the water absorption process on "gaplek" flour fortified with protein from red bead tree flour following type II.

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References


