Characteristics of Sweet Potatoes Flour Used as Emergency Food Based on the Type of Varieties and the Duration of Fermentation

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Abstract: Sweet potato breeding at the Padjadjaran University farmland has produced new clones of sweet potatoes, Awachy 5 and Biang Varieties. Both clones contain high starch content, 25.46% and 15.96% respectively, having a good potential to be processed into flour as raw material for emergency food. However, due to poorly functional and amylograph characteristics, the clones need to be modified, one of which through fermentation. The objective of the study was to select the best varieties type of sweet potatoes and to determine the appropriate duration of fermentation to produce fermented sweet potatoes with the best physical, chemical and amylograph characteristics. The research method used was Randomized Block Design, consisting of 8 treatments and 3 repetitions. Awachy 5 and Biang Varieties were fermented for 0, 24, 48 and 72 hours respectively. The results showed that the fermented sweet potatoes flour of Awachy 5 with 72 hours of fermentation have produced the best characteristics of physical, chemical and amylograph, 7.21 ml/g swelling volume, 8.4% solubility, 84.37°C initial gelatinization temperature, 5092 cP peak viscosity, 2471 cP breakdown viscosity, 1089 cP setback viscosity, 68.04% starch content and 3.51% water content.

Keywords: Awachy 5; Biang; fermentation; mashed sweet potatoes

1. Introduction

Geographically, Indonesia is located at a volcanic system known as ‘ring of fire’, making the country is highly vulnerable to disasters either from direct eruption or indirect impact. An official report from the National Disaster Relief Agency (BNPB) stated that during January 2016 alone, about 174 natural disasters have occurred in many parts of Indonesia, causing thousands of people to become homeless and has to stay in emergency places. The disaster causes the damage to public facilities and infrastructures, which resulted in the limited availability of food, water, and fuel so that many victims will face difficulties in obtaining daily food supply. This condition has clearly stated that a certain quantity of emergency food should always be available.

Emergency food, by definition, has to meet a minimum standard of criteria, such as safe, good palatability, easy to be distributed, easy to be consumed and containing high calorie [1]. The daily intake of energy from an emergency food product (EEP) should be about 2100 Kcal [2], derived from 10-15% protein, 35-45% fat and 40-60% carbohydrate. Sweet potato is a kind of local food sources that potentially utilized in the development of emergency food due to its high carbohydrate content. High
starch content that ranges from 20 – 30% [3], makes sweet potatoes can be processed into a semi-finished product in the form of flour. However, a natural functional characteristic of sweet potato such as viscosity, rehydration and solubility can be a problem in its utilization. The low viscosity of sweet potato flour is desirable in the food industries product such as cream soup, baby food and pudding [4].

Fermentation is one method to produce texture with better characteristic than tapioca flour by increasing the viscosity, gelatinization ability, rehydration power and solubility. During fermentation, the growing microbe will produce pectinolytic and cellulolytic enzymes that could destroy cell walls so that the degradation of starch occurred. The more the starch granules are swollen, the greater the viscosity values. Fermentation technique in flour production usually uses lactic acid bacteria in which Lactobacillus casei is the most often used. Duration of fermentation is one factor influencing the quality of physical characteristic of the fermented flour. The longer the fermentation process took place, the more the degraded starch by microbe activities, causing an increase in viscosities and degree of solubility.

Sweet potato of yellow varieties that introduced as Awachy 5, is very potential to be developed. It contains 261 mg/100 gram β carotene, having long ellipsoid tuber shape, purplish-red skin, and yellow tuber flesh. Sweet potato of Biang varieties has a high content of anthocyanin, long ellipsoid tuber shape, purple skin and purple tuber flesh. The difference in varieties influences the chemical and physical characteristics of sweet potato [5]. The present study will assess the influence of two different varieties of sweet potato and four different duration of fermentation on the characteristics of sweet potato flour.

2. Materials and Methods

The materials used were sweet potatoes of Awachy 5 and Biang varieties, both were 4 – 4.5 months of age, obtained from the Padjadjaran University farmland. About 500 grams was needed for every treatment. Microbe used was Lactobacillus casei.

Sweet potato flour was made through stages of processes, beginning with the preparation of bacteria culture (Figure 1), preparation of liquid bacteria culture for testing (Figure 2), and finally the making of fermented sweet potato (Figure 3).

The research method used was Experimental Design of Randomized Block Design, consisting of 8 treatments and 3 repetitions. The treatment used was a combination of variation between 2 type of sweet potato varieties and 4 fermentation duration, as follows:

A = Awachy 5 Clone, fermentation duration 0 hour
B = Awachy 5 Clone, fermentation duration 24 hours
C = Awachy 5 Clone, fermentation duration 48 hours
D = Awachy 5 Clone, fermentation duration 72 hours
E = Biang Clone, fermentation duration 0 hour
F = Biang Clone, fermentation duration 24 hours
G = Biang Clone, fermentation duration 48 hours
H = Biang Clone, fermentation duration 72 hours

The 5% level test was used to define whether the diversities occurred or not between treatments, if $F_h < F_{0.05}$, then no diversities between treatments. While if $F_h > F_{0.05}$, then diversities between treatments occurred. For a further test, Duncan’s Multiple Range Test was performed at the 5% level (LSR) to define the influences difference between treatments.
Figure 1. Flowchart of making the bacteria culture

Figure 2. Flowchart of preparation for bacteria liquid culture test

Figure 3. Flowchart of making the fermented sweet potato flour
3. Results and Discussion

Analysis was carried out on two different varieties and 4 different fermentation duration of sweet potato for swelling volume, solubility, moisture content and starch content (Table 1) and amylograph characteristics such as initial gelatinization temperature, peak viscosity, breakdown viscosity, setback viscosity (Table 2) to determine their influences on the fermented sweet potato flour.

Table 1. The Influence of the Different Varieties and Different Fermentation Duration on Some Characteristics of the Fermented Sweet Potato Flour.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Swelling Volume (mL/g b.k)</th>
<th>Solubility (% b.k)</th>
<th>Moisture Content (%)</th>
<th>Starch Content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (Awachy 5, 0 hr)</td>
<td>11.96±0.30 a</td>
<td>34.19±1.62 a</td>
<td>4.14±0.22 c</td>
<td>76.95±0.99 a</td>
</tr>
<tr>
<td>B (Awachy 5, 24 hrs)</td>
<td>10.67±0.08 b</td>
<td>29.55±0.70 b</td>
<td>3.82±0.05 d</td>
<td>69.72±0.29 bc</td>
</tr>
<tr>
<td>C (Awachy 5, 48 hrs)</td>
<td>7.69±0.14 c</td>
<td>17.97±0.27 c</td>
<td>3.77±0.01 d</td>
<td>67.32±1.18 cde</td>
</tr>
<tr>
<td>D (Awachy 5, 72 hrs)</td>
<td>7.21±0.16 d</td>
<td>8.40±0.06 d</td>
<td>3.51±0.03 e</td>
<td>68.04±4.30 cd</td>
</tr>
<tr>
<td>E (Biang, 0 hr)</td>
<td>11.96±0.15 a</td>
<td>33.21±1.61 a</td>
<td>5.19±0.03 a</td>
<td>73.16±0.68 ab</td>
</tr>
<tr>
<td>F (Biang, 24 hrs)</td>
<td>10.75±0.08 b</td>
<td>28.31±1.73 b</td>
<td>5.15±0.11 a</td>
<td>64.03±1.50 de</td>
</tr>
<tr>
<td>G (Biang, 48 hrs)</td>
<td>7.79±0.09 c</td>
<td>17.81±0.71 c</td>
<td>4.81±0.14 b</td>
<td>63.58±3.67 de</td>
</tr>
<tr>
<td>H (Biang, 72 hrs)</td>
<td>7.38±0.16 d</td>
<td>8.80±0.62 d</td>
<td>3.13±0.02 f</td>
<td>62.96±2.72 e</td>
</tr>
</tbody>
</table>

Note: The average value of treatments that are marked with the same letter, shows not significant difference at 5% level according to Duncan test.

Table 2. The Influence of the Different Varieties and Different Fermentation Duration on Amylograph Characteristics of the Fermented Sweet Potato Flour.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Amylograph Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Initial Temp of Gelatinization (°C)</td>
</tr>
<tr>
<td>A (Awachy 5, 0 hr)</td>
<td>82.96±1.41 a</td>
</tr>
<tr>
<td>B (Awachy 5, 24 hrs)</td>
<td>83.11±1.46 a</td>
</tr>
<tr>
<td>C (Awachy 5, 48 hrs)</td>
<td>83.32±0.07 a</td>
</tr>
<tr>
<td>D (Awachy 5, 72 hrs)</td>
<td>84.37±0.13 a</td>
</tr>
<tr>
<td>E (Biang, 0 hr)</td>
<td>67.60±6.97 c</td>
</tr>
<tr>
<td>F (Biang, 24 hrs)</td>
<td>72.91±2.52 b</td>
</tr>
<tr>
<td>G (Biang, 48 hrs)</td>
<td>74.63±1.47 b</td>
</tr>
<tr>
<td>H (Biang, 72 hrs)</td>
<td>75.68±0.12 b</td>
</tr>
</tbody>
</table>

Note: The average value of treatments that are marked with the same letter, shows not significant difference at 5% level according to Duncan test.

3.1. Swelling Volume

Statistical analysis result showed that the different fermentation duration gave significantly different effect on the swelling volume of the fermented sweet potato flour, whereas the different varieties did not give significant effect to the swelling volume of the fermented sweet potato flour (Table 1).

The study showed that swelling volume was influenced more by amylose content rather than type of varieties. *Awachy* 5 varieties tend to have lower swelling volume than *Biang* varieties due to its higher amylose content of 29.38% compared to *Biang* varieties of 25.44%. The presence of amylpectin can increase swelling volume, on the other hand, it can inhibit the ability of flour to swell. Sweet potato starch contains 80% amylpectin and 20% amylose [6]. High content of amylpectin and the low content of amylose, causing a relatively better swelling volume on sweet potato than other flour.
Fat content can also influence the swelling volume. The higher the fat content, the lower the swelling volume. *Awachy* 5 varieties contain 0.45% fat content, whereas *Biang* varieties have 0.59 fat content. Fat has a hydrophobic characteristic that could prevent the binding of water by granules, causing the decrease in the swelling volume. Amylose and fat component can lower swelling properties, while the long chain of amylopectin can increase swelling properties. Amylopectin is responsible for development and starch character, whereas amylose inhibits development.

Fermentation gave significant difference effect on sweet potato flour of both varieties of *Awachy* 5 and *Biang*. Fermentation on sweet potato flour can increase fat content in the material. The presence of lipid and phospholipid makes a stable structure either with amylose or with amylopectin, resulting in the water difficult to react in the stable structure. In another word, the more amount of the fat component, the smaller the decrease the resulted in swelling power. Therefore, with the longer fermentation duration, the swelling volume of sweet potato flour will decrease. The value of swelling volume of *Awachy* 5 varieties was 11.9594 ml/gr, decreases with fermentation, as well as *Biang* varieties of 11.9634 ml/gr decreases also with fermentation. Swelling power is a weight comparison of pasta and dry starch. Pasta includes amylopectin that does not soluble in water. So that, if amylopectin content (pasta) decreases, the swelling power will also decrease [7].

### 3.2. Solubility

Data on Table 1 showed that fermentation duration gave a significant difference influence on the solubility of the fermented sweet potato flour, whereas varieties type did not give a significant difference on the solubility of the fermented sweet potato flour. Although the difference in varieties type did not show significantly different influence on the solubility value, *Awachy* 5 tends to have lower solubility value than *Biang* varieties. It is probably caused by the difference in the amylose and amylopectin content. *Awachy* 5 clones contain 29.38% amylose content, whereas *Biang* clones contain 25.44% amylose content.

The solubility of sweet potato flour of both varieties showed a significantly different effect between the fermented sweet potato flour and non-fermented sweet potato flour. During fermentation, the growing lactic acid bacteria produce enzymes of pectinolytic and cellulolytic that could destroy cell walls of sweet potato, to liberate starch granules. The lactic acid bacteria also produce enzymes that hydrolyze starch into sugar, changing starch into organic acid, particularly lactic acid. The resulted glucose from the starch degradation changed into organic acid especially lactic acid that lower the pH value [8]. Acidic condition at low pH causes the starch hydrolyzed faster at the α-(1,4) bound [9], and can increase amylose group that tends to be soluble in water so that the solubility value of sweet potato flour by fermentation will be lower than sweet potato flour without fermentation. The longer the duration of fermentation, the smaller the ability of sweet potato flour to be soluble. The minimum solubility value occurred on the *Awachy* 5 varieties was 8.40% at 72 hours of fermentation, whereas the maximum solubility value on the *Awachy* 5 varieties without fermentation was 34.19%.

The solubility of sweet potato of *Awachy* 5 varieties at 48 hours, was lower than those at 24 hours of fermentation. During fermentation, the lactic acid bacteria produce extracellular amylase that causes degradation on the amylose of sweet potato flour. The longer duration of fermentation, lactic acid bacteria able to produce extracellular amylase with the highest activities if compared to the other fermentation duration. The high extracellular amylase will decrease amylose content in flour.

The ability of dissolved is related with the presence of starch component and non-starch component (protein and fat). Amylopectin can be soluble in water, while amylose solubility varies in water [10]. Amylose tends to form a bond with the lipid component to form a hydrophobic layer at the starch granules surface so that it could decrease solubility [11]. It is also because the fat that covers granules surfaces will inhibit the heat to prevent interaction of starch granules from the water.

Protein can also influence the functional characteristic of starch. Protein can decrease starch solubility and prolong the time of cooking because protein can compete with starch in binding water at the starch granules surface [11]. Protein in the fermentation process will produce more hydrophobic amino acid than hydrophilic amino acid, causing the increase of fat bond that can decrease the solubility level.
3.3. Moisture Content

The moisture content of fermented sweet potato flour shows a significantly different effect on varieties and fermentation duration (Table 1). Both varieties, the fermented Awachy 5. Biang tends to be similar in term of fermentation duration, the longer the fermentation duration, the lower the resulted in moisture content. The moisture content of the flour control of Awachy 5 varieties was 4.14%, whereas Biang varieties were 5.19%. Moisture content decreases on sweet potato flour with fermentation treatment.

On the sweet potato flour modification with natural fermentation, moisture content decreases with the longer fermentation. The moisture content of sweet potato flour that naturally fermented was about + 7% at 12 hours of fermentation and decreases into + 3.4% after 36 hours of fermentation [12].

The fermentation duration on Awachy 5at 24 hours, 48 hours and 72 hours gave significant different influence on sweet potato flour, similar with the Biang varieties. It is caused by the difference in the natural moisture content in each sweet potato. Awachy 5 varieties have initial moisture content 67.5%, higher than Biang varieties of 64.7%. The difference is caused by the difference in chemical composition of each variety. The decrease in moisture content was basically caused by fermentation duration. In the longer duration of fermentation, the starch will be degraded into simple sugar molecule, resulting in the power to bind water becomes weak [12].

In a fermentation process, enzyme activities in starch degradation are also increased, so that more amount of water is liberated, causing material becomes soft and porous making water easy to evaporate.

3.4. Starch Content

Statistical data in Table 1 shows that the treatment of varieties and fermentation duration gave significantly different influence on the starch content of fermented sweet potato flour. The fermentation duration for both varieties, Awachy 5 and Biang, did not show significant difference influence, however, Awachy 5 varieties tend to have higher starch content compared with Biang varieties. This difference is due to the difference in the chemical composition of each variety. Analysis data also shows that the starch content of sweet potato flour of Awachy 5 was 25.46%, higher than those of Biang varieties 15.96%. Starch content of the raw material is influenced by plant age and shelf-life after harvesting.

Varieties of Awachy 5 and Biang, with 0 hours of fermentation (sample control) showed significantly different influence on sweet potato flour, likewise with 24, 48 and 72 hours of fermentation. Both clones tend to have the same influence on the ability to decrease the starch content of sweet potato. The longer the fermentation duration, the lower the starch content. It is because of the fermentation process, degradation of starch occurred by microorganism activities, changing into a simple sugar that used as energy for growing up and activities.

3.5. Amylograph Characteristics

Amylograph characteristics observed in this study comprise initial gelatinization temperature, peak viscosity, breakdown viscosity and setback viscosity. The data were summarized in Table 2.

3.6. Initial Gelatinization Temperature

The analysis result of amylograph test is displayed in Table 2. The initial gelatinization temperature Awachy 5 for fermentation 0, 24, 48 and 72 hours show significantly different effect with the treatment of Biang varieties for fermentation 0 hours, 24 hours, 48 hours and 72 hours. The initial temperature of gelatinization of Awachy 5 varieties on average was higher than those of Biang varieties. Starch compounds contained in sweet potato varieties Awachy 5 was 24.46%, higher than in the sweet potato varieties Biang 15.96%, thus, the amount of starch and density or amylopectin component probably were responsible for the high initial gelatinization temperature. The initial gelatinization temperature of sweet potato starch ranges from 61.5 – 88.5°C for 20 – 30 minutes [13]. Thus, the initial gelatinization temperature of the six clones is considered to be high. Treatment of varieties type of fermented Awachy 5 at 0 hours did not show significant difference influence with the same treatment at 24, 48 and 72 hours. However, the initial gelatinization temperature with fermentation duration of 72 hours was higher compared with fermentation treatment of 24 and 48 hours. Gelatinization temperature can be used to predict the appropriate cooking temperature. If temperature used below gelatinization temperature,
cooking temperature can be saved but the resulted dough becomes less elastic and less compact because gelatinization has not occurred. If the temperature used above the initial gelatinization temperature, starch granules will be merged, forming a matrix that influences the texture of the product.

The high temperature of gelatinization probably is due to an accumulation of protein in the starch surface. The protein can be in the form of fermentation microorganism that accumulated after breeding during the fermentation process. Protein can decrease the solubility of starch and increase fermentation duration [11]. Sweet potato varieties Biang with fermentation duration 0 hours (sample control) showed a significantly different effect from those 24, 48 and 72 hours of fermentation.

Amylopectin easily dissolved in water, whereas the solubility of amylose in water varies [10]. Amylose tends to form a bond with lipid component, forming a hydrophobic layer at the surface of starch granules, so that it decreases solubility because the fat that covers granules obstruct heat and preventing interaction of starch granules from the water. The concentration of amylopectin inside starch granules and amylose at the outer edge of starch granules may explain the role of amylose compound that gives a great influence on the functional characteristics of the material [14]. An increase of initial gelatinization temperature is parallel with the decrease of swelling volume. This was due to the higher the temperature is used, the greater the starch crystalline is produced. An increase of crystalline component will decrease swelling volume to produce stable starch during heating [15].

3.7. Peak Viscosity

The treatment of varieties Awachy 5 and Biang showed a significantly different influence on the sweet potato flour. Amylose content has a negative correlation with peak viscosity where the lower the amylose content, the higher the peak viscosity. Nonfermented treatment of varieties Awachy 5 and Biang with various duration, showed low peak viscosity. The difference was due to the degree of association in the amorphous part that related with the amylose content [16]. The fermented sweet potato flour probably has lower amylose content so that having higher peak viscosity than the sweet potato flour of reference sample. Viscosity is also related with gelatinization and degree of hydration. The decrease of free water in a system occurred, due to water were trapped in swollen granules as a result of the gelatinization process. The high peak viscosity of fermented sweet potato flour showed a water binding capacity.

3.8. Breakdown Viscosity

Breakdown viscosities of sweet potato flour of Awachy 5 varieties gave significant different effect with those of Biang varieties at 0, 24, 48 and 72 hours. Breakdown viscosities of Awachy 5 was higher than Biang varieties. It results from the difference in harvesting, shelf life and the ratio of amylose to amylopectin. Higher content of amylopectin will decrease the stability of starch in heating because of the branch chain of amylopectin easy to damage by high temperature [17].

Sweet potato flour of Awachy 5 showed no significant difference influence with 24 hours of fermentation treatment but showed significant different influence with 48 and 72 hours of fermentation. Breakdown viscosities is the value of a decreasing viscosities maximum to the lowest viscosities when the suspension is heated at 95°C for 5 minutes. Breakdown viscosities of sweet potato flour of Awachy 5 with fermentation treatment, is higher than the same varieties without fermentation treatment. The high breakdown viscosities during heating indicates that the swollen starch granules overall has fragile characteristics. One factor influencing breakdown viscosities is pH value. Fermentation will produce acid that can cause the decrease in pH value and also the presence of acid will stimulate the breakdown of the glycoside bond, that causes the breakdown occurred faster [18].

Sweet potato flour of Biang varieties of 0 hours of fermentation did not show significantly different effect with the same varieties at 24 hours of fermentation but showed a tendency of decreasing breakdown value. This occurred when during the modification process, fermentation produces amylomaltase that apart from hydrolyzing the branch chain of amylopectin, also it can conduct the disproportionation. The disproportionation can reduce the amount of amylose to produce the distribution of long amylopectin chain. Distribution of the chain can change the starch structure so that starch becomes thermoreversible [19]. One characteristic of thermoreversible starch is indicated by the decrease in breakdown viscosities. The decreasing breakdown viscosities during fermentation indicates an increase viscosities stability of starch pasta from the heating process [18].
3.9 **Setback Viscosity**

Setback viscosity is a reassociation of starch molecules when cooling [18]. Setback viscosity is the difference between viscosity value at the end of constant temperature heating and viscosity at the end of cooling. This value shows a tendency of starch is retrograde. The starch that has a viscosity of less than 50 BU setback shows that the paste will not harden when cooled down and remains soft. Viscosity setback 50 – 150 BU indicates that the pasta remains soft when it is cold. Viscosity setback 150 – 500 BU showed this cold pasta will become dry. The setback viscosity of more than 500 BU indicates that the paste will harden when it is dry [17].

Setback viscosities showed a tendency of starch to undergo retrogradation during cooling [20]. The higher the setback viscosities, the higher the speed of the starch suspension to retrogradation, resulting in the increase of gel hardness [21]. The higher the setback viscosities, the higher the speed of the starch suspension to retrograde, resulting in the increase of gel hardness.

Based on the Duncan test at the level of 5%, the setback viscosities of sweet potato flour of *Awachy* 5 varieties at 0 hours of fermentation, showed a significantly different effect with the same varieties at 24 hours and *Biang* varieties at 0, 24, 48 and 72 hours of fermentation. The setback viscosities are related with retrogradation during cooling, followed by the increase in the viscosity value and is influenced by amylose content, where the higher the amylose content, the higher the setback viscosities [18]. Setback viscosities demonstrate the ability of starch to form a gel back after gelatinization and show a tendency of starch to undergo retrogradation [20].

Sweet potato flour of *Awachy* 5 varieties at 24 hours of fermentation did not give significantly different influence with the same treatment at 48 and 72 hours but showed significant different influence with those of *Biang* varieties at 0, 24, 48 and 72 hours.

4. **Conclusions**

The treatment of varieties types and fermentation duration gave significant difference influence on swelling volume, solubility, initial gelatinization temperature, breakdown viscosities, setback viscosities, peak viscosities, moisture content and starch content.

The treatment of varieties type of *Awachy* 5 and fermentation duration of 72 hours produced fermented sweet potato flour with the best chemical, physical and amylograph characteristics with 7.21 ml/g swelling volume, 8.4%, solubility, 84.37°C initial gelatinization temperature, peak viscosities of 5092 cP, breakdown viscosities of 2471 cP, setback viscosities of 1089 cP, 68.04% starch content and 3.51% moisture content that appropriate to be applied to the extrusion product so that the sweet potato starch can be used as an emergency food.

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**Conflicts of Interest:**

“The authors declare no conflict of interest.” “The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results”

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