Processing and Functional Properties of Banana Flour

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Abstract

Banana cv. Kluai Namwa (Musa ABB) was selected to study changes in the percentage of Total Soluble Solid (TSS) during the ripening process. The 1\(^{st}\)-2\(^{nd}\) days after harvesting expressed the lowest TSS (7.44-7.62%), then TSS accumulated to a stable level of 29.12% on the 8\(^{th}\) day. Banana flour should be produced within the 1st stage of two days after harvest. The three varieties of banana flour derived are Kluai Namwa (Musa ABB), Klualai Khai (Musa AA) and Kluai Hom (Musa AAA). At the mature green peel stage of ripeness, moisture content, color, swelling, solubility and viscosity were determined. Kluai Namwa flour turned out a higher amylose content, lightness and viscosity (77.63%, 90.12 and 383.75, respectively) than the Kluai Khai and Kluai Hom varieties. Banana flour could be applied and utilized in food systems to improve properties of food products, reduce production cost and might become an alternative form of starch flour.

Keywords: Banana, Flour, Musa ABB and functional properties

1. Introduction

The banana is one of the world’s main food commodities. With a world production of banana estimated 102 millions tons in 2003 [1]. Banana is an important food crop widely grown in tropical countries. About 1.8 million tons were produced in Thailand [2]. The cultivation area covers around 106,947 hectares in Thailand [3]. About 0.42 millions tons are exported [4] from Thailand. The most common banana varieties in Thailand are Klualai Hom, Klualai Khai and Kluai Namwa. The Kluai Namwa variety is grown in largest quantities and accounts for 77% of the total yield [3].Banana are harvested all year in green or unripe stage 100-110 days after the blossoms appear. Banana ripening can be divided into 7 stages by peel color. The ripening process changes the composition, appearance and structure: the green peel turns yellow, the consistence of the flesh turns firm to soft and the starch is converted to sugar [5]. Unripe bananas in 1\(^{st}\) and 2\(^{nd}\) stages are processed for banana flour, 3\(^{rd}\) and 4\(^{th}\) stage ripe banana are used for dessert processing. Ripe bananas at the 5\(^{th}\) and 6\(^{th}\) stages are processed to powder or consumed. Banana peels of the 7\(^{th}\) stage are used for alcohol production, as food for livestock or as adsorbent in water purification or as fertilizer [6].

Banana is considered a healthy source of energy in human nutrition. The ripe banana consists of 23.43% carbohydrates, 1.03% protein, 0.48% fat and 2.40% fibers, providing 385kJ (92 Kcal) per 100g [7]. It is processed to many products like desserts, banana candy, banana chips, banana powder and banana flour. Unripe bananas are processed to flour used as food ingredient or as a drug with beneficial properties [8], e.g. in treating peptic ulcer. Banana flour production is low-cost and reduces losses due to spoilage of ripe bananas.

In the process, the bananas are initially peeled, then dried, milled, and sieved to obtain the flour. Banana flour has a starch content of 73.4% [9] and might be an alternative form of starch flour. The most common starch for industrial production in Thailand is from cassava. Banana starch and flour are not produced at a commercial scale but found at household scale, employing local knowledge in production and use. Therefore, its properties and applications are interesting for a research into wider utilization as food ingredient [10] and opens a path for food carbohydrate development, various food product improvements and product cost reduction.

2. Objectives

The aim of this study was to observe banana ripening of Kluai Namwa, to produce banana flour from Kluai Namwa (Musa ABB), Klualai Khai (Musa AA) and Kluai Hom (Musa AAA) and to determine the functional properties such as moisture content, color, amylose content, swelling power, solubility and viscosity.

3. Materials and Methods

3.1 Total Soluble Solid (TSS) of ripening banana

Six hands of a Kluai Namwa bunch were harvested during the 14-16\(^{th}\) weeks or 100-110 days after unfolding of the blossoms. All bananas were kept at room temperature (26-30\(^{o}\)C).
The pulp was blended to paste. Then TSS was determined by hand refractometer. The data were collected everyday until TSS values reached stability.

3.2 Banana flour production

Raw bananas (Musa spp.) c.v. Klui Namwa, Klui Khai and Klui Hom were obtained from various local markets within Thailand. The fresh green bananas were removed from the bunch, washed, peeled and sliced at an average thickness of 1 cm. The banana pieces were soaked in a browning inhibitor solution containing 1% citric acid [11] for 30 minutes. The liquid was then drained and the banana slices were dried in an oven at 55°C [12] for 8 hours. The dried chips were milled using a hammer mill and ground with an 80 mesh sieve. The banana flour was retrieved and packaged for subsequent use.

3.3 Moisture content of banana flour

The moisture content was determined following an AOAC indirect method [13]. A two gram sample was weighed in a test dry dish, covered and stored at 130±3°C for 24 h in an oven with ventilation openings. The dish was transferred to desiccators and weighed after reaching room temperature. Moisture content was calculated from flour residue as total solids and loss of weight due to evaporation as follows:

\[
\text{moisture content} = \frac{[a-b]}{a} \times 100 \quad (1)
\]

where  
\(a\) = weight of moist sample  
\(b\) = weight of dry sample

3.4 Amylose content of banana flour

The Iodine calorimetry method [14] was used to determine the amylose content. A 100 mg sample was filled into a 100 ml volumetric flask in duplicate. Then 1 ml of 95% ethanol was added, followed by 9 ml of 1 M NaOH. The contents of the flasks were boiled in a water bath for 10 minutes to gelatinize the starch. The sample was allowed to cool. Then distilled water was added to the flask to increase the volume to exactly 100 ml and mixed well. The prepared solution was stored overnight at room temperature (25°C). Above steps were also followed to prepare a blank treatment solution. After 23 hrs, the flask was thoroughly mixed and 5 ml of the solution were pipetted out into a 100 ml volumetric flask. Then about 70 ml of distilled water were added followed by 1 ml of 1 M glacial acetic acid and 2 ml of I2-solution. The volume of the solution in the flask was adjusted to 100 ml by distilled water. The sample was thoroughly mixed and left for 20 minutes to develop a dark purple color. The absorbance of the color was measured in the spectrophotometer at 620 nm after adjusting the zero point of the equipment with the blank treatment solution. The value of the absorbance was then converted back to the amylose content using the standard calibration curve developed for the potato amylose standard.

3.5 Color of banana flour

The color of the banana flour was measured by a HunterLab spectrophotometer. The samples (about 10-20 grams) were prepared, put into a clean Petri dish and covered. The L*, a* and b* values of the samples were imported in the CIELab system.

3.6 Swelling power and solubility of banana flour

Swelling power and solubility measurements were carried out during pasting of banana flour. Aliquots of the paste necessary to get a dilution containing 0.5% flour at 80°C were taken from the cooking vessel. Samples were cooled quickly to 25°C and 8 ml of the dilution were centrifuged at 2000 rpm for 15 min. A separate volume of the dilution was dried overnight in an oven at 100°C for 24 h to get the mass of dry flour (mD). The supernatant of the centrifuged portion was carefully separated from the residue (mS). Solubility (\(S\)) was calculated as:

\[
S = \frac{m_S}{m_D} \times 100
\]

where \(m_S\) is the mass of flour in the supernatant and \(m_D\) is the mass of dry flour in the aliquot. Swelling was calculated as:

\[
SW = \frac{m_W}{m_D}
\]

where \(m_W\) is the mass of wet residue and \(m_0\) is the mass of dry residue. [15].

3.7 RVA analysis of banana flour

The Rapid Visco Analyzer was used to characterize banana flour. 3.24g of accurately weighed banana flour was added to 25.26g distilled water to prepare a suspension. The banana flour solution was kept at 50°C for 1 minute, then heated up to 95°C and held for 3.2 minutes, hereafter cooled to 50°C, followed by a final isothermal step at 50°C. The RVA curve resulting was expressed in peak viscosity, trough, breakdown viscosity, final viscosity and setback viscosity in Rapid Visco Units (RVU).

3.8 Proximate analysis of banana flour

The protein content of banana flour was measured according to the Kjeldahl method employing a Kjeltec machine. Total lipids were extracted by petroleum ether following the Soxtec method. The ash and total dietary fiber of banana flour were estimated according to the AOAC method [13]. The total carbohydrate content was obtained as the difference after subtracting protein, lipids, ash and fiber from total banana flour mass as follows:
carbohydrate = 100 - protein - lipids - ash - fiber (4)

3.9 Statistical analysis

Analysis of variance (ANOVA) and Duncan’s multiple range test (DMRT) were used to determine the significance of differences between means (p<0.05). Results were indicated by the mean of standard error values of three replication determinations.

4. Results

4.1 Total Soluble Solid (TSS) of ripening banana

The major share of banana pulp TSS is sucrose. The percentage of Brix TSS of raw banana measured by hand refractometer is close to that of Brix sucrose. Starch is the principal component of green bananas which changes during ripening. When the peel color turns yellow, the percentage of Brix sucrose increases because the starch is transformed to soluble sugar within the cells. The starch content in the banana pulp drops to less than 1% while sugar, mainly sucrose accumulates to more than 10% of the fresh weight of the fruit [16]. Sucrose is the prevailing sugar during the early stages of banana ripening. The highest percentage of TSS is 29% at the spoiled stage or 7th stage. Fruits from each hand of banana from one bunch of all 6 ripening stages were used in the experiment. The result showed the percentage of Brix sucrose in the first 1-2 storage days of the 1st stage is suitable for flour production (Fig. 1 and Table 1). The results from Siriboon and Bunlusilp [5] showed a Brix TSS of 6% for the first storage day and an increase to 30% on the 8th storage day. Emeaga et al. [1] reported an increase of the soluble sugar content from 4.2% to 38.3% from the 1st to 7th stage (from green to brown peel color).

4.2 Moisture content of banana flour

During banana flour production, the moisture content of fresh banana is reduced by about 10 times. The moisture content of the three varieties of banana flour examined was determined as 6.61-7.67% which equals 6.0% from Rodriguez-Ambriz et al. [7]. The moisture content of Klui Khai flour was higher than those of Klui Namwa and Klui Hom flour. The moisture content depends on drying duration and storage conditions. The moisture content of flour should be less than 14% to provide a stable product quality and resistance to moisture related deterioration. The properties of banana flour are shown in Table 2.

4.3 Amylose content of banana flour

The amylose content of the Klui Namwa flour examined was 37.63% which was higher than others. The result was similar to the results of Prabha and Bhagyalakshmi [17] who reported about 36% on the 2nd day after harvest at the green peel stage. An amylose content of 32% of banana flour was found by Siriwong et al. [18]. The amylose content of Klai Khai and Klai Hom flours were similar to the results of Vieira da Mota et al. [19] with 19-23%.

The green peel stage had the highest starch content of 61.7% which declined during ripening. Conversely, the sugar content of the green peel stage was low and increased during ripening.

4.4 Color of banana flour

The L value of Klui Namwa flour (90.12) was higher than that of Klui Khai flour (87.22) and Klui Hom flour (85.03). The b value of Klui Namwa flour (15.83) was lower than Klui Khai flour (17.65) and Klui Hom flour (15.89). The results from Waliszewski et al. [10] showed a low L scale of 73.6 because of slight yellowing and darkening while Siriwong et al. [18] found L values of 84.41-96.26, depending on the banana varieties and the extracting solution. Banana flour from the experiment had a higher L value and a lower b value than flour from ripe banana (L=68.29, b=21.61) because ripe banana undergo an enzymatic browning reaction whereas in the present study, the banana flour underwent a citric acid soaking process to inhibit the browning reaction.

4.5 Swelling power and solubility of banana flour

The results revealed that Klui Namwa flour has a higher swelling power than Klui Khai but a lower one compared to Klui Hom with values of 30.13, 27.04 and 34.24% at 60oC, respectively. The solubility of Klui Namwa flour was lower than that of Klui Khai and Klui Hom with values of 18.16, 34.10 and 20.41% at 60oC, respectively. This matches the results of Zhang et al. [2] who found swelling power and solubility values in the range of 30.1-35.3% and 16.3-21.7%, respectively. Nimsung et al. [20] reported a swelling power in the range of 1.81-18.31% and solubility of around 3.31-27.88% whereas Torre-Gutierrez et al. [21] reported a value of 17.1% for swelling power and 16.8% solubility at 90oC. However, Zhang et al. [2] reported that a temperature rise from 65 to 95oC increased swelling power and solubility considerably as both depend on the interaction between starch chains of both the amorphous and crystalline domains which are influenced by amylose. Swelling power increased rapidly due to the progressive breaking of intermolecular hydrogen bonds in amorphous areas by water absorption. The solubility was associated with a high gelatinization temperature. Swelling power and solubility of banana flour provide for a better aqueous starch dispersion in food application [21].

4.6 RVA analysis of banana flour

The RVA curve of the examined banana flour showed a resistance to mechanical force. Viscosity profiles showed higher concentrations due to a slight increase in viscosity during cooking.
and a breakdown after. At high viscosity, swollen granules occupy most of the space and cannot move off each other. As a result, banana flour in higher concentrations underwent a distinct setback (retrogradation) during cooling. The RVA properties of banana flour are shown in Table 3. Klui Namwa had the highest peak viscosity, trough, final viscosity and setback viscosity. This indicates that this sample had the highest water-binding potential. Klui Khai had the highest resistance to heating, shear-thinning as revealed by its breakdown viscosity. Klui Hom had the shortest cooking time because the pasting temperature provided an indication of the minimum temperature required to cook the sample. The Klui Hom flour was similar to potato starch [22] which showed high peak viscosity and breakdown but it had low setback and amylopectin content. The results were similar to the results of Daramola and Osanyinlusi [23] who reported 434.75 RVU, 115.42-487.92 RVU and 355.0-504.92 RVU in peak viscosity, breakdown and final viscosity, respectively.

4.7 Proximate analysis
Protein, ash, fat, fiber and carbohydrate contents were 2.46, 2.46, 0.83, 1.73 and 92.52% (db), respectively. These results are similar to those of Daramola and Osanyinlusi [23] who found 1.18-3.68% protein, 0.62-4.08% ash, 0.23-0.80% fat, 90.83-97.24% carbohydrate in the dry mass.

5. Conclusions
Unripe bananas in the 1st and 2nd stage have a high starch content suitable for flour production. Klui Namwa flour has a higher amylose content, L value and viscosity than Klui Khai and Klui Hom flour. Moreover, it also contains more total carbohydrate. Its properties make banana flour an alternative source of starch. Especially the abundance and low cost of the Klui Namwa variety offers numerous ways to utilize banana flour for food and non-food products.

6. Acknowledgement
The authors gratefully acknowledge the Office of the Higher Education Commission and the Royal Thai Government for the scholarship.

7. References
Table 2 The properties of Klai Namwa, Klai Khai and Klai

<table>
<thead>
<tr>
<th>Results</th>
<th>% Moisture content</th>
<th>% Amylose content</th>
<th>L value</th>
<th>b value</th>
<th>Swelling power</th>
<th>% Solubility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Klai Namwa</td>
<td>6.76±0.11a</td>
<td>37.63±0.08c</td>
<td>90.12±0.07c</td>
<td>15.83±0.06a</td>
<td>30.13±1.46a</td>
<td>18.16±5.73a</td>
</tr>
<tr>
<td>Klai Khai</td>
<td>7.67±0.06b</td>
<td>25.59±0.00b</td>
<td>85.03±0.07a</td>
<td>17.65±0.04b</td>
<td>27.04±1.49a</td>
<td>34.10±4.00b</td>
</tr>
<tr>
<td>Klai Hom</td>
<td>6.61±0.09a</td>
<td>25.10±0.11a</td>
<td>87.22±0.03b</td>
<td>15.89±0.05a</td>
<td>34.24±2.23b</td>
<td>20.41±2.23a</td>
</tr>
</tbody>
</table>

Remark: The letters indicate the difference of statistical analysis between samples.
Table 3 RVA properties of Kluai Namwa, Kluai Khai and Kluai Hom flour (wet basis)

<table>
<thead>
<tr>
<th>Results</th>
<th>Peak viscosity (RVU)</th>
<th>Trough viscosity (RVU)</th>
<th>Breakdown viscosity (RVU)</th>
<th>Final viscosity (RVU)</th>
<th>Setback viscosity (RVU)</th>
<th>Peak time (min)</th>
<th>Pasting (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kluai</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Namwa</td>
<td>549.94±3.62b</td>
<td>320.08±2.14c</td>
<td>229.86±1.51b</td>
<td>383.75±1.64c</td>
<td>63.67±3.77c</td>
<td>4.82±0.04b</td>
<td>76.50±1.24ab</td>
</tr>
<tr>
<td>Khai</td>
<td>325.33±6.67a</td>
<td>193.72±4.41a</td>
<td>131.61±2.29a</td>
<td>239.00±2.75a</td>
<td>45.28±1.83b</td>
<td>4.95±0.04c</td>
<td>75.17±0.03a</td>
</tr>
<tr>
<td>Hom</td>
<td>538.98±10.67b</td>
<td>228.00±0.14b</td>
<td>310.97±10.82c</td>
<td>264.17±2.16b</td>
<td>36.17±2.05a</td>
<td>4.53±0.00a</td>
<td>77.23±0.46b</td>
</tr>
</tbody>
</table>

Remark: The alphabets indicate the difference of statistical analysis between samples.