

Compositions, Morphological and Thermal Properties of Green Banana Flour and Starch

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ABSTRACT

Banana (*Musa* sp.) is cheap and has been grown in most parts of Thailand. In its green stage, banana contains mainly carbohydrate especially starch; therefore, it is suited to use as the source of starch and flour. Banana flours and starches were investigated by using 3 Thai banana cultivars *Musa* (AA) sp. (Kluai Khai; KH), *Musa* (AAA) sp. (Kluai Hom Tong; HT), and *Musa* (ABB) sp. (Kluai Namwa; NW). Banana flours obtained from dried pulp, which were milled and sieved. Then banana flour (F) was used for starch isolation by using 0.05N NaOH. The KHF, HTF and NWF had yielded 48.12%, 56.50%, and 54.50% (based on whole fresh fruit), respectively. Banana flour had yielded starch (S) as followed, 30.37% (KHS; AA group), 29.67% (HTS; AAA group) and 33.18% (NWS; ABB group) ($p>0.05$) respectively. The chemical compositions of flours (protein, fat, and ash) were higher than those of starches as well as they were varied among cultivars. Morphology of banana starches, determined by scanning electron microscope (SEM), had smooth surface and irregular in size and shape (round, long and oblong). The pasting curves obtained by RVA of green banana flours were lower than those of green banana starches of the same varieties. The gelatinization temperature ranges obtained from differential scanning calorimetry (DSC) were 73.96-86.18°C and 70.70-81.50°C for flours and starches respectively.

Key words: banana; flour; starch; compositions; thermal properties

INTRODUCTION

Bananas (*Musa* sp.), important food crops following rice and tapioca are grown extensively in many parts of Thailand. They were produced around 2.0 million MT in 2005 that was ranked in the ninth of the worldwide top ten producer (FAO, 2005). This fruit contains high amount of sugar and is very perishable during ripening process so that there are many discarded fruits. Green bananas have a large amount of starch during its unripe stage, which consists of around

20-25% found in the pulp of the fruits (Cordenunsi and Lajolo, 1995). The banana starch might be able to use as substitution of other starches such as potato, corn and wheat. However, the banana starch is not popularly used because lack of the researches carried out on its properties. (Kayisu *et al.*, 1980 ; Lii *et al.*, 1982; Bello-Perez *et al.*, 1999) From the previous experiments, there were differences among the results due to varieties of banana species; banana's ripening stage as well as the isolation method of starches.

Starch, one of the principal and important constituents in plant materials, is usually in fruits as in the form of granules, partially crystalline. The morphologies, chemical compositions and the molecular structures of starches are unique for each particular plant species (French, 1984), particularly in their quantitative and qualitative nature as well as some of the physicochemical properties. Furthermore the methods of starch isolation could have impact on their chemical compositions as well as properties. The objectives of this study were to produce banana flour and starch, and to determine chemical composition, morphological and thermal properties of flour and starch obtained from three varieties of Thai banana cultivars (Kluai Khuai (AA group), Kluai Hom tong (AAA group), and Kluai Nam Wa (ABB group).

MATERIALS AND METHODS

Raw materials

Unripened bananas, obtained from a local market (Talad Thai), were collected at the 115th day after anthesis. The fruits had green peel and sharp edges. Bananas used for starch isolation was at the first stage of ripening process as described by Von Loesecke (1950).

Starch isolation method

Bananas were peeled and sliced into small pieces (0.5-1 cm. thick), placed in aluminum trays and dried by using hot air oven at 50°C for about 5 hrs. Dried banana slices were dry milled and passed through 100-mesh sieved. The sequences of the starch isolation were shown in Figure 1

Composition analysis

Moisture, protein, fat and ash content of three cultivars of banana flours and starches were determined by AOAC methods (AOAC, 2002).

Morphology of Thai banana varieties

Scanning electron micrographs were obtained from Scanning Electron Microscope (SEM-JSM-5600 LV, JEOL, Japan)

Pasting properties

Pasting properties of banana flour and starch were measured by using Rapid Visco Analyzer (RVA) by modified AACC method (AACC, 2000).

Sample 2.5 g (10 % w/w dry basis) were suspended in 25 ml distilled water and heated from 50 to 95°C, held at 95°C for 6 min, then cooled from 95°C to 50°C and held at 50°C for 9 min. Pasting parameters were automatically computed and reported.

Thermal properties

Thermal properties of banana starches and flours were determined by using Differential Scanning Calorimetry (DSC; Pyris Perkin-Elmer, USA) and followed method as modification from Paredes-Lopez *et al.* (1994).

Samples (7-8 mg dry basis) were placed in a stainless pan at room temperature (20°C) and added 15 mg of deionized water to get 70% moisture content and sealed in the sample pan press. The sealed pan was left still for 1 hr. at room temperature to allow complete starch hydration. Then, the pan with the sample was placed in the calorimeter and heated from 10 to 130°C (the heating rate was 10°C/min). An empty pan was used as a reference.

Statistical analysis

The statistical analysis was performed using single factor analysis of variance (ANOVA) for all data and analyzed by the SPSS for Windows program, version 11.5. Comparisons of means were carried out by Duncan's multiple range test (DMRT) at the 5% significance level.

RESULTS AND DISCUSSIONS

Compositions of banana flour and starch

Due to the differences of flour and starch characteristics among three cultivars of Thai banana, Kluai Khai (KH), Kluai Hom Tong (HT), and Kluai Nam Wa (NW) were determined for their chemical compositions.

Dried basis yield recovery (from whole fresh fruit) of Kluai Khai flour (KHF), Kluai Hom

Tong flour (HTF) and Kluai Namwa flour (NWF) was 48.12%, 56.50% and 54.50%, respectively. Then starch was isolated and the yield recovery of Kluai Khai starch (KHS), Kluai Hom Tong starch (HTS), and Kluai NamWa starch (NWS) were 30.37%, 29.67% and 33.18%, respectively (based on flour dried basis). Other compositions of all Thai banana cultivars have shown in Table 1 and 2.

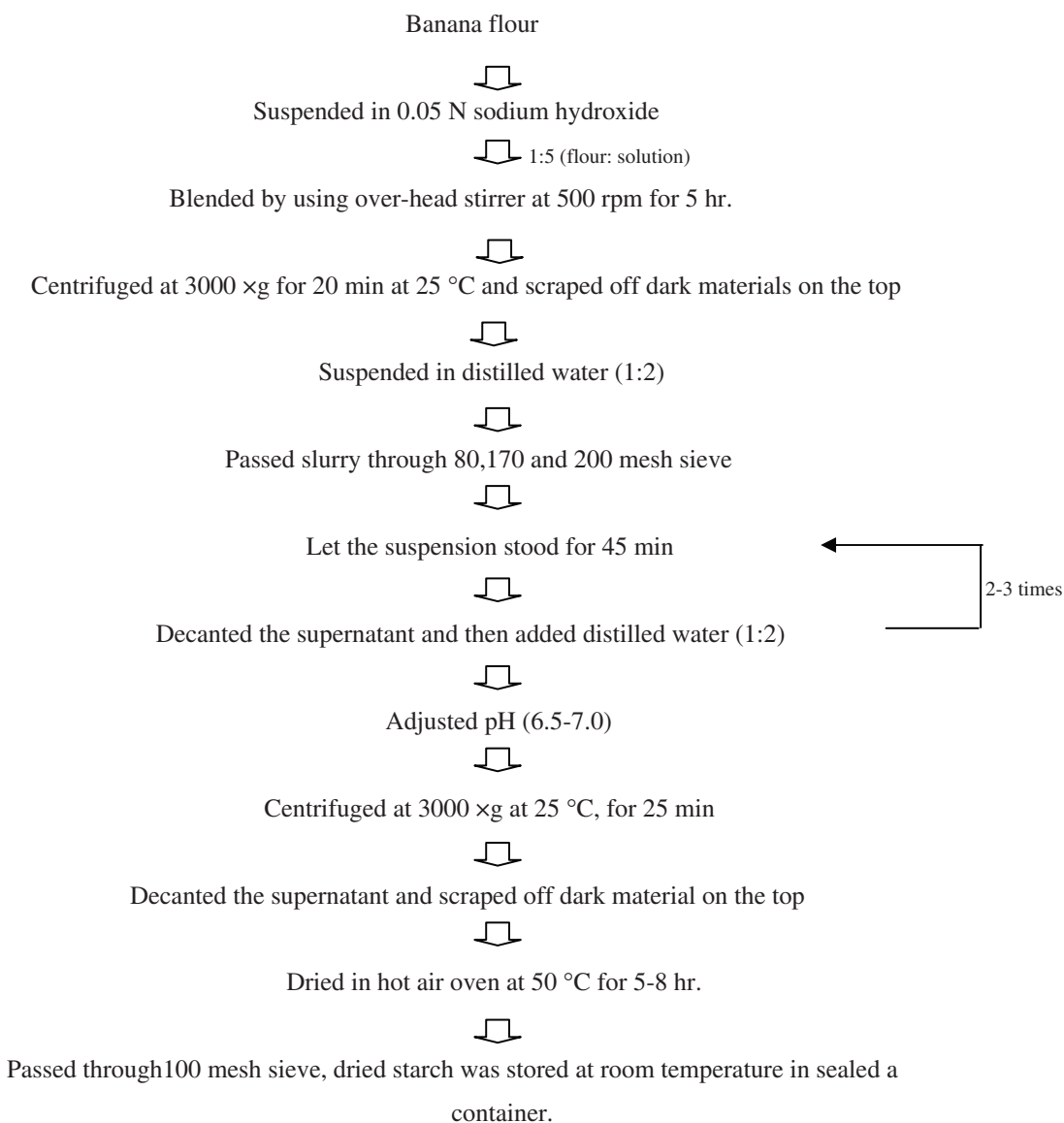


Figure 1 Banana starch isolation method.

Table 1 Compositions of Thai banana flours.

Varieties ¹	Composition (% dry basis) ²			
	Moisture	Protein(N*6.25)	Fat	Ash
KHF	6.55 ± 0.170a	4.37 ± 0.099b	1.56 ± 0.032a	2.40 ± 0.812a
HTF	6.84 ± 0.273a	4.47 ± 0.461b	4.88 ± 0.198c	4.44 ± 0.322c
NWF	6.88 ± 0.310a	1.88 ± 0.107a	2.15 ± 0.078b	3.82 ± 0.756b

¹ KH, HT, and NW mean for Kluai Khai, Hom tong, and Namwa, respectively² All compositions were averaged of two analyzed from each three replicates.^{a-b} Different letters in the same column indicated statistical difference ($p \leq 0.05$)**Table 2** Compositions of Thai banana starches.

Varieties ¹	Composition (% dry basis) ²				
	Moisture	Protein(N*6.25)	Fat	Ash	Amylose
KHS	7.83±0.042b	0.17±0.002a	0.03 ±0.001a	0.05±0.045a	20.32±0.368b
HTS	7.40±0.049ab	0.21±0.010a	0.10±0.048ab	0.06±0.037a	13.36±0.714a
NWS	7.16±0.381a	0.20±0.06a	0.12±0.064b	0.05±0.061a	28.03±0.971c

¹ KH, HT, and NW mean for 'Kluai Khai', Hom tong, and Namwa, respectively² All compositions were averaged of two analyzed from each three replicates.^{a-b} Different letters in the same column indicated statistical difference ($p \leq 0.05$)

The purity of banana starches was higher than that of flours. Banana starches consisted of 0.17-0.21% protein, 0.03-0.12% fat and 0.05-0.06% ash; whereas, banana flour contained 1.88-4.47% protein, 1.56-4.88% fat and 2.40-4.44% ash. Waliszewski *et al.* (2003) reported that Macho and Criollo cultivars contained higher protein, fat and ash content. The results of Eggleston *et al.* (1992) also reported the higher protein, fat and ash of Plantain and two cooking banana cultivars. It should be noted that the differences of the chemical composition from the other authors may be due to the different technique of starch isolation, banana cultivars and the cropped location as well.

Morphological properties

Banana flour composed of starch and other components as shown in Figure 2A. Banana starch granules from the three cultivars had irregular shapes and appeared as elongated oval. Granules of HTS (AAA cultivar) had longer elongated sides; whereas KHS (AA) had much more oval granules than the others as shown in Figure 2B and 2C. These variations of banana

starch granules could affect to the other properties such as swelling power, viscosity or gelatinization temperature. From our experiment, the sizes of banana starch granules were different among varieties. The major radius of NWS was around 40-45 μm , while those of HTS and KHS were around 47-60 and 32-55 μm respectively. The granule size of banana starches was bigger than that of cereal starches such as rice starch (3-8 μm), sorghum starch (4-24 μm) and wheat starch (2-38 μm) (Liu, 2005). In Figure 2, the surfaces of green banana starch granules appeared smooth so it could be indicated that the isolation process was efficient and it did not cause damage to starch granules.

Pasting properties

The pasting profiles of banana flours and starches are shown in Figure 3. Each of banana starch had higher peak viscosity than its flour. It may be resulted from other components in flour obstructing swelling of the starch granules. NWS (ABB cultivars) displayed the highest breakdown viscosity (peak viscosity-trough viscosity, $p \leq 0.05$), which may be resulted of its compositions such as

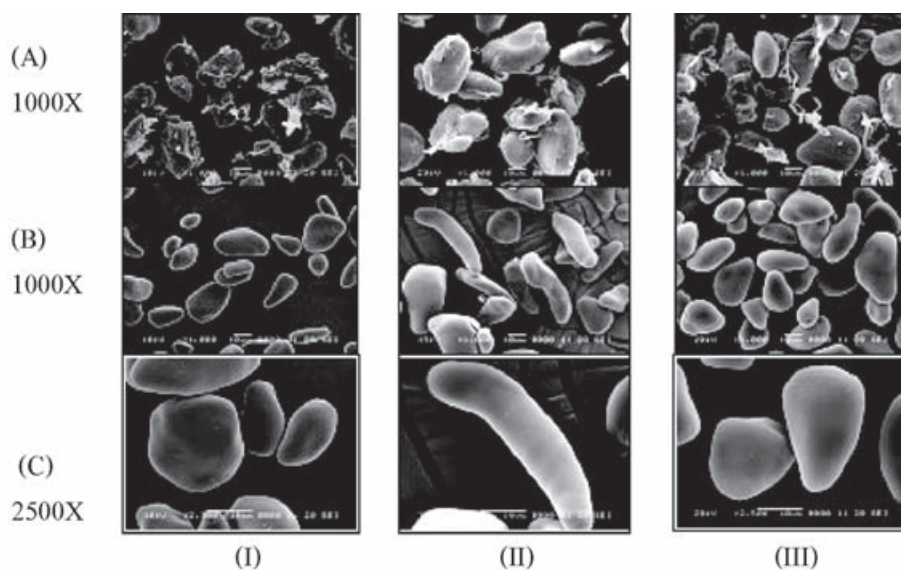


Figure 2 Scanning electron micrographs of Kluai Khai(I) Kluai Hom Tong(II) and Kluai Nam Wa (III) flour (A) and starch (B and C) granules with magnification 1000X and 2,500X.

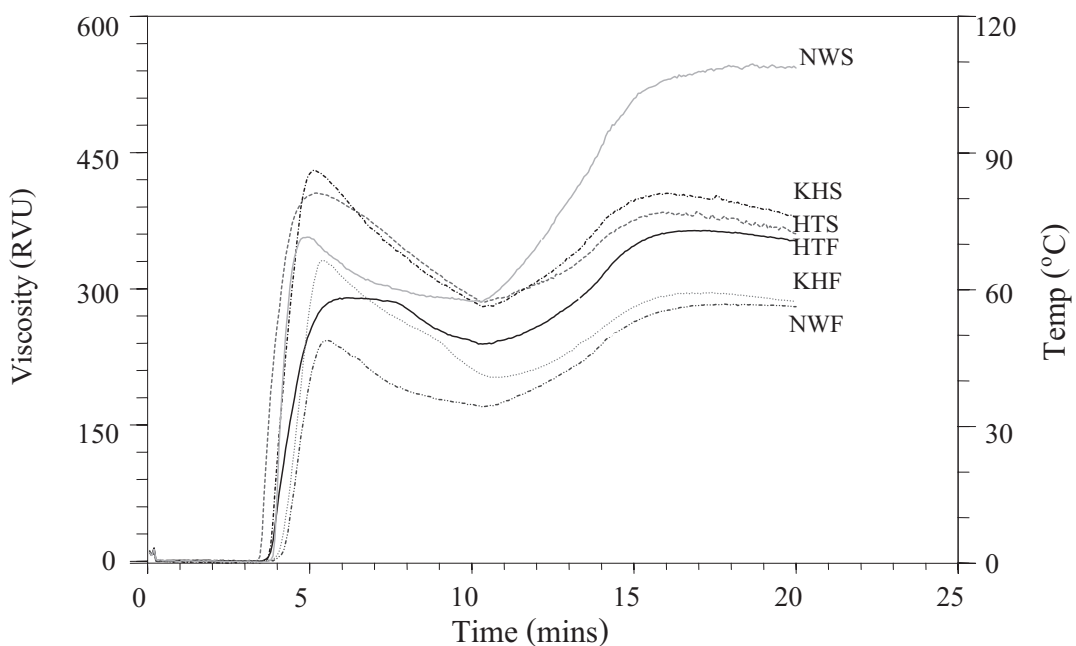


Figure 3 Pasting profiles of banana flours and starches; KHF, HGF, NWF, KHS, HGS and NWS at the concentration of 10% (w/w db).

protein, lipid and amylose content. All samples had high setback during cooling, indicated that they were highly retrograded, which might due to the effect of amylose and amylopectin contents. Since the starch with high amylose could undergo the retrogradation process faster than the starch with low amylose content (Sriroth and Piyachomkwan, 2003). As the result shown, NWS, contained the highest amylose content, had higher setback than HTS and KHS (Figure 3). These profiles could be explained based on molecular characteristics of the starch components such as amylose or lipid contents. Moreover the differences in the size and shape of starch granules could have the effect of starch property. Banana flour and starch showed restricted swelling patterns, similar to Kayisu *et al.* (1981). Peak viscosity, breakdown, setback and final viscosity were in the range of 243.25-320.58 RVU, 115.04-313.83 RVU, 192.12-337.041.92 RVU, and 280.33-344.00 RVU, respectively for a group of flour and were in the range of 356.83-432.54 RVU, 118.20-426.58 RVU, 74.583-396.88 RVU, and 361.12-542.92 RVU, respectively for starch.

Thermal properties

Average DSC gelatinization (onset, T_o ; peak, T_p ; conclusion, T_c) temperature range and enthalpy of gelatinization (ΔH) for all banana flours and starches are given in Table 3. T_o , T_p and T_c among each group of banana flours and starches

were significantly difference. T_o , T_p , T_c of the samples were 73.96-78.70-86.18°C, 73.44-77.21-81.79°C and 76.27-80.35-85.99°C for KHF, HTF, and NWF respectively and were 72.48-75.28-80.24°C, 70.70-73.91-78.20°C, and 73.50-76.54-81.50°C for KHS, HTS, and NWS, respectively. The differences in gelatinization temperature may be attributed to the differences in amylose content, size, form and distribution of starch granules, and also to the internal arrangement of starch fractions within the granules (Singh *et al.*, 2003). The enthalpy of gelatinization (ΔH) for all flours and starches was around 15.16-15.57 and 18.58-19.62 (J/g) respectively. The difference in ΔH reflects melting of amylopectin crystallites. The variations in ΔH of the samples could represent differences in bonding forces between the double helices that form amylopectin crystallites, resulting in different alignment of hydrogen bonds within starch molecules. (McPherson and Jane, 1999).

CONCLUSION

HTF had the greatest yield (56.50%) among banana flours. Banana starches can be produced by isolated with alkaline method and NWS gave the highest yield (33.18%). Protein, fat, and ash contents of banana flour were lower than those of starches. The amylose contents of KHS, HTS and NWS were 20.32, 13.36 and 28.03% respectively. Starch granules had smooth

Table 3 Thermal properties of banana flour and starch.

sample	Gelatinization temperature(°C)			Enthalpy ΔH (J/g)
	T_o	T_p	T_c	
KHF	73.96 ± 0.827 c	78.70 ± 0.973 d	86.18 ± 1.762 d	15.16 ± 1.489 a
HTF	73.44 ± 0.483 c	77.21 ± 0.894 c	81.79 ± 1.298 c	15.92 ± 1.016 ab
NWF	76.27 ± 0.120 d	80.35 ± 0.239 e	85.99 ± 0.430 d	15.54 ± 1.652 ab
KHS	72.48 ± 0.563 b	75.28 ± 0.502 b	80.24 ± 0.696 b	18.58 ± 2.496 abc
HTS	70.70 ± 0.117 a	73.91 ± 0.196 a	78.20 ± 0.323 a	18.84 ± 2.582 bc
NWS	73.50 ± 0.484 c	76.54 ± 0.641 c	81.50 ± 0.837 bc	19.62 ± 3.015 c

a-f Different letters in the same column indicated statistical difference ($p \leq 0.05$)

* Values are means of at least four determinations ± Standard deviation

surfaces, irregular in size and shape that exhibited round, long and oblong. Peak viscosity, breakdown, setback and final viscosity of banana flours and starches were in range 243.25-432.54 RVU, 115.04-426.58 RVU, 192.12-396.88 RVU, and 280.33-542.92 RVU, respectively. The gelatinization range of KHF, HTF and NWF were 73.91-86.18, 73.44-81.79 and 76.27-85.99°C and that of KHS, HTS and NWS were 72.48-80.24, 70.70-78.20 and 73.50-81.50°C correspondingly. The enthalpy changes of flours were lower than those of starches.

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