

Research Article

Effect of Heat Moisture Treatment on Functional Properties and Microstructural Profiles of Sweet Potato Flour

Widya Dwi Rukmi Putri, Elok Zubaidah and Dian Widya Ningtyas

Department of Agricultural Product Technology, Faculty of Agricultural Technology,
Brawijaya University, Veteran Street, Malang, Indonesia

Abstract: Heat moisture treatment is the physical method of modification to give sweet potato flour desired physical properties for application in the manufacture of flour based products. Two varieties of sweet potato flour were characterized to understand the changes of physicochemical properties and micro-structural profile upon heat moisture treatment. Sweet potato flours were analyzed its pasting properties, crystallinity characteristics and starch granule structure by using Rapid Visco Analyzer, X-ray Diffraction and Scanning Electron Microscopy, respectively. The results indicated that the heat moisture treatment affected characteristics of all sweet potato flour were treated at, moderate and high temperature. There were a decreasing in peak viscosity and an increase in cold paste viscosity following heat-moisture treatment compare to native sweet potato. The changes differ between yellow sweet potato and purple sweet potato. This indicates that different starches may respond differently to physical modification. The diffractograph of flour samples showed the main peak mainly in 15°, 16°, 17°, 22° and 23°, that correspond to the spacing-d in 5, 8, 5, 3, 4, 9 and 3, 8 Å, respectively. This reflection indicates the presence of a A-type crystalline.

Keywords: Heat moisture treatment, modified sweet potato flour, starch granule structure, thermal property

INTRODUCTION

Indonesia is the number four of sweet potatoes producer in the world. The production of sweet potato is quite high from total production of sweet potatoes at 1.76 million tones, 89% are used for the consumption while the rest of 18,000 tons are used as fodder and 161.000 tones are discarded. In order to improve the utilization of sweet potato, it is necessary to attempt processing of sweet potato into flour or starch. Despite being rich in starch, sweet potato has remained underutilized, though flour from this crop could be used in different industrial applications. The sweet potato flour is one of the promising substitutes for wheat and rice flour in many types of food production. The sweet potato is relatively easy to grow and high productivity (Chen, 2003), its has high starch content (6.9-30.7%) in which amylose content is 8.5-38% depending on variety.

Sweet potato starch, like other root crop starches such as cassava, potato and arrow root, is considered more free swelling and exhibits a type A Brabender amylograph. Type A amylograph is characterized by a high pasting peak followed by rapid and major thinning on cooling (Mweta *et al.*, 2008). These characteristics limit the utilization of sweet potato starch in food

industry, therefore the characteristics need to be modified. Physical modification of starch is achieved without the use of chemicals. There are two types of physical modifications: pre-gelatinization and heat moisture treatment. Pre-gelatinized starch is starch that has been gelatinized and then dried. Pre-gelatinization methods include roll drying, extrusion and spray drying. Pre-gelatinized starches are used as thickeners in foods that require minimal heating. Two types of heat-moisture treatments exist are heat-moisture and annealing. Heat-moisture treatment involves heating starch at above its gelatinization temperatures but with insufficient moisture levels (<35%) to cause gelatinization, while annealing involves heating starch in excess water (>60%) for prolonged periods but at temperatures below gelatinization (Shandu and Singh, 2007; Shin *et al.*, 2005). Both annealing and heat-moisture treatment have been shown to change functional properties of native starches. Annealing and heat-moisture treatment decreased swelling and solubility of red sorghum starch but increased water absorption capacity and pasting temperature of the starch (Adebowale *et al.*, 2005; Zhang *et al.*, 2002). Physical modifications can also change structural, thermal and pasting properties of starch. Sandhu and Singh (2007) also found a decrease in peak viscosity

Corresponding Author: W.D.R. Putri, Department of Agricultural Product Technology, Faculty of Agricultural Technology, Brawijaya University, Veteran Street, Malang, 65145, Indonesia, Tel.: +62-341-569214; Fax: +62-341-580106

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and an increase in cold paste viscosity following heat-moisture treatment of sweet potato starches. This indicates that different starches may respond differently to physical modification.

Heat moisture treatment is generally carried out on starch. Considering the current importance of sweet potato flour as raw materials for many food industries in Indonesia, this study evaluated the effect of heat moisture treatment on sweet potato flour characteristics. In this study heat moisture treatments were applied at low temperature in order to maintain its functional properties, i.e., anthocyanins contained in purple sweet potato and carotenes in yellow sweet potato. The effects of starch origin and modified method on swelling power, solubility, pasting and micro-structural properties were systemically investigated.

MATERIALS AND METHODS

Raw materials: Two varieties of sweet potato were used in this study, *Ase jantan* (yellow sweet potato) and *Ayamurasaki* (purple sweet potato). After harvest, two fresh roots selected from a pooled sample of the three replicates for each varieties were analyzed. Sweet potato flour production was carried out using a method described by Chen (2003). Sweet potato roots were washed thoroughly, peeled, sliced into thin chips (1-1.5 mm), blanched for 5 min and dried at 60°C for 12 h, then processed into 100-mesh flour and modified by heat moisture treatment. Native sweet potato flour was made by drying the flour in a cabinet dryer at 60°C for 12 h.

Starch modification of sweet potato flour: Sweet potato flours was adjusted to 30% moisture by addition of distilled water and equilibrated at 5°C overnight (refrigerated condition). The moisture adjusted samples were placed in foil covered baking pans and heated in a DV600 oven for 3 and 6 h at 50 and 77°C. Modified flour samples were then cooled to room temperature and dried at 50°C in an oven, equilibrated for 5 h and sealed in polyethylene bags (Hoover, 2000).

Physicochemical characteristics of flours: The amylose contents were measured by iodine affinity method (Knutson, 1986). Swelling power and solubility of the flours was determined according to Chen (2003) by dispersing 0.5 of flour samples in 15 mL of distilled water in a pre-weighed centrifuged tube and the suspension was heated at 85°C for 30 min with continuous stirring to avoid precipitate formation. The cool paste was centrifuged at 2250 g for 20 min and the supernatant was recovered. The supernatant was evaporated overnight at 100°C for 8 h and weighed. The relationship between the dried supernatant weight and the initial flour dry weight was used to calculate the solubility. The sediment was weighed and the swelling

power was determined as the ratio of weight of sediment to dry weight of flour solidified by swelling (g/g).

Structural and pasting properties determination:

The crystallinity pattern of flour were analyzed using X-ray diffraction (Shimadzu X-ray diffractometer XRD-6000). Pasting characteristics (10% w/dry weight) was measured using Brabender amilograph (Visco amilograph RV model, Wingather V2.5, Brookfield Engineering Laboratories).

Scanning Electron Microscope (SEM) observation:

Starch granule characteristics were obtained with Scanning Electron Microscope Hitachi Model S-800. Native and treated sweet potato flour were sprinkled onto double-sided cellophane tape attached to aluminum stubs. These samples were then coated with 25 nm of gold-palladium (60:40) at 10 milliamps for 3 min (Hummer Sputter Coater, Techincs EMS, Inc, VA). Samples were examined at 10.0 kV.

RESULTS AND DISCUSSION

Effect of heat moisture treatment on physicochemical properties of sweet potato flour:

The amylose content, swelling power and solubility of two varieties of sweet potato flour are presented in Table 1. It was observed that there were no significant differences on amylose contents. This results were in line with previous findings by Shin *et al.* (2005) and Srichuwong *et al.* (2005). Other researchers, Hoover (2000) who working on cocoyam, cassava, oat and potato starches, also found no changes in the physicochemical properties of these starches after heat moisture treatments. There were no chemical reactions because heat moisture treatment is a physical treatment.

Swelling power of all treated flours showed a similar pattern as the solubility. The purple sweet potato flour (*Ayamurasaki* variety) had higher swelling power than yellow sweet potato flour (*Ase* variety). The

Table 1: Effect of HMT on characteristics of sweet potato flour

Components	Amylose content (%)	Swelling power (g/g)	Solubility (%)
Ase (Yellow sweet potato)			
• Native flour	16.93	7.78c	44.40b
• 50°C, 3 h	16.90	7.32bc	42.62b
• 50°C, 6 h	16.64	6.77b	37.18a
• 77°C, 3 h	16.38	5.86ab	35.30a
• 77°C, 6 h	16.20	4.96a	34.46a
Ayamurasaki (purple sweet potato)			
• Native flour	11.21	8.47b	44.28b
• 50°C, 3 h	11.21	7.67b	42.64b
• 50°C, 6 h	11.59	6.33ab	40.86ab
• 77°C, 3 h	11.73	6.25ab	40.12a
• 77°C, 6 h	11.86	5.98a	39.75a

Data were collected from three replicates; Means of each properties followed by same letter are not significantly different $p < 0.05$

Table 2: Effect of heat moisture treatment on X-ray crystallinity of sweet potato flour

Flour samples	Integrated intensities with interplanar spacings (d) in Å				
	15°	16°	17°	22°	23°
Ase (yellow sweet potato)					
• Native flour	3940 (5.7)	0	6023 (5.1)	0	7840 (3.8)
• 50°C, 3 h	5044 (5.8)	0	5494 (5.2)	0	0
• 50°C, 6 h	5058 (5.8)	0	11832 (5.0)	0	9438 (3.8)
• 77°C, 3 h	5349 (5.7)	0	11562 (5.0)	0	6751 (3.8)
• 77°C, 6 h	4902 (5.7)	0	10406 (5.1)	0	9165 (3.8)
Ayamurasaki (purple sweet potato)					
• Native flour	4904 (5.8)	0	17418 (4.9)	0	9606 (3.9)
• 50°C, 3 h	1152 (5.9)	2758 (5.4)	0	0	1608 (3.8)
• 50°C, 6 h	4034 (5.8)	0	7635 (4.9)	0	5586 (3.7)
• 77°C, 3 h	5696 (5.8)	7573 (5.2)	8347 (4.9)	8361 (3.9)	3665 (3.7)
• 77°C, 6 h	4187 (5.8)	5701 (5.3)	0	9092 (3.9)	0

Data were collected from two replicates

Table 3: Effect of HMT on pasting properties of two varieties of sweet potato

Flours samples	Peak viscosity (cP)	Paste viscosity (cP)	Breakdown (cP)	Final viscosity (cP)	Setback (cP)	Pasting temp. (°C)
Ase (yellow sweet potato)						
• Native flour	326.40	128.00	198.40	588.80	262.40	80.8
• 50°C, 6 h	236.80	108.80	128.00	416.00	179.20	92.5
• 50°C, 9 h	217.60	96.00	121.60	377.60	160.00	93.1
• 77°C, 6 h	140.80	64.00	76.80	288.00	147.20	93.7
• 77°C, 9 h	89.60	25.60	64.00	185.60	96.00	94.2
Ayamurasaki (purple sweet potato)						
• Native flour	160.00	57.60	102.40	326.00	166.00	80.1
• 50°C, 6 h	108.80	38.40	70.40	262.40	153.60	83.5
• 50°C, 9 h	160.00	32.00	128.00	358.40	198.40	83.7
• 77°C, 6 h	294.40	51.20	243.20	531.20	236.80	83.5
• 77°C, 9 h	211.20	25.60	185.60	428.80	217.60	80.0

Data were collected from two replicates

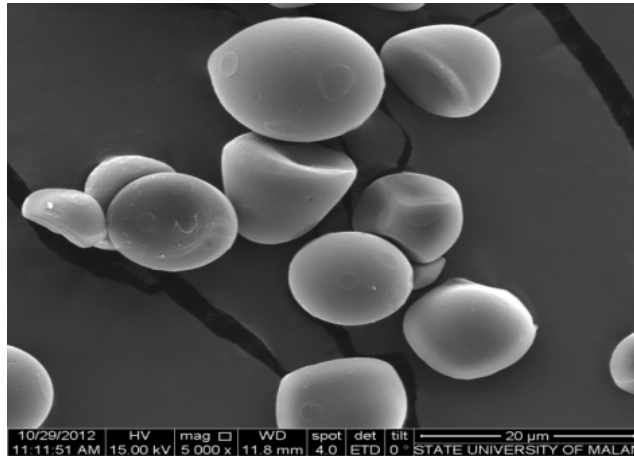
diversity of swelling power might be attributed to starch granules changes, rearrangement of amylose-amylopectin and other components relationship after heat moisture treatments. The swelling and solubility behavior indicated differences on the capacity of sweet potatoes flour to hold water through hydrogen bonding. High temperature and time length of heat moisture treatment affected their abilities, whereas heat processing below the gelatinization temperature did not much influence and had similar swelling power and solubility with native flour. The previous researcher, Adebowale *et al.* (2005) also showed that annealing and heat-moisture treatment decreased swelling and solubility of red sorghum starch but increased water absorption capacity and pasting temperature of the starch.

X-ray diffraction pattern: The diffraction pattern of flour samples showed the main peak mainly in 15°, 16°, 17°, 22° and 23°, that correspond to the spacing-d in 5, 8, 5, 1, 4, 9 and 3, 8 Angstroms (Å), respectively. Even though there were no modification in X-ray pattern of the sweet potato flours, but each variety presented different changing in the diffraction intensity (Table 2). Yellow sweet potato flours showed increasing intensity in 17° and 5,1 Å, inversely purple sweet potato decreased its diffraction intensity. Heat moisture treatments affected the molecular association of sweet potato flour components i.e., starch, protein, fiber and other minor substances. The crystallinity of starch as

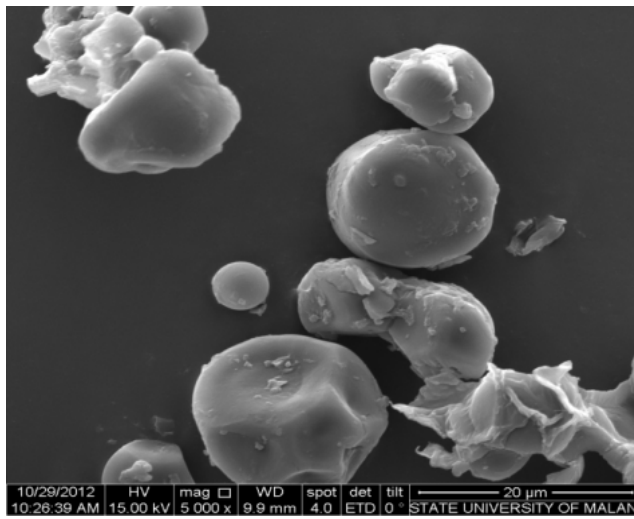
the highest compound influenced the physical characteristics and pasting properties of flour. Thus, different structure of starch granules would varied the crystallinity of flour.

Starch from different botanical sources can possess A-, B- or C-type X-ray diffraction pattern (Hoover, 2000; Mweta *et al.*, 2008; Putri *et al.*, 2011). Generally, cereal starches give A patterns, tubers yield B patterns and certain root and seed starches give C patterns (Zobel, 1988). Distinguishing features of each type as follows: A shows three strong peaks at 5, 8, 5, 2 and 3, 8 Å, B shows a peak at 12, 8-16 Å and C is the same as A except for the addition of the medium to strong peak at about 16,0 Å. Thus, all flour samples in this present study gave the strongest and broadest diffraction peak centered at an angle of $2\theta = 5.4-5.6$ Å. This reflection indicates the presence of a A-type crystalline nature, the same pattern shown by Srichuwong *et al.* (2005) and Tsakama *et al.* (2011).

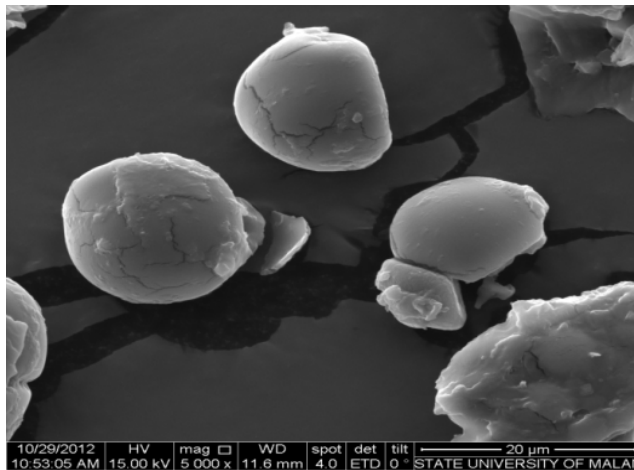
Pasting properties of sweet potato flour: Native flour reached the peak viscosity in a shorter times while the viscosity value was higher than another samples (Table 3). The yellow flour treated by highest temperature of HMT showed reduction of peak viscosity, inversely purple sweet potato flour tend to increase the peak viscosity. Heat moisture treatment increased the pasting temperature of the flours This was assumed that both amylose and amylopectin were differently attacked by heat treatment at higher



(a)



(b)



(c)

Fig. 1: (a) SEM photograph of starch granule from purple sweet potato native starch, (b) sweet potato flour without HMT and (c) HMT treated of sweet potato flour at 77°C for 6 h

temperature for long time. This recent study was in line with Adebowale *et al.* (2005), who showed that native flour presented strong connections among the molecules of flour taking them to get more stable conformation, leading to amylose having a smaller tendency to leaching out from granules. Heat easily attacks the amorphous regions of granules reducing the molecular mass of amylose and amylopectin molecules, which confirms the high solubility found for the modified flours. Pasting properties of the modified flours from the two varieties varied and showed significant differences between treatments. The presence of non-starch components is widely reported to influence the swelling and pasting properties of starch (Srichuwong *et al.*, 2005) A change was observed in the pasting profile of the starches exposed to heat-moisture treatment from type A to type C. Type C profile is characterized by no pasting peak, but rather a high viscosity which remains constant or increases during cooling.

Microscopy of sweet potato flour: SEM observation showed that after heat moisture treatment of the sweet potato flour, the starch granules had a different morphological appearance compare to native starch granules as determined in Fig. 1. Most of the sweet potato starch granules were polygonal in shape, as also shown by Chen (2003) however round and elongated truncated granules were also found within the sweet potato starch flours. It has been proven that heat moisture treatments influence the structure and starch granules porosity. Although their gelatinization properties did not much affected, the physical characteristic of starch granules could modify the dough's thermo mechanical properties of sweet potato flour.

CONCLUSION

Results of this study have indicated differences on physical characteristic of sweet potato flours with different temperature of heat moisture treatments. Higher temperature and longer heat moisture treatment were able to degrade and influenced peak viscosity and final viscosity within samples. This changes could be also attributed to different crystallinity and granule structures of starch. Enhancement of crystallinity after hydrothermal treatments limited starch swelling and amount of amylose leaching into the medium. Temperature exerted a change on the swelling capacity and solubility of the starch.

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