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EFFECT OF PROCESSING ON CASSAVA STARCH QUALITY: 1. DRYING

Abstract

The long-term outlook for cassava starch is uncertain, this is despite the economic advantage afforded to this product by recent decline in cassava price. The problems are due to a restricted portfolio of functional properties coupled with a final product that is variable in-terms of its quality. The quality of extracted cassava starch is dependent on many factors, especially processing. One key problem area is that of drying the dewatered cake. In this study, it was shown that the properties of dried starch were different to those of its non-dried counterpart (cake). After drying swelling power and solubility decreased, these changes were in-line with those exhibited by heat-moisture treated starch prepared by incubating 25% moistened starch at 100°C for 16 hr. Dried starch had higher peak temperature than its original cake but lower pasting temperature, which contrasted to the effect of heat-moisture treatment. Dried starch from moist cake had a broader endothermic peak indicated by a larger gelatinization temperature range and lower peak height index, similar to heat-moisture treated starch. Despite apparent changes in functional properties during drying of cassava starch, the cause of the change is not entirely known. Generally, changes reflect a hybrid of heat-moisture treatment and hydrothermal effect.

Introduction

Starch, unmodified as well as modified, has many properties that collectively contribute to its usefulness in a wide range of food and non-food products. The world market for starch destined for industrial use is continuously on the increase. This trend occurs despite the restricted range of crops from which starch is extracted on a commercial basis. The most important crops are potato, corn, wheat and tapioca. Corn is the main source of starch; of the total world starch production, about 83% is derived

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from corn, 7% from wheat, 6% from potato and 4% from cassava [6]. The dominant position of cornstarch is a reflection of the cost advantages of this crop. However, given the ready availability of cheap cornstarch, products are often adapted to facilitate incorporation of this starch in their formulation. The range of functional properties provided by cornstarch is on the increase as genetically modified corns are developed with specific functionality, and advances are made in starch modification technology. Cornstarch technology is therefore at state of technological sophistication whereby the starch is tailored to the needs of the product rather than the product to the starch. The cornstarch industry has also responded to the need by the user industries for a high, consistent quality product.

The cassava starch industry, in contrast, has not invested in variety development or modification for improved starch functionality. Globally, this industry is still struggling to deal with problems of starch quality variability. Given the chemical composition of cassava root, starch from this source should be more pure than cornstarch. Unfortunately, this is not necessarily the case. Further, the lack of by-products is an impediment to further income generation by the industry.

The portfolio of functional properties (quality) of cassava starch is highly variable between batches. Starch quality is influenced by many factors starting with the process of starch synthesis during plant and root development through to inconsistencies in the starch extraction process. In terms of starch properties, there is a substantial G by E effect. The main environmental effects being mediated by duration of plant growth are the rainfall immediately before harvest. Environmental effects are expressed by differences in the structural and the physicochemical properties of the starch granules deposited in roots [1, 12, 13, 16, 17]. Fluctuation in soil temperature also causes an alteration in starch properties [2, 7]. During the manufacturing process, mechanical grinding of fresh roots can lead to damage of starch granules and subsequent changes in water interactions and enzyme susceptibility. Extraction processes employing sulphur dioxide also lead to alteration in the granule stability [18].

Modification of the granular structure and property of starch can occur, accidentally or intentionally, during processing. In the starch extraction process the final stage is potentially problematic in terms of altering starch quality. The combination of high temperature and moisture can precipitate structural changes in the architecture of starch granules, known as "hydrothermal" treatment [5]. Starch granules in excess water, when subjected to sufficient heating, swell irreversibly becoming water-soluble. This process is associated with a loss of granule integrity and birefringence, a process known as gelatinization. Two further thermal treatments, heating an aqueous suspension of starch granules at a temperature below that at which gelatinization occurs ("annealing" treatment) or heating moistened starch (water content less than 30%) at a higher temperature than that at which gelatinization occurs ("heat-moisture" treat-

ment), do not result in complete loss of starch structure (starch gelatinization). Annealed and heat-moisture treated starch remains as discrete granules that are water-insoluble. Yet, modification of the granule structure and associated properties are evident. Annealed starch is characterized by an alleviate gelatinization temperature and reduced gelatinization temperature range [19]. Heat-moisture treatment also alters both structural and physicochemical properties of starch granules [4, 9, 11].

Extraction of cassava starch involves a dewatering stage consisting of a horizontal centrifugal basket running at a low speed of 800 to 900 rpm. Discharged starch cake is of high moisture content (35–40%; [16, 17]). Final moisture reduction of the moistened cake occurs in a flash dryer. Temperature fluctuation of the flash dryer occurs, often in the range 160 to 180°C. Given the profound influence of heat and moisture on the starch granule structure, inconsistencies at the drying stage could be a responsible for some of the quality variability in the final product. Strategies for eradicating this variability could involve either improvement in the dewatering process such that the final cake has lower moisture content or improvements to the heating system.

This study is part of a larger project that is investigating the influence of processing on starch quality. This paper reports on an investigation to probe the effect of commercial drying on cassava starch properties. Quality of starch cake, before and after factory drying and at different levels of cake moisture, was investigated. Comparison was also made with heat-moisture treated starch.

Materials and methods

Drying process

A cassava starch factory situated close to a cassava-producing region in the Northeastern part of Thailand was chosen for the study. The factory selected had a production capacity of 200 tons cassava starch per day. No sulphur dioxide was used in the extraction process. Eight sets of locally-made dewatering centrifuges were installed to reduce starch cake moisture. Each centrifuge had a discharge capacity of 239.0±23 kg cake/cycle (10 minutes). Feeding rate of the cake to dryer was 8 tons dry solid/hr. Starch cake was dried in a flash dryer at a temperature of 170°C. Sampling was as a pair of cake and its starch after drying. Time interval for sampling between cake in the feeder and dried starch from cyclone was determined by the dryer manufacturer to be about 10 second after feeding.

Heat-moisture treatment in laboratory

Cassava starch was extracted, in water, from fresh cassava roots and dried at 50°C. After sieving through a 90-μm screen, moisture was adjusted to 25% moisture content and samples were equilibrated overnight. One hundred grams of moistened

starch sealed in bottles was subjected to 100°C in hot air oven for 16 hours [5]. After treatment, samples were unsealed, dried at 50°C and kept in cool place.

Analytical methods

Moisture content of samples was determined by drying at 105°C to constant weight [3]. Starch content was determined by a polarimetry method [3]. Paste viscosity properties were investigated by a Rapid Visco Analyzer (RVA 4, Newport Scientific, Australia) according to Sriroth et al. [18]. Thermal analysis was determined by Differential Scanning Calorimeter (Perkin Elmer DSC 7, Norwalk, CT;). The peak height index (PHI) is reported as the ratio of enthalpy (ΔH) and the difference between peak and onset temperature (T_p-T_o) [10]. Swelling power and solubility at 85°C followed the method of Schoch [14]. Degree of hydrolysis of samples was measured using α-amylase and amyloglucosidase, following the method of Wang *et al.* [20]. Reducing sugar was analyzed using Somogyi-Nelson method [15] and total sugars by the method of Dubois et al. [8].

All data was statistically analyzed at 95% confidence level by Completely Randomized Design (STATGRAPHICS Plus Version 3.0, USA).

Results and discussion

Heat-moisture treatment is believed to cause changes to the physical order within starch granules. These changes do not affect the morphology of the granule visually but influence starch properties. Heat moisture treated samples, compared to native starch, have higher gelatinization temperature, lower peak viscosity but higher cold paste viscosity. Solubility and swelling power are lower [5, 9]. Alteration in the physical properties of cassava starch occurs when starch is moistened (25% moisture content) and kept under controlled heating conditions that are higher than the gelatinization temperature (>66°C). After subjecting cassava starch to heat-moisture treatment, solubility and swelling power were lower. This is similar to the response of wheat and potato starches, to similar treatment. Gelatinization endortherms of heat moisture treated cassava starch are broader; this is because of the final peak temperature is elevated. Despite extension of the final peak temperature enthalpy of gelatinization was lower and hence PHI (Table 1). Change in the RVA paste viscosity profile of treated cassava starch is also evident. On heat-moisture treatment, starch paste viscosity was significantly decreased; peak viscosity of untreated and treated starch were 368 and 304 RVU, respectively. Yet, paste stability during heating was increased, indicated by starch paste breakdown from 234 RVU for untreated starch to only 95 RVU for treated starch. Cold paste viscosity of treated starch was improved; final viscosity of untreated and treated starch was 205 and 330 RVU, respectively (Table 1). Change in paste vis-

cosity of heat-moisture treated cassava starch was similar to those reported in a previous study by Abraham (1993). The susceptibility of heat-moisture treated starch to enzymatic hydrolysis was also lower (Table 1).

Table 1

Change in starch property by heat-moisture treatment*.

Property**	Native starch	Heat-moisture treated starch
Swelling power at 85°C	26.33	21.99
% Solubilty at 85°C	48.71[a]	20.79[b]
Gelatinization		
- Onset temperature (°C)	65.85[b]	72.18[a]
- Peak temperature (°C)	70.95[b]	78.63[a]
- Gelatinization temperature range (°C)	10.19	12.91
- Peak height index (PHI)	2.94[a]	1.48[b]
- Enthalpy (J/g)	15.00[a]	9.52[b]
Paste viscosity		
- Pasting temperature (°C)	72.90[b]	81.33[a]
- Peak viscosity (RVU)	368[a]	304[b]
- Trough viscosity (RVU)	135[b]	209[a]
- Final viscosity (RVU)	205[b]	330[a]
- Breakdown (RVU)	234[a]	95[b]
- Setback (RVU)	71[b]	121[a]
Degree of hydrolysis (%)	41.65[a]	33.63[b]

*Moistened starch (25% moisture content) was kept with completely sealed at 100°C for 16 hr.
**Values in each row with different letters are significantly different at $p < 0.05$.

Table 2

Swelling power* and %solubility*, at 85°C, of cassava starch obtained from cakes with different moisture contents after flash drying in cassava starch factory.

Moisture content of cake** (%)	Swelling power		%Solubility	
	Cake	Starch	Cake	Starch
30.1-33.0	58.08[a]	44.75[b]	31.47[a]	28.04[b]
33.1-36.0	60.67[a]	44.79[b]	26.82[a]	23.59[b]
36.1-39.0	63.93[a]	45.03[b]	25.92[a]	21.21[b]
39.1-44.0	65.30[a]	46.12[b]	27.67[a]	24.23[b]

*Values in each row with different letters are significantly different at $p < 0.05$.
**$n = 31$.

In a cassava starch factory, hydrothermal induced changes may take place between the point at which moistened starch exits the dewatering centrifuge and the flash

dryer. The present study 73 sample pairs (cake and dry starch) were investigated for signs of heat-moisture treatment that may have occurred during the drying process. Care was taken to ensure that samples were only collected when the dryer temperature was around 172±2.0°C. The moisture of the cake varied from 30 to 44% and could be categorized into 4 levels including low moisture cake (30.1 to 33.0%), medium moisture cake (33.1 to 36.0%), high moisture cake (36.1 to 39.0%) and very high moisture cake (39.1 to 44.0%). Moisture of the dried starch samples was 10.90±0.96% and starch content was 97.97±0.82% for cake and dried starch. Changes in starch properties due to possible hydrothermal effects were evident (Table 2 to 4); these changes were expressed for certain starch properties and were dependent on cake moisture content. The changes were similar to those seen in heat-moisture treated starch produced in the laboratory. Dried starch from the cakes of different moisture content had significantly reduced swelling power (Table 2, Figure 1). Peak viscosity of dried starch was also significantly different comparable to its original cake (except the low moisture cake, Table 3). Surprisingly, viscosity change of dried starch from the factory was incompatible with the heat-moisture treated starch previously observed in the laboratory.

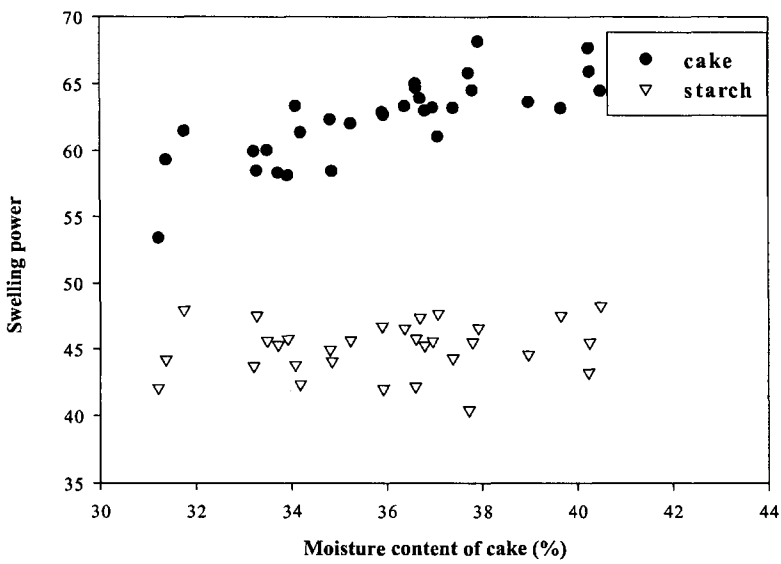

Fig. 1. Swelling power of starch cakes with different moisture contents and their equivalent dried starch samples collected from cassava starch factories.

Heat treatment of moistened starch cake in the factory produced dried starch with increased peak and cold paste viscosity; the changes are not as clear as those found for swelling power (Figure 2), but still significantly different. In contrast, to the laboratory

results, dried starch from all moisture cakes exhibited a significant reduction in pasting temperature (Table 3). Changes in gelatinization of the cake and its equivalent starch were also evident. In accordance with pasting temperature, heat treatment resulted in a lower gelatinization temperature of dried starch relative to its original cake (Figure 3). Dried starch collected from the factory also had lower enthalpy than its original cake (Figure 4). The endothermic peak of gelatinzation of dried starch was broader but of lower peak height than that of its original cake; the PHI of dried starch was thus lower than that of the cake (Table 4). Presumably, heat treatment during drying induces structural changes in starch granules thus affecting their gelatinization process.

Table 3

Paste viscosity* of cassava starch obtained from cakes with different moisture contents after flash drying in cassava starch factory.

Moisture content of cake** (%)	Peak viscosity (RVU)		Final viscosity (RVU)		Breakdown*** (RVU)		Pasting temperature (°C)	
	Cake	Starch	Cake	Starch	Cake	Starch	Cake	Starch
30.1-33.0	394	393	217	223	240	239	69.60^{a}	68.71^{b}
33.1-36.0	390^{b}	397^{a}	227	231	240	243	68.74^{a}	68.17^{b}
36.1-39.0	387^{b}	400^{a}	220^{b}	229^{a}	242	247	68.68^{a}	68.05^{b}
39.1-44.0	375^{b}	393^{a}	215	221	234	242	68.69^{a}	67.97^{b}

*Values in each row with different letters are significantly different at $p < 0.05$.
**n = 73.
***Breakdown = Peak viscosity – Trough viscosity

Table 4

Thermal analysis* of cassava starch obtained from cakes with different moisture contents after flash drying in cassava starch factoreis.

Moisture content of cake** (%)	Onset temperature (°C)		Temperature range*** (°C)		Enthalpy (J/g)		Peak height index***	
	Cake	Starch	Cake	Starch	Cake	Starch	Cake	Starch
30.1-33.0	61.00	60.39	11.03	12.19	14.58	12.21	2.66	2.01
33.1-36.0	60.97	60.29	10.24	10.67	13.42	12.66	2.70^{a}	2.39^{b}
36.1-39.0	60.92^{a}	60.43^{b}	9.24	10.42	14.30^{a}	12.45^{b}	3.13^{a}	2.40^{b}
39.1-44.0	60.72	60.48	9.87	9.45	13.91	12.15	2.84	2.59

*Values in each row with different letters are significantly different at $p < 0.05$.
**n = 21.
*** Temperature range is reported as the difference between the final and onset temperature; peak height index (PHI) is reported as the ratio of enthalpy (ΔH) and the difference between peak and onset temperature (T_p-T_o).

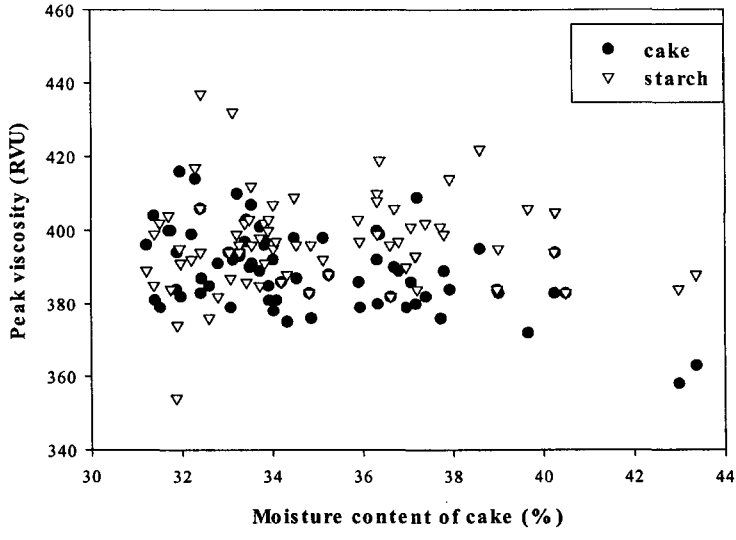

Fig. 2. Peak viscosity (RVU), as determined by a Rapid Visco Analyzer, of starch cakes with different moisture contents and their equivalent dried starch samples collected from cassava starch factories.

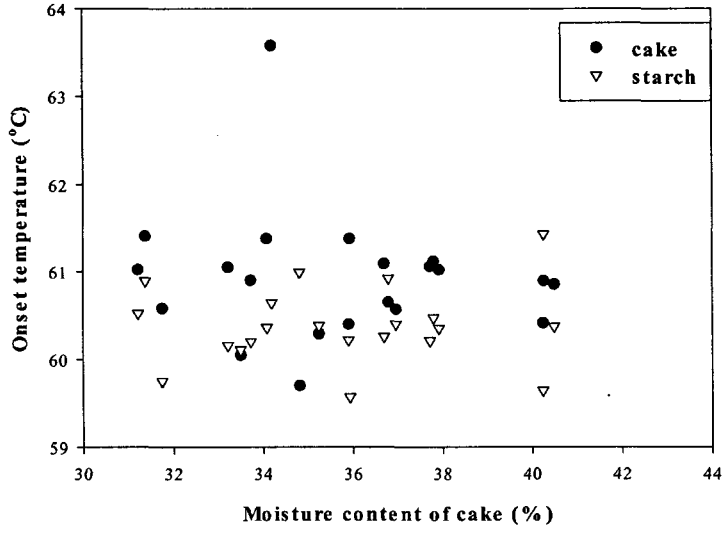

Fig. 3. Onset temperature (°C), as determined by Differential Scanning Calorimeter, of starch cakes with different moisture contents and their equivalent dried starch samples collected from cassava starch factories.

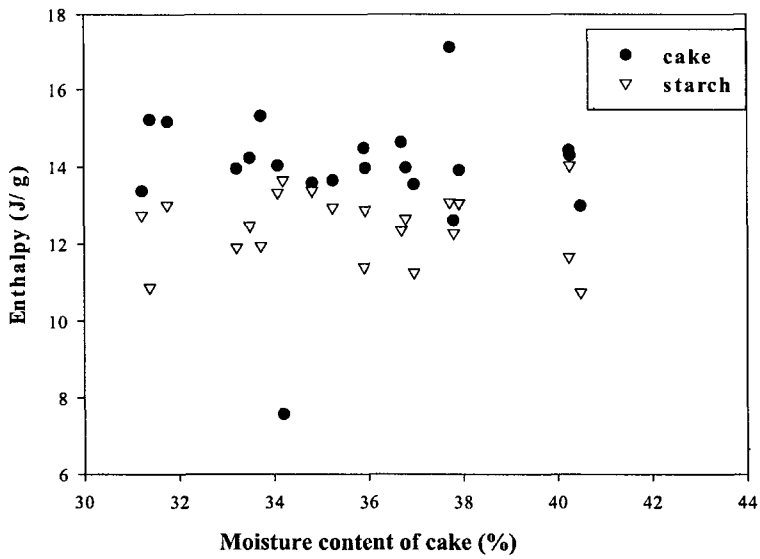

Fig. 4. Enthalpy (J/g), as determined by Differential Scanning Calorimeter, of starch cakes with different moisture contents and their equivalent dried starch samples collected from cassava starch factories.

Conclusion

Drying is a critical step in the starch extraction process and may account for final product quality inconsistency. In addition to the physical process of drying, when starch cake with 30-44% moisture content is subjected to heat treatment changes in some of the functional properties occurs. Yet, the apparent direction and magnitude of these changes, during drying, of cassava starch are not in agreement with the effects of heat-moisture treatment. It is suggested that cassava starch dried under factory conditions may undergo some form of hydrothermal treatment, which leads to alteration in the functional properties of the starch.

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WPŁYW OBRÓBKI NA JAKOŚĆ SKROBI TAPIOKOWEJ: 1. SUSZENIE

Streszczenie

Z powodu obniżenia ceny na skrobię tapiokową, długoterminowe prognozy dla tej skrobi są niepewne mimo wielu jej zalet. Wynika to z ograniczonej liczby istotnych właściwości funkcjonalnych tej skrobi i ich niekorzystnych zmian w trakcie przechowywania.

Jakość ekstrahowanej skrobi tapiokowej zależy od wielu czynników, przede wszystkim od sposobu jej wydzielania. Kluczowym problemem jest suszenie odwodnionego placka skrobiowego. W niniejszych badaniach pokazano, że właściwości skrobi suszonej i nie suszonej (placka) różniły się od siebie. Po suszeniu malała zdolność pęcznienia i rozpuszczalność. Zmiany te były liniowe względem zmian zachodzących w trakcie przechowywania skrobi zawierającej 25% wilgoci, w 100°C, przez 16 godzin. Odwrotnie niż w przypadku obróbki temperaturowej wilgotnej skrobi, skrobia suszona miała wyższą temperaturę w punkcie maksimum lepkości i równocześnie niższą temperaturę kleikowania, niż skrobia otrzymana z placka. Skrobia z placka wykazywała szerszy pik endotermiczny wskazujący na szerszy zakres temperaturowy kleikowania. Równocześnie pik ten był niższy, w czym skrobia ta przypominała produkt z termicznej obróbki wilgotnej skrobi. Nie wiadomo co jest przyczyną zaobserwowanych zmian.