International Food Research Journal 20(5): 2273-2277 (2013)
Journal homepage: http://www.ifrj.upm.edu.my

Comparative studies of the functional and physico-chemical properties of isolated Cassava, Cocoyam and Breadfruit starches

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Article history

Received: 2 June 2012
Received in revised form: 22 March 2013
Accepted: 28 March 2013

Keywords

Starch
Physico-chemical properties
Swelling power
Cassava

Abstract

Starches were isolated from cassava, cocoyam and breadfruit by wet milling process. The physicochemical, functional and pasting characteristics of the isolated starches were then examined and compared. Moisture and fat contents varied between 4.91 – 12.94% and 0.90 – 2.20% respectively. Bulk density and pH ranged between 0.64 – 0.68 and 5.53 – 6.15, respectively. Cassava and breadfruit starches exhibited higher water absorption capacity (1.03 and 1.02 g water/g sample, respectively) than breadfruit starch (0.71 g water/g sample) while all the starch samples absorbed almost equal weights of oil. The swelling power was found to increase with increasing temperature with cassava starch exhibiting highest swelling power (2.70 – 5.25) between 60-80°C and breadfruit starch showing the greatest tendency to swell (10.80) at 90°C, respectively. Cassava and breadfruit starches formed stable and firm gels at 8% w/v starch concentrations while cocoyam starch was able to form a gel at 10% starch concentration. The pasting temperatures of 63, 74 and 66°C and peak viscosities of 400, 860 and 960 BU were obtained for cassava, cocoyam and breadfruit starches respectively. The lowest setback viscosity was recorded for cocoyam starch while cassava starch demonstrated the greatest stability towards retrogradation. The starches could find suitable applications in various food products owing to the differences in their physicochemical properties.

Introduction

Starch contributes greatly to the textural properties of various foods and has many industrial applications as a thickener, colloidal, stabilizer, gelling agent, bulking agent, water retention agent and adhesive (Singh *et al*., 2003). The most important sources of starch are cereal grains, such as corn, wheat and rice, and tubers, such as potato and cassava (Betancur-Ancona, 2001). Nigeria is by far the world's largest producer of cassava, its production is currently estimated at about 49 million tons a year (Kolawole and Agbetoye, 2007) almost 19% of total world production (UNCTAD, 2012). However, despite the high production level, supply has not matched demand; this is because cassava serves both as a staple and an industrial raw material (Nweke, 2004). There is therefore need to expand the production of other carbohydrate-rich crops to provide for an alternative substitute of cassava in food and industry (Nwokocha *et al*., 2009). Cocoyam (*Colocasia* species) and Breadfruit (*Artocarpus altilis*) are tropical root crop and fruit, respectively with great potentials for starch production. The suitability of starch from these sources as substitutes for cassava starch will largely depend on their functional and physico-chemical properties. This work aimed at investigating and comparing the functional and physicochemical properties of starches isolated from cocoyam and breadfruit to that obtained from cassava starch.

Materials and Methods

Starch isolation

Starches were isolated separately from cassava, cocoyam, and breadfruit by a modified method of Perez *et al*. (1998) The cleaned roots and fruits were peeled, weighed, sliced and ground for 5 min in a milling machine (Stephan Universal Machine, Germany) with small volumes of distilled water. The homogenates were mixed with distilled water [homogenate: water (1:5)] and then sieved through a separator (Sweco Separator, Sweco Europe S.A. Nivelles, Bel.). The resultant slurries were allowed to settle for eight hours except for breadfruit slurry which was allowed to settle for only three hours before the supernatant was decanted. The sediments were washed several times by re-suspending in distilled water and precipitating until the mash appeared to be free of non-starch material. The starch mash was dried at 50°C. The starch samples were packed in

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polythene bags and stored at room temperature for further use.

Chemical analysis

Nitrogen, crude lipids and moisture contents of samples were determined by standard procedures AOAC (1990). Protein content was calculated as nitrogen x 6.25

Physico-chemical properties

Bulk density, pH and least gelation capacity

Bulk density was determined according to the method described by Okaka and Potter (1979). A 15 g sample was put into a 100 mL graduated cylinder. The cylinder was tapped forty (40) times and the bulk density was calculated as weight per unit volume (g/cm^3). The pH was determined by Okezie and Bello (1988) method while the method of Coffman and Garcia (1977) was employed in the determination of least gelling concentration.

Water and oil absorption capacities

Water and oil absorption capacities of the starch samples were determined by a modification of the centrifugal method described by Beuchat (1977). Briefly, a 5 g gram sample was transferred into a weighed centrifuge tube and 30 ml of distilled water / oil was added. The starch and water / oil were mixed thoroughly for 30 sec and the suspension was allowed a 10 min rest. The suspension was then centrifuged (MSE, Harrier 15/80) at 3500 × g for 25 min. The supernatant was decanted, and the tubes were allowed to drain at a 45º angle and subsequently weighed. Water / oil absorption was expressed as gram water / oil absorbed per gram sample

Solubility and swelling power

Solubility and swelling power were determined on starch samples at 60, 70, 80 and 90°C using a modified version of the method of Sathe and Salunkle (1981). Briefly, 40 ml of 1% starch suspension (w/v) was prepared in a previously tarred, 50 ml centrifuge tube. The tube was slowly shaken to keep the starch agitated and the temperature (60, 70, 80 and 90°C) was maintained constantly in water bath for 30 min. The suspension was then centrifuged at 3500 G for 20 min, the supernatant decanted and the swollen granules weighed. From the supernatant, 10 ml were dried in an air convention oven at 120^{o}C for 4hrs in a crucible to constant weight. Swelling power was expressed as the weight of swollen granules (final weight) divided by the initial weight. Percentage solubility was calculated thus:

$$\% \text{ Solubility} = (\text{dry wt. at } 120^oC / \text{sample wt.}) \times 100$$

Pasting characteristics

The pasting characteristics of starch samples were evaluated using a Brabender Visco-Amylograph (Brabender OHG, Germany). Flour slurry, containing 12% solids (w/w, dry basis), was heated from 30 to 95°C at a rate of 2.5°C/min, held at 95°C for 15 minutes, and cooled at the same rate to 50°C (Shuey and Tipples, 1982). The pasting performance was automatically recorded on the graduated sheet of the amylogram. The pasting temperatures, peak viscosities, viscosity at 95°C, stability, cooking times and setback viscosities were read off the amylograph.

Statistical analysis

All experiments were conducted in triplicate. Data reported are averages of three determinations. One-way ANOVA with Turkey`s post test procedures of GraphPad Prism version 4.00 for Windows (GraphPad Software, San Diego California USA) was employed.

Results and Discussion

Chemical composition

Table 1 shows the chemical composition of cassava, cocoyam and breadfruit starches. The moisture content ranged between 4.91% and 12.94%. The highest moisture content was obtained in cassava starch while the lowest was obtained in cocoyam starch. Statistical analysis showed that there was no significant difference ($p < 0.05$) between the moisture contents obtained from cassava and breadfruit starches. The variation in moisture content may be attributed to the differences in the method of starch isolation and the amount of water that exists as bound or free water. The values obtained for moisture content of cassava and breadfruit in this study were comparable with the value (12.7%) reported by Torruco-Uco and Betancur-Ancona (2007) for cassava but were higher than the value (3.07%) obtained for Phaseolus vulgaris L. starch by Sathe and Saluunkhe (1981). Cassava starch exhibited the highest fat content of 2.20% while breadfruit starch showed the lowest value of 0.90%. These values were considered high when compared to fat contents of other starches such as makal starch (1.0%) and corn starch (0.4%).

Physico-functional properties

The results of bulk density and pH as well as

Table1. Chemical composition

	Cassava starch	Cocoyam starch	Breadfruit starch
Moisture (%)	12.94 ± 0.07^a	10.91 ± 0.10^b	12.79 ± 0.23^a
Fat (%)	2.20 ± 0.10^a	1.60 ± 0.05^b	0.90 ± 0.13^c
Protein (%)	3.03 ± 0.12^a	2.08 ± 0.04^b	1.23 ± 0.09^c

Table 2. Physico-functional properties

	Cassava starch	Cocoyam starch	Breadfruit starch
Bulk density (w/v)	0.64^a ± 0.02	0.68^b ± 0.13	0.68^b ± 0.07
pH	5.82^a ± 0.09	6.15^b ± 0.21	5.53^a ± 0.05
Water absorption (g water/g sample)	1.03^b ± 0.04	1.02^b ± 0.08	0.71^a ± 0.17
Oil absorption (g oil/g sample)	1.12^C ± 0.11	0.94^a ± 0.06	1.00^b ± 0.03

Table 3. Gelation concentration of the starch samples

Concentration (%)	Cassava starch	Cocoyam starch	Breadfruit starch
4	-	-	-
6	-	-	-
8	Gel	-	Gel
10	Gel	Gel	Gel
12	Gel	Gel	Gel
14	Gel	Gel	Gel
16	Gel	Gel	Gel
18	Gel	Gel	Gel
20	Gel	Gel	Gel

functional properties (oil absorption, water absorption and swelling capacity) of cassava, cocoyam and breadfruit starches are presented in Table 2. The bulk density varied between 0.64 – 0.68 with cassava starch exhibiting the lowest bulk density (0.64) while the bulk densities of both cocoyam and breadfruit starches were the same (0.68). The higher the bulk density the greater the quantity of material that can be packaged within a specified packaging space (Fagbemi, 1999). According to Peleg and Bagley (1983) bulk density depends on the combined effects of interrelated factors such as the intensity of attractive inter-particle forces, particle size, and number of contact points. The pH values varied between 5.53 – 6.15 which indicated that all the starch samples were acidic in aqueous solution. The pH values of starch in water are important since some functional properties such as swelling, solubility, etc are affected by pH changes (Lawal, 2004). There were significant differences in the abilities of the starch samples to absorb water at their natural pH and room temperature (29°C). The water absorption capacity ranged between 0.71 – 1.03 g water/g sample. Breadfruit starch demonstrated the lowest hydrophilic tendency when compared with either cassava or cocoyam starch which did not show any significant differences in water absorption capacity. The ability of starch to absorb water is

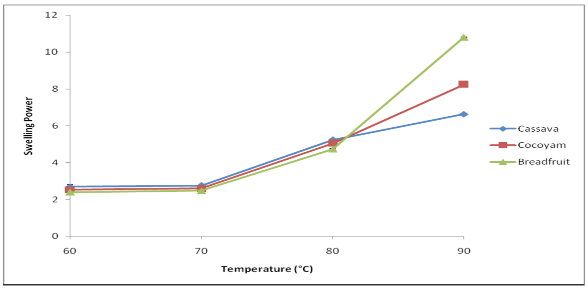

Figure 1. Effects of temperature on swelling power

desirable in food systems to improve yield and consistency and give body to the food. The starches exhibited high oil absorption capacity absorbing almost the same weight of oil as their weights. The results are in agreement with previous studies where native cocoyam absorbed approximately 95% oil as reported by Lawal (2004). The results of gelation are presented in Table 3. The formation of stable gels occurred at 8% (w/v) starch concentration for both cassava and breadfruit starches while cocoyam formed a stable gel only at 10%. This implies that cassava and breadfruit starches are likely to perform better as gelling agents than cocoyam starch.

Effect of temperature on swelling power and solubility

The swelling power of starch samples increased as the temperature increased (Figure 1). This result agrees with the observation of Hoover *et al.* (1996) for Mucuna beans starches and Adebowale and Lawal (2002). The swelling power of all the starches increased slowly between 60-70°C. The increments were rapid between 70-80°C and more rapid as the temperature increased to 90°C for cassava, cocoyam, and breadfruit starches. Cassava starch exhibited the highest swelling power between 60-80°C (2.70-5.25 g/g), but at 90°C, breadfruit starch recorded the highest swelling power of 10.80 g/g. The values (2.40-10.80 g/g starch) obtained for swelling power of cassava in this study were considerably lower than the values of 58.8 and 16.76 g/g starch reported by Betancur-Ancona *et al.* (2001) for cassava and corn starches, respectively. Swelling power has been related to the associative binding within the starch granules and apparently, the strength and character of the micellar network is related to the amylose content of starch, low amylose content produces high swelling power (Wooton and Tumaalii, 1984; Akanbi *et al.*, 2009). This study suggests that the starches may serve as useful ingredients in such products like baked goods, baby food, sauces, retorted canned foods where high temperature is required for processing.

The solubility of all the starches increased significantly with increase in temperature from 60-90°C. The solubility varied between 10 - 46.7% with

Table 4. Pasting characteristics of cassava, cocoyam and breadfruit starches

	Cassava starch	Cocoyam starch	Breadfruit starch
Pasting temperature (°C)	63	74	66
Peak viscosity (BU)	400	860	960
Viscosity at 95°C (BU)	240	840	560
Viscosity at 95°C for 15 min (BU)	170	680	500
Viscosity at 50°C	200	1020	280
Breakdown (BU)[a]	230	140	460
Consistency (BU)	-200	160	-580
Setback (BU)	30	340	-280

[a] Breakdown: peak viscosity (BU) – viscosity at 95°C after 15 min holding
Consistency: viscosity at 50°C (BU).- peak viscosity (BU)
Setback: viscosity at 50°C (BU) – viscosity at 95°C for 15 min (BU)

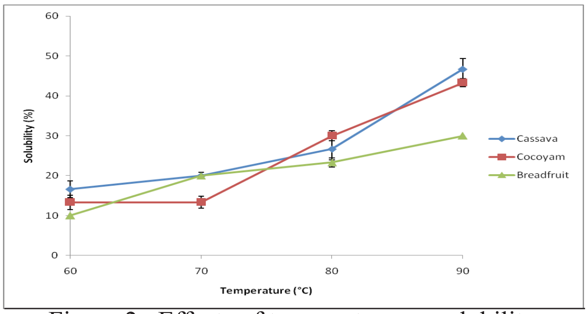

Figure 2. Effects of temperature on solubility

cassava starch exhibiting the highest solubility at all the temperatures. This was followed by cocoyam starch with solubility ranging between 13.3 – 43.3%. Gujska *et al.* (1994) reported a notable increase in solubility for pinto, navy bean and field pea starches, beginning at 70°C, because the swollen starch granules allow amylose exudation. The present studies also demonstrated significant increases in solubility of cassava, cocoyam and breadfruit starches starting from 60°C. The solubility values for cocoyam and breadfruit starches obtained in the present studies were higher than those of cassava starch (15.8%) and corn starch (15.8%) (Betancur-Ancona *et al*., 2001). Solubility increased as the temperature increased because of increase in mobility of the starch granules, which facilitated enhanced dispersion of starch molecules in water (Adebowale *et al*., 2005)

Pasting properties

The results of pasting properties of the starch samples are presented in Table 4. The pasting temperatures ranged between 63 – 74°C with cocoyam starch exhibiting the highest and cassava starch the lowest. The pasting temperature (66°C) of breadfruit starch was between those of cocoyam and cassava starches. The pasting temperature is a measure of the minimum amount of temperature required to cook a given sample which can as well have implications for the stability of other components in a formula and also indicates the cost of energy. The results show that the ease of cooking in terms of energy requirement increases from cocoyam starch to breadfruit starch and then to cassava starch. The pasting temperatures obtained in this study were within the range of values reported for cassava (69°C) by Torruco-Uco and Betancur-Ancona (2007), breadfruit (64.6°C) by Adebowale *et al.* (2005) and cocoyam (76°C) by Lawal (2004). The breakdown viscosity (BV) which is a measure of the cooked starch to disintegration was found to be lowest for cocoyam starch and highest for breadfruit starch. This implies that cocoyam starch is more stable to heat and mechanical shear than cassava and breadfruit starches. Viscosity at 50°C which indicates the ability of the starch to form a viscous paste ranged from 200 – 1020 BU with cocoyam starch exhibiting the greatest tendency to form a viscous paste. The lowest setback viscosity value (30 BU) obtained for cassava starch suggested stability towards retrogradation tendency. The consistency of cocoyam starch (160 BU) was highest and this implies that cocoyam starch could find useful applications in products requiring high temperatures during processing such as in sauces and baby food. The low retrogradation tendency exhibited by cassava and breadfruit starches makes them potentially useful in products requiring freezing and thawing such as in pie fillings.

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