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Comparative studies of physico-chemical properties of yam (*Discorea rotundata)*, cocoyam (*Collocasia taro*), breadfruit (*Artocapus artilis*) and plantain (*Musa parasidiaca*) instant flours

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Cocoyam, breadfruit and plantain usage is similar to that of white yam. They offer similar and sometimes better nutrition advantage to yam though with less prestigious value. This study is aimed at producing instant flour of yam, cocoyam, breadfruit and plantain and to compare their physico-chemical properties. The instant flours were prepared separately with slight modifications. Proximate analysis, starch, vitamin C, physico-chemical and pasting properties of the flours were determined. Significant differences existed in the protein content of the flours (p<0.05) with cocoyam flour having the highest value (8.9%). The vitamin C contents of the flours ranged from 2.4 to 7.3 mg/100 g. The water binding and swelling capacities ranged 160 to 268 and 2.72 to 3.99%, respectively. While the pasting temperature and peak viscosity ranged from 63 to 93°C and 60 to 400 BU, respectively. The instant flours (*fufu* form) of cocoyam, breadfruit and plantain compared well with that of yam and offer nutritional and economic advantages to both household and industrial production.

Key words: Starch staples, instant flour, nutritional composition, pasting properties.

INTRODUCTION

Yam (*Discorea rotundata* Poi) is an important staple food in many tropical countries (Akanbi et al., 1996). The tuber is a tropical root crop that grows extensively in West Africa and to a lesser extent in other tropical areas (Anon., 2007). The yam tuber is prepared for consumption in a variety of ways including boiling, frying and baking. One of the most important traditional culinary preparations of yam in West Africa is pounded yam (Ihekoronye and Ngoddy, 1985; Asiedu, 1989). Cocoyam, an edible aroid originated in India and South East Asia, is presently cultivated in many tropical and subtropical countries (Anon., 2007; AUSAID, 1995). It belongs to the family *Araceae* that comprises many underground food crops grown in tropical and subtropical countries with taro as one of the most important species (Opara, 2007).

Breadfruit (*Artocarpus altilis*) which belongs to the family of *Moracaera* is a tree and fruit native to the Malary Peninsula and Western pacific Island (Loos et al., 1981). It has been widely planted in the tropical regions including Nigeria. Breadfruit is extremely cheap in Nigeria as two mature fruits each weighing approximately 1.5 kg can be obtained for the equivalent of US 25 cents and can feed four adults (Omobuwajo, 2003). The plantain (*Musa paradisiaca)* resembles banana but are longer in length, have a thicker skin, and contain more starch. They are also a major staple food in Africa, Latin America

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and Asia. They are usually cooked and not eaten raw unless they are very ripe (IITA, 2012). Plantain tend to be firmer and lower in sugar content than the desert banana and are used when green or under ripe (and therefore starchy) or overripe (sweet). It is a staple food in the tropical regions of the world, treated in much the same way as potatoes and with similar neutral flavour and texture when unripe (Elevitch, 2006).

In the growing region, Nigeria for example, cocoyam, breadfruit and plantain usage is similar to that of white yam. They are used in the production of stiff porridge or their instant flours (*fufu)* form which is eaten with soup when yam is not in season or by those who could not afford the price of yam. They offer similar and sometimes better nutrition advantage to yam though, with lesser prestigious value.

There is limited scientific information on the post-harvest characteristics of these starch staples, which perhaps contributes to their very limited application of improved post-harvest technologies to maintain quality and improve marketing potential (Opara, 2007). Therefore, there is need to compare the physico-chemical properties of their instant flours. The objectives of the study were therefore to produce instant flours of yam, cocoyam, breadfruit and plantain and to compare the physico-chemical properties of the flours.

METHODOLOGY

Materials

The materials used for the research include: yam tubers (*D. rotundata*), cocoyam corms (*Colocasia esculenta* or taro), breadfruit (*A. artilis*) and plantain (*M. parasidiaca*). These materials were purchased at a local market in Ile-Ife, Nigeria.

Processing of the instant flours

Yam tubers were peeled, diced into cubes with dimension 1.0×1.5×1.5 cm. They were sulphited with 40 ppm of Na_2SO_3 and washed, steamed for eight minutes and dried in cabinet drier at 60°C for twenty hours. The dried yam cubes were milled with attrition mill and packaged. Cocoyam flour, breadfruit flour and plantain flour were similarly prepared with appropriate modifications according to the method of Oladeji and Akanbi (2011).

Chemical analyses of instant flours

Moisture, protein, crude fat, crude fibre and ash contents of the flours were determined by the standard official methods (AOAC, 1990), while carbohydrate was determined by difference. The starch analysis was done by the modification of Lane and Eynon process (James, 1995). Ascorbic acid was determined by dyestuff titration. Sample (5 g) was digested by 0.4% oxalic acid. The aliquot was titrated against dyestuff, which was previously standardized by standard ascorbic acid solution, and the ascorbic acid content was calculated using the following expression.

$$\text{Vitamin C (mg/100 g} = \frac{\text{Titre} \times 0.606 \times 100}{\text{Wt of sample}} \quad (1)$$

Physicochemical properties

Bulk density

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)

Water binding capacity

Water binding capacity was determined according to the procedure described by Medcalf and Gilles (1965). The sample (2 g) was transferred into a weighed centrifuge tube to which 30 mL of distilled water was added. The bottle was tarred and agitated in a shaker for one hour. It was then centrifuged at 500 rpm for 10 min. The supernatant was decanted immediately and the bottle was tipped up and allowed to drain for 10 mins more. The bottle was weighed and the amount of water held by the flour was determined using the formula:

$$\text{Water binding capacity} = \frac{\text{g bond water} \times 100}{\text{Wt. of the sample (2 g)}} \quad (2)$$

Swelling capacity

The swelling capacity of the samples was determined by modification of Leach et al (1959) method. Each sample (5 g) was dispersed in 40 mL distilled water. The resultant slurry was heated at a temperature of 70°C for thirty minutes in water bath, cooled to room temperature and centrifuged at 2300 rpm for thirty minutes. The supernatant liquid was decanted and the centrifuge tube was placed in a hot air oven to dry for 25 minutes at 50°C. The residue was then weighted (W_2). Centrifuge tubes containing samples alone were weighed prior to adding distilled water (W_1).

$$\text{Swelling capacity} = \frac{\text{W (2g)} - \text{W (g)}}{\text{Wt of sample (g)}} \quad (3)$$

pH value

The pH was measured by preparing 10% (w/vol) suspension of each sample in distilled water; this was achieved by dissolving 10 g of the sample in 100 mL of distilled water. Each sample was mixed thoroughly and filtered. The pH of the filtrate was measured using pH meter (Combo pH and EC, model H19812, Hanna, England.

Pasting characteristics

The pasting characteristics of the flours were evaluated using a Brabender visco-amylograph. Flour slurry, containing 8% solids (w/w, dry basis), was heated from 30 to 90°C at a rate of 1.5°C /min, held at 95°C for 15 min, and cooled at the same rate to 50°C (Shuey and Tripples, 1982). The pasting performance was automatically recorded on the graduated sheet of he amylograph. The pasting temperature, peak viscosities, viscosity at 95°C, stability, cooking time and setback viscosities were read off the amylograph.

Statistical analysis

The sensory and objective data were subjected to analysis of variance to find out whether a significant difference existed between the samples or not. Least significant difference (LSD) test was calculated for the parameters to determine the level of significance

Table 1. Proximate composition of the flours.

Sample	Composition (%)					
	Moisture	Crude protein	Crude Fibre	Crude fat	Ash	Carbohydrate
Yam	5.6±0.40 ^{b}	4.8±0.03 ^{b}	0.2±0.01^{b}	1.0±0.50 ^{b}	1.5±0.00^{c}	87.0
Cocoyam	6.3±0.06^{a}	8.9±0.34^{a}	1.2±0.14^{a}	1.1±0.06^{a}	3.5±0.05^{a}	78.7
Breadfruit	5.6±0.14^{b}	5.7±0.08^{ab}	1.1±0.02^{a}	1.7±0.03^{a}	3.0±0.07 ^{b}	82.9
Plantain	4.9±0.01^{c}	5.1±0.08 ^{b}	1.4±0.01^{a}	1.5±0.03 ^{b}	2.5±0.04 ^{c}	84.7

Values are means of triplicate sample ±SD. Values with different superscript in the same column are significantly different at p<0.05.

Table 2. Starch and ascorbic acid contents of the flours (mg/100 g).

Sample	Composition	
	Starch	Ascorbic Acid
Yam flour	75.3±0.35^{b}	6.1±0.12 ^{b}
Cocoyam flour	78.5±0.70^{a}	2.4±0.95^{c}
Breadfruit flour	69.2±0.28^{c}	7.3±0.51^{a}
Plantain flour	78.3±0.42^{ab}	3.0±0.98^{c}

Values are means of triplicate sample ±SD. Values with different superscript in the same column are significantly different at p<0.05.

at 95% confidence interval as described by Akindele (2004).

RESULTS AND DISCUSSION

Proximate composition of the flours

The proximate compositions of instant flours of yam, cocoyam, breadfruit and plantain (Table 1) show that significant differences existed (p<0.05) in the percentage protein contents of cocoyam flour and that of others, and cocoyam having the highest value (8.9%), followed by breadfruit (5.7%), while yam has the least value of 4.8%. The value obtained for cocoyam was higher than that reported by Ajewole (2004) for *Zanthosoma* variety, due to possible variation in chemical composition of different varieties. Also, a lower value of protein content (3.16%) for yam flour (Amala) was reported by Jimoh and Oatiloye (2009). This may be due to the browning reaction involved in the production of “amala” which did not require any sulphiting to control browning reaction.

Significant differences existed in the ash contents of all the flour samples at p<0.05, with cocoyam having the highest value (3.5%), followed by breadfruit. Though, the ash content of cocoyam was lower than 4.0% reported by Ajewole (2003), that of breadfruit was close to 2.7% reported by Mayaki et al. (2003), the high value of ash recorded for cocoyam and breadfruit is an indication that they are rich in mineral elements. The flours are also rich in crude fibre (0.2 to 1.4%) indicating their usefulness in the production of roughage and bulk and in contributing to a healthy condition of the intestine when consumed (AUSAID, 1995). The range of 1.0 to 1.7% of crude fat recorded for the instant flour is desirable in the products as fat constitutes the largest percentage of calorie needed by the body (Smith and Ojofeitimi, 1995).

Starch and Ascorbic acid contents of instant flours

The starch contents of the flours ranged between 69.2 and 78.5% (Table 2). This is an expected range for starch staples (Smith and Ojofehintimi, 1995). Cocoyam had the highest starch content of 78.5% followed by plantain (78.3%) (Table 2), and breadfruit with the least (69.2%). The starch result of breadfruit was a bit lower than 71.1% which was reported by Mayaki et al. (2003) and higher than 68% reported by Loos et al. (1981). This may be due to difference in preparation operations which may have resulted in greater loss of starch.

Moreover, breadfruit had the highest vitamin C content of 7.3 mg/100g followed by yam 6.1 mg/100 g while cocoyam and plantain were found to be poor in terms of vitamin C content; 2.4 and 3.0 mg/100 g were recorded for cocoyam and plantain flours, respectively. This suggests that plantain and cocoyam are better cooked with their peel to retain their water soluble vitamins such as vitamin C which might have been partially removed with the peels.

Mineral contents of the instant flours

Yam had the highest iron content (2.37 mg/100 g) but its zinc value was the lowest (0.035 mg/100 g) (Table 3). Breadfruit seemed to be richer in mineral elements than cocoyam and plantain from the result in Table 3. The mineral composition of breadfruit however agrees with

Table 3. Mineral elements content (mg/100g) of the flours.

Sample	Calcium	Iron	Magnesium	Zinc
Yam flour	0.015±0.00	2.37±0.39	0.174±0.05	0.035±0.01
Cocoyam Flour	0.044±0.01	0.24±0.11	0.167±0.04	0.057±0.01
Breadfruit flour	0.011±0.00	0.36±0.02	0.332±0.02	0.072±0.02
Plantain Flour	0.055± 0.03	0.21±0.04	0.225± 0.01	0.081± 0.01

Values are means of triplicate sample ± SD.

Table 4. Physicochemical properties of the instant flour samples

Sample	Bulk density (g/ml)	Water Binding Capacity (%)	Swelling Capacity (%)	pH
Yam flour	0.65±0.12[b]	160.2±0.28[b]	2.72±0.04[c]	5.88±0.03[b]
Cocoyam Flour	0.71±0.03[ab]	163.1±0.14[b]	3.89±0.13[b]	5.23±0.01[ab]
Breadfruit flour	0.56±0.14[c]	268.4±0.57[a]	3.99±0.15[a]	5.84±0.07[a]
Plantain Flour	0.71±0.14[ab]	236.4±0.57[ab]	3.22±0.06[c]	5.74±0.03[c]

Values are means of dublicate sample ±SD. Values with different superscript in the same column are significantly different at p<0.05.

the report of Itiola (1991) and that of plantain, though not the same value but followed almost the same trend with the report of Ahenkora et al. (1997).

Physico-chemical properties

Bulk density

The bulk density is generally affected by the particle size and the true density of the matter in flour. Bulk densities of flours from cocoyam and plantain were the same (0.71 g/ml). This value was greater than the bulk densities of yam and breadfruits flours with 0.65 and 0.56 g/ml, respectively (Table 4). This suggests that the particle size of cocoyam and plantain flours are smaller compare to that of yam and breadfruit with breadfruit flour having the biggest particle size. The small particle size of cocoyam flour is in connection with taro's smaller starch grains (1 to 4 µm) compared to the large grain of tannia (17 to 20 µm) (Opara, 2007). He also noted that this makes taro suitable for several products especially as food for potentially allergic infants and persons with gastro intestinal disorder. Bulk density is important for determining package requirement, materials handling, and application in wet processing in the food industry (Kulkarni et al., 1996).

Water binding capacity

Breadfruit flour had the highest water binding capacity, that was comparable ($p<0.05$) to the water binding capacity of plantain flour (Table 4). The reason for high water binding capacity recorded for breadfruit flour would have been due to higher content of undamaged starch granules in the flour (Mayaki et al., 2003). However, there was no significant difference ($p<0.05$) in the water binding capacity of yam and cocoyam flour samples. Little wonder, cocoyam is the closest alternative to yam especially in term of pounding for food. Both the crude fibre content of plantain flour (Table 1) and its starch content (Table 2) were high. The high water binding capacity of plantain may be due to its high crude fibre (Mayaki et al., 2003) and starch contents.

Swelling capacity

The swelling capacity, does not follow the same trend with starch contents of the flours but followed the same trend with the bulk densities (Table 4). This suggests that particle size of the starch granules and damages done to starch by milling operation had great effect on the swelling capacity of the flour. Breadfruit flour has the highest swelling capacity (3.99) followed by cocoyam flour (3.89), while yam flour recorded the lowest value (2.71) and significant differences existed in the swelling capacity of all the flour samples at $p<0.05$.

Pasting performance of instant flours

Amylographic plot generated by computer shows the pasting performance of yam, cocoyam, breadfruit and plantain instant flour samples (Figure 1). The apparent temperatures (Tp) of the flours ranged from (63 to 93°C). Yam and plantain instant flours had the lowest and highest pasting temperatures, respectively (Table 5). The peak viscosities; 150, 60 and 190 BU for cocoyam, bread fruit and plantain, respectively were low compared to that of yam flour (400BU), an indication that the starch

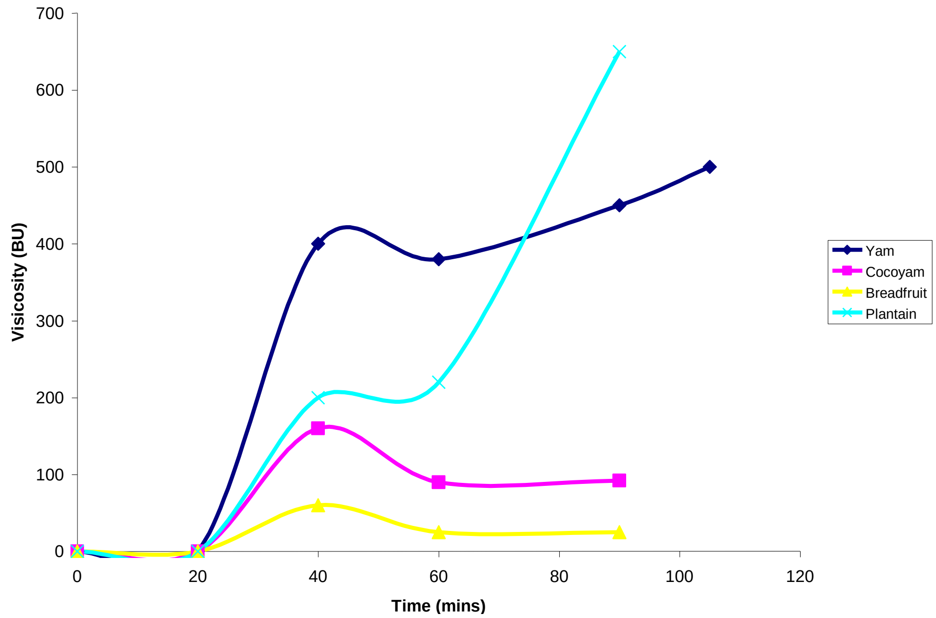

Figure 1. Pasting profile of yam, cocoyam, breadfruit and plantain.

Table 5. Pasting characteristics of the instant flours.

Parameter	Yam flour	Cocoyam flour	Breadfruit flour	Plantain flour
Tp (°C)	63	63	93	81
Mg (Mins)	22	22	42	34
Tvp (°C)	93	93	96	95
Vp (BU)	400	150	60	190
Mn (,in)	42	42	44	42
VI (BU)	390	150	60	190
Vr (BU)	480	80	25	360
Vc (BU)	540	80	20	640
Mn-Mg (Mins)	20	20	2	8
Vp-Vr (BU)	-80	70	35	-170
Vc-Vp (BU)	140	-70	-40	450
Vc-Vr (BU)	60	0	-5	280

Tp, Pasting temperature; Mn, time at peak viscosity; Mg, gelatinization time; VI, viscosity at 95°C; Tvp, peak temperature; Vr, viscotity at 95°C after 15 mins; Vp, peak viscosity; Vc, viscosity at 50°C; Vp-Vr, stability cooking; Vc-Vp, set-back value; Vc-Vr, gelatinization index.

structure of yam flour is stronger than other starch staples (Svanberg, 1987). The lowest peak viscosity recorded for breadfruit flour may be due to its high fat content (Table 1) which might have caused a buffering effect on the gelling properties of its starch (Oluwamukomi et al., 2005).

After a 15 mins hold at 95°C, viscosities of cocoyam and breadfruit flour sample were reduced while that of yam and plantain increased considerably. This is a pointer to stability (Vp -Vr) of cooking cocoyam flour and breadfruit flours seems to be more stable compared to yam and plantain (Table 5). The high Vp reflects fragility of the swollen granules, which first swell and break down under continuous mechanical shearing condition of brabender visco-amylograph (Oluwamukomi et al., 2005). However, when cooled to 50°C, there were significant increases in the viscosities of yam and plantain flours compared to that of cocoyam and breadfruit. On the other hand the low viscosities obtained on cooling cocoyam and breadfruit pastes may be due to early breakdown of their starch structures thereby preventing formation of a stronger cohesive force or network.

Conclusion

The investigation concluded that all the starch staples could be used to produce acceptable instant flour for reconstitution in boiling water and eaten with soup. Though, yam instant flour showed a better pasting performance than others, the pasting characteristics of cocoyam, breadfruit and plantain instant flours compared relatively well with that of yam and can be used in it stead. Not only that they have better nutritional advantage over yam flour, a combination of plantain with either cocoyam or breadfruit will reduce cost of production and improve nutritional qualities of the instant flour samples. The products will still remain cheaper than whole yam flour which will offer an economic advantage
to both industrialists and consumers.

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