African Journal of Food Science Vol. 5(10), pp. 574-579, 30 September, 2011
Available online http://www.academicjournals.org/AJFS
ISSN 1996-0794 ©2011 Academic Journals

Full Length Research Paper

Characterization of prime starches from some plant food crops for industrial exploitations

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Accepted 5 September, 2011

Starches fractionated from red and white cocoyams, giant taro, Ghana cocoyam and local cassava (Yaro) were studied for their physical, chemical and physico-functional characteristics. All starches exhibited low crude protein (0.33 to 0.48%), low fat (0.37 to 0.96%), low ash (0.26 to 0.45%), crude fibre - nil, low bulk densities, very high starch and dry matter (93 to 95%), high gelatinization rate, high peak viscosities, short pasting time (11.3 to 32.0 mm), low breakdown (7.65 to 102.50 BU), moderate consistency (35 to 55 BU), low swelling capacities at 50 and 60°C, with each showing its maximum swelling capacity at 90°C. Cocoyam starches are more resistant to swelling at 50 to 70°C than other starches. At 90°C, cassava and red cocoyam starches displayed lower swelling capacities of between 200 to 250 g water absorbed/100 g. Observably, starch swelling capacity was temperature dependent.

Key words: Cassava, cocoyam, gelatinization, starch, swelling capacity.

INTRODUCTION

All major plant crops contain starch stored as food reserve in their seed/endosperm, root, stems/corms etc. Starch occurs in plant tissue as discrete granules with a good carry-through property during fabrication, including grating/milling of raw materials, purification of diet of man and his ancestors. Cassava tubers of different cultivars have not only being largely consumed in different forms as food crops but have also being exploited as cheap energy source in animal feed ration. Cyanide-free cassava starch may be used in baby food as a filler material and bonding reagent. Giant taro, a major starch food in some part of the world (Bourke, 1982), stores its bulk of starch in its corms.

In Africa, giant taro is planted mainly as ornamentals and biological controls. Ghana cocoyam, like giant taro, stores its starch in bulky corms. Red and white cocoyams are the most popular cocoyam consumed as staple food in Nigeria. Their tubers grow out of condensed corms which are not normally eaten but are used as cutting for their propagation. Cocoyam has been found to be the prime source of starch throughout the world, including Nigeria (Vose, 1980).

The need to produce starch from different botanical sources, in spite of the heavy constraint placed on them as foods, can be found in its industrial application in life. As a modifier, starch gives texture to products such as sausage, gravies, soups, salad dressing, and pie filling. Starch can be used in the manufacture of confection and biscuits because of its ability to gel firmly on cooling. Starch is useful in frozen foods because of its excellent freeze thaw stability. Starch may be used in baking industries (Whistler and Daniel, 2003). Its enzyme and acid conversion can produce maltotriose, maltose, glucose syrup, fructose syrup (Vuilleumier, 1993; Ihekonronye and Ngoddy, 2000; Tan et al., 1984). It can be exploited as a source of ethanol for fuel (Adeniji et al., 1997). Starch has found use in pharmaceutical, textile and paper industries. It is used as an adhesive, and improver of detergent and viscosity of drilling oil in oil-wells cannot, however, be under-estimated.

The objective of this study is to extract starch from five different botanical sources and characterize them physically and chemically to ensure their feasibility for

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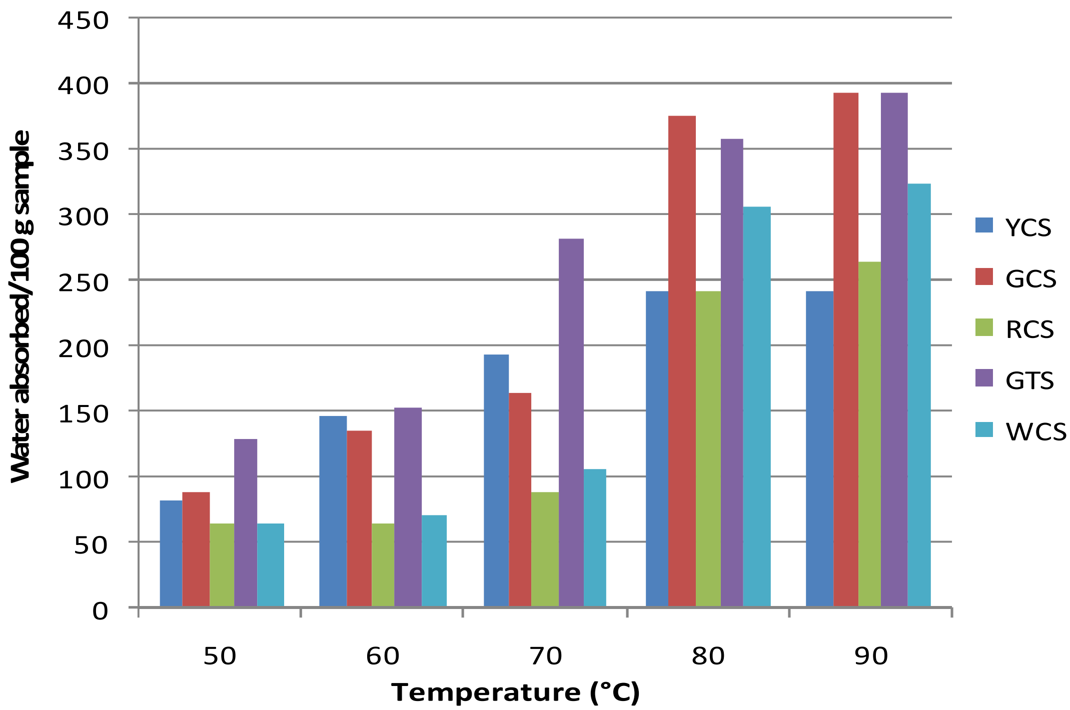

Figure 1. Swelling capacities of the starches. Key: GCS – Ghana cocoyam starch; GTS – Giant taro starch; YCS – Yaro cassava starch; RCS – Red cocoyam starch, WCS – White cocoyam starch.

industrial purpose.

MATERIALS AND METHODS

Sources of material

Fresh local cassava tuber, (Yaro cassava), white and red cocoyam tubers were collected from Agricultural Research station located around the University of Ado Ekiti environment. Giant taro corm was harvested in the wasting area within/around the University campus. Ghana cocoyam corm was bought from Oba's market in Ado Ekiti.

Sample treatments and starch fabrication

All the raw materials were peeled and washed clean with water. 5 kg weight of each peeled raw material was grated and sieved under water using sieve of mesh size 200 m. The subsequent slurries were made to pass through 75 mm mesh size under water, and tabled severally to separate residual dirt from the prime starch samples. Finally, the starches were purified with 50% alcohol to remove traces of glucose. After the purification and further tabling the solvent was decanted and products were sun dried for 72 h in screened rectangular wooden tray.

Analytical methods

Proximate composition

All starch samples were milled and sieved to get uniform size, and packaged into labeled screw- capped bottles pending analysis and further use. Proximate composition was achieved by AOAC (1990) Official Methods of Analysis. Crude protein was determined by multiplying crude nitrogen by 6.25. Carbohydrate (mainly starch) was deduced by deference.

Determination of physico-chemical properties of starches

Ionic characteristics of starch samples were determined by staining with an acid solution of methylene blue (Kahn, 1987; Agunbiade and Longe, 1999). The samples were also analyzed for bulk density, using the method of Okezie and Bello (1988); water and oil absorption capacities (WAC and OAC) were estimated following the methods adopted by Quinn and Paton (1979) and Lin et al. (1974) respectively. Water-Oil Absorption Index (WOAI) was estimated as outlined by De Kanterewics et al. (1987), swelling capacity was determined by the method of Sathe et al. (1981) at 10°C intervals between 50 and 90°C and pasting characteristics of 4.5% starch (on dry weight basis) slurried in water was measured with a Brabender Visco-amylograph with 6.85 × 10 dyne/cm torque operated at 75 rpm bowl speed.

RESULTS AND DISCUSSION

In this study, Figures 1 and 2 shows the Brabender amylograph having five viscosity reference points denoted as I to V. I: Peak viscosity, irrespective of the temperature at which the pasting peak is attained, II: the viscosity of the paste reaching a temperature of 95°C, employed as the maximum safe operating temperature of the instrument to achieve development of optimal

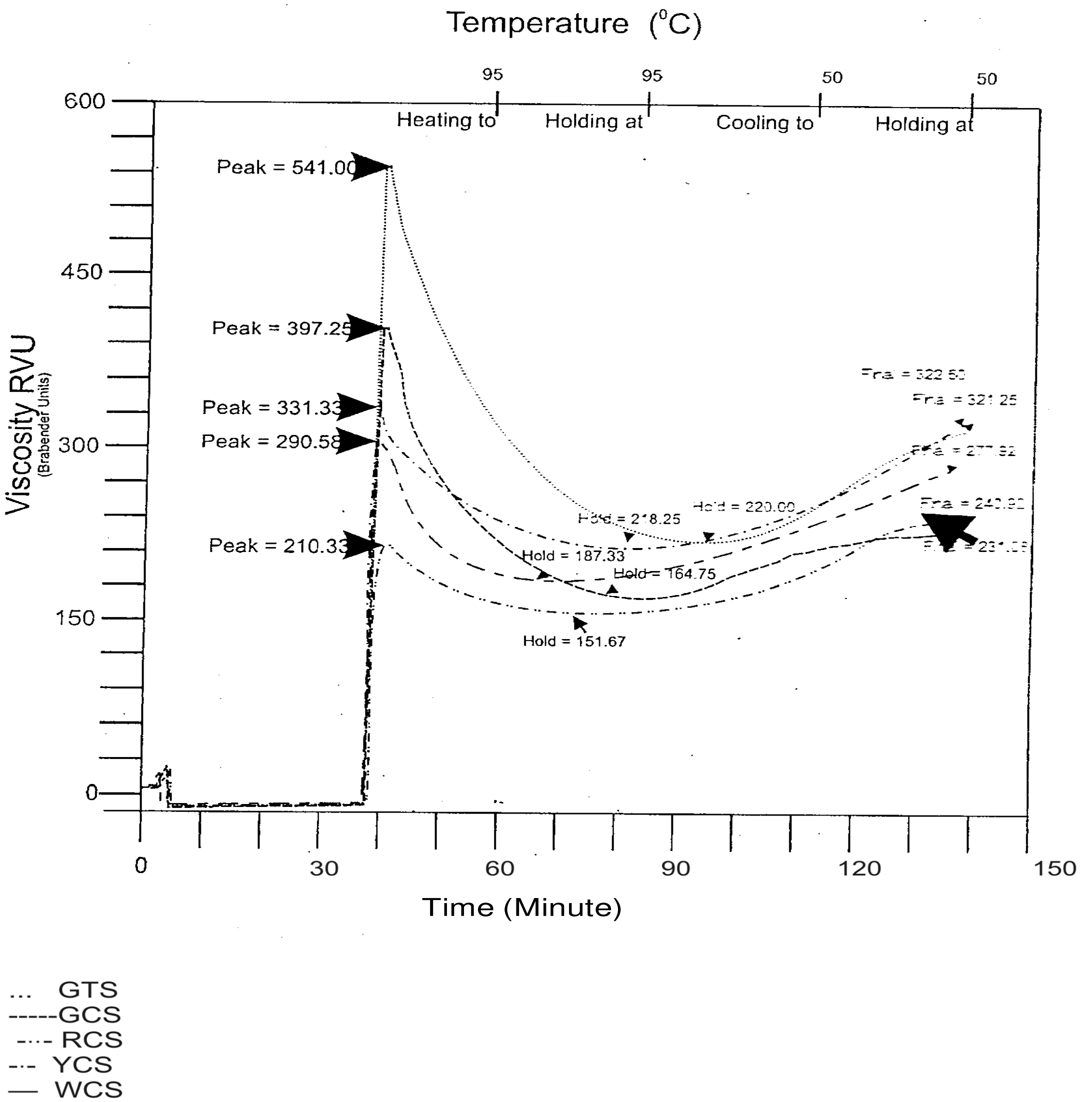

Figure 2. Brabender Amylograph (showing the viscosity of starches from five botanical sources). Key: GCS – Ghana cocoyam starch; GTS – Giant taro starch; YCS – Yaro cassava starch; RCS – Red cocoyam starch, WCS – White cocoyam starch.

swelling of the starch granules, III: viscosity after cooking at specified time in the Brabender at 95°C, which indicates the stability or breakdown of the paste during cooking/gelatinization, IV: the viscosity when the gelatinized paste is cooled to 50°C in the instrument, as a measure of set-back produced by cooling, V: the final viscosity after stirring in Brabender for a specified time at 50°C to indicate stability of the gelatinized paste in actual use. The starches displayed peak viscosities at temperatures lower than 95°C, the standard operating temperature of Brabender. Maximum viscosities on heating to 95°C were determined from Brabender curves. Viscosities cooled to 50°C were also similarly determined. Table 1 shows the proximate compositions of the five starches. They were all high carbohydrate, high dry matter, low ash, non-fibrous, low fat and low crude protein.

A similar result has been reported by Agunbiade (1992) and Mac Gregor and Ballance (1980) indicating that all the starches are of good quality for industrial purposes (Table 2).

All starch samples were non-ionic and low bulk densities. Water absorption capacity of the starches, recorded as the amount of water absorbed per 100 g sample varied from 56.30 to 96.0. The oil-absorption capacity of the starches, recorded as the amount of oil absorbed per 100 g sample varied from 55.1 to 76.2. However, it is observable that both Ghana cocoyam and Giant Taro starches exhibited the highest water and oil absorption capacities. The water-oil absorption indices

Table 1. Proximate composition of five starches on dry weight basis (dwb).

Determination	Red cocoyam starch (RCS)	Ghana cocoyam starch (GCS)	White cocoyam starch (WCS)	Giant taro starch (GTS)	Yaro cassava starch (YCS)
% Dry matter	94.94±2.1	95.05±2.1	94.73±2.2	94.78±3.1	94.66±1.4
% Starch	93.63±2.1	93.40±3.1	93.62±1.1	93.62±2.0	93.00±2.4
% Crude protein	0.33±0.01	0.41±0.00	0.43±0.01	0.48±0.00	0.47±0.01
% Ash	0.45±0.01	0.41±0.02	0.31±0.02	0.26±0.01	0.33±0.01
% Crude fibre	Nil	Nil	Nil	Nil	Nil
% Fat	0.53±0.01	0.82±0.01	0.42±0.02	0.37±0.02	0.96±0.03

Values are means of triplicate determinations ± Standard error (S.E).

Table 2. Some physicochemical properties of five starches from different botanical Sources at room temperature (29 to 30°C).

Determination	Red starch (RCS) cocoyam	Ghana cocoyam starch (GCS)	White cocoyam starch (WCS)	Giant taro starch (GTS)	Yaro cassava starch (YCS)
Ionic characters	Non-ionic	Non-ionic	Non-ionic	Non-ionic	Non-ionic
Bulk density	0.71±0.01	0.60±0.01	0.67±0.01	0.72±0.02	0.62±0.01
Water absorption	60.10±4.2	87.30±4.1	56.30±2.31	96.0±4.5	64.5±3.2
Capacity (% dwb)					
Oil absorption	55.10±2.1	75.05±3.1	59.30±2.2	76.2±3.4	57.1±2.1
Capacity (% dwb)					
Water-Oil absorption index (WOAI)	1.09	1.16	0.67	1.26	1.13

Values are means of triplicate determinations ±SE.

of all the starches, varying from 0.67 to 1.26, were all below 2.0 signifying them to be lipophilic (De Kanterewicz et al., 1987).

All these properties are characteristics of pure, industrial starches as previously reported by Agunbiade and Longe (1999). Table 3 shows the pasting characteristics of the five starches. Generally all samples displayed high gelatinization temperatures (Tg) of 78 to 84°C, all of which are obviously lower than 95°C. The times (Mn-Mg) in minutes taken by the starches to reach peak viscosities were seemingly short, 11.3 min in GTS to 22.0 min in RCS. The peak viscosity recorded at temperatures lower than 95°C reflects: the ease of gelatinization of the starches or starch-containing foods, greater stability of their swollen granules against mechanical disintegration (Mazurs et al., 1957). Viscosity is a function of water inhibition followed by (or possibly concurrently with) swelling of the starch granules (Agunbiade and Longe, 1999).

Breakdowns

The Vn-Vr values in Ghana cocoyam starch (GCS), yaro cassava starch (YCS), local cassava starch (LCS) and red cocoyam starch (RCS) are very much less than those of giant taro starch (GTS) (102.50 BU) and (60.25 BU). Low breakdown indexes the stability of the swollen granules against disintegration during gelatinization, which is corroborated by previous reports (Adeyemi, 1983; Juliano, 1985; Agunbiade and Longe, 1999).

Setback

This work has shown giant taro starch (GTS) and white cocoyam starch (WCS) to display very low setback values (Ve-Vm) being -67.5 and -5 BU respectively. The setback values of GCS and RCS are similar but apparently higher than that of YCS with a setback value of 20.00 BU. The less this value the worse, meaning that GTS with Ve-Vm value of -67.5 BU was more retrogradable followed by WCS, and YCS while GCS and RCS with Ve-Vm value of 35 BU were less susceptible to retrogradation than others. A link has been shown between a starch peak viscosity and its amylose content. Rice varieties with highest peak viscosities have been reported to have the highest contents (Mazurs et al., 1957). Increase in viscosity (Ve-Vm) on cooling to 50°C

Table 3. Pasting characteristics of five starches from different botanical sources.

Starch	Initial pasting temp. Tg (°C)	Time taken to reach peak viscosity (Mn) (min.)	Gelatinization time (Mg) (min.)	Pasting time (Mn-Mg) (min.)	Brabender pasting viscosities (BU) I Peak viscosity	II Max. on heating to 95°C (Vm)	III After 20 min. 95°C at (Vr)	IV Cooled to 50°C (Ve)	V After 30 min. at 50°C	Breakdown (Vm-Vr)	Setback (Ve-Vm)	Consistency (Ve-Vr)
GCS	83.15	44.7	26.1	18.6	290.58	195.00	187.35	230.00	277.92	7.65	35.00	42.65
GTS	77.50	43.30	32.00	11.30	541.00	322.50	220.00	255.00	321.25	102.50	-67.50	35.00
YCS	81.60	51.30	31.00	20.30	331.33	240.00	218.25	260.00	322.50	21.75	20.00	41.75
RCS	84.20	44.70	23.00	21.70	210.33	165.00	151.69	200.00	240.92	13.31	35.00	48.31
WCS	84.00	43.00	24.00	19.30	397.25	225.00	164.75	220.00	231.08	60.25	-5.00	55.25

Determinations at 4.5% concentration/starch. Key: GCS – Ghana cocoyam starch; GTS – Giant taro starch; YCS – Yaro cassava starch; RCS – Red cocoyam starch; WCS – White cocoyam starch.

reflects retrogardation tendencies (Leach et al., 2001). From this study, it seems that GTS, and WCS with the highest peak viscosities but with the least Ve-Vm values are supposedly retrogradable and are therefore more amylase-laden compared to others in conformity with the reports of Mazurs et al. (1957).

Consistency

The final viscosities of the starches held at 50°C and stirred in Brabender for 30 min were very high. Increased viscosities of the starches at this point reflected the stability of their cooked paste in actual use (Mazurs et al., 1957). The starches, on the basis of their Ve-Vr values varying from 35 BU in GTS to 55 BU in WCS indicate that they all showed distinct tendency to gel. The higher these value the better (Agunbiade and Longe, 1999) when starch paste is cooled to 50 from 95°C.

Swelling capacities of the five starches

All starches displayed increased swelling capacities at ten minutes time intervals from 50 to 90°C. The swelling capacities, described as the amount of water/100 g absorbed by samples, have been shown to be influenced by increasing temperature at times intervals (Agunbiade and Longe, 1999). At temperatures of 50 to 70°C RCS and WCS were relatively more resistant to swelling, a feature which is probably attributable to their granular arrangement held together by strong intermolecular bonds (Agunbiade and Longe, 1999). LCS and GCS seemingly exhibited intermediate swelling patterns presumably due to their possession of much less strongly held intermolecular areas than RCS and WCS. Ghana cocoyam starch (GCS) at 80 and 90°C exhibited remarkably high swelling capacities as GTS. This observation may be due to the elevated gelatinization temperatures (78 to 84°C) disrupting more hydroxyl bonds to which excess water may be attached to cause further granule swelling in line with the observation of Leach et al. (2001). Giant Taro starch obviously underwent very rapid and continuous swelling at relatively low temperature probably indicating its possessions of very weak OH bonding. This loose associative bonding in the open intermolecular areas may therefore sublet itself to modification by hydration, resulting in the swelling of granules at gelatinization temperatures (Biliaderis, 1992; Agunbiade and Longe, 1999). The observed differences in the swelling capacities of the starches may be due to the following factors among others. their botanical sources, species of cultivar differences or their granular composition and granular arrangement; the extent of abrasion suffered by starch granules during raw material grating as a catalyst to pre-gelatinization and exposure to starch polar region which may engineer more water absorption even at low temperature (Agunbiade, 1992).

Conclusion

The five starches studied in this work exhibited low fibre, low ash, low fat, high dry matter, good swelling capacities and pasting temperatures, good pasting characteristics for example, low setback and low breakdown and high consistency. The starches, having satisfied the aforementioned conditions, are deemed to be of high commercial value which therefore suggests that they may find application in brewery, pharmaceutical and food industries.

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