INVESTIGATIONS ON STARCHES FROM SOME WEST AFRICAN ROOT CROPS

by

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Starch crops including the starch root crops, play a very important role in the diet of the West African population. Hitherto, they have been utilised in this area almost entirely for the preparation of food at the domestic level. Therefore, in spite of their importance as tropical food crops, comparatively little is known about the properties of their starches. In general, very little information is available in the literature on the properties of those starches which have not been of any commercial use. However, with the development of food processing industries that is beginning to take place in West Africa much more detailed knowledge of the technological qualities of the materials processed is needed. Recently, a project on the mechanisation of the processing of a very popular traditional West African dish — fufu — has been started in Ghana and this project attracted attention to the study of the rheological properties of starches prepared from starchy materials used for fufu making. The general aim of this study was to find out whether there is any relationship between the quality of the final product and the qualities of the starches involved in the process of fufu making.

In the traditional way, fufu is prepared by pounding peeled and boiled yam, cassava or cocoyam tubers or plantain fruits either alone or as a mixture in a wooden mortar until an elastic and somewhat glutinous dough is formed. Yams *(Dioscorea L)* are preferred for fufumaking — especially in the yam zone of Africa — as it is believed that yam fufu is the most palatable, having the optimum texture. Amongst the other starch crops which can be used for fufu pounding, the most serious competitor of yam is cassava. The displacement of yam by cassava has been accelerated during the last ten years mostly as the result of increasing urbanisation in West Africa with the concomitant evolution of the urban proletariat, creating a higher demand for the cheapest food even if it is less acceptable and less nutritious (Coursey, 1965). On the other hand, recent dietary surveys made in Ghana suggest that the so called new cocoyam *(Xanthosoma sagittifolium)*, the cormels of which are also used for fufu making, is now less common in diets than it used to be. It is, however, still a very important starch crop, typical for the forest area, whereas the so called old cocoyam *(Colocasia esculenta)* is grown to a small extent, chiefly by the older people. As the old cocoyam cormels become too soft when boiled, they are quite unsuitable for pounding fufu (Irvine, 1961).

Finally, the last starchy material used in fufu making is the fruit of plantain. The fruits of some cultivars contain a considerable amount of starch. To complete the study of starches present in materials used for fufu making, the results of the investigations on plaintain starches have been included in this paper, in spite of the fact that plantains do not belong to the class of root crops.

Except from cassava starch which is commercially used, very little is known about starches of all other crops mentioned. Up to now, some attention has been paid to the study of *Dioscorea* starches, since yams are food crops of major importance in many tropical countries, most notably in West Africa, the Caribbean area, and parts of South-East Asia and Oceania. The most important yam species in West Africa is the indigenous *Dioscorea rotundata* Poir (White Guinea Yam), which exists in a very wide range of cultivars. The Asiatic *D. alata L.* (Water Yam), introduced to West Africa some hundreds of years ago, is also fairly widely grown as well as *D. cyanensis Lam.* (Guinea or Yellow Yam). In West Africa these three species predominate and account for at least 95 per cent of the total production (Coursey, 1965). In addition, *D. bulbifera* L. (Potato of Aerial Yam), *D. esculenta* (Lour.) Burk. (Chinese Yam) are also grown to a very limited extent while a number of wild species, e.g. *D. dumetorum* Pax., are only occasionally collected for food.

Both white and yellow yams are generally used for fufu making, while water yams are generally not used for this purpose; they are considered of poorer quality than either white or yellow yams.

The starches of several Asiatic species have been described in a series of articles by Rao and Beri (1952, 1955, 1964, 1965). Of the species discussed, only *D. alata* and *D. bulbifera* are cultivated in West Africa. The starch of *D. esculenta* as grown in the Ivory Coast has been figured by Miege (1948) and the particle size distribution given. A later paper by the same author (Meige, 1957) describes briefly some investigations on the starches of *D. cyanensis* and *D. alata* grown in that country. Single samples of each of the major West African species grown in Nigeria, have been described in an unpublished report by Greenwood-Barton (1961); this report includes studies with the Amylograph on the viscosities of the starches, and notes very considerable variation between species. An amylogram and some other data for *D. opposita* Thunb. starch are given by Hollo (1964). A recent review article by Seidemann (1964) illustrates the microscopical structure of a number of *Dioscorea* starches, and also gives some data on their viscous and other properties. The information on other starches concerned is far more limited.

The present study describes an examination of some rheological properties of the starches prepared from the representatives of the major West African *Dioscorea* species, from several cultivars of old and new cocoyams and from several cultivars of plantain. One starch sample was prepared from the tubers of *Coleus dysentericus* Baker, var. nigra Chev. (Salaga or Fra-Fra Potatoes). (This plant is grown as a food tuber in the savannah part of tropical Africa. In Ghana, it is grown in the northern part; the tubers are either boiled and eaten alone or cooked in soup). The amylose content of these starches have also been investigated. The study has been completed by microscopic examination of individual samples.

MATERIALS

Most of the *Dioscorea* tubers used in these investigations were grown on the University Farm at Legon, a few miles north of Accra. The last two varieties of *D. rotundata* were collected at Ejura about 200 miles northwest from Legon. The species and varieties studied were :

D. rotundata var. "Puna"
var. "Labreko"

var. "Kplinjo"
var. "Tantanpruka"
var. "Tempi"

D. alata
D. esculenta
D. dumetorum

Two local cultivars of *Xanthosoma sagittifolium,* two local cultivars of *Colocasia esculentum* and seven local cultivars of plantain were grown at the Agricultural Research Station, at Kade, about 80 miles north of Accra. The tubers of *Coleus dysentericus* var. *nigra* Chev. were collected from a private farmer in the Northern Region of Ghana.

Some well-studied starches were used as standards for comparison : two samples of corn starch, white potato starch and cassava starch prepared from *Manihot utilissima* var. Ankra.

The starches were prepared by peeling the tubers (with plantains by peeling the fruits), grating, extracting with water and allowing the starch to settle out. The soluble impurities were removed by repeated washings and settlings in water. Some difficulty was experienced in obtaining the starch from *Dioscorea* tubers which on grating produced very sticky and mucilagineous pulp *(D. rotundata* var. "Kplinjo," *D. alata* and *D. esculenta*). Because of the very high viscosity of the slurries prepared from these tubers, the settling velocity of the starch granules was very low and the settling process took a very long time. In the case of *Dioscorea dumetorum* and *Colocasia esculentum* the starch granules were so small that centrifuging instead of settling was necessary to separate the starch. Starch after purification was carefully dried at temperatures not exceeding 35°C.

METHODS

The consistency of starch pastes referred to as "viscosity" during the entire course of the gelatinisation process was derived from curves obtained by means of the Brabender Viscograph, using the following procedure : A weighed amount of starch equivalent to 25.0 g. dry weight was suspended in 450ml. of distilled water at 25°C, and the suspension poured into the measuring vessel of the Viscograph. The viscosity was recorded at a constant rotational velocity of 75 r.p.m. using the 500 cmg. measuring box with the temperature rising uniformly at 1.5°C/minute. After reaching a temperature of 95°C the starch paste was maintained at this temperature with constant stirring for a further 30 minutes; after this "holding period" the paste was cooled uniformly at 1.5°C/minute for a further 30 minutes, i.e. until the temperature reached 50°C. The viscosity was expressed in Brabender Units (BU).

The *pasting temperature* was read off from the viscosity curves as the temperature at which the viscosity started to rise. This pasting temperature is often referred to as gelatinisation temperature; this, however, is incorrect as the starch granules start to gelatinize before this point is reached. The pasting temperatures obtained with different samples are relative only since it has been shown that the pasting temperature depends on the concentration of the suspension (Pagenstedt, 1951).

The *gel strength* was measured using F.R.I.A. Jelly Tester on starch gels prepared as follows Starch equivalent to 25.0 g. dry weight was suspended in 450 ml. distilled water and starch paste was prepared from this suspension using Brabender Viscograph (as described above) to ensure constant heating and stirring conditions. As soon as the paste reached its maximum viscosity, the heating and stirring was continued for a further five minutes. Similar samples of starch gels were prepared by heating the starch pastes for twenty minutes at 95°C. The samples thus prepared in the form of a hot solution were poured into boxes (5 x 5 x 6.25 cm.) and allowed to set at an ambient temperature of 25°C. To prevent evaporation and consequent skin formation, a thin film of liquid paraffin was poured on to the surface of the paste. The strength was tested after a period of 2, 4 and 7 days and was expressed as the number of mls. of water required to be run into the counterpoised bucket of the Jelly Tester to bring about 10° and 20° rotation of the spade immersed in the gel. The iodine absorption and *amylose content* were determined by an amperometric titration according to Hollo and Szejtli (1956) taking the theoretical iodine absorption of pure amylose to be 26.1. Other determinations were done according to A.O.A.C. methods.

RESULTS

The results of viscosity measurements, characterising the gelatinisation process of individual starches are summarised, together with data on gel strengths in Tables 1, 2 and 3.

No great differences were observed among the viscosities derived from the viscograms of *D. rotundata* starches; the maximum viscosities ranged between 600 and 780 BU, except for starch extracted from vat. "Tantanpruka," yielding a paste of relatively very high viscosity (895 BU), which ranked second to white potato starch only. On further heating and stirring after attaining the maximum viscosity, the pastes thinned down only slightly so that the curves had no distinct peaks. On cooling, however, the viscosity increased very distinctly which indicated the formation of a very firm gel. The strength of gels prepared from these starches varied with the source of the starch, being relatively very high when compared with other starches examined. With the samples of gels prepared from var. "Tempi" and "Kplinjo" by boiling the pastes for 5 minutes after attaining the maximum viscosity, the retrogradation after 4 days standing was observed followed by a very distinct decrease of gel strength.

The pasting of *D. alata* starch resulted in a paste with considerably lower viscosity (410 BU) when compared with *D. rotundata* starches. However, the gel produced from this paste was of an exceptionally high gel strength and of a very"brittle" nature, so that it was not possible to avoid splitting the sample by the rotating spade of the F.I.R.A. Jelly Tester when the samples were tested after more than 4 days standing.

A slightly higher viscosity was shown by paste prepared from the *D. esculenta* starch (500 BU), while *D. dumetorum* starch yielded paste of an extremely low viscosity (180 BU). This starch did not form any gel, the strength of which could be measured under the given conditions.

The transition temperatures of all *Dioscorea* starches at the concentration given ranged from between 77 and 83°C.

Xanthosoma sagittifolium starches produced pastes less viscous than

D. rotundata, D. esculenta or cassava starches, but more viscous than corn starch pastes. The viscosity curves at given concentration have the same character as the curves of *Dioscorea* starches; there is no distinct decrease of viscosity after attaining the maximum viscosity. The gels have roughly the same gel strength as the corn starch gels. Unlike the *Dioscorea* starch gels, the strength of these gels does not show any measurable increase on standing. Heating the pastes for 20 minutes after the attainment of maximum viscosity did not increase the gel strength; a very slight decrease was observed. The viscosity of *Colocasia esculenta* starch pastes was very close to the viscosity of corn starch pastes; the strength of the gels produced from this starch, however, was very low.

The starches of all the cultivars of plantains examined did not show any significant differences either in viscosity of gel strength. The maximum viscosity ranged between 550 and 730 BU, which is relatively very near the range of the viscosities of *D. rotundata* starches. The pasting temperatures of all the starches under given conditions lie betwen 75.5°C and 77°C. The gels have been found to be in the range as the strength of gels prepared from *D. rotundata,* var. "Puna" and "Labreko."

The results of chemical analysis of starches are given in Table 4. These results indicate that samples were of sufficient purity for further investigations. The starches of very small particle size (*D. dumetorum, C. esculenta*) were found to have relatively higher "non-starch" content than other samples. This was presumably caused by difficulties in the separation of the starch granules from the slurry, resulting in incomplete removal of the impurities.

The starches examined vary in the proportion of amylose as shown in Table 4. Evidently, gel formation is facilitated by the presence of amylose. However, it would be very difficult to find out any general relationship between the amylose content and the theological properties of starches from various botanical sources, since the amylose content is only one of the many factors affecting these properties.

The results of the microscopic examination of the starches are summarised in Table 5, which includes a brief description and the results of granules size measurements.

CONCLUSIONS

The rheological properties of the starches extracted from several West African starch crops, grown in Ghana, have been investigated. Considerable variations between the different *Dioscorea spp.* (yam) have been found. The indigenous West African *D. rotundata* with large granules (the longitudinal diameter of the granules varies from 35—50 u, the majority being about 40 u), and the Asiatic *D. alata* (the diameter of the granule varies from 17—26 u), form gels of considerable strength, but the viscosity of the starch of the former species is much higher. The starch from *D. esculenta* and wild species *D. dumetorum,* both with very small granules (1—5 u and 1—3 u respectively), produce gels with lower strength, the latter being so soft that no measurement could be taken.

The viscograms of all *Dioscorea* starches at the concentration given have the same character. After attaining the maximum, the viscosity does not fall appreciably, even when the solutions are heated for 30 minutes at 95°C on constant stirring. In this respect, the *Dioscorea* starches resemble corn and rice starches and differ from cassava and white potato starches.

The viscograms of cocoyam, plantain and *Coleus* starches have also the same character. The paste, prepared from *Coleus* starch is found to be relatively very viscous; the gel formed resembled the white potato gel. The plantain starches are found to be very near the range of the viscosity of corn starch. The gels prepared from cocoyam starches do not change their consistency appreciably during the period of seven days, thus resembling the corn starch gels.

All these results, however, must be taken as relative, since the course of gelatinisation depends on the pretreatment of the starch, the rate of heating, the pH of the suspension and many other factors.

The *Dioscorea* starches, except from those prepared from *D. esculenta* and *D. dumetorum,* have been found to have relatively high amylose content when compared with other starches. This explains the very high increase of the viscosity of the pastes on cooling, since amylose facilitates the gel formation. Any unambiguous relationship between the amylose content and the intensity of gel formation with all the samples can hardly be expected, as other factors affecting the process of gel formation must be considered.

As far as the relationship between the quality of fufu and the rheological properties of the starch present in the material used is concerned, it has been shown that there must be some other factors, too, which determine the suitability of the plant for fufu making. For example, no significant differences have been found between plantain starches. Nevertheless, some of the cultivars investigated are preferred, while some cannot be used for fufu making at all. These other factors involved are the subject of further study.

Table 1. Rheological Properties of Dioscorea Starches

Sample	Viscosity in BU: Pasting temperature °C	At 95°C	Maximum viscosity	At the end of the 'holding' period	At the end of the 'cooling' period	Gel Strength/mls/: Boiled 5 minutes after attaining the maximum viscosity: 2 days 10°	2 days 20°	4 days 10°	4 days 20°	7 days 10°	7 days 20°	Boiled 20 minutes at 95°C: 2 days 10°	2 days 20°	4 days 10°	4 days 20°	7 days 10°	7 days 20°
Dioscorea rotundata																	
var. "Tantanpruka"	79.5	895	895	870	1430	10.0	21.1	14.6	23.6	20.5	32.8	10.5	19.5	15.5	24.0	22.0	33.5
" "Kplinjo"	78	640	780	780	1520	15.2	23.0	11.8	16.2	——	——	17.9	27.0	22.0	34.0	23.3	39.2
" "Tempi"	80	740	740	620	1180	11.3	19.5	11.6	18.8	11.7	18.5	12.0	20.0	15.0	24.0	19.5	31.0
" "Puna"	77.5	730	750	705	1310	9.5	17.2	13.0	23.5	18.0	27.0	10.2	18.5	13.6	23.8	19.0	29.0
" "Labreko"	78	550	600	540	1010	5.7	11.2	7.7	14.5	9.5	16.7	6.2	14.5	10.1	18.0	11.3	22.2
Dioscorea alata	83	250	410	410	600	18.5	27.8	28.6	50.2	**	**	20.0	29.5	30.0	54.0	**	**
Dioscorea esculenta	78.5	415	500	510	670	——	——	6.3	14.5	7.5	15.7	6.9	13.5	8.3	15.7	9.2	17.0
Dioscorea dumetorum	82	180	180	185	210	*	*	*	*	*	*	*	*	*	*	*	*

(*) The strength was too low for any measurement.

(**) The sample was too brittle to avoid splitting in measuring.

Table 2. Rheological Properties of Plantain Starches

Sample	Viscosity/in BU/					Gel Strength/in mils/					
						Boiled 20 min. at 95°C					
	Pasting temperature °C	At 95°C	Maximum viscosity	At the end of the 'holding' period	At the end of the 'cooling' period	2 days		4 days		7 days	
						10°	20°	10°	20°	10°	20°
Cultivar "Soboaso"	76.5	550	550	475	700	6.7	14	8.5	16.6	9.2	15.2
"Csabum"	77	580	620	540	810	9.1	15.9	10.0	18.0	11.0	20.0
"Assamiensa"	77	490	565	540	740	8.8	17.8	9.2	19.2	10.3	20.5
"Apantum"	77	480	585	570	730	9.8	17.5	10.1	19.0	12.0	25.0
"Brodewio"	77	480	520	515	710	8.6	16.7	10.7	17.1	11.0	20.0
"Assamienu"	75.5	600	630	585	860	8.7	16.5	10.0	17.0	11.8	20.5
"Onieba"	77	595	730	660	900	10.0	18.0	13.3	22.0	14.1	25.2

Table 3. Rheological Properties of Various Starches

Sample	Viscosity in BU: Pasting temperature °C	At 95°C	Maximum viscosity	At the end of the 'holding' period	At the end of the 'cooling' period	Gel Strength/in mls/: Boiled 5 minutes after attaining the maximum viscosity: 2 days 10°	2 days 20°	4 days 10°	4 days 20°	7 days 10°	7 days 20°	Boiled 20 minutes at 95°C: 2 days 10°	2 days 20°	4 days 10°	4 days 20°	7 days 10°	7 days 20°
Xanthosoma spp. I	78	370	380	330	610	8.0	13.3	9.0	14.5	—	—	7.0	13.2	7.0	13.5	7.0	13.0
” ” II	82.5	360	360	340	650	8.2	14.5	8.4	16.6	8.6	16.6	7.5	14.0	7.4	15.8	7.5	15.6
Colocassia spp. I	77	220	260	260	420	2.7	4.4	3.6	7.5	2.9	5.8	2.2	5.0	3.0	5.4	Liquified	
” ” II	76	160	160	140	200	—	—	—	—	—	—	1.8	3.6	1.7	4.0	Liquified	
Coleus dysenterious	74	760	770	715	930	4.5	—	5.2	—	5.8	—	—	—	—	—	—	—
Corn +	84	200	210	190	280	7.5	13.6	7.9	14.7	7.5	14.7	8.0	15.5	8.3	15.5	8.3	15.6
Corn ++	85	250	290	265	370	8.0	14.0	8.5	14.0	9.0	14.2	9.5	17.0	9.2	17.0	9.6	17.0
Cassava	69	540	630	280	440	1.8	3.5	2.0	3.6	2.0	3.6	*	*	*	*	*	*
White potatoes	63	1920	1180	460	580	6.2	11.8	6.0	12.8	6.1	12.0	*	*	4.6	3.0	1.7	3.4

(+) The sample was kindly supplied by Hercules Powder Company, Inc., U.S.A.

(++) The sample was kindly supplied by Corn Products (Sales) Ltd., Great Britain.

(*) The strength was too low for any measurement.

Table 4. Chemical Composition of Starch Samples Investigated

Species and Variety	Water %	Ash %	Ph	Protein (N x 6.25) %	Iodine Absorp-tion	Amglose %
D. rotundata var. "Puna"	17.9	0.26	6.9	——	6.5	24.9
var. "Labreko"	16.7	0.30	6.4	0.14	6.1	23.0
"var. "Kplinjo"	18.6	0.17	7.3	0.14	6.6	25.3
var. "Tantanpruka"	16.8	0.19	7.5	0.07	6.3	24.0
var. "Tempi"	16.7	0.19	7.4	0.05	6.0	23.0
D. alata	18.2	0.26	7.2	0.16	5.9	22.4
D. esculenta	16.8	0.46	6.2	0.08	4.0	15.3
D. dumetorum	16.5	0.30	4.4	1.55	3.9	15.0
Xanthosoma sagittifolium I	16.5	0.22	5.9	——	6.0	22.9
— „ — II	15.4	0.19	——	——	6.1	22.4
Colocassia esculentum I	16.6	0.81	6.4	——	3.8	14.5
— „ — II	17.4	0.92	5.8	——	3.9	14.9
Coleus dysenterious	15.1	0.27	6.5	0.12	5.7	22.0
Corn +	7.4	0.21	6.5	——	4.7	18.0
Corn ++	14.0	0.29	5.9	——	5.2	19.9
White potatoes	17.4	0.38	6.8	——	5.5	21.0
Cassava	14.8	0.32	7.2	——	5.1	19.5
Plantain, cultivar "Soboaso"	15.6	0.21	6.9	——	5.1	19.5
"Osabum"	16.8	0.17	7.3	——	5.4	20.7
"Assamiensa"	15.2	0.29	6.6	——	5.3	20.3
"Apantum"	18.0	0.23	6.8	——	5.7	21.8
"Brodewio"	16.2	0.19	7.0	——	5.4	20.7
"Assamienu"	16.4	0.25	7.1	——	5.8	22.2
"Oniaba"	18.8	0.22	6.9	——	5.9	22.8

Table 5. Microscopic Characteristics of Starches Investigated

Species and Variety	Granule shape	Granule size	
		Length	Width
D. rotundata var. "Puna"	long-oval, mostly flattened at one end (sack shaped)	52 (20 — 70)	23 (10 — 35)
var. "Kplinjo"	long-oval, mostly sack-shaped some granules slightly bent	43 (15 — 55)	26 (10 — 35)
var. Tantanpruka	long-oval (some sack-shaped) or rounded-triangular	40 (20 — 50)	27 (15 — 35)
var. "Tempi"	rounded-triangular or oval	35 (15 — 45)	25 (10 — 35)
		Diameter	
var. "Labreko"	shell or pear shaped	40 — 50	
D. alata	irregular, oval or eliplical very few rounded-triangular	17 — 26	
D. esculenta	polyhedral, mostly compound	1 — 5	
D. dumetorum	very small, polygonal	1 — 3	
Xanthosoma sagittifolium	round shaped	9.3 (2.8 — 22)	
Colocasia esculentum	very small, round shaped	9.3 (0.6 — 3.3)	
		Length	Width
Plantain	long-oval, or pear shaped, oval	27 (5 — 50)	12 (28 — 33)

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