Variation in the Physical, Chemical and Physico-Functional Properties of Starches from Selected Cassava Cultivars

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Abstract: Starches, fabricated from fresh cassava cultivars TMS series 4(2)1425, 91934, 30001, 30555 and Odongbo, were analysed for their % yields, granular structures, granule sizes and distribution, proximate composition, chemical composition and physico-functional properties. TMS 91934, with the highest moisture content (MC) [65.0%] produces the least starch yield [13.86%] compared with TMS 30001 with 58% MC & 24.68% starch yield, TMS 1425 with 61.0% MC &19.68% starch yield, TMS 30555 with 60.5% MC & 20.13% starch yield, and odongbo (local cultivar) with 59.0% & 21.19% starch yield. All the starches from these cassava cultivars exhibit similarities in their granular structures being oval/round, some truncated. Other observed features are: granule sizes ranging from 11.25µm in TMS 4(2)1425 to 15µm in TMS 91934; high dry matter (87%), low phosphorus (0.01 ï 0.03%); low crude protein (0.18 ï 0.88%); low ash (1.0%); pH 5.15 value; low water activity (a_w) of 0.51 ï 0.67; bulk density of 0.81 ï 0.82; non-ionic characteristic; nil cyanide content, and salivary amylolysis of the starches, showing TMS 30001 and Odongbo to be more enzyme resistant than other starches. The swelling of water slurries of the starches is temperature dependent.The higher the temperature, the greater the swelling capacities of the starches. [New York Science Journal 2010;6(3):48-53]. (ISSN: 1554-0200).

Key words: Cassava,starch,granule,morphology,swelling

1. Introduction

Starch, a high polymer compound, is built up in plants by condensation of a long chain containing hundreds of glucose units. As a reserve carbohydrate it is stored in seeds, roots, stems, and fruits of plants. The food materials in which starch is appreciably found in easily extractable forms are cereals, fruits, tubers (root & stem), etc. In some plants starch combines with other organic compounds such as protein to form complexes (Agunbiade & Longe, 1999, Anon, 1988). This characteristic association between starch and protein imposes a careful use of an alkali in the course of extraction of starch (Schoch and Maywald, 1968; Agunbiade and Longe, 1999). Starch has been found to be present in plants in the form of discrete particles or granules whose behaviour at any time is a sum of its previous history (Greenwood, 1979; Blanshard, 1979). The external morphology of starch granule displays some typical features sufficient to predict its botanical source, shape and behaviour (Rasper, 1971; Greenwood, 1979). The greater majority of starch behaviours (physical, chemical or physiocochemical) are controlled by a number of factors among which areamylase -amylpectin ratio, nature of granules, retrogradation tendency, swelling capacity, gelatinization capacity etc. (Calfano & Anon, 1990; OöDell, 1979) and its pasting characteristics as evidence of its suitability and stability when used in food and pharmaceutical products.

The present work was to investigate the variations in the physical, chemical and physico-functional properties of starches from cassava cultivars with a view to determining their suitability for use in industries.

2. Materials and Methods

Fresh cassava cultivars namely, TMS 4(2) 1425, TMS 91934, TMS 30001, TMS 30555 and Odongbo, a local variety, used in this study were all obtained from International Institute of Tropical Agriculture (IITA) Idi-Ose, Ibadan, Nigeria.

2.1. Extraction of Starch from Cassava Cultivars

Fractionation scheme of Arguedas and Cooke (1982) was used to produce prime starch from each cassava cultivar, employing the following unit operations- peeling, washing and grating each cassava pulp. Cassava mash was filtered through nylon cloth under water. The colloidal starch slurry was tabled, using ice cold water, by the method of Agunbiade and Longe (1999). Finally the starch was sieved under water using a sieve of 106µm mesh size. Each starch was refined using 50% ethanol to remove soluble sugar, usually glucose. The starch was air-dried for 48h by the method of Agunbiade and Longe (1999), milled, weighed, packaged and stored in screw capped 500cm^3 glass bottles pending use or analysis.

2.2. Analytical Methods

Ground starch samples were analysed for ionic characters (Kahn, 1987), bulk density by method of Okozie and Bello (1988), swelling capacity at 5^0C intervals between 50^0C and 75^0C using the method of Sathe et al (1981), diameter sizes (Anderson, 1978), water activity (a_w) using a_w-value Analyzer Model 5803, amylose (Sowbhagya and Bhattacharya 1979), viscosity, syneresis and qualitative amylolysis of 1% starch solution, photomacrographs of starch dust mounted in 50% glycerine-water mixture and taken with a Carl microscope, ash, moisture, crude protein, phosphorus and cyanide analysed by AOAC (1993). All measurements were done in triplicate and the mean values along with their standard errors were recorded.

Results and Discussion

Table 1 shows the moisture contents of five different cassava tubers and their % starch yields. The cassava tubers had moisture contents varying from 58-65%. Their % starch yields,varying from 13.86% in TMS 91934 to 24.68% in TMS 30001, indicates that the lower the moisture content the higher the % starch yield.

Plate 1 shows the photomicrographs of the starch granules. All the starches are characterized by oval or round granules, some of which are truncated on one side. The high water content of cassava tubers may be the main reason for their seemingly low starch yields. The characteristic morphological structures of the cassava granules, round, oval or truncated has been previously reported (Richard, 1991; Meduna, 2008). These features may serve as identification for starch of cassava origin (Agunbiade and Longe, 1999), as well as an advantage in starch functional properties (Lorenz and Collins, 1990).

Table 2 reports the starch granule sizes (µm), and % granule distribution of all starches from five different cassava cultivars. All the starches have in common, 5µm as their smallest granule size. Thus their granule sizes range between 5-17.5µm in TMS 4(2) 1425, 5-20.0µm in TMS 30001 and Odongbo, and 5-22.5 in TMS 91934 and TMS 30001. The overall mean percentage distributions of starch granules are as follows: 5µm (12.5) 7.5µm (17.5), 10µm (19.6) 12.5µm (20.4), 15µm (16.5), 17.5µm (8.20), 20µm (4.80), 22.5µm (1.00). These percentage distributions are in increasing order from 5µm-12µm and thereafter declined consistently from 15µm ï 22.5µm. About 94% of the starch granules consist of diameters falling between 5 and 17.5µm. The largest granules of TMS 4(2) 1425 with 17.5µm granule size constitute just 3.5%. TMS 30555 and Odongbo make up 3% and 7% respectively with their largest granule size being 20µm. TMS 91934 and 30001 are the most widely distributed with 7-12% granule sizes of 20µm and 22.5µm. The granule size of 5-22µm obtained in this work, in comparison with 4-50µm reported by Richard (1991), may be due purely to varietal differences. In general, starch granule size of 5-22µm are seemingly very small. Small size may be a factor in the exhibition of starch physico-functional charcterics such as retrogradation, amylolysis or culinary properties.

Table 3 shows the chemical composition of the starches on dry weight basis. The dry matters of the starches are very high and similar, about 87%. The crude protein contents vary from 0.18% in TMS4 (2)1425 and Odongbo to 0.88 in TMS 30001. TMS 91934 and TMS 30001 contain 0.53 and 0.88% crude protein respectively. Phosphorous content of the starch vary from 10mg/100g in Odongbo and TMS 91934, while TMS4(2)1425 is 30mg/100g followed by 20mg/100g found TMS 30001 and 30555 respectively. All the starches are cyanide free and all of them have very low ash content (1.0%). Phosphorous in starch granules has been shown to be esterified on staining with methylene or eosin (Schoch and Maywald, 1956; Georing and Parrels Ford, 1965). Therefore the existing phosphorous serves to reinforce starch granular structure as cross-bonded linkages in the starch granules. However, the presence of non carbohydrate constituent of starch granules may sometimes significantly influence the functional properties of starch (Richard, 1991). Low ash, low crude protein, low cyanide and absence of fiber signify cassava starch to be of industrial quality. Cassava starch can be used as carrier binders and disintegrants of tablets and capsules on the basis of absence of cyanide. As a developing country, Nigeria, a large producer of cassava stands to gain economically from this high quality, highly functional fabricated starch in agreement with the report of Satin (2004).

Table 4 reports the physico-functional properties of the starches. All samples, except Odongbo cassava starch exhibit pH values ranging from 6.40 to 6.85. pH of Odongbo cassava starch is significantly ($p < 0.05$) lower than those of other starches, being apparently more acidic. The water activity of TMS 30555 is significantly ($p < 0.05$) lower than the other starch samples. Low a_w displayed by starch samples is indicative of their resistance to attack by most bacteria and fungi. Starches other than TMS30555 can be attacked or spoilt by xerophilic moulds operating between 0.60 and 0.65 aw (Troller, 1980, Agunbiade and Longe, 1999). TMS30555, by virture of its very low a_w, can be viewed as enjoying greater resistance to microbial attack and hence higher shelf-life. Dry food a_w near zero does not support microbial growth (Bauman et al, 2006. All starch samples display identical but very low bulk densities, much less than the bulk densities of legume starches reported by Agunbiade & Longe, (1999). The common non-ionic properties of the starches indicate that they are all fibre-free. Of the five different starches, both TMS 30001 and Odongbo with 18 and 19% amylose content respectively, show some sign of retrogradation implying that they may not function well in food preparations (OõDell, 1979). High amylose content of starch may thus cause problems for food companies because of its implication in retrogradation.

Fig 1 shows the swelling capacities (SW) of the five starches at 5^0C intervals from 50 - 75^0C The moisture absorbed by the starches at 50^0C was less than 1.0gram per gram sample and at 55^0C it was about 1.25g moisture absorbed per gram sample. Apparently the swelling capacities of the starches at 50^0C and 55^0C are respectively low and similar. At 60^0C swelling capacities of al starches become three times and two times their swelling capacities at 50^0C and 55^0C respectively. At 65^0C all the starches exhibit swelling capacities in this decreasing order:
TMS 30005 > 30555 > 4(2)1425 > 91934 > Odongbo. At 70^0C the swelling capacities (SW) of the starches have increased, having absorbed between 3.5 ï 4.0g water per gram sample, following this (SW) decreasing order:
TMS 91934 > 30001 > 30555 > 4(2) 1425 > Odongbo. Up to 70^0C Odongbo exhibit the highest resistance to swelling. At 75^0C all starches exhibits peak swelling capacities with TMS > 91934 > 30555 > 30001 > Odongbo > 4(2) 1425. At the climax of swelling TMS 4(2) 1425 exhibits the least swelling capacity compared to others. The result shown in this study is indicating that starch swelling is a function of increase in temperature as supported by the report of Agunbiade and Longe (1999).

Table 1: Cassava moisture content, prime starch yields (%) And starch morphological structures

Cassava Cultivar	**Pulp Moisture**	**%Starch Yield**	**Structure**
TMS 4(2) 1425	61.0 ± 1.4	19.68 ± 0.2	Oval, frequently
TMS 91934	65.0 ± 2.2	13.86 + 0.1	Truncated flask-shape
TMS 30001	58.0 ± 1.1	24.68 ± 0.4	ñ
TMS 30555	60.5 ± 1.5	20.13 ± 0.2	ñ
Odongbo (Local Cultivar)	59.0 ± 1.6	21.19 ± 0.3	ñ

Values are means ± Standard Error (SE).

Table 2: Granule size distribution of 5 different cassava cultivar starches

	Average size	**Distribution in Percentage (%)**								
Cultivar	**µm**	**5µm**	**7.5µm**	**10µm**	**12.5µm**	**15µm**	**17.5µm**	**20µm**	**22.5µm**	**Total**
TMS 4(2) 1425	11.25	13.0	22.5	17.5	25.5	18.0	3.5	Nil	Nil	100
TMS 91934	15.00	13.0	16.0	17.5	17.5	17.0	12.0	5.0	2.0	100
TMS 30001	13.75	08.0	15.0	17.0	17.5	18.0	13.0	9.0	3.0	100
TMS 30555	12.75	16.0	19.0	21.5	20.5	14.5	5.5	3.0	Nil	100
Odongbo	13.75	10.0	15.0	25.0	21.0	15.0	7.0	7.0	Nil	100
Mean ±	13.50 ± 0.40	12.0 ± 1.54	17.5 ± 1.62	19.6 ± 1.70	20.4 ± 2.52	16.5 ± 1.48	8.2 ± 2.07	4.8 ± 0.99	1.0 ± 0.64	100

Values are means of granule sizes and % distribution

Table 3**:** Chemical composition of isolated starches from the cassava cultivars on dry weight basis (dwb).

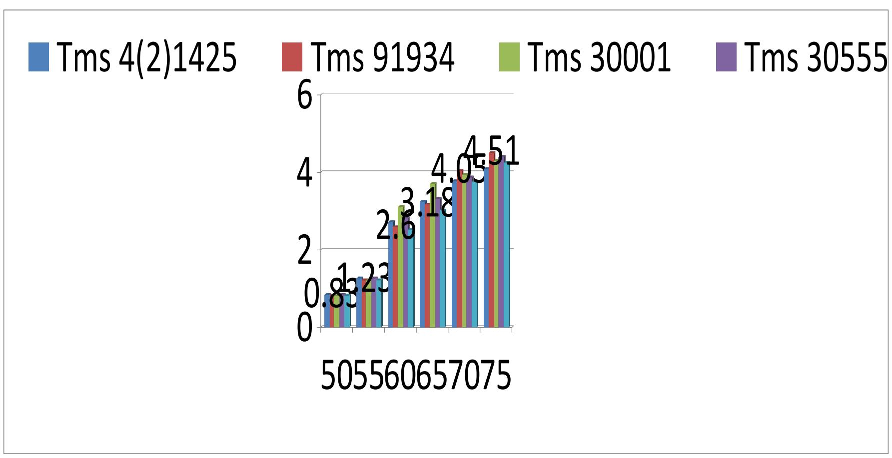
Cultivar	**% Dry Matter**	**% Protein**	**% Phosphorus**	**% Cyaride**	**% Ash**
TMS 4(2) 1425	87.18 ± 1.45	0.18 ± 0.01	0.03 ± 0.01	0.00	1.00 ± 0.01
TMS 91934	87.17 ± 1.50	0.53 ± 0.01	0.01 ± 0.00	0.00	1.00 ± 0.01
TMS 30001	87.57 ± 1.60	0.88 ± 0.01	0.02 ± 0.00	0.00	0.99 ± 0.01
TMS 30555	86.80 ± 2.10	0.35 ± 0.01	0.02 ± 0.00	0.00	1.00 ± 0.01
Odongbo	86.71 ± 2.20	0.18 ± 0.01	0.01 ± 0.00	0.00	0.99 ± 0.01

Values are means ± SE

Table 4: Physico -chemical properties of the prime starches on dry weight basis

Characteristic	**TMS 4(2)1425**	**TMS 91934**	**TMS 30001**	**TMS 30555**	**Odongbo**
pH	6.55±0.25	6.85 ± 0.30	6.40 ± 0.26	6.75 ± 028	5.15 ± 0.10[a]
Water activity (aw)	0.610± 0.02	0.665± 0.02	0.630 ± 0.02	0.506 ± 0.01[a]	0.610 ± 0.02
Bulk density	0.82 ± 0.02	0.84 ± 0.02	0.81 ± 0.02	0.083 ± 0.02	0.84 ± 0.02
Amylolysis (min)	70 ± 3.0[b]	70 ± 2.4[b]	75 ± 3.5[ab]	70 ± 2.4[b]	80 .00 ± 3.8[a]
Syneresis (ml)	Nil	Nil	0.20	Nil	0.49
Amylose (%)	17	17	18	17	19
Ionic property	Non-ionic	Non-ionic	Non-ionic	Non-ionic	Non-ionic

Values are means ± SE. Values differently superscripted are significantly different ($p< 0.05$) higher



Temperature (°C)

Figure 1**:** Water Holding/ Swelling Capacity

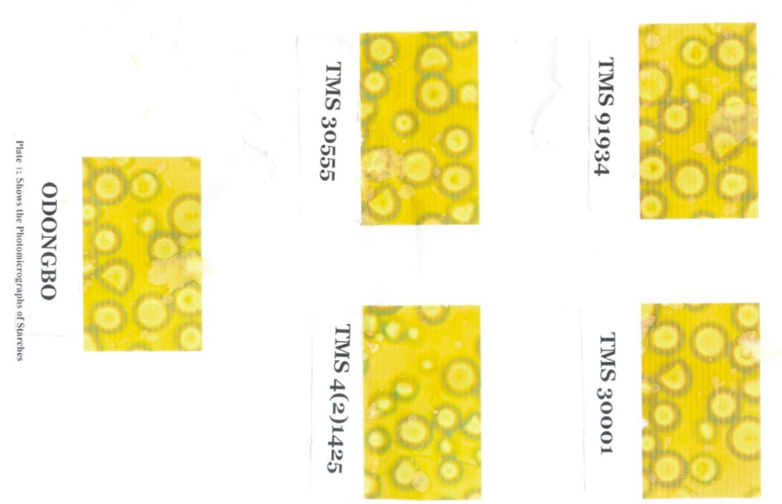


Figure 2: Photomicrograph of starches

Conclusion

The major storage component of cassava has been shown to be starch. This study has elicited a lot of information in favour of cassava starch as a versatile raw material for industrial use. Its extraction is not impeded by protein-starch complex commonly found with legumes and cereals. Its chemical and physico-functional properties are all favourably disposed to its pharmaceutical and food application. The major limitation in cassava products is cyanogen. This compound has been completely eliminated by the starch extraction adopted in this work. On the basis of the above listed factors cassava starch is a high economic product capable of increasing Nigerian foreign earnings.

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12/24/2009