WFL Publisher
Science and Technology

Meri-Rastilantie 3 B, FI-00980
Helsinki, Finland
e-mail: info@world-food.net

Journal of Food, Agriculture & Environment Vol.5 (3&4) : 36-42. 2007

www.world-food.net

Seasonal variations in the chemical and functional properties of starches from local and improved cassava varieties in high rainfall region of Nigeria

J. Eke [1*], S. C. Achinewhu [1], L. Sanni [2, 3], I. S. Barimalaa [1], B. Maziya-Dixon [3] and A.Dixon [3]

[1] Department of Food Science and Technology, Rivers State University of Science and Technology, Nkpolu, Port Harcourt, Nigeria. [2] Department of Food Science and Technology, University of Agriculture, Abeokuta, Nigeria. [3] International Institute of Tropical Agriculture, Ibadan, Nigeria.
**e-mail: joyekee@yahoo.co.uk, l.sanni@cgiar.org, a.dixon@cgiar.org*

Received 11 May 2007, accepted 28 July 2007.

Abstract

The aim was to investigate the chemical and functional properties of starches produced from 39 different cassava varieties (36 varieties resistant to cassava mosaic disease and three checks TMS 30572, 4(2) 1425 and 82/00058) in two planting seasons at the experimental farm of the International Institute of Tropical Agriculture, Onne, Rivers State, Nigeria. Varieties screened showed significant seasonal and varietal differences ($p<0.05$) in all the properties over two harvesting seasons. Amylose content ranged from 19.25 to 25.08% in Year 1 and from 16.19 to 20.29% in Year 2; amylopectin ranged from 77.88 to 79.71% in Year 1 and from 80.75 to 83.71% in Year 2. Protein content ranged from 0.7 to 1.06% in Year 1 and from 0.06 to 0.34% in Year 2. Sugar content ranged from 0.39 to 1.45% in Year 1 and from 0.52 to 1.13 % in Year 2. Starch damage ranged from 0.81 to 1.67% in Year 1 and from 0.58 to 0.89% in Year 2. pH ranged from 3.73 to 6.88 in Year 1 and from 5.25 to 9.30 in Year 2. Moisture content ranged from 7.47 to 14.55% in Year 1 and from 7.51 to 15.52% in Year 2. Ash content ranged from 0.05 to 0.36% in Year 1 and from 0.03 to 0.77% in Year 2. Starch content ranged from 61.36 to 91.78% in Year 1 and from 64.67 to 84.21% for Year 2. Dispersibility ranged from 79.50 to 87% in Year 1 and from 79.50 to 85.50% in Year 2. Swelling power ranged from 10.91 to 17.47% in Year 1 and 8.57 to 14.28% in Year 2. Solubility index ranged from 4.68 to 26.36% in Year 1 and from 2.07 to 14.36% in Year 2. Color ranged from 85.05 to 94.49% in Year 1 and from 90.27 to 92.96% in Year 2. The study therefore showed significant genotypic and seasonal variations in the chemical and functional properties of native starches from cassava.

Key words: Cassava varieties, starch, chemical, functional, Nigeria.

Introduction

The outbreak of cassava mosaic disease (CMD), which led to a decline of cassava root production in several parts of Africa, has initiated research efforts to develop disease-resistant varieties of cassava. The overview of these efforts is presented elsewhere[1, 2]. Currently, the International Institute for Tropical Agriculture (IITA), Ibadan, Nigeria, has developed about 43 CMD-resistant varieties of cassava that are currently receiving multilocational field trials for full integration into the cropping system in Nigeria[3]. We are aware that several hundreds of resistant cassava clones are currently being developed across the CMD-prone areas in Africa. In addition to environmental effects, genetic variations existing in the new plant breeds may introduce some changes that could be important to the food and industrial applications of their roots. Therefore, screening of the new crop breeds to determine their potential end uses is imperative.

Across all civilizations, cultures and continents, starch (a polymer of alpha glucose) has been the major source of energy in human diet since time immemorial [4]. It is the major reserve polysaccharide of higher plants. It serves as a basic thickener and a source of carbohydrate in food [5]. It is one of the most abundant substances in nature; it is renewable and nearly unlimited [6]. The major reason for the importance of cassava starch has been the ease of its extraction; the starch settles rapidly and the yield is good [7]. Cassava starch has been prized for its clarity of paste, neutral flavor, light color and reasonably good adhesive strength [8]. Starch has a number of commercial and industrial applications and these invariably find their way into our routine life.

Cassava starch is used not only for the production of starch derivatives and food products, but also for sizing of paper and textiles and in the manufacture of adhesives and alcohol. Screening starches from newly developed CMD-resistant cassava varieties for industrial applications becomes imperative [3]. This paper reports our findings on the chemical and functional properties of native starch produced from CMD-resistant and local cassava varieties harvested in two successive planting seasons in a high rainfall region of Nigeria.

Materials and Methods

Cassava varieties: A total of 36 newly developed CMD-resistant clones of cassava with 3 susceptible (existing) cassava varieties were obtained from a multilocational trial plot of the IITA, high rainfall planting area, Onne, Rivers State, Nigeria. Onne (Lat. 4.4°N, Long. 7.1°E) has a mean annual rainfall of 2600 mm. The cassava varieties were planted during the rainy season (June 2003/2004 and 2004/2005) in a randomized complete block design with three replications. No fertilizers or herbicides were applied during the course of the experiment. Hand weeding was done when necessary. Harvesting was done at 12 months after planting (MAP). Only the two middle rows were harvested/plot and cassava roots processed were collected from only one replication. Processing of the harvested cassava roots commenced within 60 min. after harvesting.

Preparation of starch: The method described by Osunsami *et al.*[9] was used for the production of various cassava starches. The cassava roots were harvested from the farm and washed to remove dirt from the skin. Ten kg of freshly harvested cassava roots/clone were peeled manually using a stainless steel knife and washed thoroughly with potable water to remove dirt and adhering sand particles. The peeled roots were grated and sieved. The mixture was filtered through a fine mesh sieve (muslin cloth). The filtrate was allowed to settle for about 6 hours. The supernatant was decanted and sediment washed three times with potable water to obtain a white, odorless and tasteless starch. The resultant wet starch was thinly spread over a black high density polyethylene (HDPE) according to Shittu *et al.*[3] in the open air for drying under ambient conditions (28-30°C, 70-80% RH) for 5 hours. The dried cake was milled using a locally fabricated hammer mill (IITA, Ibadan) fitted with a screen of 250 µm aperture size and packaged using food grade polyethylene bags and kept in the cold room (at about 4°C) for laboratory analysis.

Determination of chemical and functional properties: The moisture, protein (Kjeldahl nitrogen × 6.25) and ash content of starch samples were determined using the AOAC[10] methods. Starch and sugar contents were determined using the phenol-sulfuric method of Dubois *et al.*[11]. Amylose content was determined according to Williams *et al.*[12]. The pH was determined with the aid of a pH meter (Orion Model 720A, USA). The starch damage was determined using the extractability method of McDermott[13]. Swelling and solubility of starches were determined as described by Ruales *et al.*[14]. Least gelation capacity was determined according to Sathe and Salunkhe[15].

Data analyses: Descriptive analysis and two-way analysis of variance (ANOVA) were performed to explore the general trend of the experimental data. Mean separation was performed on the analysed data using Duncan's multiple range test with the aid of SAS version 9.1[16] software.

Results and Discussion

Chemical properties: The chemical properties of different CMD-resistant cassava varieties for two planting seasons are presented in Tables 1 and 2. There was a significant varietal difference ($p<0.05$) in starch, amylose, starch damage, protein, sugar, pH, moisture and ash content. Products from cassava roots have been shown to have very low protein and sugar content but a high content of starch[17]. The results of chemical analyses from this study also showed similar trends to results from previous authors.

Protein content ranged from 0.7% for variety 97/2205 to 1.60% for varieties TMS 30572, 92/0067, 92B/00068, 96/1642, 97/0162, 97/0211, 97/3200, 97/4769 and 98/0002 for Year 1. For Year 2, variety 98/0505 had the lowest value (0.06%) and variety 97/3200 had the highest value (0.34%). The protein content of 0.7-1.06% (Year 1) and 0.06-0.34% (Year 2) falls within the findings of previous authors[23, 24].

Sugar content ranged from 0.39% for TMS 4(2)1425 to 1.45% for 97/2205 in Year 1 and from 0.52% for 98/2226 to 1.13% for TMS 419 in Year 2. The result obtained for sugar in the present study agreed with the range (0.51 -3.56%) reported by Onitilo *et al.*[25].

Starch content of the different CMD varieties ranged from 61.36% for 92/0326 to 91.78% for 94/0026 for Year 1 and from 64.67% for 97/4763 to 84.21% for 97/0162 for Year 2. Starch content of the different CMD varieties ranging from 64.13% to 86.45% for two years falls within values reported by previous authors[29, 30].

Amylose content was 19.25- 25.08% in Year 1 and 16.19-20.29% in Year 2. Varieties with lowest values were 96/0603 in Year 1 and 94/0039 in Year 2. Varieties with the highest contents were 98/2226 in Year 1 and 96/0603 in Year 2. The amylose contents of starches fall within previous values of 13.6 to 35.8% as reported by Rickard *et al.*[5] and 17.3 to 23.5% by Charoentrath *et al.*[18]. Amylose is the linear component of starch. It imparts a definite characteristic to starch and, therefore, its content is an important criterion in starch quality[7]. Cassava starch contains amylose molecules which have substantially higher degree of polymerization than the amylose from corn and wheat starches[19].

For amylopectin contents, variety 98/2226 (74.88%) in Year 1 and 96/0603 (79.71%) in Year 2 had the least and 96/0603 (80.75%) in Year 1 and 94/0039 (83.71%) in Year 2 had the highest content. The amylopectin content of 74.88-80.75% (Year 1) and 79.71-83.71% (Year 2) is in agreement with that recorded by the International Starch Trading A/S as at 2003 of 70-85%. The relative proportion of amylose (15-20) and amylopectin (75-85%) greatly influences the physicochemical properties of starch and its nutritional and industrial importance[20]. The functional property of most starches depends on the amylopectin constituent[21, 22].

Starch damage ranged from 0.81 to 1.67% for Year 1 and from 0.58 to 0.89% for Year 2 with 30572, which is a check, and 99/3073 as lowest and 96/2101 as highest. Starch damage agreed with the range 0.39-2.10% reported by Onitilo *et al.*[25]. The degree of starch damage is a function of processing especially during grating and drying. The finer the mash size, the higher the degree of starch damage. Howling[26] and Evers and Stevens[27] also reported that the extraction procedure used can influence the degree of starch damage, which has been shown to have a profound effect on the properties of starch.

The pH values obtained for the different CMD varieties ranged from 3.73 to 6.88 for Year 1 and from 5.25 to 9.3 for Year 2. The initial pH, apart from its role as a starting point in the determination of acid factor, may be used as an indication of the presence of molds or other impurities in the starch[28].

Year 1 had moisture content ranging from 7.47% for M98/0028 to 14.55% for 98/0501; Year 2 had 7.51% for TMS 4(2)1425 and 52% for 91/0234. Starches from CMD-resistant cassava varieties had moisture within the recommended maximum value of 14%[24].

Ash content ranged from 0.05 for 92B00068 to 0.36% for M98/0068 for Year 1 and from 0.03% for 95/0166 to 0.77% for 96/1632 for Year 2. A minimum ash content of 0.06% and a maximum of

Table 1. Chemical properties (%) of cassava starch 39 different CMD-resistant varieties for Year 1.

Clone	Amylose	Amylopectin	Protein	Sugar	Starch damage	pH	Moisture	Ash	Starch
30572	21.97^{hijkl}	78.03^{efghi}	1.06^{a}	1.04^{bcdefgh}	0.81^{n}	5.69^{ij}	8.51^{jklm}	0.23^{ab}	66.50^{bcde}
4(2)1425	23.81^{cd}	76.19^{mn}	0.82^{ab}	0.39^{j}	1.14^{hijkl}	5.25^{L}	8.33^{klm}	0.28^{ab}	71.89^{bcde}
82/00058	21.21^{klmn}	78.79^{cdef}	0.94^{ab}	1.82^{a}	1.22^{fghijk}	5.56^{jk}	8.03^{lm}	0.25^{ab}	76.11^{abcde}
91/02324	21.36^{jklmn}	78.64^{cdefg}	0.94^{ab}	0.56^{ghij}	1.49^{abcde}	5.51^{k}	14.12^{ab}	0.08^{ab}	71.74^{bcde}
92/0067	19.71^{p}	80.29^{a}	1.06^{a}	0.53^{ghij}	1.37^{cdefg}	5.72^{i}	8.03^{lm}	0.25^{ab}	71.59^{bcde}
92/0325	23.87^{cd}	76.13^{mn}	0.70^{b}	0.41^{ij}	1.37^{cdefg}	3.77^{Uv}	9.39^{fghijkl}	0.15^{ab}	70.82^{bcde}
92/0326	21.08^{lmn}	78.92^{cde}	0.82^{ab}	0.68^{efghij}	1.34^{defgh}	6.88^{a}	15.46^{a}	0.10^{ab}	61.36^{e}
92B/00061	21.05^{lmn}	78.95^{cde}	0.94^{ab}	0.81^{defghij}	1.44^{cde}	5.06^{Mn}	9.08^{hijklm}	0.14^{ab}	78.49^{abcde}
92B/00068	21.57^{ijklmn}	78.43^{cdefgh}	1.06^{a}	0.77^{defghij}	1.27^{efghij}	5.99^{gh}	8.98^{ijklm}	0.05^{b}	81.35^{abc}
94/0026	21.33^{klmn}	78.67^{cdefg}	0.82^{ab}	1.14^{bcdef}	1.09^{jkl}	5.21^{Lm}	8.67^{jklm}	0.12^{ab}	91.78^{a}
94/0039	23.32^{cdef}	76.68^{klmn}	0.70^{b}	1.39^{abc}	1.42^{cdef}	6.25^{ef}	10.04^{efghijk}	0.19^{ab}	81.06^{abc}
94/0561	23.56^{cd}	76.44^{mn}	0.70^{b}	1.21^{bcde}	1.27$_{efghij}$	3.90^{Tu}	10.48^{defghi}	0.04^{b}	73.22^{bcde}
95/0166	23.93^{cd}	76.07^{mn}	0.70^{b}	0.81^{defghij}	1.02^{klm}	6.52^{cd}	9.26^{ghijkl}	0.29^{ab}	73.31^{bcde}
95/0289	23.68^{cd}	76.32^{mn}	0.82^{ab}	0.85^{cdefghij}	1.14^{hijkl}	3.73^{v}	9.08^{hijklm}	0.15^{ab}	70.41^{bcde}
96/0523	22.19^{ghijk}	77.88^{fghij}	0.93^{ab}	0.72^{efghij}	0.94^{lmn}	4.37^{qr}	10.80^{defgh}	0.09^{ab}	77.86^{abcde}
96/0603	19.25^{p}	80.75^{a}	0.93^{ab}	0.91^{bcdefghij}	1.37^{cdefg}	6.11^{fg}	9.27^{ghijkl}	0.22^{ab}	64.74^{cde}
96/1089A	19.46^{p}	80.54^{a}	0.82^{ab}	1.10^{bcdefg}	1.67^{a}	6.73^{ab}	9.04^{ijlkm}	0.28^{ab}	70.30^{bcde}
96/1632	20.68^{no}	79.31^{bc}	0.93^{ab}	0.67^{efghij}	1.47^{bcde}	5.47^{k}	8.28^{klm}	0.27^{ab}	73.48^{bcde}
96/1642	23.26^{cdef}	76.74^{klmn}	1.06^{a}	0.72^{efghij}	0.89^{mn}	4.60^{o}	11.52^{cde}	0.12^{ab}	77.86^{abcde}
97/0162	21.79^{hijklm}	78.21^{defghi}	1.06^{a}	0.85^{cdefghij}	1.04^{klm}	5.06^{Mn}	8.09^{lm}	0.20^{ab}	78.26^{abcde}
97/0211	24.11^{bc}	75.89^{no}	1.06^{a}	0.78^{defghij}	1.32^{defghi}	4.01^{T}	11.03^{def}	0.17^{ab}	77.89^{abcde}
97/2205	23.47^{cde}	76.53^{lmn}	0.70^{b}	1.45^{ab}	1.17^{ghijk}	6.17^{f}	9.87^{efghijk}	0.19^{ab}	83.94^{ab}
97/3200	21.05^{lmn}	78.95^{cde}	1.06^{a}	0.88^{bcdefghij}	1.64^{ab}	6.20^{f}	13.72^{b}	0.33^{ab}	70.87^{bcde}
97/4763	22.46^{fghi}	77.54^{hijk}	0.82^{ab}	0.48^{hij}	1.12^{ijkl}	6.40^{de}	8.49^{jklm}	0.05^{b}	63.60^{cde}
97/4769	20.93^{mno}	79.07^{bcd}	1.06^{a}	1.04^{bcdefgh}	1.32^{defghi}	5.09^{Lmn}	8.31^{klm}	0.32^{ab}	71.90^{bcde}
97/4779	22.95^{defg}	77.05^{jklm}	0.82^{ab}	1.19^{bcdef}	1.22^{fghijk}	4.20^{s}	11.75^{cd}	0.15^{ab}	77.29^{abcde}
98/0002	23.87^{cd}	76.13^{mn}	1.06^{a}	0.48^{hij}	1.44^{cde}	4.53^{op}	10.23^{defghij}	0.29^{ab}	68.04^{bcde}
98/0505	20.07^{op}	79.93^{ab}	1.06^{a}	1.00^{bcdefgh}	1.27^{efghij}	5.25^{L}	10.91^{defg}	0.26^{ab}	75.15^{abcde}
98/0510	21.08^{lmn}	78.92^{cde}	0.82^{ab}	1.31^{abcd}	1.39^{cdef}	6.86^{a}	14.55^{ab}	0.15^{ab}	83.16^{ab}
98/0581	21.66^{hijklmn}	78.34^{cdefghi}	1.06^{a}	1.19^{bcde}	1.57^{abc}	4.32^{opqrs}	8.38^{klm}	0.13^{ab}	81.11^{abc}
98/2101	21.54^{ijklmn}	78.46^{cdefgh}	0.94^{ab}	0.62^{fghij}	1.07^{jklm}	4.40^{pqr}	8.82^{ijklm}	0.05^{b}	76.48^{abcde}
98/2226	25.08^{a}	74.88^{p}	0.94^{ab}	0.95^{bcdefghij}	1.17^{ghijk}	4.28^{rs}	8.76^{ijklm}	0.07^{ab}	75.68^{abcde}
99/2123	23.72^{cd}	76.29^{mn}	0.82^{ab}	0.98^{bcdefghi}	1.17^{ghijk}	5.45^{k}	9.55^{fghijkl}	0.14^{ab}	63.03^{de}
99/3073	20.81^{mno}	79.19^{bcd}	0.82^{ab}	1.09^{bcdefg}	0.94^{lmn}	4.48^{opq}	7.805^{lm}	0.20^{ab}	80.14^{abcd}
99/6012	24.99^{ab}	75.00^{op}	0.82^{ab}	1.04^{bcdefgh}	1.32^{defghi}	5.52^{K}	11.45^{de}	0.16^{ab}	69.45^{bcde}
M98/0028	22.31^{ghij}	77.69^{ghij}	0.82^{ab}	0.95^{bcdefghij}	1.17^{ghijk}	4.96^{N}	7.47^{m}	0.10^{ab}	70.96^{bcde}
M98/0040	24.11^{bc}	75.89^{no}	0.70^{b}	0.81^{defghij}	1.17^{ghijk}	5.95^{h}	9.41^{fghijkl}	0.24^{ab}	68.93^{bcde}
M98/0068	23.47^{cde}	76.53^{lmn}	0.82^{ab}	0.75^{defghij}	1.27^{efghij}	5.52^{k}	8.93^{ijklm}	0.36^{a}	73.16^{bcde}
TME419	22.58^{efgh}	77.42^{ijkl}	0.72^{b}	1.00^{bcdefgh}	1.17^{ghijk}	6.58^{bc}	13.04^{bc}	0.18^{ab}	71.55^{bcde}

Values are means of three replicates Means having different superscript within column are significantly different ($p<0.05$)

0.52% over a two-year period are in agreement with previous value of 0.5% reported by Benesi *et al.* [24].

Functional properties: Tables 3 and 4 show the functional properties of the different CMD-resistant varieties for two years. Dispersibility ranged from 79.5 to 87% in Year 1 and from 79.5 to 85.5% in Year 2; water absorption capacity (WAC) ranged from 3.52 to 105.9% in Year 1 and from 57.59 % to 81.39 % in Year 2. Percentage dispersibility of the starches is in agreement with the result obtained by Onitilo *et al.*[25] who reported dispersibility value of 81.5-89.5%. Kulkarni *et al.* [30] reported that the higher the dispersibility, the better the starch reconstitutes in water to give a fine and consistent paste. Significant differences ($p<0.05$) were observed for values of water absorption capacity of starches from the two-year experiments.

Swelling power had values ranging from 10.91 to 17.47% in Year 1 and from 8.57 to 14.28% in Year 2; solubility index ranged from 4.68 to 26.36% in Year 1 and from 2.07 to 14.36% in Year 2; the least gelation concentration ranged from 4.0 to 7.0% in both years. Swelling power values obtained for Year 1 and 2 fall within the range of 10.3-36.5% reported by Sanni *et al.* [23]. Kay [31] defined swelling power as the swollen sediment weight (g) per gram of dry starch and reported swelling power of 17.44% for cassava starch. Solubility values (Year 1 and 2) agreed with results of

Table 2. Chemical properties (%) of cassava starch 39 different CMD-resistant varieties for Year 2.

Clone	Amylose	Amylopectin	Protein	Sugar	Starch damage	pH	Moisture	Ash	Starch
30572	19.65^{abcde}	89.36^{efghijk}	0.16^{n}	0.91^{cdefg}	0.86^{ab}	9.1^{abc}	12.98^{abcdefgh}	0.40^{abcde}	75.08^{hijkl}
4(2)1425	19.80^{abcde}	80.2^{efghijk}	0.15^{o}	0.66^{lmn}	0.74^{defg}	9.1^{abc}	7.51^{m}	0.49^{abcd}	79.34^{bcdefgh}
82/00058	19.65^{abcde}	80.36^{efghijk}	0.19^{k}	0.78^{fghijkl}	0.76^{cdef}	9^{abc}	11.51^{bcdefghijkl}	0.33^{bcde}	82.06^{abcd}
91/02324	19.52^{abcdef}	80.48^{efghijk}	0.24^{f}	0.74^{ghijkl}	0.61^{hi}	7^{ijkl}	15.52^{a}	0.31^{cdef}	74.21^{jklm}
92/0067	19.77^{abcde}	80.23^{efghijk}	0.09^{s}	0.03^{abcd}	0.81^{abcd}	6.45^{klm}	12.17^{bcdefghijk}	0.18^{cdef}	79.31^{bcdefgh}
92/0325	19.16^{abcdefgh}	80.85^{bcdefghijk}	0.15^{o}	0.72^{ijklm}	0.81^{abcd}	8.95^{abc}	11.69^{bcdefghijk}	0.48^{abcde}	72.81^{lmn}
92/0326	19.65^{abcde}	80.36^{efghijk}	0.13^{q}	0.74^{ghijkl}	0.76^{cdef}	6.45^{klm}	9.24^{klm}	0.39^{abcde}	75.88^{ghijkl}
92B/00061	19.24^{abcdefgh}	80.26^{efghijk}	0.17^{m}	0.79^{fghijkl}	0.76^{cdef}	9^{abc}	11.75^{bcdefghik}	0.20^{cdef}	79.86^{abcdefg}
92B/00068	19.25^{abcdefgh}	80.75^{cdefghijk}	0.19^{k}	0.73^{hijkl}	0.74^{defg}	7.7^{efghij}	13.06^{abcdefgh}	0.27^{cdef}	77.04^{efghijkl}
94/0026	18.18^{efgh}	81.83^{bcd}	0.26^{e}	0.67^{klmn}	0.74^{defg}	8.8^{abcd}	10.14^{hijklm}	0.39^{abcde}	81.12^{abcdef}
94/0039	16.19^{l}	83.71^{a}	0.20^{j}	0.66^{lmn}	0.84^{abc}	7.7^{efghij}	13.85^{abcd}	0.53^{abcd}	79.66^{abcdefgh}
94/0561	19.65^{abcde}	80.36^{efghijk}	0.23^{g}	0.99^{abcde}	0.74^{defg}	9.05^{abc}	10.76^{fghijklm}	0.13^{def}	80.03^{abcdefg}
95/0166	18.06^{efgh}	81.95^{bc}	0.12^{r}	0.73^{ghijkl}	0.81^{abcd}	8.15^{bcdefg}	11.63^{bcdefghijkl}	0.03^{f}	81.67^{abcde}
95/0289	19.06^{abcdefgh}	80.94^{bcdefghijk}	0.14^{p}	0.74^{ghijkl}	0.76^{cdef}	9^{abc}	10.23^{ghijklm}	0.20^{cdef}	81.02^{abcdef}
96/0523	19.19^{abcdefgh}	80.82^{bcdefghijk}	0.29^{c}	0.74^{ghijkl}	0.84^{abc}	6.25^{lm}	14.48^{ab}	0.50^{abcd}	81.13^{abcdefg}
96/0603	20.29^{a}	79.71^{k}	0.23^{g}	0.84^{efghijk}	0.79^{bcde}	8.65^{abcde}	12.72^{abcdefghi}	0.10^{ef}	77.49^{defghijk}
96/1089A	19.13^{abcdefgh}	80.88^{bcdefghijk}	0.29^{c}	0.66^{lmn}	0.86^{ab}	9^{abc}	11.85^{abcdefghijk}	0.24^{cdef}	70.06^{mn}
96/1632	19.00^{abcdefgh}	80.91^{bcdefghijk}	0.26^{e}	0.90^{cdefgh}	0.81^{abcd}	8.95^{abc}	9.46^{ijklm}	0.77^{a}	74.56^{ijkl}
96/1642	18.54^{cdefgh}	81.46^{bcde}	0.29^{c}	0.05^{abc}	0.74^{defg}	6.5^{klm}	8.30^{klm}	0.35^{bcde}	74.14^{bcdefghi}
97/0162	18.15^{efgh}	81.86^{bcd}	0.20^{j}	0.10^{ab}	0.76^{cdef}	7.6^{fghij}	13.77^{abcde}	0.45^{abcde}	84.21^{a}
97/0211	18.58^{cdefgh}	81.43^{bcde}	0.18^{L}	0.62^{lmn}	0.71^{efg}	7.05^{hijkl}	13.62^{abcdef}	0.39^{abcde}	80.57^{abcdef}
97/2205	19.65^{abcde}	80.36^{efghijk}	0.21^{i}	0.62^{lmn}	0.84^{abc}	7.8^{defghi}	10.50^{efghijklm}	0.12^{def}	76.78^{fghijkl}
97/3200	19.77^{abcde}	80.23^{efghijk}	0.34^{a}	1.05^{abc}	0.81^{abcd}	6.85^{ijklm}	10.71^{defghijklm}	0.16^{def}	73.17^{klmn}
97/4763	19.33^{abcdefg}	80.66^{defghijk}	0.23^{g}	0.88^{cdefghij}	0.81^{abcd}	6.45^{klm}	9.31^{jklm}	0.49^{abcd}	64.67^{n}
97/4769	18.12^{efgh}	81.86^{bcd}	0.30^{b}	0.54^{mn}	0.86^{ab}	7.4^{ghijk}	10.10^{hijklm}	0.62^{ab}	83.05^{ab}
97/4779	18.88^{bcdefgh}	81.12^{bcdefghi}	0.26^{e}	1.02^{abcde}	0.76^{cdef}	8.15^{bcdef}	12.63^{abcdefghijk}	0.22^{cdef}	78.96^{bcdefghi}
98/0002	20.19^{ab}	79.81^{k}	0.24^{f}	0.50^{n}	0.76^{cdef}	9.3^{a}	13.86^{abcd}	0.37^{abcde}	82.29^{abc}
98/0505	18.27^{cdefgh}	81.73^{bcd}	0.06^{t}	0.71^{jklm}	0.69^{fgh}	6.7^{jklm}	10.34^{fghijklm}	0.23^{cdef}	82.45^{abc}
98/0510	19.71^{abcde}	80.14^{ghijk}	0.14^{p}	0.75^{ghijkl}	0.76^{cdef}	9.1^{abc}	8.94^{klm}	0.46^{abcde}	77.95^{cdefghij}
98/0581	17.96^{gh}	82.04^{b}	0.34^{a}	0.95^{bcdef}	0.66^{ghi}	6.95^{ijklm}	14.09^{abc}	0.25^{cdef}	79.13^{bcdefghi}
98/2101	19.77^{abcde}	80.23^{efghijk}	0.20^{j}	0.71^{ijklm}	0.89^{a}	8.8^{abcd}	10.85^{cdefghijkl}	0.10^{ef}	77.28^{efghijkl}
98/2226	20.14^{ab}	79.87^{jk}	0.28^{d}	0.52^{n}	0.66^{ghi}	7.75^{efghi}	13.96^{abcd}	0.26^{cdef}	76.49^{fghijkl}
99/2123	20.26^{a}	79.74^{k}	0.13^{q}	1.09^{ab}	0.81^{abcd}	5.25^{N}	8.99^{klm}	0.48^{abcde}	77.20^{efghijkl}
99/3073	19.94^{abcd}	80.06^{ghijk}	0.20^{j}	0.65^{lmn}	0.59^{i}	5.95^{mn}	14.20^{ab}	0.33^{bcde}	75.04^{hijkl}
99/6012	18.57^{cdefgh}	81.43^{bcde}	0.09^{s}	0.96^{defghij}	0.74^{defg}	6.25^{lm}	10.18^{hijklm}	0.26^{cdef}	83.06^{ab}
M98/0028	20.20^{a}	79.81^{k}	0.17^{m}	0.89^{cdefghij}	0.76^{cdef}	9.10^{abc}	11.86^{abcdefghijk}	0.25^{cdef}	77.05^{efghijkl}
M98/0040	19.98^{abcd}	80.02^{hijk}	0.14^{p}	0.85^{efghijk}	0.76^{cdef}	8.10^{bcdefg}	10.17^{hijklm}	0.56^{abc}	81.14^{abcdef}
M98/0068	20.11^{abc}	79.90^{ijk}	0.22^{h}	0.53^{n}	0.81^{abcd}	9.10^{abc}	10.00^{hijklm}	0.26^{cdef}	76.87^{fghijkl}
TME419	20.26^{a}	79.75^{k}	0.14^{p}	1.13^{a}	0.81^{abcd}	8.60^{abcdef}	11.51^{bcdefghijkl}	0.17^{cdef}	84.19^{a}

Values are means of three replicates. Means having different superscript within column are significantly different ($p<0.05$)

Onitilo *et al.* [25] and Sanni *et al.* [23]. Cassava starch has a higher solubility than other crops [32]. Rasper [33] stated that the differences in swelling and solubilization patterns of various starches can be explained on the basis of the differences in the character and strength of the miscellar network within the granules. The least gelation concentration is in agreement with the findings of Adebowale *et al.* [34]. Least gelation concentration can be described as a measure of the minimum amount of starch or blends of starch that is needed to form a gel in a given volume of water. The higher the least gelation concentration, the higher the amount of the starch needed to form a gel [34]. Lower gelation capacity will definitely have a favorable economic impact on use, since this implies that less starch is required to make food gels. The gelation capacity is an important quality factor considered for starches or flour used in pasta production [3].

Conclusions

The study has shown that there are significant varietal and seasonal differences in the chemical and functional properties of the 39 CMD-resistant varieties studied. The cassava roots under review were collected from a high rainfall region and environmental factors such as rainfall are contributory factors to

Table 3. Functional properties (%) of cassava starch 39 different CMD-resistant varieties for Year 1.

Clone	Dispersibility	Water absorption capacity	Swelling power	Solubility	Least gelation concentration
30572	84.50[def]	105.90[a]	14.27[abcdef]	16.29[abcdef]	5.00[bc]
4(2)1425	82.50[hi]	90.40 [abcd]	13.23[bcdef]	10.20[cdefg]	7.00[a]
82/00058	84.50[def]	3.52 [f]	12.66 [bcdef]	16.97[abcdef]	5.00[bc]
91/02324	84.00[efg]	76.92 [abcd]	13.50 [bcdef]	8.97[cdefg]	7.00[a]
92/0067	84.50[def]	91.96 [abcd]	14.02 [bcdef]	7.95 [cdefg]	5.00[bc]
92/0325	84.00[efg]	86.43 [abcd]	15.86[ab]	9.37 [cdefg]	5.00[bc]
92/0326	84.50[def]	70.89 [abcd]	14.16[abcdef]	7.41[defg]	5.00[bc]
92B/00061	84.50[def]	92.39 [abcd]	14.32 [abcdef]	10.39[cdefg]	5.00[bc]
92B/00068	85.50[bcd]	58.57 [bcd]	14.38 [abcdef]	13.90[bcdefg]	5.00[bc]
94/0026	84.50[def]	91.15 [abcd]	13.27[bcdef]	12.64[bcdefg]	4.00[c]
94/0039	84.50[def]	45.41 [df]	13.76 [bcdef]	17.09[abcdef]	5.00[bc]
94/0561	84.00[efg]	89.93 [abcd]	13.99 [bcdef]	13.79[bcdef]	5.00[bc]
95/0166	85.00[cde]	91.38 [abcd]	12.90 [bcdef]	17.98[abcde]	4.00[c]
95/0289	84.00[efg]	86.47 [abcd]	13.34 [bcdef]	6.22[fg]	5.00[bc]
96/0523	82.00[ij]	92.99[abc]	15.38[abcd]	14.84[bcdef]	6.00[ab]
96/0603	84.50[def]	61.69 [abcd]	13.49 [bcdef]	26.36[a]	6.00[ab]
96/1089A	86.00[abc]	72.21 [abcd]	13.35 [bcdef]	8.39[cdefg]	4.00[c]
96/1632	84.00[efg]	96.05[abc]	12.84 [bcdef]	14.12[bcdefg]	6.00[ab]
96/1642	83.50[fgh]	70.72 [abcd]	11.99[def]	9.12[cdefg]	6.00[ab]
97/0162	84.50[def]	91.73 [abcd]	14.36[abcdef]	4.72[g]	6.00[ab]
97/0211	82.50[hi]	88.59 [abcd]	13.64[bcdef]	11.19[cdefg]	5.00[bc]
97/2205	85.50[bcd]	96.47[abc]	14.38[abcdef]	15.05[bcdefg]	5.00[bc]
97/3200	84.50[def]	93.21[abc]	12.61[bcdef]	18.36[abcd]	6.00[ab]
97/4763	84.00[efg]	92.40 [abcd]	13.07[bcdef]	16.51[abcdef]	4.00[c]
97/4769	83.50[fgh]	14.00[ef]	14.90[abcde]	14.16[bcdefg]	7.00[a]
97/4779	79.50[k]	63.42 [abcd]	11.44[ef]	6.12[fg]	4.00[c]
98/0002	82.00[ij]	97.66[abc]	15.50[abc]	4.68[g]	6.00[ab]
98/0505	84.50[def]	89.11 [abcd]	14.30[abcdef]	8.12[cdefg]	5.00[bc]
98/0510	86.50[ab]	56.51[cd]	10.91[f]	12.34[bcdefg]	6.00[ab]
98/0581	83.00[ghi]	105.64[ab]	15.33[abcd]	15.60[abcdefg]	6.00[ab]
98/2101	82.50[hi]	90.72 [abcd]	17.47[a]	18.94[abc]	6.00[ab]
98/2226	81.00[j]	101.72 [abc]	13.84 [bcdef]	12.13[bcdefg]	4.00[c]
99/2123	85.00[cde]	79.69[abcd]	14.77 [abcde]	16.90[abcdef]	5.00[bc]
99/3073	83.00[ghi]	98.31 [abc]	14.21 [abcdef]	12.03[bcdefg]	6.00[ab]
99/6012	85.00[cde]	89.02[abcd]	12.89 [bcdef]	7.09[defg]	7.00[a]
M98/0028	84.00[efg]	45.32 [de]	14.81[abcde]	12.92[bcdefg]	7.00[a]
M98/0040	86.00[abc]	83.12[abcd]	13.04[bcdef]	10.43[cdefg]	5.00[bc]
M98/0068	82.50[hi]	98.29 [abc]	13.45 [bcdef]	6.83[efg]	7.00[a]
TME419	87.00[a]	72.95 [abcd]	12.08[cdef]	23.12[ab]	5.00[bc]

Values are means of three replicates. Means having different superscript within column are significantly different ($p<0.05$).

the observed differences. These wide differences in the starch properties present characteristics of great interest for food and industrial application and this is important information to effective research and development.

Acknowledgement

This publication is an output from Integrated Cassava Project (CMD and CEDP) funded by the Federal Government of Nigeria, USAID, SPDC, Oil Companies and State Government in South-South and South-East Nigeria.

Table 4. Functional properties (%) of cassava starch 39 different CMD-resistant varieties for Year 2.

Clone	Dispersibility	Water absorption capacity	Swelling power	Solubility	Least gelation concentration
30572	84.50^{ab}	61.64^{cd}	12.03^{abcdef}	4.31^{ghij}	5.00^{ab}
4(2)1425	82.50^{e}	65.02^{abcd}	13.68^{ab}	3.65^{hij}	6.00^{ab}
82/00058	84.50^{bcd}	67.52^{abcd}	13.95^{ab}	4.92^{fghij}	6.00^{ab}
91/02324	84.00^{ab}	67.99^{abcd}	10.20^{cdefgh}	3.53^{hij}	6.00^{ab}
92/0067	84.50^{ab}	61.98^{cd}	12.18^{abcde}	5.46^{efghij}	7.00^{a}
92/0325	84.00^{abc}	63.79^{cd}	12.26^{abcd}	5.10^{efghij}	7.00^{a}
92/0326	84.50^{abc}	57.60^{d}	10.66^{cdefgh}	2.07^{j}	4.00^{b}
92B/00061	84.50^{abc}	68.07^{abcd}	14.11^{ab}	$8.23^{abcdefghij}$	5.00^{ab}
92B/00068	85.50^{de}	64.34^{bcd}	10.71^{cdefgh}	$7.75^{abcdefghij}$	7.00^{a}
94/0026	84.50^{a}	71.85^{abcd}	12.08^{abcdef}	$6.13^{defghij}$	4.00^{b}
94/0039	84.50^{de}	67.02^{abcd}	11.69^{abcdef}	11.77^{abcdef}	6.00^{ab}
94/0561	84.00^{cde}	69.13^{abcd}	10.17^{cdefgh}	5.35^{efghij}	6.00^{ab}
95/0166	85.00^{abc}	68.49^{abcd}	10.06^{defgh}	$9.07^{abcdefghi}$	7.00^{a}
95/0289	84.00^{ab}	63.08^{cd}	11.46^{bcdefg}	13.51^{ab}	7.00^{a}
96/0523	82.00^{ab}	63.74^{cd}	10.59^{cdefgh}	$8.02^{abcdefghij}$	6.00^{ab}
96/0603	84.50^{abc}	61.69^{cd}	12.04^{abcdef}	5.25^{efghij}	6.00^{ab}
96/1089A	86.00^{cde}	66.80^{abcd}	14.05^{ab}	$8.24^{abcdefghij}$	6.00^{ab}
96/1632	84.00^{e}	67.40^{abcd}	12.22^{abcde}	12.71^{abcd}	4.00^{b}
96/1642	83.50^{ab}	66.03^{abcd}	11.88^{abcdef}	14.36^{a}	4.00^{b}
97/0162	84.50^{ab}	77.46^{abc}	12.81^{abc}	4.09^{ghij}	6.00^{ab}
97/0211	84.50^{a}	65.46^{abcd}	10.08^{defgh}	5.14^{efghij}	7.00^{a}
97/2205	83.00^{cde}	65.69^{abcd}	14.28^{a}	2.49^{ij}	7.00^{a}
97/3200	84.50^{ab}	66.99^{abcd}	12.16^{abcde}	$8.58^{abcdefghij}$	6.00^{ab}
97/4763	84.00^{abc}	65.12^{abcd}	11.74^{abcdef}	13.31^{abc}	7.00^{a}
97/4769	79.50^{e}	64.59^{bcd}	9.54^{efgh}	$8.43^{abcdefghij}$	5.00^{ab}
97/4779	82.00^{e}	69.94^{abcd}	9.43^{fgh}	11.94^{abcde}	7.00^{a}
98/0002	83.50^{bcd}	68.44^{abcd}	12.40^{abcd}	$6.55^{cdefghij}$	7.00^{a}
98/0505	84.50^{ab}	64.66^{bcd}	8.85^{gh}	$8.76^{abcdefghij}$	5.00^{ab}
98/0510	84.00^{abc}	61.98^{cd}	12.22^{abcde}	$6.90^{bcdefghij}$	6.00^{ab}
98/0581	84.00^{abc}	70.12^{abcd}	$10.77^{bcdefgh}$	4.86^{ghij}	5.00^{ab}
98/2101	84.50^{ab}	69.86^{abcd}	10.42^{cdefgh}	$6.40^{defghij}$	6.00^{ab}
98/2226	84.50^{ab}	68.75^{abcd}	10.38^{cdefgh}	5.39^{efghij}	6.00^{ab}
99/2123	82.00^{e}	71.15^{abcd}	9.54^{efgh}	$5.87^{defghij}$	5.00^{ab}
99/3073	82.50^{de}	67.56^{abcd}	8.57^{h}	3.23^{ij}	7.00^{a}
99/6012	83.00^{cde}	80.54^{ab}	11.97^{abcdef}	$10.42^{abcdefgh}$	6.00^{ab}
M98/0028	83.00^{cde}	66.89^{abcd}	12.76^{abcd}	4.40^{ghij}	4.00^{a}
M98/0040	84.50^{ab}	89.29^{d}	12.24^{abcde}	$6.35^{defghij}$	5.00^{ab}
M98/0068	84.50^{ab}	66.69^{abcd}	12.71^{abcd}	4.59^{ghij}	6.00^{ab}
TME419	83.00^{cde}	81.39^{a}	10.53^{cdefgh}	$6.91^{bcdefghij}$	6.00^{ab}

Values are means of three replicates. Means having different superscript within column are significantly different ($p<0.05$).

References

[1]FAO 1999. Food Outlook 22. FAO Agricultural Services Bulletin, Rome,Italy.

[2]Anon 2004. Preemptive management of the virulent cassava mosaic disease through an integrated cassava development approach for enhanced rural sector economy in the south–south and south–east zones of Nigeria. Multiple Investor Development Project Document, IITA, Ibadan, Nigeria.

[3]Shittu, T. A., Sanni, L.O., Awonorin, S. O., Maziya-Dixon, B. and Dixon, A. 2007. Effect of genotype on the flour making properties of some CMD-resistant varieties of cassava. Food Chemistry **101**:1634–1643.

[4]Sajid, A. 2003. Starch research over the years. Food Research International **36**:307-308.

[5]Rickard, J. R., Asaoka, M. A. and Blanshard, J. M. V. 1991. The physicochemical properties of cassava starch. Trop. Sci. **31**:189-207.

[6]Chang, L. T. 1996. The manufacture of sugars from starch. Inter. Meeting on Syrup Carbohydrate, South China Univ. Technology, China, March 6-7.

[7]Kurup, G. T. 1994. Tuber Crop Starches. Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram, Kerala, India, Tech. Bulletin Series 18.

[8]Abraham, E.T. 1993. Stabilization of paste viscosity of cassava by heat moisture treatment. Starch/Stärke **45**(3):131-135.

[9]Osunsami, A.T., Akingbala, J. O. and Oguntimehin, G. B. 1989. Effect

of storage on starch content and modification of cassava starch. Starch/ Stärke **41**:54-57.
[10]AOAC 1990. Official Methods of the Association of Official Analytical Chemists. Arlington, Virginia, USA.
[11]Dubois, M., Gillies, K. A., Hamilton, J K., Reberts, P. A. and Smith, F. 1956. Colorimetric method for determination of sugar and related substances. Anal. Chem. **28**:350–356.
[12]Williams, P.C., Kuzina, F. D. and Hlynka, I. A. 1970. A rapid colorimetric procedure for estimating the amylose content of starches and starch. Cereal Chemistry **47**(4):411-413.
[13]McDermott, E. E. 1980. The rapid non-enzymatic determination of damaged starch in flour. J. Sci. Food Agric. **31**:405–413.
[14]Ruales, J., Valencia, S. and Nair, B. 1993. Effect of processing on the physico-chemical characteristics of quinoa flour. Starch/Stärke **45**:13-19.
[15]Sathe, S. K. and Salunkhe, D. K. 1981. Functional properties of the great northern bean (*Phaseolus vulgaris*) flour. J. Food Sci. **46**:71-74.
[16]SAS 2003. Statistical Analysis Software (SAS) System for Windows, SAS Institute Inc., Cary, NC, USA.
[17]Eggleston, G., Omoaka, P. E. and Arowoshegbe, A. C. 1993. Flour, starch and composite breadmaking quality of various cassava clones. J. Sci. Food Agric. **62**:49-59.
[18]Charoentrath, S., Boonsang, O. and Narkviot, C. 2004. Biochemical composition in cassava root and physicochemical properties of starch. Paper presented at the sixth International Scientific Meeting of the Cassava Biotechnology Network, 8-14 March, IITA, Cali, Columbia.
[19]Swinkels, J.J.M. 1992. Composition and properties of commercial native starches. Starch/Stärke **37**(1):1-5.
[20]Bornet, F., Champ, M., Cloarec, D. and Slama, G. 1990. Importance de la nature physicochimique des amidons sur leurs effets nutritionnels chez l'homme. Cahiers de Nutrition et de Dietetique (FRA) **25**(4):254-264.
[21]Manners, D. J. 1989. Recent development in our understanding of amylopectine structure. Carbohydrate Polymer **11**:87-112.
[22]Paredex-Lopex, O., Bell-penex, L. A. and Lopex, M.M. 1994. Amylopectin - Structural, gelatinization and retrogradation studies. Food Chem. **30**:441-418.
[23]Sanni, L., Onitilo, M., Oyewole, O.B., Keiths, T. and Westby, A. 2004. Studies into the production and qualities of cassava grits (Tapioca) in Nigeria. The sixth International Scientific Meeting of the Cassava Biotechnology Network, 8–14 March 2004, CIAT, Cali, Columbia.
[24]Benesi, I. R. M., Labuchagne, M.T., Dixon, O.G. and Mahungu, M. N. 2004. Native starch quality of Malawian cassava genotype in different environment. The sixth International Scientific Meeting of the Cassava Biotechnology Network, 8-14 March, CIAT, Cali, Columbia, pp. 104.
[25]Onitilo, M., Sanni, L., Maziya-Dixon, B. and Dixon, A. 2004. Varietal differences in the physicochemical, functional, pasting properties and granule size of starches from different CMD-resistant varieties. Proceeding of International Tropical Root Society, Africa Branch, Mombassa, Kenya (in press).
[26]Howling, D. 1980. The influence of the structure of starch and its rheological properties. Food Chem. **6**:51-61.
[27]Evers, A.D. and Stevens, D. J. 1988. Production and measurement of starch damage in flour. Part 4. Effect of starch damage on hot pasting properties. Starch/Stärke **40**(8):297-299.
[28]FAO 1977. Cassava Processing and Utilization of Cassava Products, Quality Control of Cassava Products. FAO Agricultural Services Bulletin, Rome, Italy.
[29]Moorthy, S. N., Rickard, J. and Blanshard, J. M. V. 2002. Influence of Gelatinization Characteristics of Cassava Starch and Flour on the Textural Properties of Some Food Products. Centro Internacional de Agricultura Tropical, CIAT Publication No. 271, Cali, Colombia.
[30]Kulkarni, K.D., Kulkani, D.N. and Ingle, U.M. 1991. Sorghum malt-based weaning formulations preparation, functional properties and nutritive values. Food Nut. Bull. **13**(4):322-327.
[31]Kay, D.E. 1987. Crops and Products Digest. No. 2: Root Crops. 2nd edn, Tropical Development and Research Institute, London, UK, pp. 30-56.
[32]Moorthy, S. N. 1985. Acetylation of cassava starch using perchloric acid catalysis. Starch/Stärke **37**:307-308.
[33]Rasper, V. 1969. Investigation on starches from major starch crop grown in Ghana. 11. Swelling and solubility patterns and amylo elastic susceptibility. J. Sci. Food Agric. **20**:642-646.
[34]Adebowale, A.A., Sanni, L.O. and Awonorin, S.O. 2005. Effect of texture modifiers on the physicochemical and sensory properties of dried fufu. Food Sci. Techn. Int. **11**(5):373-382.