CONTRIBUTION TO THE UNDERSTANDING OF THE COOKING QUALITY OF CASSAVA (*Manihot esculenta* L. Crantz)

O. SAFO-KANTANKA*, J. OWUSU-NIPAH*, R. ACQUISTUCCI**,
M. OSEI-MINTA*, A. AUBYN*, C. QUANSAH*

* Crop Science Department,
University of Science & Technology,
Kumasi, Ghana

** National Nutrition Institute,
Rome, Italy

Abstract

Cassava cooking quality was investigated from the mealiness of the cooked roots, and elasticity and freedom from lumpiness of the pounded paste. Microscopic study of the cells of raw and cooked roots showed that the cooking quality was related to the size of the starch granules, and the difference between varieties could be explained on the basis of cell disorganization. Dry matter and starch content were related to the differences in mealiness, and amylose content of the starch to the elasticity and smoothness of the pounded paste. Fibre content was negatively correlated with cooking quality. The loss in cooking quality during rainy season was due more to the reduction of dry matter than starch content. Changes in the gelatinization properties of the starch were also related to the loss in cooking quality. Addition of common salt to fufu paste reduced the retrogradation tendency of the starch and made fufu acceptable for consumption long after its preparation. Application of mulch during the dry season minimized soil temperature fluctuations, maintained high soil moisture, which in turn reduced changes in tuber composition.

1. INTRODUCTION

Cassava is an important starchy staple food in many parts of Africa and other tropical regions. In Ghana, the fresh roots are cooked or pounded into a paste known as 'fufu' and eaten with soup. For the Ghanaian consumer, the mealiness of the cooked roots and the elasticity and smoothness or freedom from lumps of the pounded paste are important cooking quality parameters. Local cassava cultivars, which have the desired cooking quality, are often low yielding and susceptible to many diseases and pests. Some high yielding and improved varieties, developed by the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria, were found to lack the cooking quality preferred by the Ghanaian consumer. The main objective of this research was to improve the cooking quality of the IITA lines through mutation breeding. In addition, investigations were carried out to understand the cooking quality of cassava starch to develop simple selection criteria.

2. MATERIALS AND METHODS

Three M_1V_2 populations and a number of selected varieties were investigated for starch quality characters, dry matter, starch content and cooking quality. Microscopic study of the raw and cooked tubers was carried out; starch granule size was measured with a stage and eyepiece micrometer by the method of MacMaster [1]. Dry matter content was measured by drying chips at 80°C to a constant weight in an oven. Starch content was determined as the amount of starch recovered from a known quantity of root tuber. Cell condition and cell disorganization were determined by the method of Shewfelt et al [2]. These parameters were compared with the cooking quality of the varieties and M_1V_2 plants, as judged by a taste panel of cassava consumers.

The study on the proximate composition of cassava roots and starch was carried out at two locations. The cooking quality ranking of two sets of varieties harvested at 6 and 13 months were determined in Ghana, and dry chips were taken to the National Nutrition Institute, Rome, Italy where the rest of the research was carried out. The AOAC [3] methods of analysis were used to determine the fat, protein, ash and fibre contents of the samples. The acid hydrolysis method as described by Rickard and Behn [4] was followed to determine starch content. Amylose content was determined by the iodine calorimetric method as described by McCready and Hassid [5].

The changes in viscosity during starch gelatinization and its relationship to cooking quality of the cassava varieties was determined. This was undertaken at the National Nutrition Institute, Rome, Italy. Both the hot paste viscosity and swelling power and solubility of the starch were studied. To determine hot-paste viscosity, a starch suspension (70g l^{-1}, 500 mi) was placed in the cup of the standard Brabender amylograph and heated from 50°C to 95°C, and held for one hour, then cooled to 50°C and held for an hour. The heating rate was 1.5°C min^{-1} and the bowl speed was 75 rev min^{-1} using 700cm g^{-1} measuring cartridge. The flour was run at two concentrations of 70 and 100g l^{-1}.

Swelling power (SWP) and solubility were determined by the method of Schoch [6] using 1 g starch (db) suspended in 50 ml distilled water in 75 ml centrifuge bottles and varieties Ankra, 91934 and 30474 which showed distinct differences in their amylograms were analyzed between 60-95°C at 5°C intervals. All measurements were made in triplicate.

3. RESULTS AND DISCUSSION

3.1. Granular character of starch and cooking quality

In the M_1V_2 population, plants with mealy tubers had large starch granules, while non-mealy types had small granules [7]. There was a strong correlation between mealiness, starch and dry matter content and the size of the starch granules. Similar results have been reported in mealy potato varieties which have relatively large starch granules [8,9]. It seems that the gene(s) controlling mealiness were altered by mutagenic treatment and reflected in the size of the starch granules. This supports the observation [10] that mealiness in potato is under a simple genetic control. In potato, mealiness has been explained on the basis of cell separation; that is a loosening of the pectic intercellular substances leads to the freeing of the cooked cells. When the cells are not easily loosened, the cooked product becomes non-mealy, hard or glassy. The mealiness in cassava may also be explained on the basis of cell disorganization or separation.

3.2. Composition of cassava roots and starch and its relationship to cooking quality

The proximate composition of the roots and starch showed significant difference between varieties harvested at the same age and those harvested at different ages (Tables I and II). Even though many of the correlation coefficients between the components and cooking quality rankings were not statistically significant (Table III), the magnitude of the coefficients were high in many cases. The study showed that the mealiness of the cooked root depends on its starch content. While the elasticity and smoothness of the pounded paste depends largely on the amylose content of the starch. The varieties with high fibre content produced roots with unacceptable cooking quality. The ash and protein contents were the only minor components that were related to cooking quality, which may have implications in fertilizer application in cassava.

TABLE I. PROXIMATE COMPOSITION OF 6-MONTH OLD CASSAVA ROOT (SET B).

VARIETY	STARCH CONTENT gK-1g	AMYLOSE CONTENT OF STARCH (%)	ASH CONTENT gK-1g	FIBRE CONTENT gK-1g
ANKRA	684	20.9	12.2	42.9
AKOSUA TUNTUM	662	22.6	16.5	39.3
60142	680	18.6	16.9	40.6
ISU-W	662	22.0	13.6	45.6
ATRA	665	20.8	21.1	61.2
518-DB	677	21.8	13.5	54.5
3000-W	668	20.9	16.7	51.5
ISU-DB	668	20.3	17.7	55.6
1425-DB	660	20.1	15.8	55.9
LSD (5%)	9.49	1.53	0.8	5.9
LSD (1%)	12.7	2.04	1.1	7.9
CV	0.70	3.63	2.61	6.04

3.3. Cassava starch gelatinization and its rheological properties

There was difference among the varieties in gelatinization or pasting temperature. Moorthy [11] in India observed similar varietal differences. The gelatinization range, estimated as the difference between the temperature of peak viscosity and pasting temperature also varied among the varieties. The peak viscosity also differed among the varieties. This study showed that the varieties differed in the rate and extent of swelling of starch granules. According to Tipples [12], the viscosity at 95°C in relation to the peak viscosity reflects the extent of fragility of the swollen granules, which varied among varieties.

In most cases, correlation between cooking quality scores and points on the amylograph were not statistically significant (Table IV), suggesting that it is difficult to predict cooking quality using the amylograph, confirming previous reports [13]. However, three varieties which differed in their cooking quality showed very distinct differences in their hot-paste viscosities. The variety 91934 had one of the highest peak viscosities and narrowest gelatinization range; its starch granules swelled very rapidly. However, it had the most fragile swollen granules, especially in the flour, and at the end of the 95°C hold, it was no longer a viscous paste. It did not have a good cooking quality. The variety 30474 had the lowest peak viscosity and a relatively wide gelatinization range. This implies that its starch granules swelled very slowly because of strong bonding forces between the granules. It is also not a good cooking variety. The variety Ankra which was the best cooking variety had the highest peak viscosity, and at 95°C, it still produced the most viscous paste.

The differences in the swelling ability of the starch granules and the fragility of the swollen granules were confirmed in the swelling power and solubility studies. The SWP and solubility of the starch at 85°C are shown in Table V. They demonstrate large differences between the varieties. The SWP of an aqueous suspension indicates the strength of the hydrogen bonding between the granules, and this was reflected in the differences observed between the varieties. This became even more evident when the SWP and solubility of varieties 91934, 30474 and Ankra were studied over a range 60-95°C. The results showed that Ankra, the best cooking varierty had granules which did not swell and break down as rapidly as in 91934. The

SWP and solubility studies revealed that for good cooking quality a gradual swelling of the starch granule on heating is desirable. Too rapid swelling with weak bonding forces between granules results in poor cooking quality. Whereas, the proximate composition and the gelatinization properties of the starch may help to explain the difference in cooking quality between cassava varieties, none seems to provide a simple method of objective assessment for selection.

TABLE III. CORRELATION BETWEEN COOKING QUALITY AND PROXIMATE COMPOSITION (SET A).

	MEALINESS	ELASTICITY	SMOOTHNESS
Ash Content of Starch	0.80 *	0.85 *	0.68 ^{ns}
Ash Content of Root	0.83 ^{ns}	0.55 ^{ns}	0.30 ^{ns}
Fat Content of Starch	-0.06 ^{ns}	-0.36 ^{ns}	-0.18 ^{ns}
Fat Content of Root	0.03 ^{ns}	-0.43 ^{ns}	-0.14 ^{ns}
Protein Content of Starch	0.64 ^{ns}	0.83 *	0.68 ^{ns}
Protein Content of Root	0.81 *	0.35 ^{ns}	0.71 ^{ns}
Starch Content of Root	0.64 ^{ns}	0.33 ^{ns}	0.36 ^{ns}
Amylose Content of Starch	0.22 ^{ns}	0.45 ^{ns}	0.51 ^{ns}
Fibre Content of Root	-0.45 ^{ns}	0.17 ^{ns}	-0.49 ^{ns}
SET B			
Starch Content	0.61 ^{ns}	-0.10 ^{ns}	0.30 ^{ns}
Amylose Content	0.09 ^{ns}	0.58 ^{ns}	0.33 ^{ns}
Ash Content of Root	-0.12 ^{ns}	-0.09 ^{ns}	0.03 ^{ns}

^{ns} Not significant.
* 5% Level of significance.

3.4. The Effect of common salt on hot-paste viscosity of starch

In Ghana, housewives add salt to the pounded starch paste or 'fufu', if a family member is delayed for meal. If this is not done, the paste becomes hardened, loses its elasticity and becomes watery. It is reported that the addition of 2.5% NaCl to wheat starch increased its peak viscosity [14] by enhancing the "granule integrity" of the starch; the granules swelled and remained intact for a long time before fragmentation occurred.

The solutions of 0.43 M, 0.86 M and 1.29 M (2.5, 5.0 and 7.5%) salt (NaCl) were used. Thirty-five grams (db) cassava starch was dissolved in solution, and the standard Brabender procedure was followed. The starch and flour of the three varieties, 'Ankra', 91934 and 30474 were studied. The viscosity changes in the starch and flour in the presence of common salt showed that both the pasting temperature and the temperature of peak viscosity increased (Tables VI), suggesting that salt affected the rate of swelling of the granules. More energy is required to gelatinize the starch granules in the presence of salt. The effect of salt on the hot-paste viscosity changes differed among the varieties. In the varieties 91934 and 30474, high salt concentrations tended to increase the peak viscosity and viscosity at 95°C, but in cv. 'Ankra', there was a reduction in viscosity with increase in salt concentration.

TABLE IV. CORRELATION BETWEEN COOKING QUALITY AND PASTING CYCLE.

	Viscosity changes during gelatinization				
Cooking quality parameters	Peak viscosity	Viscosity at 95°C	Viscosity after 95°C hold	Viscosity at 95°C	Viscosity after 50°C hold
Set A Starch (70 gl^{-1})					
Mealiness	0.16	0.35	0.88	0.74	0.76
Elasticity	-0.39	-0.16	0.44	0.40	0.45
Smoothness	-0.07	0.09	0.63	0.48	0.49
Set A Flour (70 gl^{-1})					
Mealiness	0.45	0.96 **	0.91 *	0.92 **	0.92 **
Elasticity	-0.26	0.62	0.64	0.62	0.64
Smoothness	0.37	0.93 **	0.89 *	0.83 *	0.87 *
Set B Starch (70 gl^{-1})					
Mealiness	-0.02	0.25	0.06	0.15	0.22
Elasticity	0.28	0.40	0.06	0.11	0.19
Smoothness	0.18	0.18	-0.23	-0.12	-0.06
Set B Flour (70 gl^{-1})					
Mealiness	-0.36	-0.34	-0.23	-0.25	-0.22
Elasticity	0.12	0.18	0.35	0.38	0.37
Smoothness	-0.18	-0.29	-0.07	-0.01	-0.07

* 5% level of significance.
** 1% level of significance.

The increase in viscosity when the paste is cooled to 50°C shows the extent of retrogradation of the starch paste. In all varieties, salt reduced retrogradation as compared to the control. Retrogradation leads to increased rigidity of the starch gel as a result of re-association of the starch granules upon cooling, which leads to release of water called syneresis. Therefore, when the consumption of 'fufu' is delayed, retrogradation of the starch takes place, making the paste no longer acceptable. The observed decline in the extent of retrogradation in all varieties with the addition of common salt showed that what the Ghanaian housewife has been practising is to reduce the retrogradation tendency of the pounded paste in order to extend the "table-life" of 'fufu'.

3.5. Effect of harvest time on cooking quality

In Ghana, there is loss in the cooking quality of cassava with the onset of rainy season in March/April. Two local varieties with acceptable cooking quality, 'Ankra', 'Atra' and two introductions 91934 and 30474, from IITA with poor cooking quality, were investigated. Harvesting began at 7 months and continued monthly until 13 months. Harvesting was planned to begin in December in the dry season and end at the peak of the rainy season in June. At each harvest, the cooking quality was determined by a taste panel, and the dry matter and starch contents were determined. The SWP and solubility of the starches were also determined. Starch samples were sent to the Natural Resources Institute, Chatham Maritime, United Kingdom where the hot-paste viscosities were determined using the standard Brabender. From the tenth month onwards, which coincided with the beginning of the rains, there was a drop in the cooking quality of all the varieties. The cooking quality of the introduced varieties were completely unacceptable at this period. Dry matter content of all the varieties was at its lowest during this period, but there was no distinct drop in the starch content. The swelling power of the starch, however, showed a distinct change in the 9th and 10th months. Since the drop in cooking quality of the varieties coincided with the drop in the dry matter content rather than the starch content, it was concluded that changes in the dry matter content had a more direct effect on cooking quality than changes in starch content. However, the changes in the gelatinization properties of the starch at the onset of the rains may also explain the changes in cooking quality. It has been postulated that the resumption of growth after the dry season may be the main reason for the drop in dry matter content [15]. Since a change in cassava root dry matter content is directly related to the change in cooking quality, root dry matter content may be an important selection criterion for improved cooking quality.

TABLE V. SWELLING POWER AND SOLUBILITY AT 85°C.

Variety	Swelling Power	Solubility (%)
SET A		
ANKRA	33.60	22.46
91934	47.79	31.12
ISU-W	25.96	19.31
30001-W	22.48	21.12
30474	21.71	19.96
60142	27.11	17.69
LSD (5%)	9.93	1.08
LSD (1%)	13.36	1.45
SET B		
ANKRA	24.63	16.33
AD-T	34.96	25.23
ATRA	32.13	20.84
60142	27.21	22.57
ISU-W	38.44	20.49
518-DB	33.31	25.58
30001-W	31.94	27.02
ISU-DB	35.94	19.39
1425-DB	34.51	25.15
LSD (5%)	1.46	0.75
LSD (1%)	1.96	1.00

3.6. Effect of mulching on cooking quality

The local variety 'Ankra' was used to study the effect of mulching on cooking quality, and dry *Panicum maximum* mulch was applied at 3, 6, 9 and 12 tons/ha at the beginning of the dry season, and compared with clean weeding throughout the study and no weeding from the

TABLE VI. VISCOSITY CHANGES OF STARCH DURING GELATINIZATION IN THE PRESENCE OF NaCl.

VARIETY	SALT CONC'N	PASTING TEMP °C	TEMP OF PEAK VISC	PEAK VISC*	VISC AT 95°C	VISC AFTER 1 HR AT 95°C	VISC AT 50oC	VISC AFTER 1 HR AT 50°C
ANKRA	0	74	82°C	560	460	260	480	420
	0.43M	75.5	89°C	360	340	150	220	180
	0.86M	74	92°C	300	300	160	200	160
	1.29M	79.3	93.5°C	360	360	200	300	260
91934	0	74	77°C	500	380	145	280	240
	0.43M	75.5	81.5°C	460	380	30	50	40
	0.86M	77	84.5°C	500	440	60	90	80
	1.29M	77.8	87.5°C	560	500	100	140	100
30474	0	71	85°C	340	290	140	280	260
	0.43M	78.5	92°C	340	270	110	160	120
	0.86M	81.5	95°C	380	380	180	260	200
	1.29M	81.5	95°C	380	380	260	340	280

* Brabender viscosity units (b.U.).

beginning of the dry season. Soil temperature, soil moisture, infiltration rate, bulk density, organic matter content and the amounts of Ca, Mg, K and available P in the soil were recorded at the beginning and end of the experiment. The harvesting was started at the end of the dry season in March when the plants were 10 months old and the final harvest was after the onset of the rains when the plants were 12 months old. The cooking quality, dry matter and starch contents were determined at each harvest.

The no-weeding treatment had the highest dry matter and starch content at 12 months growth and produced some of the most mealy cooked roots and elastic paste. The clean-weeding treatment had the lowest cooking quality. The dry-grass mulch treatment produced better cooking roots than the clean-weeding treatment, though the differences in most cases were not statistically significant (data not shown). The difference between the highest soil temperature (measured at 15:00 hrs) and the lowest (measured at 09:00 hrs) was largest for the bare plots and decreased as the amount of mulch increased. The large diurnal soil temperature fluctuations on the clean-weeded plots may have indirectly affected the root cooking quality through the daily warming and cooling of the root tubers in the soil. Scaramelia-Petri [16] found that in Italy, when the early summer was very warm and dry, the centres of potatoes remained firm after cooking. Infiltration rate increased with increased mulching. Consequently the cumulative soil moisture content, measured fortnightly till the end of the dry season showed that more water was conserved in the soil as the amount of mulch increased. Root dry matter and starch contents were negatively correlated with soil temperature and positively with soil moisture (data not shown). High soil temperatures decreased root dry matter and starch content, and these in turn adversely affected the cooking quality. Similarly, water stress during the dry season leads to a decrease in dry matter and starch content, and has adverse effect on root cooking quality. The practice to leave land unweeded at the beginning of the dry season to prevent deterioration in cooking quality may be instrumental in decreasing moisture stress.

REFERENCES

[1] MACMASTER, M.M. Microscopic techniques for determining starch granule properties. Methods in carbohydrate chemistry VOL.IV. (Whistler, R.L. Ed.) Academic Press, New York (1964).

[2] SHEWFELT, A.L., BROWN, D.R., TROOP, K.D. The relationship of mealiness in cooked potatoes to certain microscopic observations of the raw and cooked product. Can. J. Agric. Sci. 35 (1955) 513-517.

[3] AOAC Official Methods of Analysis, 20th Edn. Association of Official Analytical Chemists, Washington DC (1990).

[4] RICKARD, J.E., BEHN, K.R. Evaluation of acid and enzyme hydrolytic methods for the determination of cassava starch J. Sci. Food Agric. 41 (1987) 37.

[5] McCREADY, R.M. and HASSID, W.Z. The separation and quantitative estimation of amylose and amylopectin in potato starch. J. Am Chem. Soc. 65 (1943) 1154.

[6] SCHOCH, T.J. Swelling Power and Solubility of Granular Starches. In Methods in Carbohydrate Chemistry. Vol. IV Starch ed. Whistler RL Academic Press New York, USA (1964).

[7] SAFO-KANTANKA, O., OWUSU-NIPAH, J. Cassava varietal screening for cooking. quality: relationship between dry matter, starch content, mealiness and certain microscopic observations of the raw and cooked tuber. J. Sci. Food Agric. 60 (1992) 99-104.

[8] BARRIOS, E.P., NEWSON, P.W., MILLER, J.C. Some anatomical characters associated with the quality of Irish potatoes. II. Physical characters Am Potato J. 40 (1963) 200-208.

[9] GRAY, D. Some effects of variety, harvest date and plant spacing and tuber breakdown on canning, tuber dry matter and cell surface in the potato. Potato Res. 15 (1972) 317-334.

[10] MOLLER, K.H., VOGEL, J. Selektionsverfahren für die Züchtung von Spiesekartoffeln. Züchter 3I (1961) 265-267.

[11] MOORTHY, S.N. Cassava starch and its modifications. Technical Bulletin Series 4. Central Tuber Crop Research Institute, Trivandrum, India (1985).

[12] TIPPLES, K.H. Uses and Applications Chapt. 3 Brabender Viscoamylograph Handbook 1982.

[13] ASAOKA, M., BLANSHARD, J.M.V., RICKARD, J.E. Effects of cultivar and growth season on the gelatinization properties of cassava starch. J. Sci. Food Agric. 59 (1992) 53-58.

[14] GANZ, A.J. Effect of sodium chloride on the pasting of wheat starch granules Cereal Chem. 42 (1965) 429.

[15] KAWANO, K., FUKUDA, W.M.G., CENPUKDEE, U. Genetic and environmental effects on dry matter content of cassava root. Crop Sci. 27 (1987) 69-74.

[16] SCARAMELLA-PETRI, P. The influence of ecological factors on some structural characters of the parenchyma of tubers in relation to their commercial quality. Eur. Potato J. 7 (1964) 251.