Effects of cultivar and age at harvest on the dry matter, starch gelatinization properties and the cooking quality of cassava

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SUMMARY

The top-growth, root yield, dry matter and starch contents, swelling power, solubility and the pasting cycle of four cassava varieties harvested at monthly intervals from 7 to 13 months after planting were determined and related to the changes in cooking quality at the onset of the rainy season. The harvesting period coincided with the dry and part of the wet season. All four varieties lost their mealiness and poundability at the onset of the rainy season. Cassava root dry matter (RDMC) was the single most important factor which influenced the changes in cooking quality. The utilization of the stored carbohydrates for vegetative growth at the commencement of the wet season, possibly led to a great drop in RDMC which coincided with the seasonal loss in cooking quality. Local varieties went through the same changes but recovered faster than the introduced varieties. Total starch content did not explain the seasonal loss in cooking quality, but changes in some properties of the starch such as swelling power, solubility and gelatinization range could be related to the changes in cooking quality. Cultivars with high fresh root yield were not necessarily those with high dry matter and starch contents.

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RÉSUMÉ

SAFO-KANTANKA, O. & OSEI-MINTA, M.: *Effets de variété et âge de récolte sur la matière sèche, les propriétés de la gélatinisation de fécule et la qualite de cuisson de manioc.* La croissance du sommet, le rendement de racine, les contenus de matiére séche et fécule, le pouvior de gonflement, la solubulité et cycle de raclée de quatre variétés de manioc récoltés à intervalles mensuels de 7 à 13 mois aprés la plantation étaient déterminés et liés au changement de qualité de cuisson au début de la saison des pluies. La période de récolte coïncidait avec la saison séche et une partie de la saison humide. La matiére séche de la recine de manioc (RDMC) était la seule facteur la plus importante qui influençait le changement en qualité de cuisson. L' utilisation de féculents mis en réserve pour la croissance végetative au commencement de la saison humids, a peut-être mené à une grand diminution de RDMC qui coïncidait avec la perte saisonniére en qualité de cuir. Les variétés indigénes ont passé à travers les mêmes changements, mais se sont récupées plus vite que les variétés introduites. Le contenu total de fécule n' a pas expliqué la perte saisonniére en qualité de cuisson mais des changements en quelques propriété de la fécule comme le pouvior de gonflement, la solubilité et l' étendue de la gélatinisation pourraient être liés aux changements en qualité de cuisson. Les variétés avec un haut rendement de racine fraîche, n' étaient pas nécessairement celles avec les hauts contenus de matiére séche et fécule.

Introduction

The Ghanaian consumer of fresh cassava root faces the perennial problem of the seasonal loss in cooking quality. It has been observed that every year from the beginning of the rainy season in March/April to about June/July, even the best cooking cultivars lose their mealiness and poundability. During this period, fresh cassava roots when cooked become non-mealy or glassy and housewives and many restaurants, locally called 'chop bars' end up throwing away large quantities of unpoundable cooked cassava roots. The most desirable cassava cultivar would be one which combines high root yield with stability in cooking quality. Before plant breeders can select for such genotypes, there is a need to understand the physico-chemical changes that take place in the cassava storage root over the seasons. This kind of information is meagre in the literature.

Moorthy & Ramanujam (1986) reported that granule size, molecular weight of starch and amylose content did not show any significant variation with the age of cassava.

However, they found that the swelling properties of the starch differed significantly between varieties. While some varieties showed constant swelling volumes at all the harvesting times, others showed distinct peaks and lows. They identified a stable variety which showed almost uniform swelling pattern and was also a good table variety. Asaoka, Blanshard & Rickard (1992) did not find any significant relationship between the cooked quality of cassava roots, the season of harvesting (dry or rainy season) and the cultivars. They concluded that there was some difficulty in explaining the differences in eating quality simply on the basis of differences in the physico-chemical properties of the starch. In spite of this lack of clear relationship, they found that starch granules from cassava roots harvested during the rainy season always had lower gelatinization onset temperatures than those harvested in the dry season. Cultivar differences were also observed. They also found that starch pastes from roots, harvested in the rainy season, reached their peak viscosity at lower temperatures than those harvested in the dry season.

Kawano, Fukuda & Cenpukdee (1987) observed that cassava root dry matter (RDMC) tended to be higher at the beginning of the dry season than at the beginning of the wet season. In three locations with different soil and climatic conditions, they found that RDMC tended to be higher with cassava harvested at 8 months than at 12 months. Wheatley & Gomez (1985) also found that RDMC varied with age, being lower at 6 and 12 months than at 8 and 10 months. They attributed the low RDMC at 6 months to incomplete root-bulking and the decline in RDMC at 12 months to renewed top growth after the onset of the rainy season. They also found that root cooking quality was good from 6 to 10 months but declined at 12 months.

According to Wholey & Booth (1979), the age at which cassava should be harvested to obtain maximum fresh root yield may not necessarily be the same as that to obtain maximum starch yields. Ketibu & Oyenuga (1972) reported that a peak starch content in cassava is reached at 8 months growth after which it falls, but Obigbesam & Agboola (1973) reported peak starch content after 15 months. Moorthy & Ramanujam (1986), on the other hand, stated that the storage roots of cassava continue to accumulate starch as long as the plant possesses sufficient leaves to support photosynthesis but the cooking quality of the root may change beyond a certain period. Wholey & Booth (1979) also found that cassava starch content increased with age, but there was period of depression which coincided with a rainy period when precipitation exceeded potential evaporation.

In the present study, we have examined the growth, storage root yield, dry matter content, starch yield, swelling power and solubility and the pasting cycle of four cassava varieties harvested at monthly intervals beginning from 7 months to 13 months after planting. The harvesting period coincided with the dry and part of the wet season. The aim was to find out how these traits varied with age and/or season and how these related to changes in cooking quality.

Materials and methods

Experimental design

The experiment was set up as a 7 × 4 complete factorial in randomized complete block design with four replications. There were 7 harvesting ages and 4 varieties. Two local cultivars, Ankra and Atra and segregants of two lines initially introduced from the International Institute of Tropical Agriculture (IITA), Nigeria, as seeds, 30474 and 91934 were used in the study. Cuttings were planted on 29 May 92 at the Arable Crops Research Farm of the University of Science and Technology, Kumasi which is in the forest zone, and enjoys two rainfall maxima as shown in the rainfall data for the experimental period recorded at the Agricultural Engineering Weather Station as shown in Fig. 1. Harvesting began in December in the dry season at the age of

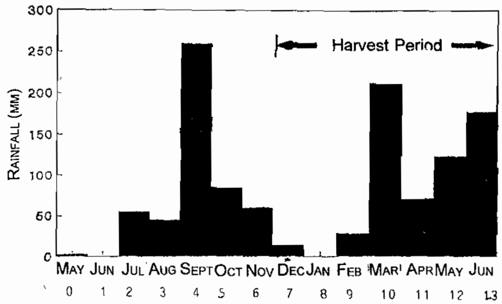

Fig. 1. Monthly rainfall data for experimental period (May 1992-June 1993)

7 months and continued at monthly intervals till 13 months of age, in June 1993. At each harvest, five plants of each variety per block were uprooted and separated into shoot and roots. The weight of the top growth and the roots were taken.

Sensory evaluation of cooking quality

A random sample of the roots was taken and peeled, washed, cut into cubes 100 mm × 100 mm × 100 mm, and cooked in boiling water for 20 minutes. Portions of the cooked roots were pounded into a paste as fufu is prepared in Ghana. Two workers were assigned to prepare all the samples into pastes. The man pounded with the pestle while the woman turned it around in the mortar and added water as necessary until a uniformly pounded paste was produced. A "trained" taste panel of six made up of regular cassava consumers scored the cooked roots for texture or mealiness also referred to as mouthfeel.

The pounded paste was also scored for elasticity which refers to how the whole paste holds together when the paste is pulled between the thumb and fingers. The paste was also scored for smoothness which refers to the presence or absence of lumps when the paste is squeezed between the thumb and the fingers. A scoring system of 0-3 was used for all the cooking quality parameters. A very non-mealy cooked root or very inelastic or very lumpy paste was scored 0 and the highest ranking of 3 was given for a very mealy cooked root or very elastic or very smooth paste. Safo-Kantanka & Owusu-Nipah (1992) used the same method.

Dry matter, starch and pasting characteristics of starch

In the determination of the dry matter and starch contents, the roots were peeled, washed and cut into thin slices. Duplicate samples were taken and dried in the oven at 80°C until a constant weight was attained and the percentage dry matter determined. The method of Krochmal & Kilbride (1966) was used in determining starch content which is considered as the percentage of starch recovered after isolation from a known quantity of fresh root and not by a quantitative or chemical analysis. The swelling power and solubility at 85°C was determined following the method of Schoch (1964).

The starch obtained from the different blocks was bulked, samples taken and sent to the laboratories of the Natural Resources Institute at Chatham Maritime, United Kingdom where the pasting cycle was determined using the Brabender Amylograph. A starch suspension (50 gl^{-1}, 500 ml) was heated until a base temperature of 50°C was reached. Heating continued at the rate of 1.5°C per min to 95°C, maintained there for 20 min, then cooled at the same rate to 50°C and held there for 20 min. The bowl speed was 75 rpm with the 700 cm g^{-1} torsion.

Results and discussion

The data were analysed by the Analysis of Variance Method (ANOVA) to show differences between the ages at harvest, the varieties and the interactions between these two factors. The main effects are presented in Tables 1 and 2 and the interactions are presented graphically in Fig. 2-4.

Vegetative growth and root yield

The major rainy season of 1992 was a bit unusual, as May and June were relatively dry, but there was sufficient rainfall in the minor season to promote the growth of the cassava plants (Fig.1). The two varieties introduced from IITA grew more vigorously and produced higher yields than the local varieties. There was little or no growth during

TABLE 1

Mean Effects of Age at Harvest on Characters Studied

Age at harvest (months)	Vegetative growth	Tuber yield		Cooking quality scores*			Per cent			
	Shoot wt (kg)	Mean tuber size/ plant	Mean no. of tubers/ plant	Mealiness	Elasticity	Smoothness	Dry matter content	Starch content	Swelling power	Solubility
7	1.54	0.84	3.81	1.73	2.29	2.22	40.5	16.4	36.2	22.8
8	1.51	1.19	4.09	1.84	2.38	2.23	45.3	11.5	32.5	17.6
9	1.57	1.69	4.25	1.61	1.90	1.72	43.3	11.4	23.2	12.0
10	1.52	1.14	3.27	0.89	0.75	0.72	32.9	14.4	33.3	22.9
11	2.62	1.96	3.71	1.01	1.42	1.35	38.2	21.7	31.2	19.5
12	4.38	3.75	5.09	1.66	2.36	2.13	40.4	19.0	32.5	18.9
13	3.52	3.48	5.70	1.71	2.0	1.87	42.5	20.8	41.6	27.9
LSD (5 %)	0.78	0.72	1.19	0.31	0.36	0.39	3.25	1.80	4.03	5.82

* Score are the average of 6 panelists

the dry season. Growth resumed during the 10th month when there was a lot of rain (March) and this reflected in the high top growth and storage root yield in the 11th month. While top-growth and root yield began to decline after the 12th month in the introduced varieties, the local varieties continued to show increases, indicating that the introduced varieties are earlier in maturity. The resumption of growth did not only result in increases in the bulking of already-formed roots but bulking seems to have been initiated in new roots as well (Fig. 2 and Table 1).

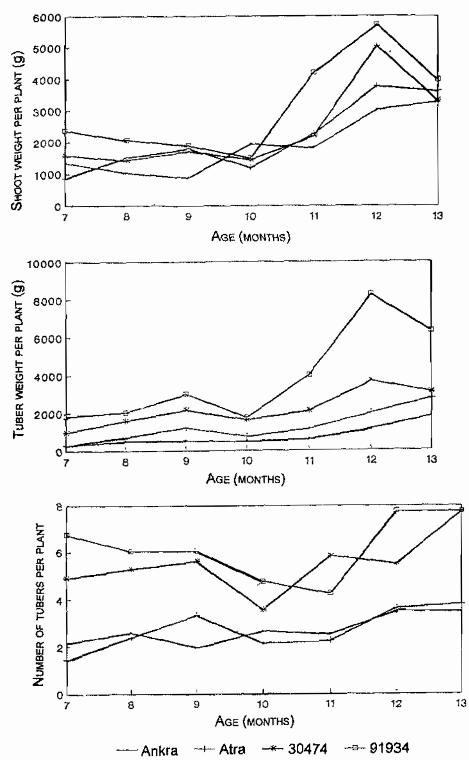

Fig. 2. Effect of age at harvest and cultivar on vegetative growth and tuber yield

Cooking quality

The local varieties Ankra and Atra were superior to the introduced varieties in all three aspects of cooking quality (Fig. 3 and Table 2). Harvesting always took place around the middle of the month and especially in the introduced varieties 91934 and 30474, the cooking quality began to decline as early as the 9th month (February) which was the beginning of the rainy season for 1993. By the 10th month (March), a lot of rain had fallen and cooking quality had dropped drastically in all the varieties. In the introduced varieties, the cooked roots were now glassy and non-poundable. By the 11th month, the local varieties had recovered the cooking quality they had before the rains.

Root dry matter content

The root dry matter content (RDMC) followed a slightly different trend from the storage root yield. The variety 91934, which had the highest fresh root yield, had the lowest dry matter content of all the varieties (Fig. 2 and 4a, and Table 2), in agreement with results from Wholey & Booth (1979). The RDMC reached a peak during the 8th month (Table 1) and this agrees with the observation of Kawano, Fukuda & Cenpukdee (1987). The RDMC of all the varieties dropped to their lowest levels in the 10th month (March) which coincided with the period of maximum rains and the resumption of vegetative growth. Kawano, Fukuda & Cenpukdee (1987) made a similar observation and postulated that the resumption of growth after the dry season may be the main reason for the low RDMC at the beginning of the wet season as the stored carbohydrates are used up for growth. The drop in RDMC at the 10th month also coincided with the drop in cooking quality, in all the varieties (Table 1). This suggests that the changes in RDMC greatly influenced the changes in cooking quality in all the varieties. This agrees with the observation of Kawano, Fukuda & Cenpukdee (1987) that RDMC is believed to be positively correlated with eating quality when the cassava root is consumed after boiling. Safo-Kantanka & Owusu-Nipah (1992) obtained similar results. Ankra which was the best cooking variety, had the greatest drop in RDMC at the 10th month (Fig. 4), but it recovered very quickly.

TABLE 2

Mean Varietal Effects of Characters Studied

Variety	Vegetative growth	Tuber yield		Cooking quality scores*			Per cent			
	Shoot wt (kg)	Mean tuber size/ plant (kg)	Mean no. of tubers/ plant	Mealiness	Elasticity	Smoothness	Dry matter content	Starch content	Swelling power	Solubility
ANKRA	1.90	0.75	2.69	2.52	2.51	2.50	40.6	16.0	33.7	19.9
ATRA	2.14	1.25	2.71	2.15	2.58	2.44	42.1	17.4	34.3	22.2
30474	2.38	2.16	5.49	0.86	1.55	1.25	42.5	18.8	28.7	19.1
91934	3.09	3.87	6.19	0.44	0.84	0.81	36.6	13.7	35.0	21.1
LSD (5 %)	0.59	0.54	0.90	0.24	0.27	0.29	2.46	1.36	3.04	4.40

* Score are the average of 6 panelists

Starch content

Statistically significant differences were established between the varieties and age at harvest in the amount of starch that could be recovered from equal quantities of fresh root (Tables 1 and 2). The variety 91934 which produced the highest fresh root yield, but the lowest RDMC also had the lowest starch content. Wholey & Booth (1979) also found that, except for a brief sampling period, a high-yielding variety they worked with did not have higher starch content than a lower yielding variety. Even though starch content dropped slightly from the 8th to the 10th month, there was no large decline at the 10th month as was found in RDMC and the cooking quality (Fig.3 and 4). This would suggest that the changes in cassava cooking quality over the seasons should be related more to changes in RDMC or non-starch components than to changes in total starch content. Linehan & Hughes (1969) also concluded from their review that variations in the texture of the cooked potato can be only partly explained by variations in the starch content of the tuber.

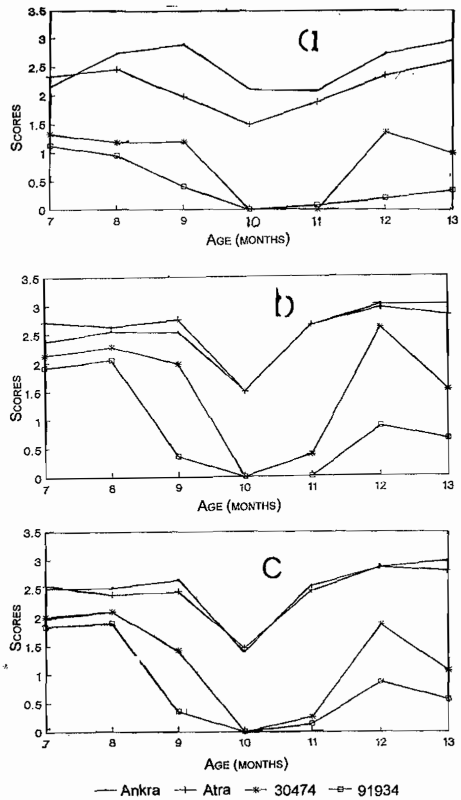

Fig. 3. Effect of age at harvest and cultivar on cooking quality: (a) Mealiness (b) Elasticity (c) Smoothness

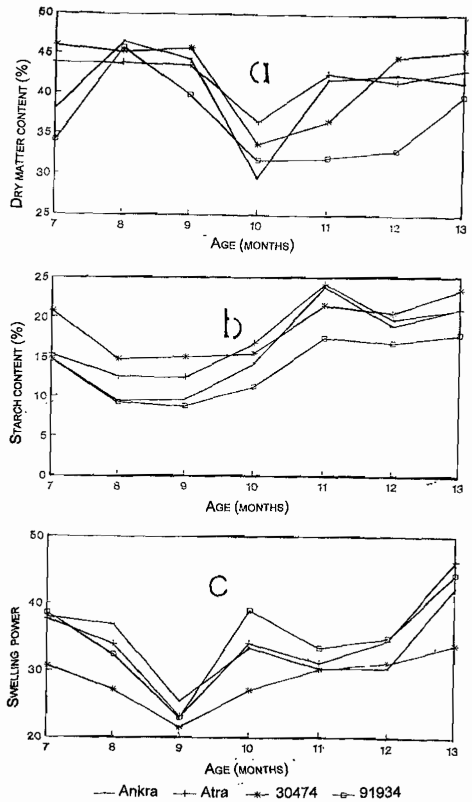

Fig. 4. Effect of age at harvest and cultivar on (a) dry matter content (b) starch content (c) swelling power

Swelling power and solubility

Although the pattern of changes in total starch content did not correspond to the changes in cooking quality, the swelling power (SWP) and solubility of the starch did. There was a significant decrease in SWP and solubility at the beginning of the rainy season just as it occurred with cooking quality and dry matter content. The only difference was that this decrease occurred in the 9th month while the other decrease was in the 10th month which suggests that the early rains in February were enough to cause changes in the properties of the starch (Fig. 3 and 4). Moorthy & Ramanujam (1986) similarly observed that the SWP and solubility of the starches of the varieties they worked with varied with the genotype, season and/or the age at harvest. Asaoka, Blanshard & Rickard (1992) also found that the SWP values of starch resulting from harvest in the rainy season were higher than those harvested in the dry season. The variety 30474 had the lowest SWP and solubility values even though it had one of the highest dry matter and starch contents (Table 2). The low SWP and solubility values of 30474 were recently attributed to the strong bonding forces between its granules (Safo-Kantanka & Acquistucci, 1996).

Pasting cycle

The results of the pasting characteristics of the starches are presented in Table 3. In general, there were no very clear patterns which could be related to the cooking quality. Asaoka, Blanshard &

TABLE 3

Effect of Variety and Age at Harvest on Pasting Cycle, Variety/Age, Temperature (°C), Brabender Viscosity Units (BU)

Month	*Pasting*	*Peak*	*Δ T*	*Peak visc.*	*Δ P*	*Visc. at 95 °C*	*Holding at 95 °C*	*Visc. at 50 °C*	*Holdings at 50 °C*
ANKRA									
7	69.5	83	13.5	265	45	220	170	280	260
8	71	86	15.0	310	10	300	240	400	360
9	78.5	95	16.5	300	0	300	210	320	290
10	71	89	18.0	390	40	350	230	400	380
11	69.5	84.5	15.0	320	40	280	200	370	330
12	69.5	86	16.5	270	20	250	170	290	270
13	71	77	6.0	240	140	100	70	100	100
ATRA									
7	68	87.5	19.5	360	10	350	240	370	350
8	69.5	84.5	15.0	400	60	340	220	390	360
9	71	83	12.0	290	40	250	170	290	270
10	68	74	6.0	260	60	200	170	290	270
11	69.5	78.5	9.0	310	60	250	180	310	290
12	69.5	83	13.5	380	80	300	190	140	320
13	69.5	75.5	6.0	220	170	50	30	50	50
30474									
7	71	90.5	19.5	350	10	340	260	440	400
8	69.5	87.5	18.0	290	10	280	230	390	370
9	72.5	86	14.0	260	20	240	190	310	290
10	69.5	75.5	6.0	240	70	170	130	240	230
11	71	83	12.5	270	30	240	190	330	300
12	72.5	83	10.5	230	20	210	150	260	240
13	71	75.5	4.5	200	90	110	70	110	110
91934									
7	68	84.5	16.5	400	100	300	190	310	290
8	69.5	84.5	15.0	370	60	310	210	310	300
9	69.5	89	19.5	340	20	320	210	320	290
10	71	90.5	19.5	390	20	370	240	380	340
11	72.5	86	13.5	370	40	330	210	320	310
12	69.5	86	16.5	320	40	280	190	290	280
13	69.5	74	4.5	290	120	170	100	150	150

ΔT = Temperature of peak viscosity - Pasting temperature
Δ P = Peak viscosity - Viscosity at 9 °C

Cenpukdee (1992) arrived at a similar conclusion in their work. A few things were noteworthy. Firstly, the gelatinization range ΔT, estimated as the difference between the temperature of peak viscosity and pasting temperature, was lowest for the month of June samples for the four varieties. This again agrees with Asaoka, Blanshard & Rikard (1992) who also found that the gelatinization temperature of the starch was lower for cassava harvested in the rainy season than those harvested in the dry season. Secondly, the viscosity of the starch paste at 95 °C to the end of the pasting cycle was lowest for the month of June for all the varieties. The drop in viscosity from the peak to 95 °C, Δ P was highest for the month of June. According to Tipples (1982), the viscosity at 95 °C, in relation to the peak viscosity reflects the fragility of the swollen granules. This may probably explain the drop in cooking quality at the 13th month (June), especially in the introduced varieties (Fig. 3). The cumulative amount of moisture received by the plants from the onset of rains was highest for those harvested in June. When the soil moisture content is high, it can bring about changes in soil temperature in the immediate environment of the growing root and this can affect the gelatinization properties of the starch in a way different from that obtained at the beginning of the rainy season. Asaoka *et al.* (1984) found that changes in environmental temperature, during the formation of starch granules in rice affect its gelatinization temperature and Asaoka, Blanshard & Rickard (1992) considered this as a possible explanation for the differences they observed in the starch gelatinization temperatures of cassava harvested in the dry and wet seasons. This suggests that it is not only the onset of the rainy season after the long dry season which leads to changes in cassava starch gelatinization properties and cooking quality, but very high and continuous rainfall may also affect these traits.

It may be concluded that the changes in cassava cooking quality with the season may be partly explained by the changes which occur in the characteristics of the starch such as swelling power, solubility and gelatinization range rather than changes in the total starch content. It has also been clearly demonstrated that the changes in cassava RDMC over the seasons, is the major cause of the poor cooking quality of cassava during parts of the rainy season.

Cassava RDMC is simple to measure and it is even simpler to measure the specific gravity of the root which Kawano, Fukuda & Cenpukdee (1987) have shown to be highly correlated with RDMC. They also demonstrated that RDMC has a high narrow sense heritability. Cassava RDMC or the specific gravity of the root, can, therefore, be used as a reliable selection criterion in breeding for cooking quality in cassava.

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