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Effect of Genotype, Age and Location on Cassava Starch Yield and Quality

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Abstract: Trials were conducted at 6 selected districts in the Forest and Transition ecozones of Ghana to determine the influence of age and location on cassava starch yield and its physicochemical and functional properties. Four elite varieties-NKZ-009, NKZ-015, DMA-002 and WCH-037 were used. Harvesting was done from 12 to 15 months on monthly interval. Twenty five kilogram of fresh tubers from each genotype were commercially processed into starch. This was done by women trained by Women In Agricultural Development (WIAD) in agro-processing at their local factory at Ashanti Mampong. Samples were analysed at the Plant breeding Laboratory of Kwame Nkrumah University of Science and Technology for their physicochemical and functional properties-solubility, swelling power and water-binding capacity. Starch yield was analysed using line graphs with Excel. Data from the physicochemical and functional properties were analysed using the analysis of variance (ANOVA) in a split-split plot design with location as main plot, genotype as subplot and age as the sub-subplot. The peak starch yield was generally at 13 months for all the varieties except for NKZ-015 in the Transition belt. Solubility generally increase with age with the lowest (7.29%) and highest (8.63%) being recorded at 12 and 15 month, respectively. Swelling power peaked at 13 months but water-binding capacity decreased with age and the interaction between age and genotype and location was significant for all the three functional properties.

Key words: Cassava, genotype, starch yield, quality, functional properties

INTRODUCTION

Root and tuber crops are the most important food crops for man after cereals and grain legumes and cassava because of its potential for high dry matter production per day stands out among the root and tuber crops (Srinivas and Anantharuman, 2000). Cassava is the main starch staple of many people in Africa (Manu-Aduening *et al*., 2006). In Ghana, a mean per capita production of 465 kg/annum provides about 20% of calories in the diet, far ahead of any other single crop or animal source (FAOSTAT, 2005. http://faostat.fao.org.). According to Manu-Aduening *et al*. (2006) most cassava produced is consumed fresh as fufu but there are many small-scale and a few medium to large-scale enterprises currently in Ghana that processing cassava into diverse foods and starch for industrial uses.

Lack of cassava market outlets was identified as the reason why it was not considered among the model crops for sustainable development (Kleih *et al*., 1994). However, a number of industrial uses have been found for cassava, which is rapidly turning it into a well-deserving industrial crop. Cassava starch has unique properties, such as its high viscosity and its resistance to freezing, which make it competitive with other industrial starches. Cassava starches are potential substitutes for wheat and maize-based starches (Rickard *et al*., 1991; Tian *et al*., 1991). On wet basis, cassava starch yield is between 24 and 26% but 40% is achievable (Olivier, 2000) and Asia is reported to lead the way in the production of starches derived from cassava. According to FAO (2004), at least $3 billion is earned by Nigeria through the export of cassava and related products. Cassava contributes 16% of the total Agricultural Gross Domestic Product (AGDP), which is higher than any other crop including cocoa in Ghana (Safo-Kantanka, 2004). Starch-derived products are used in almost every industry. In the textile industry, starch is used in the sizing operation to coat yarn; in the finishing operation, to modify appearance, change stiffness and add weight to fabric and in the printing operation to prepare the paste of dyestuff (Balagoplan *et al*., 1998). Starch hydrosates are also a basic input in the manufacture of industrial chemicals such as alcohol, gluconic acid and acetic acid (Balagoplan *et al*., 1998). It is used in making of adhesives for use in the packaging industry, for lamination in plywood, paperboard and footwear. In the cable industries, starch is used in the production of paper tubes, cans and cones; as printing,

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publishing and library paste and as label adhesive for envelopes, postage stamps, gummed tapes, safety matches and many other items. Starch hydrosates which are obtained by starch hydrolysis with acid or enzyme treatment are used to impart sweetness, texture and cohesiveness to drinks such as soft drinks, fruit juice and dairy drinks and to a variety of foods such as soup, cake and cookie (Balagoplan *et al.*, 1998).

A survey by Dziedzoave *et al.* (2000) indicates that 5000 t ha^{-1} of starch is used in Ghana per annum which includes textiles (40%), plywood (27%), pharmaceuticals (20%), paper (10%) and food (3%). Cassava starches are potential substitutes for wheat and maize-based starches (Rickard *et al.*, 1991; Tian *et al.*, 1991). This is because of its unique properties, such as high viscosity and resistance to freezing, which makes it competitive with other industrial starches. With the anticipated increase in industrialisation in Ghana and vast export market for starch and its products, more starch and starch-derived products will be needed to feed local industries and export to cushion the government on its exports-imports deficits. This demands the development of varieties that meets the requirements of end users, which includes higher starch yield, early maturity and stable physicochemical and functional properties. The objective of this work was to determine the effect of age, genotype and location on the starch yield and its physicochemical and functional properties.

MATERIALS AND METHODS

The experiment was undertaken in 2004/2005. The field work was carried out at six selected districts in Ghana. These were Mampong, Kumasi, Dormaa-Ahenkro (Forest ecozone) and Techiman, Kintampo and Kwame Danso in the Transition ecozone. Four elite varieties- NKZ-009, NKZ-015, DMA-002 and WCH-037 were studied at planting space of 1×1 m with a plant population of 10,000 plants ha^{-1}. Four weedings were carried out at 2, 5, 9 and 14 months after planting. Harvesting began at 12 months and continued on monthly interval until 15 months after planting. Twenty five kilogram of fresh tubers were commercially processed into starch. This was done by women trained by Women In Agricultural Development (WIAD) in agro-processing at their local factory at Ashanti Mampong. The tubers were peeled, washed with tap water and grated. The dough was washed with tap water to extract the starch through a piece of muslin cloth. This was repeated until the filtered water was relatively clear. The filtered water was allowed to stand for 24 h for the starch to settle after which the supernatant was poured away and the starch sun dried. Samples of the starch were analysed at the plant breeding Laboratory of the Kwame Nkrumah University of Science and Technology, Kumasi for their physicochemical and functional properties in triplicate. Parameters determined were solubility, swelling power and water-binding capacity. The solubility and swelling power were determined by the method of Leach *et al.* (1959). The method of Yamazaki (1953) as modified by Medcalf and Gilles (1965) was used to determine the water-binding capacity. Starch yield was analysed using line graphs with Excel. Data from the physicochemical and functional properties were analysed using the analysis of variance (ANOVA) in a split-split plot design with location as main plot, genotype as the subplot and age as the sub-subplot.

RESULTS AND DISCUSSION

Starch yield in the Forest ecozone for all the varieties except of NKZ-009 increased from 12 to 13 months and thereafter decline steadily to 15 months (Fig. 1a). However, in the Transition ecozone, the starch yield of all the varieties generally decrease from 13 months to 15 months except NKZ-015, which increased sharply from 14 to 15 months after planting (Fig. 1b). For both Forest and Transition ecozones, the peak starch yield was generally at 13 months except for NKZ-015 in the Transition ecozone (Fig. 1b), which declined thereafter. The variation in response of the genotypes with age at the ecozones suggests that different varieties must be harvested at different ages to obtain the optimum starch yields. These have very important breeding and cassava improvement implications for the emerging starch industry in Ghana.

The three parameters that were studied to define starch quality were solubility, swelling power and water-binding capacity. Solubility is a solute's ability to dissolve in a solvent. According to Moorthy (2001), it depends on a number of factors such as source, inter-associative forces, swelling power and presence of other components. The solubility values obtained (6.20-11.67%) as shown in Table 1 and 2 were lower than the 25 to 48% reported for cassava starch (Moorthy, 2001). Montero (2002) reported a range of 17.20-27.20% in his study on some cassava varieties in India. Even though values obtained were lower than those of Moorthy (2001), they were comparable to Barimah *et al.* (1999) in Ghana, which was 9.60-14%. Variations in these results may be due to differences in the location and cultivar.

Significant variations ($p<0.05$) were observed between the solubility values (Table 1). NKZ-015 produced the highest solubility value of 8.68% and was significantly ($p<0.05$) higher than the other varieties except WCH-037 (8.18%) (Table 1). Solubility generally appeared to increase with age with the lowest (7.29%) and

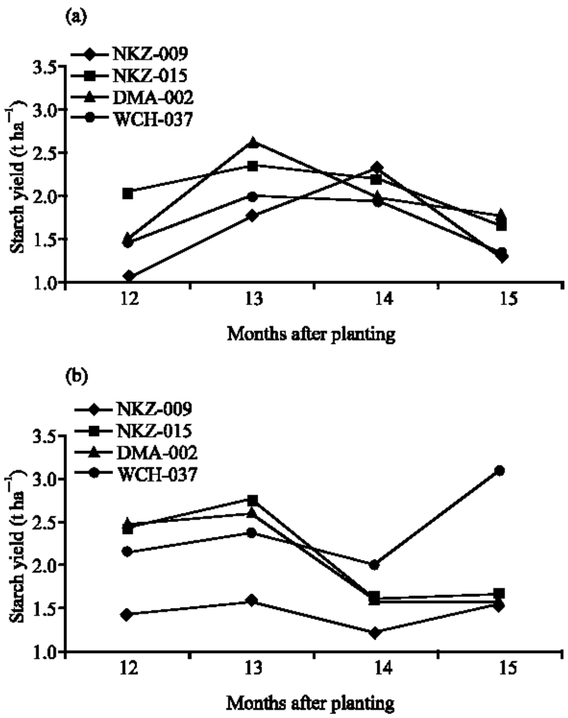

Fig. 1: Starch yield of the four cassava genotypes at different harvest dates in the (a) Forest ecozone and (b) Transition ecozones

Table 1: Solubility (%) of starch at different times of harvesting

Variety	Age (Months after planting) 12	13	14	15	Mean
NKZ-015	9.50	9.00	8.06	8.17	8.68
DMA-002	6.72	7.78	6.78	8.39	7.42
WCH-037	6.67	8.82	7.33	9.89	8.18
NKZ-009	6.28	7.56	7.28	8.06	7.30
Mean	7.29	8.29	7.36	8.63	

LSD (5%); Variety (V) = 0.66; Age (A) = 0.71, A×V = 1.66

Table 2: Solubility (%) of starch at different Locations

Variety	[a]Location MAP	DMA	KSI	KIN	KSO	TEC	Mean
NKZ-015	11.67	7.17	8.50	8.25	8.75	7.75	8.68
DMA-002	9.80	6.20	6.20	8.15	8.10	6.08	7.42
WCH-037	8.92	7.25	7.83	9.15	7.98	7.93	8.18
NKZ-009	7.77	6.82	6.93	6.50	8.53	6.93	7.30
Mean	9.54	6.86	7.37	8.01	8.34	7.17	

LSD (5%); Variety Location (L) =1.02; (V) = 0.66; KSI: Kumasi; KIN: Kintampo; KSO: Kwame-Danso; TEC: Techiman; V×L = 1.40 [a]: Location: DMA: Dormaa-Ahenkro; MAP: Mampong;

Table 3: Swelling power (g g^{-1}) of starch at different times of harvesting

Variety	Age (Months after planting) 12	13	14	15	Mean
NKZ-015	18.75	19.38	18.24	21.39	19.44
DMA-002	20.25	18.92	17.24	19.70	19.03
WCH-037	18.84	19.65	17.98	20.19	18.17
NKZ-009	17.41	19.21	16.15	17.71	17.62
Mean	18.81	19.29	17.40	19.75	

LSD (5%); Variety (V) = 0.90; Age (A) = 1.02; V×A = 2.39

highest (8.63%) being recorded at 12 and 15 months after planting, respectively. The differences between the varieties may be attributed to variation in their amylose content and granule sizes since these affect the bonding forces between the granules and water molecules. Moorthy (2001) also observed genotypic differences in solubility of cassava varieties studied in India. The interaction between age and variety was significant ($p<0.05$). For example, the highest solubility value of 9.89% was recorded for WCH-037 at 15 months while the lowest value of 6.28% was recorded for NKZ-009 at 12 months (Table 1).

Significant variations ($p<0.05$) were also established between the locations for solubility (Table 2). The range was 6.86 to 9.54%. Mampong and Dormaa-Ahenkro produced the highest and lowest values, respectively. The relative ranking of the varieties was affected by location except NKZ-015, which was generally highest at every location. The genotype by location interaction was significant ($p<0.05$).

Balagoplan *et al.* (1998) defined swelling power of starch as the maximum increase in volume and weight, which starch undergoes when allowed to swell freely in water. This occurs because of increase in temperature of aqueous suspension above gelatinization temperature range. Significant differences were established between the varieties and the range was 15.73-21.93 g g^{-1} (Table 3). The range for the age and variety means were 17.40-19.75 and 17.62-19.44 g g^{-1}, respectively and the differences were significant ($p<0.05$) (Table 3). Swelling power appeared to have slightly peaked at the 13th month (Table 3). NKZ-009 and NKZ-015 gave the lowest and highest, respectively (Table 1). Significant interaction ($p<0.05$) was established between age and variety. Swelling power values obtained were lower than the range 42-71 g g^{-1} reported by Moorthy (2001). Low values obtained compared with Moorthy (2001) was expected due to the corresponding low solubility values of the varieties. This is because, according to Rikard *et al.* (1991) and Moorthy (2001), a positive relationship exists between solubility and swelling power of starch. NKZ-015 and NKZ-009 gave the highest and lowest values swelling power values. Moorthy and Ramanujam (1986) also found genotypic effect on swelling power of starch on some cultivars studied in India. In a swelling power mean range of 16.22-21.38% produced across the locations (Table 4), significant differences ($p<0.05$) were established. The lowest and the highest values were produced at Techiman and Mampong (Table 4). The interaction between variety and location was also significant ($p<0.05$) for swelling power.

Table 4: Swelling power ($g\ g^{-1}$) of starch at different Locations

	[a]Location						
Variety	MAP	DMA	KSI	KIN	KSO	TEC	Mean
NKZ-015	21.69	18.24	20.76	18.20	19.55	18.22	19.44
DMA-002	21.93	19.42	18.40	19.57	19.70	15.15	19.03
WCH-037	20.90	20.77	18.96	20.58	18.01	15.77	18.17
NKZ-009	20.98	16.34	17.86	16.94	17.89	15.73	17.62
Mean	21.38	18.69	19.00	18.82	18.79	16.22	

LSD (5%); Location (L) = 1.47; Variety (V) = 0.90; KSI: Kumasi; KIN: Kintampo; KSO: Kwame-Danso; TEC: Techiman; V×L = 1.36 [a]Location: DMA: Dormaa-Ahenkro; MAP: Mampong

Table 5: Water-binding capacity (%) of starch at different times of harvesting

	Age (Months after planting)				
Variety	12	13	14	15	Mean
NKZ-015	68.83	65.56	57.59	61.22	63.30
DMA-002	67.00	66.64	55.32	68.16	64.28
WCH-037	64.86	65.40	61.65	58.78	62.67
NKZ-009	72.06	67.98	62.11	60.31	65.62
Mean	68.19	66.40	59.17	62.12	

LSD (5%); Variety (V) = 5.68; Age (A) = 6.09; V×A = 14.23

Table 6: Water-binding capacity (%) of starch at different locations

	[a]Location						
Variety	MAP	DMA	KSI	KIN	KSO	TEC	Mean
NKZ-015	61.71	62.33	65.58	68.96	60.17	65.92	63.30
DMA-002	70.50	54.84	65.58	67.71	52.75	74.29	64.28
WCH-037	70.38	50.60	56.21	67.54	61.00	70.42	62.67
NKZ-009	68.17	55.02	62.87	70.58	61.79	70.38	65.62
Mean	67.69	55.72	62.56	68.70	58.93	70.25	

LSD (5%); Location (L)= 8.75; Variety (V) = 5.68; KSI: Kumasi; KIN: Kintampo; KSO: Kwame-Danso; TEC: Techiman; V×L = 13.24 [a]Location: DMA: Dormaa-Ahenkro; MAP: Mampong

According to Niba *et al.* (2001), water-binding capacity is an important parameter that determines starch use in products like sauces since it affects functional properties such as viscosity, which is a very important indicator of bulking and consistency of products. The values obtained range from 50.60 to 74.29%. This is comparable to 41.18-82.92% reported by Amagloh (2005). There were no significant differences ($p>0.05$) between the genotypes for water-binding capacity (Table 5). Water-binding capacity decreased with age and the interaction between age and genotype was significant (Table 5). It was also affected by location (Table 6).

CONCLUSIONS

Cassava starch yield is variety, age and location dependent. Cassava starch solubility however increases with age. Swelling power of the genotypes studied was affected by age and location. Water-binding capacity decreased with age. This study has shown that cassava starch yield, solubility, swelling power and water-binding capacity are affected by age, variety and location. These therefore may complicate selection and evaluation of genotypes for specific industrial starch-based application.

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