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

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Abstract: Flour yield and its solubility, swelling power and water-binding capacity from four genotypes of cassava were studied. This was to study the effect and relative importance of age and environment on cassava flour yield and quality. Trials were conducted at six selected districts from the Forest and the Transition ecozones of Ghana. Harvesting was done at monthly intervals from 12th to the 15th month after planting. At each harvest, 25 kg of fresh tubers of each of the genotypes from each location were commercially processed into flour. Flour yield of the genotypes produced at the ecozones across ages at harvest indicated significant genotype by location interaction effect. While solubility and swelling power steadily increased with age, the opposite was true for water binding capacity. Solubility values ranged from 6.89 to 12.00%. That of swelling power and water-binding capacity was 16.55-20.46 g g^{-1} and 111.92-139.17%, respectively. Significant differences ($p<0.05$) were established between the locations for traits studied. Interaction between genotype and locations were also significant ($p<0.05$).

Key words: Cassava, flour yield, solubility, swelling power, water-binding capacity

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INTRODUCTION

Cassava (*Manihot esculenta*, Crantz) is the main starch staple of many people in Africa (Manu-Aduening *et al*., 2006). It can yield in relatively infertile soils and tolerates long periods of drought, making it particularly important for poor rural households farming marginal lands. In Ghana, a mean per capita production of 465 kg $annum^{-1}$ 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 process cassava into diverse foods and starch for industrial uses.

Cassava has become an important crop in Ghana because of its diverse uses, potential in the economy and its relatively high productivity under conditions which many other crops fail. Cassava flour is a potential substitute for wheat and maize-based flours (Rickard *et al*., 1991; Tian *et al*., 1991). One fifty thousand tons of wheat flour is imported per annum into Ghana. This is mainly used by the bakeries, with about 1,200 t $annum^{-1}$ used by the plywood industry (Dziedzoave *et al*., 2000). Much of this can be replaced by cassava flour to reduce government spending on balance of payment deficit. This is because a preliminary technical and economic study indicated a potential substitute of local cassava flour for imported products in the areas of plywood glue extenders and paperboard adhesives in Ghana (Graffham *et al*., 2000).

Because cassava has traditionally been the crop of the poor, expanding its market can bring direct benefit to those who need it most (Porto, 2004). Thus farmers who form about 70% of the population

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and are mostly poor will enjoy the benefits leading to solving the problem of poverty. To benefit from cassava as elaborated, Dziedgoave *et al*. (2000) indicated that the logical step to take was to place research emphasis on requirements of end users, market demands, industrial specification and the development of other technologies with potential for wider commercial uptake and dissemination. This suggests that in addition to selecting genotypes for desired agronomic traits such as higher yield, physicochemical and functional properties such as swelling power, solubility and water binding capacity should also be known. These traits and properties are affected by variety, age and the environment. For example, Moorthy and Ramanujam (1986) observed a number of physicochemical properties to increase with age up to the sixth month for six varieties studied. According to Asaoka *et al*. (1992) and Defloor *et al*. (1998), season at harvest has influence on physicochemical and rheological properties of cassava.

Thus, the objective of this study was to investigate the effect of cassava varieties on flour yield and its functional and physicochemical properties as influenced by different dates of harvesting and location.

MATERIALS AND METHODS

The study was done in 2004/2005. Four elite varieties-NKZ-009, NKZ-015, DMA-002 and WCH-037 were studied at selected districts in the Forest and Transition ecozones of Ghana. The selected districts were Mampong, Kumasi and Dormaa-Ahenkro (Forest ecozone) and Techiman, Kintampo and Kwame Danso in the Transition ecozones. In the Forest locations, land preparation was by slashing and removal of stumps before planting. For the Transition ecozone, the land was ploughed and harrowed before planting. The spacing was 1×1 m and four weedings were carried out at 2, 5, 9 and 14 months after planting. Harvesting began at 12 months and continued at monthly interval until the 15th month. At each harvest, 25 kg of fresh tubers from the four elite genotypes were commercially processed into flour. This was done by some women trained by Women in Agricultural Development (WIAD) in agro-processing at their local factory at Ashanti Mampong. Sample from genotype at each harvest and location were analysed at the Plant Breeding Laboratory of Kwame Nkrumah University of Science and Technology (KNUST), Kumasi for their physicochemical and functional properties. The analysis was carried out in triplicate and parameters determined were solubility, swelling power and water-binding capacity. The solubility and swelling power was 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. Flour yield of the elite varieties at the various locations were subjected to statistical analysis by line graphs using 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 factor, genotype as subplot factor and age as the sub-subplot factor using COSTAT.

RESULTS AND DISCUSSION

Varieties NKZ-009 and WCH-037 gave the lowest and highest flour yield respectively in the Forest belt occurring at 12 and 15 months after planting. In the Transition ecozone, the lowest and the highest flour yields were produced at 13 and 12 months after planting and these were produced by NKZ-009 and WCH-037, respectively. While flour yield of DMA-002 and WCH-037 was highest at 12 months after planting in the Transition belt, it was highest at 13 and 15 months after planting, respectively in the Forest ecozone. Again while flour yields of the NKZ-lines appear lowest at 12 months after planting in both ecozones (Fig. 1a and b), the highest yield for NKZ-015 occurred at 15 months in the two ecozones but that of NKZ-009 was at 14 and 15 months, respectively in the

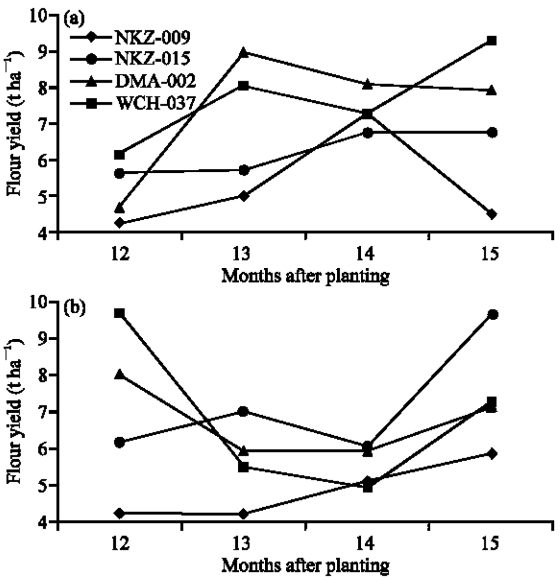

Fig. 1: Flour yield of the cassava genotypes at different harvest dates. a): Forest ecozone and b): Transition ecozone

Forest and Transition ecozones. Flour yield of the genotypes produced at the ecozones across ages at harvest indicated significant genotype by location interaction effect. This indicates that growing conditions as well as harvesting time are critical for realising potential flour yield of cassava varieties (Fig. 1a and b).

Quality of flour is explained by its solubility, swelling power and water-binding capacity. Solubility is a solute's ability to dissolve in a solvent while swelling power defines the maximum increase in volume and weight, which a solute undergoes when allowed to swell freely in water. These occur when the adhesive force between the solute and the solvent becomes greater than the cohesive force between the solute molecules. No significant differences were established between the genotypes (Table 1). NKZ-009 and NKZ-015 gave the highest and lowest values respectively in a range of 8.50 to 9.56%.

Solubility steadily increased with age from 7.57% at 12 months to 10.15% at 15 months and the difference was significant ($p<0.05$) (Table 1). The interaction between age and genotype were also significant (Table 1). The average solubility values across the locations ranged from 8.02 to 10.46%. Values obtained at Mampong and Kintampo did not differ statistically ($p>0.05$) but were lower than values produced at the other locations (Table 2). A great deal of variation was observed among the varieties across the locations indicating significant interaction between genotype and location (Table 2).

The swelling power values obtained ranged from 16.55 to 20.46 $g\ g^{-1}$ (Table 3 and 4) and these agreed with the range observed by Apea Bah (2003) which was 14.88-26.58 $g\ g^{-1}$. DMA-002 and WCH-037 gave the lowest and highest mean values respectively (Table 3). In a narrow range of 17.55-19.82 $g\ g^{-1}$ swelling power steadily increased with age, but only the mean value at 15 months was significantly different ($p<0.05$) (Table 3). Interaction between age and variety was significant ($p<0.05$). Even though genotypic differences were not significant ($p>0.05$) (Table 3), differences between locations were significant ($p<0.05$) (Table 4). Values obtained were generally higher among the Forest locations than the Transition locations (Table 4) and the interactions between genotype and location were significant ($p<0.05$).

Table 1: Solubility (%) of flour harvested at different ages

	Age (Months after planting)				
Varieties	12	13	14	15	Mean
NKZ-015	6.89	10.83	7.17	9.11	8.50
DMA-002	8.44	8.22	8.72	10.11	8.87
WCH-037	7.78	7.33	11.44	11.33	9.47
NKZ-009	7.17	9.22	11.78	10.06	9.56
Mean	7.57	8.90	9.78	10.15	

LSD (5%): Variety (V) = 1.06; Age (A) = 1.15; V × A = 2.80

Table 2: Solubility (%) of flour harvested at different locations

	[a]Location						
Varieties	MAP	DMA	KSI	KIN	KSO	TEC	Mean
NKZ-015	8.58	8.33	10.08	8.00	7.75	8.25	8.50
DMA-002	7.92	11.25	7.42	9.25	8.67	8.75	8.87
WCH-037	9.92	10.25	9.25	8.08	10.00	9.33	9.47
NKZ-009	8.25	12.00	11.58	6.75	9.50	9.25	9.56
Mean	8.67	10.46	9.58	8.02	8.98	8.90	

LSD (5%): Variety (V) = 1.06; Location (L) = 1.72; V × L = 2.12; [a]: Location, MAP: Mampong, DMA: Dormaa-Ahenkro, KSI: Kumasi, KIN: Kintampo, KSO: Kwame-Danso, TEC: Techiman

Table 3: Swelling power (g g^{-1}) of flour harvested at different ages

	Age (Months after planting)				
Varieties	12	13	14	15	Mean
NKZ-015	17.34	18.02	17.03	20.12	18.13
DMA-002	16.93	17.53	18.23	19.18	17.97
WCH-037	18.30	17.05	18.91	20.32	18.65
NKZ-009	17.62	18.11	17.09	19.67	18.12
Mean	17.55	17.68	17.82	19.82	

LSD (5%): Variety (V) = 0.78; Age (A) = 0.84; V × A = 2.04

Table 4: Swelling power (g g^{-1}) of flour harvested at different Locations

	[a]Location						
Varieties	MAP	DMA	KSI	KIN	KSO	TEC	Mean
NKZ-015	18.18	19.92	17.26	17.78	17.97	17.66	18.12
DMA-002	18.64	20.46	16.55	17.19	17.14	17.81	17.89
WCH-037	19.73	19.98	17.79	17.64	18.32	18.38	18.65
NKZ-009	18.78	19.95	17.04	16.58	18.07	18.30	18.12
Mean	18.83	20.08	17.16	17.30	17.88	18.04	

LSD (5%): Variety (V) = 0.78; Location (L) = 0.84; V × L = 1.27, [a]Location: DMA-Dormaa-Ahenkro, MAP: Mampong, DMA: Dormaa-Ahenkro, KSI: Kumasi, KIN: Kintampo, KSO: Kwame-Danso, TEC: Techiman

Unlike the other two rheological parameters-solubility and swelling power which showed no significant differences ($p>0.05$) between the genotypes, there was significant differences ($p<0.05$) between the genotypes for water-binding capacity (Table 5). According to Niba *et al*. (2001), water-binding capacity relates to the viscosity of the starch granules. This means that while there may not be major differences in the cohesive forces between the granules of starch in the flour of the genotypes, their viscosity when heated could be different. Water-binding capacity also determines the bulking and consistency of products. The NKZ-lines produced the highest values. This shows that the NKZ-lines have greater water holding capacity and will be more viscous when heated than DMA-002 and WCH-037. Thus, the NKZ-lines would provide more consistency and would therefore, be better genotypes for bakery products than DMA-002 and WCH-037. Water-binding capacity declined with age from 12 months at 128.89 to 121.58% at 14 months after planting (Table 5). Significant differences

Table 5: Water-binding capacity (%) of Flour harvested at different ages

	Age (Months after planting)				
Varieties	12	13	14	15	Mean
NKZ-015	128.67	126.00	123.14	122.78	125.15
DMA-002	125.67	128.50	114.47	118.42	121.77
WCH-037	128.14	126.53	121.94	119.03	123.91
NKZ-009	133.08	127.22	126.78	128.58	128.92
Mean	128.89	127.06	121.58	122.20	

LSD (5%): Variety (V) = 4.54; Age (A) = 4.90; V × A = 9.93

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

	[a]Location						
Varieties	MAP	DMA	KSI	KIN	KSO	TEC	Mean
NKZ-015	130.92	127.17	130.54	118.83	125.54	117.88	125.15
DMA-002	120.75	126.13	121.58	127.23	123.08	111.92	121.77
WCH-037	127.71	119.67	121.67	124.63	134.96	114.83	123.91
NKZ-009	129.08	127.79	124.42	126.00	139.17	127.04	128.92
Mean	127.12	125.19	124.55	124.17	130.69	117.92	

LSD (5%): Variety (V)= 4.54; Location (L)= 4.90; V × L = 15.47, [a]Location:DMA-Dormaa-Ahenkro, MAP: Mampong, DMA: Dormaa-Ahenkro, KSI: Kumasi, KIN: Kintampo, KSO: Kwame-Danso, TEC: Techiman

($p<0.05$) were established between the locations. The mean range was 117.92-130.69% and Techiman and Kwame-Danso produced the lowest and highest values respectively (Table 6). Interaction between genotype and locations was also significant ($p<0.05$).

CONCLUSIONS

The variations and interactions between genotype and environment may complicate evaluation and selection of cassava genotypes for cassava flour utilization. This is due to the wide variation in the environmental conditions during growth period of cassava. Age at harvest of cassava genotypes also has significant effect on flour yield, physicochemical and functional properties of cassava flour.

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