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Genotype-Environment Interaction (GXE) Effects on Some Major Rheological Properties of Cassava (*Manihot esculenta*, Crantz)

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Abstract: Trials were conducted at two different locations in the Forest and Transition ecozones of Ghana to determine the presence and relative importance of GXE interactions on rheological properties of cassava using 8 genotypes. Data collected include solubility, swelling power, water-binding capacity (flour and starch) and swelling capacity and pH for the gari. The data were subjected to the Analysis of Variance (ANOVA) in a Factorial Randomised Complete Block Design (RCBD). Genotypic differences ($p<0.05$) were observed for all the traits studied except water-binding capacity and swelling power of starch. GXE interaction was significant ($p<0.05$) for all traits studied. These differential genotypic responses across locations means that the relative performance of varieties will differ across environments and this can complicate evaluation and selection of genotypes for specific domestic and industrial uses. Thus, indicating the importance of GXE interactions on cassava improvement and industry in Ghana.

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

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^{-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). Cassava contributes 16% of the total Agricultural Gross Domestic Product (AGDP) which is higher than any other crop including cocoa (Safo-Kantanka, 2004). According to Manu-Aduening *et al*. (2006), most cassava produced is consumed fresh as fufu. It has therefore, been described as the last line of food security in Ghana (Arku-Kelly, 2001).

Cassava is a model crop that can singly put Ghana on the world economic map because of its diverse uses in industry and export potential of its products. Cassava flour and starch have potential usage in the food, plywood, paperboard, textiles, pharmaceutical, petroleum and brewery industries. The use of cassava in animal industry is another area where cassava utilization can greatly increase also in Ghana. At least $3 billion is earned by Nigeria through the export of cassava and related products according FAO (2004). Because cassava has traditionally been a crop of the poor in Ghana, according to Porto (2004) expanding the market for cassava can bring direct economic benefits to those who need it most. Thus farmers who form about 70% of the population and are mostly poor will enjoy the benefits leading to solving the problem of poverty. To benefit from cassava as elaborated above and even more, Dziedzoave *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

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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 mealiness, dry matter content, disease and pest tolerance and higher yield, the rheological properties such as swelling power and solubility, water binding capacity, amylose and amylopectin ratio/content, swelling capacity and pH must be known before appropriate usage can be recommended.

These rheological properties are affected by variety and the environment. For example, according to Asaoka *et al*. (1992); Defloor *et al*. (1998) and Safo-Kantanka and Asare (1993), season at harvest was found to influence rheological properties of cassava. Therefore, studies into genotype by environment interaction effect on cassava utilization are an important area of study in Africa in general and Ghana in particular. Though some GXE studies have been reported on agronomic traits of cassava in West Africa (Dixon *et al*., 1991; Dixon and Nukenine, 2000), very little is known on its effects on rheological properties of cassava. Again this knowledge is lacking in Ghana. Dixon *et al*. (1991) defines GXE interaction as the change in a cultivar's relative performance over environments, resulting from differential response of the cultivar, to various edaphic, climatic and biotic factors. GXE limits progress of crop improvement beyond the breeder's station. Cassava for example is grown in diverse agroecologies which differ in rainfall, temperature regimes and soil type and variation among ecozones and seasonal changes in one zone may also be very large. The knowledge of GXE will advance cassava industrialization in Ghana since production of varieties with desired traits for specific domestic and industrial use would be identified. This way industry can demand specific cassava varieties grown under specific conditions for their specific products.

The objective of this study therefore was to determine genotype by environment interaction (GXE) effect on some major rheological properties of cassava in Ghana.

MATERIALS AND METHODS

The field experiments were set up at Kwame Nkrumah University of Science and Technology (KNUST) and Wenchi Agricultural Research Station representing the Forest and Transition ecozones respectively. The experiment was carried out in 2004 and 2005. Four elite varieties which were at an advanced state of evaluation prior to release were used. These were NKZ-009, NKZ-015, DMA-002 and WCH-037. These four elite varieties were compared to four already released varieties namely Afisiafi, Abasafitaa, Gblemoduade and a mutant variety Tek-bankye. 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 three months interval starting from three months after planting. Harvesting was at 12 months after planting. At each harvest, 25 kg of fresh tubers from each variety were commercially processed into flour, starch and gari. This was done by some women trained by Women in Agricultural Development (WIAD) in agro-processing at their local factory at Ashanti Mampong. Samples from genotype at each location were analysed at the Plant breeding Laboratory of Kwame Nkrumah University of Science and Technology (KNUST), Kumasi for their rheological properties. The analysis was carried out in triplicate and parameters determined were solubility, swelling power and water-binding capacity for the flour and the starch. Swelling capacity and pH were the parameters determined for the gari. 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. Swelling capacity was determined by weighing 10 mL of gari into a 100 mL measuring cylinder. Forty milliliter distilled water was added to it and shaken manually for the water to thoroughly mix with the gari particles. It was then allowed to stand for 3 min and the final volume noted in the measuring cylinder. The swelling capacity was calculated as the ratio of the final volume of gari to the initial volume. After the swelling capacity determination, the content of the measuring cylinder was topped with distilled water to the 80 mL mark. The content was further shaken and allowed to stand for 2 min after which, the supernatant was poured into a 40 mL beaker and a corning pH meter 430 used to determine the pH. Data collected were analysed using the Analysis of Variance (ANOVA) in a Factorial Randomised Complete Block Design (RCBD) using CoStat.

RESULTS AND DISCUSSION

Genotypic differences ($p<0.05$) were established between the varieties for all the traits studied except water-binding capacity and the swelling power of starch. The solubility values of flour and the starch were in a range of 7.17 to 13.83% and 5.33 to 14.17%, respectively. The respective varieties that produced these values were NKZ-009 and Afisiafi and DMA-002 and Abasafitaa. These values are comparable to the range 9.60-14.70% reported by Barimah *et al*. (1999) who worked with some local varieties but not that of 17.20-27.20% reported by Moorthy (2002) in India. GXE effect ($p<0.05$) was present in both the flour and starch (Table 1, 2).

Swelling power values for the flour was in a range of 15.52-19.27 g g^{-1}. That of starch was in a range of 14.43-20.52 g g^{-1}. These values did not agree with 42-71 g g^{-1} reported by Moorthy (2002) in India, but were comparable to 15.28-21.74 g g^{-1} reported by Appea Bah (2003). The highest and the lowest values for the flour were produced by WCH-037 and DMA-002 (Table 3). Gblemoduade and DMA-002 produced the highest and the lowest values for the starch (Table 4). Even though genotypic differences were not significant ($p>0.05$) for the swelling power of starch, Moorthy and Ramanujam (1986) found differences in swelling power of starch for some cultivars studied in India. GXE interaction was however significant ($p<0.05$) for the swelling power of starch and flour, respectively.

Table 1: Effect of genotype and location on solubility (%) of flour

Variety	Location KNUST	Wenchi	Mean
DMA-002	9.83	9.50	9.67
WCH-037	8.67	10.67	9.67
NKZ-009	8.00	7.17	7.59
NKZ-015	8.00	9.33	8.67
Tek-bankye	9.17	6.50	7.84
Afisiafi	13.83	9.00	11.42
Abasafitaa	10.17	11.17	10.67
Gblemoduade	10.83	8.83	9.83
Mean	9.81	9.02	

LSD (5%): Variety (V)= 2.26; Location (L) = 1.13 VXL =3.80

Table 2: Effect of genotype and location on solubility (%) of starch

Variety	Location KNUST	Wenchi	Mean
DMA-002	5.33	7.33b	6.33
WCH-037	12.83	10.00	11.42
NKZ-009	7.83	7.50	7.67
NKZ-015	10.00	7.67	8.84
Tek-bankye	7.50	6.17	6.84
Afisiafi	7.00	7.83	7.42
Abasafitaa	14.17	11.17	12.67
Gblemoduade	7.50	5.50	6.50
Mean	9.02	7.90	

LSD (5%): Variety (V) = 2.69; Location (L) = 1.35; VXL = 3.20

Table 3: Effect of genotype and location on swelling power (g/g) of flour

	Location		
Variety	KNUST	Wenchi	Mean
DMA-002	15.52	17.22	16.37
WCH-037	16.39	19.27	17.83
NKZ-009	16.67	16.18	16.43
NKZ-015	16.24	18.49	17.37
Tek-bankye	16.87	16.80	16.84
Afisiafi	18.67	17.49	18.08
Abasafitaa	16.32	17.70	17.01
Gblemoduade	17.47	16.57	17.02
Mean	16.77	17.47	

LSD (5%): Variety (V) = 1.74; Location (L) = 0.87; VXL = 3.50

Table 4: Effect of genotype and location on swelling power (g/g) of starch

	Location		
Variety	KNUST	Wenchi	Mean
DMA-002	16.67	14.43	15.55
WCH-037	18.71	16.32	17.52
NKZ-009	18.93	15.39	17.16
NKZ-015	18.65	16.47	17.56
Tek-bankye	17.62	15.56	16.59
Afisiafi	16.58	17.73	17.16
Abasafitaa	15.44	15.36	15.40
Gblemoduade	20.52	18.45	19.49
Mean	17.89	16.21	

LSD (5%): Variety (V) = 1.24; Location (L) = 1.23; VXL = 2.46

Table 5: Effect of genotype and location on water-binding capacity (%) of flour

	Location		
Variety	KNUST	Wenchi	Mean
DMA-002	134.08	131.00	132.54
WCH-037	144.75	133.42	139.09
NKZ-009	138.42	135.42	136.92
NKZ-015	135.50	142.50	139.00
Tek-bankye	133.58	131.58	132.58
Afisiafi	143.83	142.58	143.21
Abasafitaa	135.83	129.00	132.42
Gblemoduade	142.08	125.00	133.54
Mean	138.51	133.81	

LSD (5%): Variety (Variety) = 9.32; Location (L) = 4.66; VXL = 17.60

Water-binding capacity is an important parameter since it has implication for viscosity and is an important indicator for bulking and consistency of products especially in the baking industry (Niba *et al*., 2001). The range of values for the flour and starch were 125.00-144.75% and 46.58-82.67%, respectively. These were given by Gblemoduade and WCH-037 (flour) (Table 5) and Afisiafi in the case of starch (Table 6). GXE effect ($p<0.05$) was also present in the water-binding capacity flour and starch.

Swelling capacity determines the extent to which a sample of gari increases in volume when soak in water in relation to its initial volume. According to Apea Bah (2003), the higher the swelling capacity, the greater its suitability for use in foods such as eba. The values obtained (2.90-3.41) (Table 7) were comparable to those reported by Apea Bah (2003) which ranged between 2.00 and 3.00. Thus, both the elite and the released varieties have the potential to increase their volume three-fold on the average when soaked with water. Significant GXE effects ($p<0.05$) were established. For example, DMA-002, WCH-037 and NKZ-009 gave higher values at KNUST than the already released varieties except Abasafitaa. At Wenchi however, though the values of DMA-002 and

Table 6: Effect of genotype and location on water-binding capacity (%) of starch

	Location		
Variety	KNUST	Wenchi	Mean
DMA-002	53.33	73.67	63.50
WCH-037	57.08	68.42	62.75
NKZ-009	70.25	65.17	67.71
NKZ-015	81.12	59.44	70.28
Tek-bankye	54.17	76.08	65.13
Afisiafi	46.58	82.67	64.63
Abasafitaa	48.16	74.00	61.08
Gblemoduade	71.42	70.50	70.96
Mean	60.26	71.24	

LSD (5%): Variety (V) = 12.45; Location (L) = 6.22, VXL = 13.18

Table 7: Effect of genotype and location on swelling capacity of gari

	Location		
Variety	KNUST	Wenchi	Mean
DMA-002	3.34	3.33	3.34
WCH-037	3.33	3.33	3.33
NKZ-009	3.32	3.02	3.17
NKZ-015	3.10	3.07	3.09
Tek-bankye	3.19	3.41	3.30
Afisiafi	3.11	3.33	3.22
Abasafitaa	3.35	3.37	3.36
Gblemoduade	2.90	3.37	3.14
Mean	3.21	3.28	

LSD (5%): Variety (L) = 0.14; Location (L) = 0.07; VXL = 0.02

Table 8: Effect of genotype and location on pH of gari

	Location		
Variety	KNUST	Wenchi	Mean
DMA-002	4.82	4.91	4.87
WCH-037	4.72	4.76	4.74
NKZ-009	4.62	4.72	4.67
NKZ-015	4.66	4.64	4.65
Tek-bankye	4.53	4.67	4.60
Afisiafi	4.72	4.62	4.67
Abasafitaa	4.83	4.79	4.81
Gblemoduade	4.84	4.71	4.78
Mean	4.72	4.73	

LSD (5%): Variety (V) = 0.02; Location (L) = 0.01; VXL = 0.36

WCH-037 were not significantly different from the already released varieties, those of the NKZ-lines were significantly lower than the already released ones.

pH is another important criterion for quality of gari since it influences the taste. The values obtained from the study ranged between 4.53 and 4.91 (Table 8) and were greater than 3.58-4.59 reported by Apea Bah (2003). The interaction between genotype and environment was significant ($p<0.05$). At KNUST, an already released variety gave the highest pH and the values produced by *Abasafitaa* and *Gblemoduade* were higher than most of the elite local varieties. Elite local variety also gave the highest pH at Wenchi and the values produced by DMA-002 and WCH-037 were higher than some of the already released varieties.

CONCLUSION

These differential genotypic responses across locations means that rheological properties of cassava varieties will differ across environments and this can complicate evaluation and selection of varieties for specific domestic and industrial use. This therefore, means that weak inferences may be made from field data since the interaction reduces the correlation between genotype and phenotype.

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