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Time of harvesting and its effect on the quality of flour from four cassava varieties

Apea Bah F.B.[1], Oduro I.[1], Ellis W.O.[1] and Safo-Kantanka O.[2]
[1]Biochemistry Department. [2]Crop Science Department, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana

Abstract. Four varieties of cassava (*Afisiafi*, *Tek bankye*, *Abasafitaa* and *Gblemoduade*) were harvested each month from 9 to 15 months after planting and processed into flour. The yield of flour and some of its physicochemical properties were studied to determine how they were affected by harvesting time and varietal difference. The properties of flour studied were: moisture, ash, crude protein, crude fibre, pH, swelling power, solubility, starch yield, amylose content and pasting characteristics. *Afisiafi* and *Tek bankye* both had their peak flour yields (23% and 22.4% respectively) at 13 months after planting while *Abasafitaa* and *Gblemoduade* had their peak flour yields (23.4% and 20% respectively) at 12 months after planting. Both *Afisiafi* and *Tek bankye* had flour yields increasing uniformly from 11 to 13 months after planting after which they fell while *Abasafitaa* and *Gblemoduade* had their flour yields increasing from 9 through 12 months after planting after which they fell. Moisture content ranged between 6.3% and 14.6%, while ash content was between 0.70% and 2.21%. All flour samples had pH ranging between 5.07 and 6.65 indicating unfermented flour of high quality. All the varieties had a minimum crude protein content of 0.22%; *Afisiafi* and *Tek bankye* had maximum values of 1.53% and 1.68% respectively at 9 months after planting while *Abasafitaa* and *Gblemoduade* had maximum values of 1.68% and 1.53% respectively at 15 months after planting. Starch yield was between 53.60% and 76.01% while solubility ranged between 7.81% and 18.80%. Age significantly affected ($p<0.05$) flour yield, crude protein, ash and moisture, while pH, crude fibre, amylose and swelling power were neither affected significantly ($p>0.05$) by age nor variety. Starch yield of flour, solubility, ash content and pasting characteristics were all significantly affected ($p<0.05$) by variety. *Afisiafi* and *Tek bankye* had higher peak viscosities than *Abasafitaa* and *Gblemoduade*. Both hot paste stability and hot paste breakdown were highest for *Gblemoduade* and lowest for *Abasafitaa*. *Afisiafi* and *Tek bankye* had higher retrogradation while that of *Abasafitaa* and *Gblemoduade* were close to zero.

Introduction

Cassava is one of the most important root crops in the world providing energy to consumers due to the large amount of carbohydrates in its roots. It contributes significantly to the economy of most tropical countries through its processing into various products. In Ghana, its multiplication in the formal planting material sector started in the nineties, with the release of four new varieties; *Afisiafi, Tek bankye, Abasafitaa* and *Gblemoduade*. These varieties are high yielders, disease and pest resistant when compared to existing local varieties (RTIP Factsheet, 2002). Apart from *Tek bankye*, the other three varieties are not mealy, thus, their acceptability by farmers is low. In Ghana, cassava is mostly pounded into *fufu*, a thick paste prepared by pounding peeled, boiled cassava roots, and eaten with soup *fufu*

requires mealy cassava. It has therefore become necessary to find alternative uses for these high yielding and disease resistant cassava varieties. They may be processed among others into, high quality flour and starch for industrial use. Little, however, is known about their physicochemical properties of flour in relation to age at harvest.

The objective of this study, therefore, was to determine the effects that age and varietal difference had on the yield and physicochemical properties of flour obtained from these four varieties.

Materials and Methods

Source of raw materials. Cassava varieties were obtained from experimental plots at the Wenchi Agricultural Research Station (WARS). The four varieties studied are *Afisiafi (AF), Tek bankye (TEK), Abasafitaa (AB)* and *Gblemoduade (GB)*. The varieties were harvested at 9, 10, 11, 12, 13, 14 and 15 months after planting and processed into flour.

Processing of cassava tubers into flour. Fresh tubers were peeled a day after harvesting and washed. They were grated finely, and the mash packed into porous woven polyethylene sacks and dehydrated manually by pressing with a screw-press. The cakes obtained from pressing were stored in a freezer to prevent fermentation. The frozen cakes were thawed and pulverized the following day, sieved and spread thinly on raised wooden platforms lined with black polyethylene film, and allowed to dry in the sun with intermittently stirring. The dry granules obtained after 2 days of sun drying were milled and sieved through a 60μm mesh. The resulting fine flour was packaged in transparent polyethylene bags and stored at room temperature. The yield of flour was determined by weighing the amount obtained from processing 100kg of fresh tubers.

Physicochemical analyses. Moisture, ash, crude fibre and crude protein contents of the flour were determined by the AOAC (1990) method. pH was determined by mixing 10 g of flour with 25 ml distilled water, stirring thoroughly and measured with a pH meter (HANNA Instruments, model 8521) at room temperature. Starch yield of flour was determined by preparing a slurry with 10 g of the flour in water and repeatedly washing out the starch with water. The starch was allowed to settle and decanted after which it was dried in a hot-air oven at 50°C overnight and weighed. It was then expressed as a percent of the flour weight. Amylose content, swelling power and solubility of the flour were determined by the method of Barimah (1999). Pasting characteristics was also determined by using the Brabender Amylograph (700cmg cartridge, 6% flour suspension).

Statistical analysis. Two way analysis of variance without replication was used to determine the effects that harvesting time or age and variety had on the selected physicochemical properties. Least significant difference (LSD) was used for mean separation.

Results and Discussion

Flour yield. Flour yield was between 8-23% for *Afisiafi*, 10.6-22.4% for *Tek bankye*, 13-23.4% for *Abasafitaa* and 9.4-20% for *Gblemoduade* (Table 1). Flour yield of *Afisiafi* fell from 9 months through 11 months after planting (March to June), after which it rose uniformly reaching a peak at 13 months after planting, from where it fell again through 15 months after planting. *Tek bankye* had its flour yield falling from 9 months to 10 months after planting, after which it rose uniformly until 13 months after planting; it then fell uniformly until it reached 15 months after planting. *Abasafitaa* and *Gblemoduade* had a similar trend for flour yield. They both rose sequentially from a minimum yield at 9 months old until they reached a peak at 12 months after planting, after which their yields fell uniformly until 15 months after planting. All the cassava varieties had low flour yield in

April. This is because the rains started in late March, and by April the plants had mobilized most of the starch stored in their tubers for germination or new shoots formation (Githunguri *et al.*, 1998). This clearly shows that apart from the age of plant at harvest, the month in which harvesting of the tubers occurred also affects yield of the flour. *Afisiafi* and *Tek bankye* had optimum flour yields at 13 months after planting while *Abasafitaa* and *Gblemoduade* had optimum yields at 12 months after planting. Flour yield was significantly affected ($p<0.05$) by both age and variety.

Moisture. Moisture content of the flour samples ranged between 6.34-14.58% (Table 2). Flour samples were sun dried from March to December, when rainfall and sunshine patterns were unpredictable and non-uniform. It is worth noting that moisture content of flour is influenced by the extent of drying and the rainfall pattern during the period of sun drying. Statistical analysis revealed that age significantly affected ($p<0.05$) the moisture content of the flour samples.

Ash. Ash content of *Afisiafi* ranged between 0.80-1.47%, respectively, while *Tek bankye* had values between 0.70-1.26% with the lowest value at 9 months and the highest at 10 months after planting. *Abasafitaa* had ash content between 0.87-2.21%, representing 15 months and 12 months after planting respectively, while *Gblemoduade* had ash values in the range of 0.88-1.94% with the lowest value at 14 months and the highest at 12 months after planting.

With the exception of *Tek bankye* which had its highest value at 10 months after planting, all the other varieties had peak ash content at 12 months after planting (Table 3).

Table 1: Yield of flour from four cassava varieties at different ages.

Flour yield	*Afisiafi*	*Tek bankye*	*Abasafitaa*	*Gblemoduade*
9 months	13.8	14.4	13.0	9.4
10 months	14.4	10.6	15.5	12.6
11 months	8.0	14.8	16.4	16.2
12 months	14.2	21.0	23.4	20.0
13 months	23.0	22.4	20.0	14.0
14 months	14.0	21.0	15.0	13.6
15 months	12.6	19.4	13.6	10.0

LSD for age =3.77; LSD for variety =2.85.

Table 2: Moisture content of flour from four cassava varieties at different ages.

Moisture	*Afisiafi*	*Tek bankye*	*Abasafitaa*	*Gblemoduade*
9 months	9.90 (0.01)	9.53 (0.03)	12.10 (0.01)	10.64 (0.02)
10 months	8.89 (0.02)	12.47 (0.11)	10.84 (0.00)	10.64 (0.01)
11 months	11.26 (0.02)	13.20 (0.01)	12.37 (0.01)	14.58 (0.00)
12 months	11.47 (0.01)	13.18 (0.00)	11.00 (0.04)	11.52 (0.01)
13 months	10.96 (0.00)	10.15 (0.01)	6.68 (0.01)	6.34 (0.01)
14 months	11.14 (0.01)	7.24 (0.01)	7.80 (0.02)	12.23 (0.00)
15 months	11.37	11.75 (0.00)	11.34 (0.00)	11.29 (0.00)

LSD for age =2.07.

The ash content of *Tek bankye* fell sequentially from 10 months after planting until 15 months after planting. There was an inconsistent trend in ash content for the other three varieties. Age significantly affected ($p<0.05$) ash content of the cassava flour samples.

pH. pH is an important parameter in determining the quality of cassava flour since pH of 4 or less indicates appreciable level of fermentation, and hence some starch breakdown. Such fermentation also imparts undesirable flavour to the cassava flour making it less preferred when used in baking. The flour samples had pH between 5.07 and 6.65 (Table 4), indicating that they were of good quality. pH was neither significantly affected ($p>0.05$) by age nor by variety.

Crude protein. Crude protein content of *Afisiafi* ranged between 0.22% and 1.53%. The lowest and highest values occuring at 12 and 9 months after planting, respectively. *Tek bankye* had crude protein values between 0.22-1.68% with the lower limit at 11 months and the upper limit at 9 months after planting. For *Abasafitaa* the range was 0.22% - 1.68% with the lowest value at 13 months and the highest at 15 months after planting. The protein content range for *Gblemoduade* was 0.22% - 1.53% with the lowest value at 12 and 13 months after planting and the highest at 15 months after planting.

Age significantly affected ($p<0.05$) crude protein content. Other factors such as nitrogen content of the soil and the differing rates of nitrogen metabolism in the growing plants may be responsible for the differing trends in crude protein content (Table 5) among the four varieties. It is important to note that both *Afisiafi* and *Tek bankye* had maximum crude protein content at 9 months after planting while *Abasafitaa* and

Table 3: Ash content of flour from four cassava varieties at different ages.

Ash	*Afisiafi*	*Tek bankye*	*Abasafitaa*	*Gblemoduade*
9 months	0.80 (0.00)	0.70 (0.00)	1.36 (0.00)	1.21 (0.00)
10 months	1.21 (0.00)	1.26 (0.00)	1.00 (0.00)	1.31 (0.00)
11 months	1.15 (0.00)	1.12 (0.00)	1.17 (0.00)	0.95 (0.00)
12 months	1.47 (0.00)	1.06 (0.00)	2.21 (0.00)	1.94 (0.01)
13 months	1.23 (0.00)	0.83 (0.00)	1.15 (0.00)	0.99 (0.00)
14 months	0.82 (0.00)	0.83 (0.00)	1.24 (0.00)	0.88 (0.00)
15 months	0.82	0.79 (0.00)	0.87 (0.00)	0.99 (0.00)

LSD for age =0.28.

Table 4: pH of flour from four cassava varieties at different ages.

pH	*Afisiafi*	*Tek bankye*	*Abasafitaa*	*Gblemoduade*
9 months	5.86 (0.01)	5.46 (0.00)	5.53 (0.00)	5.47 (0.00)
10 months	5.49 (0.01)	5.13 (0.01)	6.21 (0.00)	6.61 (0.01)
11 months	5.63 (0.00)	6.51 (0.01)	5.27 (0.00)	5.30 (0.00)
12 months	6.40 (0.01)	5.31 (0.01)	6.15 (0.00)	6.54 (0.00)
13 months	5.07 (0.00)	6.65 (0.00)	5.67 (0.00)	5.97 (0.01)
14 months	6.27 (0.02)	6.02 (0.01)	5.32 (0.00)	5.55 (0.01)
15 months	5.28	5.11 (0.00)	5.49 (0.00)	5.31 (0.00)

Gblemoduade had maximum crude protein at 15 months after planting. All varieties had a minimum value of 0.22%.

Crude fibre. *Afisiafi* had crude fibre content of between 0.77-2.62%, with the lower limit at 14 months and the upper limit at 11 months; *Tek bankye* had values in the range of 1.45-2.07% with the lower and the upper limits at 9 and 10 months respectively. *Abasafitaa* on the other hand, had crude fibre values between 1.27-2.11% with the lowest value at 12 months and the highest at 9 months, while *Gblemoduade* had its fibre content in the range of 1.62-2.56% with the lower and upper limits at 13 and 9 months respectively (Table 6). There was no significant difference ($p>0.05$) in crude fibre content between ages and varieties. This may be due to the fine sieving of the flour after milling that removed most of the fibre and therefore shielded the effects of age and variety on the fibre content.

Starch yield. Starch yield of *Afisiafi* was between 53.6-75.5% with the lowest value at 9 months and the highest at 10 months, *Tek bankye* had starch yield values between 67.3-73.8%, with the lower limit at 10 months and the upper limit at 13 months. *Abasafitaa* starch yield ranged from 64.1-75.7% with the lowest value at 11 months and the highest at 14 months, while *Gblemoduade* had values between 63.8-76.0% with the lower and upper limits respectively at 14 and 13 months after planting. Suprisingly, starch yield was neither significantly affected ($p>0.05$) by age nor by variety (Table 7).

Amylose. Amylose content of *Afisiafi* ranged between 16.5-34.6% with the lower and upper limits respectively at 9 and 12 months, while *Tek bankye* had values between 20.3-36.0% with the lowest value at 14 months and the highest at 10 months. *Abasafitaa* had amylose content of 20.8-36.0% with the lower and upper

Table 5: Crude protein of flour from four cassava varieties at different ages.

Crude Protein	*Afisiafi*	*Tek bankye*	*Abasafitaa*	*Gblemoduade*
9 months	1.53 (0.00)	1.68 (0.06)	0.51 (0.06)	0.66 (0.00)
10 months	0.80 (0.06)	0.66 (0.00)	0.66 (0.00)	0.36 (0.06)
11 months	0.66 (0.00)	0.22 (0.00)	0.66 (0.00)	0.66 (0.00)
12 months	0.22 (0.00)	0.66 (0.00)	0.66 (0.00)	0.22 (0.00)
13 months	0.36 (0.06)	0.66 (0.00)	0.22 (0.00)	0.22 (0.00)
14 months	1.09 (0.00)	0.66 (0.00)	1.09 (0.00)	1.24 (0.06)
15 months	1.52	0.95 (0.06)	1.68 (0.06)	1.53 (0.00)

LSD for age =0.41.

Table 6: Crude fibre of flour from four cassava varieties at different ages.

Crude Fibre	*Afisiafi*	*Tek bankye*	*Abasafitaa*	*Gblemoduade*
9 months	1.90 (0.00)	1.45 (0.00)	2.11 (0.00)	2.56 (0.00)
10 months	2.22 (0.00)	2.07 (0.00)	1.84 (0.00)	2.54 (0.00)
11 months	2.62 (0.00)	1.57 (0.00)	1.92 (0.00)	1.82 (0.00)
12 months	2.52 (0.00)	1.67 (0.00)	1.27 (0.00)	1.69 (0.00)
13 months	1.89 (0.00)	1.52 (0.00)	1.69 (0.00)	1.62 (0.00)
14 months	0.77 (0.01)	1.46 (0.00)	1.47 (0.00)	1.78 (0.00)
15 months	1.98	1.58 (0.00)	1.76 (0.00)	1.99 (0.00)

limits at 14 months and 9 months respectively, while *Gblemoduade* also had values in the range of 23.1-34.6% with the lowest and highest values at 13 and 15 months, respectively. *Afisiafi* amylose values rose sequentially from 9 months after planting to a peak at 12 months after planting after which it fell sequentially until 14 months after planting. The other varieties showed no consistent trend in amylose content (Table 8). Amylose content of fresh cassava starch were reported to range between 22.6-26.2% for five cassava varieties (Moorthy *et al.*, 1992). When the amylose content of six varieties of cassava was compared during growth period, there were insignificant differences among the varieties (Moorthy, 1994). Barimah (1999) reported amylose content of starch from dry chips ranging between 22.3-24.5% for the varieties *Afisiafi*, *Abasafitaa*, *Gblemoduade* and *Isu-white*. These values were obtained for varieties at one particular age. On the other hand, Rickard *et al.* (1991) reported amylose content of 13.6-23.8%. Amylose content obtained in this study were high probably because of the presence of amylose-like substances produced by the hydrolytic action of both endogenous and microbial amylolytic enzymes on the amylopectin in the cassava mash during its processing into flour. Neither age nor variety significantly affected ($p>0.05$) amylose content.

Swelling power. Swelling power of *Afisiafi* ranged between 17.2-28.0 with the lower and upper limits at 13 and 9 months, respectively. For *Tek bankye* the values were 18.1-31.1, with the lowest value at 12 months and the highest at 9 months after planting. *Abasafitaa* had swelling power in the range of 20.7-28.5 with the lower and upper limits at 11 and 15 months respectively, while *Gblemoduade* had values between 18.7-32.0 with the lowest value at 11 months and highest value at 13 months. *Tek bankye* had its swelling power falling sequentially from a peak at 9 months till 12 months after planting, after which it began to rise (Table 9). No significant difference ($p>0.05$)

Table 7: Starch yield of flour from four cassava varieties at different ages.

Starch Yield	*Afisiafi*	*Tek bankye*	*Abasafitaa*	*Gblemoduade*
9 months	53.60 (0.05)	71.55 (0.47)	68.46 (0.18)	70.36 (0.23)
10 months	75.50 (1.01)	67.33 (0.13)	71.24 (0.20)	69.95 (0.37)
11 months	63.94 (0.18)	73.65 (0.14)	64.06 (0.89)	68.16 (0.22)
12 months	72.40 (0.09)	71.72 (0.03)	72.93 (0.24)	75.35 (0.03)
13 months	69.63 (0.85)	73.83 (0.07)	74.24 (0.03)	76.01 (0.13)
14 months	66.19 (0.65)	72.45 (0.43)	75.69 (0.15)	63.75 (0.06)
15 months	67.71	73.45 (0.25)	68.63 (0.27)	73.87 (0.03)

Table 8: Amylose content of flour from four cassava varieties at different ages.

Amylose	*Afisiafi*	*Tek bankye*	*Abasafitaa*	*Gblemoduade*
9 months	16.48 (0.00)	21.71 (0.00)	36.00 (0.00)	34.57 (0.00)
10 months	22.19 (0.00)	36.00 (0.00)	30.29 (0.00)	34.57 (0.00)
11 months	30.29 (0.00)	26.48 (0.00)	32.19 (0.00)	28.86 (0.00)
12 months	34.57 (0.00)	31.71 (0.00)	23.14 (0.00)	23.62 (0.00)
13 months	26.00 (0.00)	23.62 (0.00)	27.43 (0.00)	23.14 (0.00)
14 months	20.29 (0.00)	20.29 (0.00)	20.76 (0.00)	34.57 (0.00)
15 months	23.49	22.67 (0.00)	23.14 (0.00)	34.57 (0.00)

existed between ages and varieties. There was a positive correlation between swelling power and peak temperature for *Abasafitaa* (r^2=0.509) and *Gblemoduade* (r^2=0.883). Barimah (1999) reported a strong correlation between swelling power and peak viscosity for starch from dried cassava chips, while Balagopalan *et al.* (1988) also reported that starches capable of high swelling are less resistant to break down. Even though there was a relationship between swelling power and peak viscosity for *Afisiafi* and *Tek bankye*, correlation between them was weak (r^2=0.378 & 0.135 respectively). Similarly, a relationship with weak correlation existed between swelling power and paste breakdown for *Afisiafi*, *Tek bankye* and *Abasafitaa*. There was a very weak correlation (r^2=0.134) between starch yield and swelling power for *Gblemoduade*.

Solubility . The solubility of *Afisiafi* ranged between 8.1-17.4% with the lowest value at 12 months and the highest at 14 months, while for *Tek bankye* it was between 7.8-11.9%, with the lower and upper limits respectively at 11 and 14 months. *Abasafitaa* also had solubility values ranging between 13.1-18.7%, with the lowest value at 11 months and the highest at 9 months, while *Gblemoduade* had solubility between 11.7-18.8% with 11 and 12 months having the lowest and highest values respectively. With the exception of *Afisiafi*, all other varieties had lowest values at 11 months after planting. *Tek bankye* had the lowest solubility values, followed by *Afisiafi* and then *Gblemoduade*, while *Abasafitaa* had the highest solubility values. Barimah (1999), working on four cassava varieties: *Afisiafi*, *Isu-white*, *Abasafitaa* and *Gblemoduade*, reported solubility values between 9.6-14.7% for starch obtained from fresh tubers, with the lower and upper limits representing *Gblemoduade* and *Abasafitaa* respectively. For starch from dried cassava chips, Barimah (1999) reported values between 11.4-19.7%, representing *Gblemoduade* and *Abasafitaa* respectively. The values obtained in this study (Table 10) compare well with those reported by Barimah (1999).

There was no significant difference ($p>0.05$) in solubility between ages, but significant difference ($p<0.05$) existed among varieties. There was weak correlation (r^2=0.447 and 0.285, respectively) between moisture content and solubility for *Tek bankye* and *Gblemoduade*. *Gblemoduade* showed correlation (r^2=0.502) between starch yield and solubility while *Afisiafi* showed correlation (r^2=0.518) between amylose content and solubility. Swelling power also correlated (r^2=0.658, 0.428 and 0.568, respectively) with solubility for *Tek bankye*, *Abasafitaa* and *Gblemoduade*. It is expected that high solubility flour gelatinizes at low temperature since water readily enters its starch granules resulting in easy solubilization and subsequent gelatinization upon heating. However, *Afisiafi* showed a weak correlation (r^2=0.305) between solubility and gel temperature while that for *Tek bankye* was strong (r^2=0.828). Peak temperature also correlated with solubility for both *Afisiafi* (r^2=0.664) and *Tek bankye* (r^2=0.787). Even though solubility showed a relationship with

Table 9: Swelling power of flour from four cassava varieties at different ages.

Swelling Power	*Afisiafi*	*Tek bankye*	*Abasafitaa*	*Gblemoduade*
9 months	28.95 (0.15)	31.07 (0.35)	24.26 (0.54)	30.40 (0.25)
10 months	27.80 (0.35)	25.21 (0.07)	21.92 (0.28)	31.65 (0.07)
11 months	20.30 (0.31)	21.98 (0.21)	20.71 (0.14)	18.74 (0.23)
12 months	28.41 (0.09)	18.13 (0.13)	26.10 (0.14)	30.08 (0.27)
13 months	17.15 (0.17)	26.61(0.29)	28.23 (0.19)	31.97 (0.21)
14 months	27.24 (0.39)	29.85 (0.38)	21.41 (0.40)	28.03 (0.38)
15 months	27.40	30.39 (0.34)	28.45 (0.16)	26.16 (0.24)

both paste breakdown and retrogradation, correlation was weak. There is therefore a clear indication that starch loss during processing affected the relationship between solubility and other functional properties such as pasting characteristics.

Pasting characteristics. Pasting temperature of *Afisiafi* ranged between 67.7-70°C with the lower limit at 15 months and the upper limit at 13 months; *Tek bankye* had values between 68.7-73.2°C representing 10 months and 11 months respectively. *Abasafitaa* had values between 69-71°C, representing 15 and 11 months respectively, while *Gblemoduade* also had pasting temperatures in the range of 68-71°C, representing 15 and 11 months respectively. There was no significant difference in pasting temperature between ages but significant difference ($p<0.05$) existed among varieties (Table 11).

Gelatinization temperature was recorded as the temperature at which paste viscosity rose from 0 to 20BU. This temperature was attained after pasting temperature had been recorded. Gelatinization temperature of *Afisiafi* ranged between 69.7-75.3°C with the lower and upper limits respectively at 9 and 13 months, while *Tek bankye* had values between 70.15°C (14 months) and 78.6°C (11 months). *Abasafitaa* also had its gelatinization temperature in the range of 70.8°C (13 months) and 76.0°C (11 months), while *Gblemoduade* had values between 69.3°C and 75.3°C, with the lowest and highest values at 13 and 11 months after planting respectively. Both *Abasafitaa* and *Gblemoduade* had lowest and highest values respectively at 13 and 11 months after planting. There was no significant difference ($p>0.05$) between ages, but significant

Table 10: Solubility of flour from four cassava varieties at different ages.

Solubility	*Afisiafi*	*Tek bankye*	*Abasafitaa*	*Gblemoduade*
9 months	12.73 (0.03)	10.37 (0.01)	18.65 (0.01)	16.87 (0.01)
10 months	12.85 (0.01)	10.37 (0.01)	15.27 (0.03)	16.33 (0.00)
11 months	10.70 (0.01)	7.81 (0.00)	13.11 (0.01)	11.72 (0.01)
12 months	8.02 (0.01)	8.84 (0.02)	14.87 (0.01)	18.80 (0.04)
13 months	8.58 (0.00)	10.04 (0.00)	17.06 (0.01)	16.22 (0.00)
14 months	17.42 (0.01)	11.89 (0.01)	13.44 (0.01)	12.38 (0.01)
15 months	12.61	11.86 (0.00)	16.91 (0.01)	14.57 (0.01)

LSD for variety =2.18.

Table 11: Pasting temperature of flour from four cassava varieties at different ages.

PastingTemperature	*Afisiafi*	*Tek bankye*	*Abasafitaa*	*Gblemoduade*
9 months	67.85 (1.20)	72.80 (2.69)	70.45 (0.49)	68.25 (0.35)
10 months	69.25 (0.78)	68.70 (0.28)	70.15 (1.63)	69.80 (0.14)
11 months	68.05 (0.07)	73.20 (1.84)	71.00 (0.71)	71.00 (0.00)
12 months	69.55 (0.92)	71.05 (0.64)	69.80 (0.42)	70.50 (0.42)
13 months	69.95 (0.92)	69.80 (1.41)	69.60 (0.57)	68.55 (0.49)
14 months	69.10 (0.00)	69.10 (0.14)	69.00 (0.14)	68.80 (0.28)
15 months	67.69	69.50 (0.00)	68.95 (1.34)	68.00 (0.00)

LSD for variety =1.03.

difference ($p<0.05$) existed among varieties for gelatinization temperature (Table 12).

Peak temperature. Peak temperature for *Afisiafi* was between 82.2-89.2°C with 14 and 13 months having the lowest and highest values respectively, while *Tek bankye* had values between 82.6-91.1°C with the lower and upper limits at 14 and 11 months after planting respectively. *Abasafitaa* had peak temperatures ranging from 80.7-90.7°C with 13 and 11 months having the lowest and highest values respectively, while *Gblemoduade* also had values ranging from 77.6-92.1°C with the lowest value at 13 months and the highest at 11 months old.

Both *Afisiafi* and *Tek bankye* had their lowest peak temperatures at 14 months after planting, while *Abasafitaa* and *Gblemoduade* had their lowest and highest values at 13 and 11 months after planting respectively. Apart from *Afisiafi* whose upper limit for peak temperature was at 13 months, all the other varieties had their upper limits at 11 months after planting. There was no significant difference ($p>0.05$) in peak temperature between ages but significant difference ($p<0.05$) existed among varieties (Table 13). Barimah (1999) reported peak temperatures between 73.7-74.8°C for flour from the above-mentioned cassava varieties. However, values reported by Barimah (1999) are lower than that obtained in this study. The reason may be due to a difference in processing method; Barimah's flour was produced from dry chips while that used in this study were from dried, grated mash.

Aryee (2001) reported peak temperatures of cassava flour from thirty-one varieties to range between 73.1°C to 84.5°C; the age at harvest, however, was not reported. Other factors such as size and shape of starch

Table 12: Gelatinisaton temperature of flour from four cassava varieties at different ages.

GelatinizationTemperature	*Afisiafi*	*Tek bankye*	*Abasafitaa*	*Gblemoduade*
9 months	69.70 (1.13)	75.60 (0.99)	73.00 (0.85)	70.20 (0.00)
10 months	71.25 (0.64)	72.15 (0.49)	74.00 (0.71)	70.65 (0.21)
11 months	70.25 (0.07)	78.60 (0.57)	76.00 (0.71)	75.30 (0.14)
12 months	72.15 (0.07)	78.20 (0.28)	71.50 (0.28)	72.55 (0.92)
13 months	75.25 (1.34)	73.55 (1.06)	70.80 (0.28)	69.35 (0.07)
14 months	70.80 (0.42)	70.15 (0.07)	71.10 (0.28)	69.45 (0.07)
15 months	69.75	72.15 (0.07)	71.40 (0.99)	69.70 (0.00)

LSD for variety =1.88.

Table 13: Peak temperature of flour from four cassava varieties at different ages.

Peak Temperature	*Afisiafi*	*Tek bankye*	*Abasafitaa*	*Gblemoduade*
9 months	83.55 (0.35)	89.05 (0.49)	88.30 (2.69)	80.35 (0.07)
10 months	85.50 (0.85)	86.10 (0.00)	88.55 (0.07)	78.80 (0.00)
11 months	84.10 (0.42)	91.05 (0.35)	90.75 (1.91)	92.10 (0.42)
12 months	86.55 (0.92)	90.60 (1.70)	84.65 (1.20)	80.25 (1.91)
13 months	89.20 (0.14)	87.05 (0.78)	80.70 (1.56)	77.60 (0.71)
14 months	82.20 (0.00)	82.60 (0.00)	83.80 (0.85)	78.40 (0.57)
15 months	83.98	85.85 (0.21)	84.00 (1.41)	81.65 (0.21)

LSD for variety =2.83.

granules may also affect the pasting, gelatinization and peak temperatures of flour.

Peak viscosity of *Afisiafi* was between 210-305BU with the lowest and highest values at 14 and 10 months respectively, while *Tek bankye* had values between 220-300BU with the lower and upper limits at 10 and 9 months respectively. *Abasafitaa* had peak viscosities between 145-225BU with the lowest and highest values at 10 and 12 months respectively, while *Gblemoduade* had values between 160-220BU, with the lowest value at 12 months and highest at 13, 14 and 15 months after planting. Peak viscosity was significantly affected ($p<0.05$) by variety but not age (Table 14).

Hot paste breakdown for *Afisiafi* ranged between 60-85.3BU, with the lowest and highest values respectively at 11 and 15 months, while that of *Tek bankye* was between 60-105BU, with 10 months and 9 months having the lowest and highest values respectively. *Abasafitaa* had values between 10-80BU, with the lowest at 9 months and the highest at 13 months while that of *Gblemoduade* was between 70BU (12 months) and 115BU (15 months). *Abasafitaa* had the lowest paste breakdown while *Gblemoduade* had the highest. Paste breakdown was significantly affected ($p<0.05$) by variety but not by age (Table 15). There was a relationship with strong correlation ($r^2=0.717$ & 0.807 respectively) between paste breakdown and both amylose content and crude fibre for *Tek bankye*. A similar relationship with moderate correlation ($r^2=0.594$ & 0.593 respectively) existed between paste breakdown and both amylose content and crude fibre for *Abasafitaa*. As stated in the previous section, both amylose and fibre molecules (cellulose and hemicelluloses) interact with water molecules through hydrogen bonding, in an aqueous suspension of starch or flour when heated. This results in gelatinization and

Table 14: Peak viscosity of flour from four cassava varieties at different ages.

PeakViscosity	*Afisiafi*	*Tek bankye*	*Abasafitaa*	*Gblemoduade*
9 months	280 (14.14)	300 (0.00)	155 (7.07)	190 (0.00)
10 months	305 (7.07)	220 (14.14)	145 (7.07)	210 (0.00)
11 months	245 (7.07)	290 (0.00)	180 (14.14)	175 (7.07)
12 months	290 (0.00)	235 (7.07)	225 (7.07)	160 (14.14)
13 months	215 (7.07)	280 (14.14)	180 (14.14)	220 (0.00)
14 months	210 (0.00)	270 (0.00)	210 (0.00)	220 (0.00)
15 months	261	250 (0.00)	185 (21.21)	220 (0.00)

LSD for variety =31.86.

Table 15: Hot paste breakdown of flour from four cassava varieties at different ages.

Breakdown	*Afisiafi*	*Tek bankye*	*Abasafitaa*	*Gblemoduade*
9 months	75	105	10	80
10 months	85	60	40	95
11 months	60	90	50	85
12 months	70	80	75	70
13 months	70	80	80	105
14 months	80	100	60	110
15 months	85	85	65	115

LSD for variety =15.63.

subsequent increase in the viscosity of the paste. When the hot paste is agitated for a long period at high temperature, as is caused by the rotation of the Brabender amylograph bowl, the weak hydrogen bonds between some of the amylose molecules and water molecules break and the amylose molecules coil up forming intramolecular and intermolecular hydrogen bonds within and between its molecules. This causes a sharp decrease in viscosity and a consequent breakdown of the hot paste. The hydrogen bonds between cellulose or hemicelluloses and water molecules may also break in a similar manner causing hot paste breakdown.

Retrogradation profile of *Afisiafi* started at 9 months with a value of 40BU and rose to 50BU at 10 months from where it fell to 0 (zero) at 11 months. It then rose to 30BU at 12 months but fell again to 5BU at 13 months and remained there till 14 months, from where it rose to 12.2BU at 15 months after planting. *Tek bankye*, on the other hand, started from 45BU at 9 months and fell to 10BU at 10 months, but rose to 20BU at 11 months. It fell again to 15BU at 12 months, rose to 20BU at 13 months and fell to 5BU at 14 and 15 months after planting. *Abasafitaa* and *Gblemoduade* had their retrogradation values between -5BU and 10BU. *Afisiafi* and *Tek bankye* therefore had high values for retrogradation while *Abasafitaa* and *Gblemoduade* had low values. Retrogradation was significantly affected ($p<0.05$) by variety but not by age (Table 16).

Conclusion

Age had significant effect on yield, moisture, ash and crude protein, while variety significantly affected solubility, flour yield and all the pasting characteristics. To obtain optimum flour yield from *Afisiafi* and *Tek bankye*, harvesting should be done at 13 months after planting while for *Abasafitaa* and *Gblemoduade*, harvesting should be at 12 months after planting.

References

AOAC. 1990. Official Methods of Analysis 15th ed. Association of Official Analytical Chemists, Arlington, Virginia.

Aryee, F.N.A. 2001. Screening of Cassava Varieties- Physicochemical Properties and Cyanogenic Potential. M.Sc. Thesis, Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana.

Balagopalan, C., Padmaja, G., Nanda, S.K. and Moorthy, S.N. 1988. Cassava in Food, Feed and Industry. CRC Press Inc. Boca Raton, Florida. USA. pp. 113-127.

Barimah, J. 1999. Studies on the Characteristics of Cassava Starch. M.Sc. Thesis, Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana.

Githunguri, C.M., Chweya, J.A., Ekanayake, I.J. and Dixon, A.G.O. 1998. Climatic and growth stage influence on tuberous root

Table 16: Retrogradation or setback or flour from four cassava varieties at different ages..

Retrogradation	*Afisiafi*	*Tek bankye*	*Abasafitaa*	*Gblemoduade*
9 months	40	45	0	5
10 months	50	10	5	0
11 months	0	20	5	0
12 months	30	15	5	10
13 months	5	20	0	-5
14 months	5	5	0	0
15 months	12	5	-5	-5

LSD for variety =10.20.

yield and cyanogenic potential, leaf water potential and leaf area duration of divergent cassava (*Manihot esculenta* Crantz) clones. In: Root Crops in the 21st Century. Proceedings of the 7th Triennial Symposium of the ISTRC-AB, Cotonou, Benin. 11-17 October 1998. pp. 272-279.

Moorthy, S.N., Blanshard, J.M.V. and Rickard, J. 1992. Starch Properties in relation to Cooking Quality of Cassava. In: Proceedings of the first International Scientific Meeting of the Cassava Biotechnology Network. Roca, W.M. and Thro, A.M. (eds.). Cartagena, Colombia, 25-28 August 1992. Working document No. 123, Centro Internacional de Agricultura Tropical (CIAT), Cali, Colombia. pp. 265-269.

Moorthy, S.N. 1994. Tuber Crop Starches. Central Tuber Crops Research Institute. Kerala, India. pp.31.

Rickard, J.E., Asaoka, M. and Blanshard, J.M.V. 1991. The Physicochemical Properties of Cassava Starch. J. Trop. Sci. 31: 189-207.

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