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Effect of processing procedures on the colorimetry and viscoelastic properties of cassava starch, flour and cassava-plantain fufu flour

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Abstract: Cassava starch, cassava flour and cassava-plantain fufu flour colour were evaluated in terms of L, a, and b values and the total colour difference. The cassava-plantain fufu flours were formulated using two particle sizes with cassava starch and plantain flour and others with cassava starch, cassava flour and plantain flour. The local cassava variety, (Bosom nsia) starch gave the highest L-value, while 065 cassava starches yielded the lowest L value. The high yielding variety, (Yebeshie) flour recorded the highest L-value of 95.80. The 065 cassava starch recorded the largest colour differences (3.96) while Bosom nsia starch gave the least value (1.10). Bosom nsia starch was whiter. The least colour difference was obtained by the 061 flour and 094 flour recorded the highest value. The variables of colour for the cassava-plantain fufu flour increased with the increase in percentage of starch added. The differences in colour of the cassava starch and flour may be due to the different processing procedures. The viscoelastic properties for both starch and flour from Yebeshie cassava stood out greatly compared to the local variety (bosom nsia) and the experimental accessions. Yebeshie starch recorded a peak viscosity of 1057 BU and a viscosity at 50°C of 522 BU. The peak viscosity, viscosity at 95º for the <180 and 250 micron cassava-plantain fufu flour increased as the starch percentage increased for all the combinations of starch, plantain flour and cassava flour. The viscosity at 50˚C values increased as the starch added increased for <180 and 250-180 micron cassava- plantain fufu flour formulated using starch, plantain flour and Yebeshie cassava flours. Starches from the high percentage starch cassava- plantain fufu flour had larger granules which swelled at lower temperature. The fufu flours which were formulated with low percentage starch might have had smaller granules. The cassava- plantain fufu flour formulated with the BT7D54.1 Yebeshie cassava flour and 40% starch recorded the highest cold paste value of 245 ± 28BU. This increase may be attributed to the processing parameter used for the Yebeshie cassava flours compared to the drying temperature of 60˚C for the BT10D60 and BT15D60. The setback values for the <180 micron cassava-plantain fufu flour were higher than those of the 250-180 micron fufu.

Keywords: Processing procedure, cassava flour, cassava starch, cassava-plantain fufu, particle size

Introduction

Cassava (*Manihot esculenta* Crantz*)* is an important tropical crop having high amount of starch (25-35%) and has got extensive application in feed, food and industrial sector (Edison, 2005). The starch content in the tubers varies according to varieties and contains the highest amount of starch (Nanda *et al*., 2005). Cassava starch when processed properly is very white in colour. When the tubers are crushed without removing the rind, the colour of the resultant starch is very dull. The reduction in whiteness affects the quality as well the price (Balagopalan *et al*., 1998). Cassava flour contains fiber, sugars, smaller quantities of lipids and other components. It exhibits properties different from those of cassava starch, which results in a more cohesive paste after cooking (Enwere, 1998). There are many processes used for producing cassava flour. They may involve all or some of the following unit operations- peeling of the roots, washing, slicing or grating, drying, milling, sieving, and storage. The flours produced have different physico chemical properties and are used for various purposes (Enwere, 1998).

Fufu flour has been developed as a convenient form of the traditional pounded fufu as it requires a much shorter time for the preparation. It is safe and has long shelf-life (Kordylas, 1991). Varying technologies exist for making fufu flour. Some are

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based on efficient dehydration of pre-cooked cassava *(*Manihot esculenta crantz) and plantain (Musa AAB). Fufu flour processing involves washing and peeling of raw materials, chipping, milling, sieving, drying and packaging (Olumakinde, 2000). Color is one of the most important attributes of food, both for its aesthetic value and for quality judgement (Vamos-Vigyazo, 1981). It affects our overall judgment on the worth of food from both an aesthetic and safety point of view (Clydesdale, 1984). It plays an important role in taste thresholds, flavor identification, food preferences, pleasantness, acceptability and ultimately food choice. However its role is elusive and difficult to quantify (Clydesdale, 1984). Consumers frequently look at a product and make a decision largely based on overall appearance including color (Vamos-Vigyazo, 1981). Manufacturing processes such as extrusion and baking can affect final product color. Ingredient color can also affect the color of products. Thus to obtain and maintain the desired color, it is important to monitor and control ingredient color as well as monitoring the product through the manufacturing process (Vamos-Vigyazo, 1981). Color measurement systems are used to measure a broad range of food products. Degradation during processing and storage can have a major impact on the color of finished products. Maillard reaction products, ascorbic acid, glucose, and fructose with their degradation products may accelerate the color loss catalyzed by high temperature and oxygen (von Elbe and Schwartz 1996).

Since the color of the finished processed food is a critical quality parameter for consumer's acceptance, its measurement has gained much attention from food scientists and industry. The major objective of this study was to compare the effect of processing procedures on the colorimetry and visco elastic properties of cassava starch, cassava flour and formulated fufu flour samples.

Materials and Methods

Raw materials

Five Ghanaian cassava varieties (*Bosom nsia*, Yebeshie, 061, 065 and 094) and plantain (var. *False Horn*), obtained from an experimental farm of the University of Ghana, were used for the study.

Preparation of cassava flour, starch and plantain flour

Cassava flour

The harvested cassava tubers were weighed, washed and peeled. The peeled tubers were weighed again and cut into 2 to 5 mm thick pieces using a food slicer (Fold-up electric Food Slicer *mod.CFE 1954, Philips Atlantis*.). After weighing the slices were dried in a mechanical dryer (Apex, Royce Ross Ltd) at 54.0ºC for 10 h, to attain moisture content of about 8-10%. The dried slices were weighed and milled using a disc attrition mill (Premier No. 2A, India) and after cooling stored in air tight containers ready for analysis (Badrie and Mellowes, 1992). This process was carried out for all five varieties of cassava.

Cassava flour processing for Fufu flour

Based on an optimisation studies, the cassava flour samples for the formulation of the *fufu* flour were prepared by blanching cassava slices for 7minutes and drying at 54.1ºC (BT7D54), 10 mins and drying at 60ºC ($BT_{10}D_{60}$) and 15 mins and drying at 60ºC ($BT_{15}D_{60}$) respectively in a mechanical dryer (Apex, Royce Ross Ltd) to attain moisture content of about 8-10%. The dried slices were immediately milled into flour using two particle size ranges, 250 -180 micron and < 180 micron, with the help of laboratory mill (Premier No. 2A, India) and electrical sieve shaker (Meinzer 11 sieve shaker, 0610-03, UK).

Cassava starch

The cassava starch was prepared by the sedimentation method (Trim *et al*. 1993). The harvested roots were first thoroughly washed, peeled and washed again with plentiful potable water. The peeled roots were then cut into 0.5 to 1 cm chunks. 100 gm samples of the chunks were placed together with 200 g of potable water into a Waring blender (Phillips 80109 USA) and blended into slurry. The slurry was immediately filtered through a double-layered cheese cloth. The solids retained by the cloth were washed with more water and filtered through the cheese cloth. The washing process was repeated five times until there was little or no starch in the filtrate. Starch in the filtrate was allowed to sediment overnight and the liquid decanted and discarded. The starch was dried in a mechanical dryer (Apex 27585 Royce Ross Ltd, London) at 50ºC for 4 h and weighed. The starch was pulverised with a disc attrition mill (Premier No 2A India). The extraction was done in three batches for each of the five varieties of cassava.

Plantain flour

The plantain flour was obtained by slicing the peeled plantain fingers into 3.5 mm slices, blanching time for 10 min and drying temperature of 70˚C in a mechanical dryer (Apex, Royce Ross Ltd) to attain moisture content of about 8-10% (based on an optimisation studies (Badrie and Mellowes, 1992).

Preparation of cassava –plantain fufu flour

The cassava-plantain fufu flours were formulated using Yebeshie cassava starch at (20%, 30%, and 40%) and plantain flour, cassava flour mixtures ($BT_7D_{54.1,}$ $BT_{10}D_{60}$, $BT_{15}D_{60}$,) and others were formulated with Yebeshie cassava starch at (20%, 30%, and 40%) and plantain flour alone. The formulated samples were passed through <180microns and 250-180 micron sieves to obtain <180microns and 250-180micron fufu flour samples.

Analysis

Colour determination

The colour measurements of the cassava starch, cassava flour and cassava-plantain fufu flour samples were determined with the Minolta Chroma Meter (Model CR 310, Minolta Camera Co. Ltd. Japan), using the L* a* b* colour system in duplicates. The Chroma meter was calibrated with a standard white background. (L* = 97.63 a*=-0.48 b* = +2.12). Colour measurement of plantain fufu flour produced by CSIR- Food Research Institute, Ghana served as the control. This was because this fufu flour is preferred by consumers. **ΔE** value which defines the size of the total colour difference, but does not give information about how the colours differ was determined.

ΔE is defined by the following equation:

$$\Delta \mathbf{E} = \sqrt{(\Delta \mathbf{L})^2 + (\Delta \mathbf{a})^2 + (\Delta \mathbf{b})^2}$$

(Morrison and Laignelet 1983) (12).

All colours that can be perceived visually can be measured in any L,a,b scale.These scales can also measure the colour difference between a sample and a standard and is frequently stated as

ΔL = Color difference is calculated as the sample L value minus standard.
Δa = Color difference is calculated as the sample a value minus standard.
Δb = Color difference is calculated as the sample b value minus standard.

The standard is (L* = 97.63 a*=-0.48 b* = +2.12).

Viscoelastic analysis

A smooth paste was made of the prepared flour (40g) in 420 ml distilled water (8.8 % slurry) for viscoelastic analysis using Brabender Viscoamylograph (Viskograph-E, Brabender Instrument Inc. Duisburg, Germany) equipped with a 1000 cmg sensitivity cartridge. The smooth paste was heated at a rate of 1.5 °C min^{-1} to 95°C and maintained for 15 min. It was then cooled at 1.5 °C min^{-1} to 50°C and maintained for 15 min. Viscosity profile indices were recorded for pasting temperature, peak temperature, peak viscosity, viscosity at 95°C, viscosity after 15 min hold at 95°C (95°C Hold), viscosity at 50°C, viscosity after 15 min hold at 50 °C (50 °C-Hold), breakdown and setback as described by Zobel (1984).

Data analysis

Analysis of variance (ANOVA) was used to determine differences in the L, a and b values and the least significant difference (LSD) test at $P \leq 0.05$ was run and mean comparisons were performed using SPSS 10.0 (SPSS Ltd, Chicago, IL, USA). Differences between means were tested for significance by using GLM (general linear model) procedure with Duncan test, using a level of significant of $P < 0.05$.

Results and Discussion

Colour determinations of cassava flour and cassava starch are shown in Table 2. The Bosom nsia starch recorded the highest L-value (lightness values) of 97.92 but cassava starch from cassava variety *065* gave the lowest L value of 93.93. The starch from the *065* cassava gave the darkest colour. The cassava starches from *094* cassava recorded higher b value (deeper yellow) of +1.30 and a lower b value of +0.90 was recorded by *065* cassavas. These could be attributed to the age of the *061* cassava (24months) which made it very fibrous and resulted in the conversion of starch granules to sugars. The Yebeshie cassava flour recorded the highest L-value of 95.80 and Bosom nsia cassava flour gave the lowest L- value of 93.85 (L=100-white). This implied that the Yebeshie cassava flour was whiter than the rest of the samples. The cassava flour from cassava variety *094* gave the highest b value (yellowish) and that from *061* cassava recorded the lowest b- value. The *094* cassava flour was deeper yellow than the other sample. Cassava flour obtained from *061* cassava was less yellow.

The larger the **E** value, the larger the colour difference (Morrison and Laignelet 1983). The starch extracted from the *094* cassava gave the largest colour differences. However the Bosom nsia starch recorded the least colour difference. This showed that the sample was very white. The differences in colour could be attributed to the variety, age and also on different processing procedures for the starch and

Table 1. Variety, age and sources of raw materials

Sample	Source	Age at harvest (months)	Type
Cassava 061	Botany Dept. Univ. of Ghana, Legon	24	Experimental accession
094	Botany Dept. Univ. of Ghana, Legon	24	Experimental accession
065	Botany Dept. Univ. of Ghana, Legon	24	Experimental accession
Yebeshie	Ministry of Food and Agriculture, Pokuase	12	High yielding
Bosom nsia	Ministry of Food and Agriculture, Pokuase	12	Local

Table 2. Colorimetric measurement on cassava flour and cassava starch

Starch	L	a	b	ΔE
Yebeshie starch	97.85± 0.51	+0.16± 0.01	+0.78±0.18	1.50
Bosom nsia starch	97.92± 0.08	+0.12± 0.02	+1.24±0.15	1.10
061 cassava starch	97.45± 0.14	+0.23± 0.05	+0.94±0.19	1.39
094 cassava starch	97.28± 0.14	+0.19± 0.02	+1.30±0.10	1.12
065 cassava starch	93.93± 5.48	+0.22± 0.01	+0.90±0.31	3.96
Flour				
Yebeshie cassava flour	95.80± 0.15	-0.42± 0.04	+6.07± 0.40	4.35
Bosom nsia cassava flour	93.85± 0.21	-0.59±0.03	+8.47± 0.09	7.39
061 cassava flour	95.71± 0.01	-0.32±0.02	+5.88±0.12	4.22
094 cassava flour	93.88± 0.40	-0.97±0.05	+10.22±0.12	8.94
065 cassava flour	94.77± 0.61	-0.62± 0.05	+7.08± 0.24	5.72

flour.

The highest colour difference was recorded by the *065* cassava starch. The colour of the *065* cassava flour was far from white and this could be attributed to the old age of 24month of the cassava at the time of harvesting and processing.

The Yebeshie cassava flour recorded the highest L* value and the least L* value was obtained by bosom nsia cassava flour. The least colour difference was obtained by the *061* cassava flour and the highest colour difference was recorded by the *094* cassava flour. The *061* cassava flour was closer to white than the other samples. The colour of the *094* cassava flour was far from white and this could be attributed to the age of 24month old of the cassava at the time of processing.

Effect of different particle sizes and starch Content on colour of cassava-plantain fufu flour for the colour determination of <180 and 250-180micron cassava-plantain fufu flour are shown in Tables 3. There were significant differences at ($p \leq 0.05$) in the L values, a values and b-values for both the <180 and 250-180 microns cassava-plantain fufu flours. The 250-180 micron fufu flour formulated with 40% starch, plantain flour and $BT_{10}D_{60}$ cassava flour recorded higher L* values. The higher a* value of -0.81 was recorded by the 250-180 micron fufu flour formulated with 20% starch with plantain flour and $BT_7D_{54.1}$ cassava flour. The <180micron cassava plantain *fufu* flour formulated with 20% starch with $BT_{15}D_{60}$ cassava flour and plantain flour recorded the highest b* value (Table 3). The L-value, a -value and b-value increased as the percentage of starch added increased. L values increased as the percentage of starch added was increased for the Yebeshie cassava starch and plantain flour *f*ufu flour. The 250-180 microns cassava plantain fufu flour formulated using 30% starch and plantain flour, recorded the largest colour difference. Figure 1 compares the colour difference of the <180 and 250-180microns fufu flour formulated with 30 % starch. In both particle sizes, the fufu flour formulated using plantain flour and starch recorded the highest colour difference. The colour difference observed for the samples were more than that for the control. This implied that the control recorded the least colour difference and was whiter. The least colour difference was recorded by 250-180 microns cassava plantain fufu flour formulated with 40% starch; plantain flour and $BT_{10}D_{60}$ cassava flour (Table 3). This showed that the sample was close to white.

Considering the <180 particle size fufu flours, the 40% starch, plantain flour with $PF+BT_{10}D_{60}$ and $PF+BT_{15}D_{60}$ cassava flour formulations recorded the highest L* value. The sample was very white. The least L* value of 84.24 was recorded by the 20% starch with plantain flour formulation. For the <180microns particle size, the changes in $\Delta \mathbf{E}$ were observed to be greater for the fufu flour with the 20% starch and plantain flour combination (Table 3).

For the 250-180micron fufu flour, the formulation using 40% starch with plantain flour and $BT_{10}D_{60}$ cassava flour recorded the highest L* value. The greatest change in $\Delta \mathbf{E}$ was recorded by the 30% starch with plantain flour formulation of the fufu flour (figure 1). That sample recorded a larger colour difference from the standard. The control recorded the second highest L* value of 90.11 and the second least colour difference value of 10.85. This proved the earlier observation that the control was very white.

Viscoelastic Analysis of cassava flour and starch

The flour from the high yielding and experimental cassava varieties Yebeshie and *061* recorded the highest peak viscosity (Table 4). This showed that the Yebeshie and *061* Cassava had a greater ability to form a paste because of the high swelling of the starch granules in their flours. There was significant difference ($p \leq 0.05$) in the peak viscosities of the flours from the rest of the varieties. The flour from experimental cassava variety (061*)* recorded 218 ± 15.04 BU for viscosity at 95ºC. This meant the granules of the *061*cassava absorbed water and became very swollen and fragile at the viscosity of 95ºC. Highly significant differences existed ($p \leq 0.05$) in the viscosity at 95ºC of the flours.

The flour from the *061* cassava recorded the highest viscosity at 50ºC value of 244 ± 18.72 BU and flour from the experimental cassava variety (*094*) recorded the lowest value of 137 ± 2.31 BU (Table 4). The high yielding cassava flour (Yebeshie) gave the second highest viscosity at 50ºC. The implications are that the 061 and Yebeshie cassava flours had starch pastes that were high in amylose and cooled easily to form a gel. Highly significant difference ($p \leq 0.05$) existed at the viscosity at 50ºC for the cassava flours. The viscosities at 50ºC values for the cassava flour were greater than that recorded by Niba *et al*. (2001) which ranged from 15.9 to 232.7BU. This indicated that the cassava flour from the five varieties of cassava in this study would probably have a better ability to form a stable gel. The setback value of the flours ranged from 55.3 ± 1.53 for cassava flour from *094* cassava to 118 ± 5.68 BU for flour from *061* cassava.

High peak viscosity indicates high swelling of the starch granules. The high yielding (Yebeshie) cassava starch recorded the highest viscosity (Table

Table 3. Colorimetric Determination of <180 and 250-180 micron cassava plantain *fufu* flour (PF)

Particle size(micron)	Fufu flour samples	%Starch	L	a	b	ΔE
<180	PF	20%starch	84.24	-1.14	+14.35	18.15
	PF+BT7D54.1		87.61	-1.22	+ 12.16	14.20
	PF+BT10D60		86.97	-1.27	+13.18	15.38
	PF+BT15D60		87.67	-1.82	+16.08	17.20
	PF	30%starch	85.51	-1.12	+13.38	16.56
	PF+BT7D54.1		88.37	-1.19	+11.45	13.16
	PF+BT10D60		87.71	-1.30	+12.67	14.50
	PF+BT15D60		88.35	-1.72	+14.84	15.79
	PF	40%starch	86.77	-1.13	+ 12.60	15.10
	PF+BT7D54.1		89.63	-1.28	+ 10.82	11.85
	PF+BT10D60		89.86	-1.79	+13.87	14.15
	PF+BT15D60		89.86	-1.79	+13.87	14.15
	Control		90.11	-0.90	+ 9.93	10.85
250-180	PF	20%starch	82.92	-0.94	+ 13.23	18.44
	PF+BT7D54.1		85.44	-0.81	+12.49	16.00
	PF+BT10D60		86.00	-1.22	+12.86	15.85
	PF+BT15D60		86.55	-1.25	+14.16	16.38
	PF	30%starch	84.93	-1.36	+15.65	18.58
	PF+BT7D54.1		87.92	-1.09	+12.43	14.18
	PF+BT10D60		87.77	-1.46	+14.34	15.73
	PF+BT15D60		88.31	-1.21	+12.66	14.09
	PF	40%starch	86.80	-1.00	+12.76	15.19
	PF+BT7D54.1		89.09	-1.04	+11.50	12.69
	PF+BT10D60		90.57	-1.07	+10.28	10.81
	PF+BT15D60		89.25	-1.22	+12.13	13.08
	Control		90.11	-0.90	+9.93	10.85

Mean of two determination, PF= Plantain flour

Table 4. Pasting characteristics of starches and flour from 5 Cassava varieties

Sample	Peak viscosity (BU)	Viscosity at 95 ºC (BU)	Viscosity at 50ºC	Setback
Starch				
061	690 ± 38.97	262 ± 3.46	331 ± 60.93	137 ± 35.23
094	741.3 ± 55.89	325 ± 8.14	339 ± 21.28	221 ± 13.45
065	633 ± 263	300 ± 86.31	399 ± 117	189 ± 50.82
Bosom nsia	773 ± 30.57	411 ± 32.92	486 ± 14.01	222 ± 11.15
Yebeshie	1057 ± 56.02	366 ± 4.04	522 ± 19.65	258 ± 12.09
flour				
061	482 ± 4.36	218 ± 15.04	244 ± 18.72	106 ± 4.16
094	299 ± 12	151 ± 4.04	137 ± 2.31	55.3 ± 1..53
065	384 ± 2	169 ± 5.77	164 ± 3.46	76.6 ± 0.58
Bosom nsia	400 ± 17.00	197 ± 10.69	162 ± 6.08	66 ± 4.51
Yebeshie	482 ± 8.39	207 ± 7.51	219 ± 8.50	118 ± 5.68

the required texture desired by consumers.

The peak viscosity, viscosity at 95º for the <180 and 250 micron cassava-plantain *fufu* flour increased as the starch percentage increased for all the formulation of starch, plantain flour and cassava flour considered (Table 5). This was because as the starch percentage is increased, more starch granules are available for swelling and amylose will leach out resulting in thickening of the solution, hence the increased viscosity value (Kim *et al*., 1995). The cassava-plantain *fufu* flour formulated using 30% starch, plantain flour and Yebeshie cassava flour $BT_7D_{54.1}$recorded the highest viscosity at 95ºC of 248.67 ± 5.51(Tables 5). This could be attributed to the processing parameter used for the $BT_7D_{54.1}$ Yebeshie cassava flour, which was 2.60mm thick size of slices of the cassava, 7minutes blanching time and drying temperature of 54.1˚C. At the blanching time of 7minutes and drying temperature of 54.1˚C, some of the starch granules were ungelatinized, making them available for gelatinization during pasting. The least value of 206.67 ± 6.81BU was obtained by the formulation with 30% starch, plantain flour and the Yebeshie cassava flour $BT_{15}D_{60}$ (Table 5). The processing parameter used for $BT_{15}D_{60}$ Yebeshie cassava flour was 3.50mm thick size of slices of the cassava, 15minutes blanching time and 60˚C drying temperature, because of this most of the starch granules underwent gelatinization during blanching and drying.

The 250-180 micron particle size cassava-plantain *fufu* flour formulated using 20% starch and plantain flour recorded the least viscosity at 95ºC while that formulated with 20% starch and plantain flour and $BT_7D_{54.1}$ Yebeshie cassava flour recorded the highest value (Table 5). The differences in peak viscosity and the viscosity at 95ºC values were highly significant at ($p \leq 0.05$).

The viscosity at 50˚C values increased as the starch added increased for <180 and 250-180 micron cassava- plantain fufu flour formulated using starch, plantain flour and Yebeshie cassava flours (Table 5). This could be due to the fact that the starches of the high percentage starch cassava- plantain fufu flour had larger granules which swelled at lower temperature. The fufu flours which had low percentage starch

Table 5. Pasting properties of <180 and 250-180 micron cassava-plantain fufu flour (PF) formulations

Particle size	samples	%Starch	Peak viscosity (BU)	Viscosity at 95 ºC (BU)	Viscosity at 50ºC	Setback
<180	PF	20% starch	205.67± 4.73	196.33 ± 3.21	181.67± 3.51	56 ± 1.73
	PF+BT15D60	20% starch	194 ±3.46	179.7 ±2.03	194±3.61	74.67 ± 2.08
	PF+BT10D60	20% starch	205.7	183.33	185.7	69.33
	PF+BT7D54.1	20% starch	268.33 ±20.25	226.67 ±11.93	260.33 ± 16.20	111.33 ± 8.08
	PF	30% starch	270.67 ±4.04	234.33 ±3.21	210.67 ±5.51	63 ± 3.46
	PF+BT15D60	30% starch	236 ±7.81	206.67 ±6.81	217.67 ±11.06	82.67 ± 5.51
	PF+BT10D60	30% starch	263 ±3.46	214.67 ±4.62	214.33 ± 7.50	79.33 ± 4.04
	PF+BT7D54.1	30% starch	317.67 ±7.02	248.67 ±5.51	272 ± 8.89	111.3 ±4.93
	PF	40% starch	333 ± 6.58	257 ± 2.89	230 ± 3.51	71.33 ±1.53
	PF+BT15D60	40% starch	282.67 ± 4.16	232 ±2.65	241 ± 8.72	91.33 ± 5.13
	PF+BT10D60	40% starch	308 ±10.53	239.67 ±5.03	228.67 ±2.08	81 ±1.73
	PF+BT7D54.1	40% starch	375	276	294	115
250-180	PF	20% starch	142.7± 4.62	142.33 ± 4.04	146.67 ± 2.89	46 ± 0.58
	PF+BT15D60	20% starch	183 ±1.73	171.67 ± 1.15	201.33 ± 1.15	83.33 ± 1.15
	PF+BT10D60	20% starch	166.33± 2.08	161.67 ± 1.53	182.6 ± 2.89	72 ± 2.65
	PF+BT7D54.1	20% starch	222.33 ± 2.89	205 ±1.73	246.33 ± 2.89	106.67 ± 0.58
	PF	30% starch	254.7 ±9.24	238.33 ± 6.35	240.33 ±6.35	79 ± 4.46
	PF+BT15D60	30% starch	234.33 ± 5.13	203 ± 5.19	221.33± 2.08	88.67± 4.93
	PF+BT10D60	30% starch	235.33 ±5.86	207± 3.61	229.7 ± 6.35	92 ± 2.15
	PF+BT7D54.1	30% starch	313.33 ±5.77	246 ± 3.61	268 ± 3.61	110 ± 1
	PF	40% starch	255.7 ± 4.04	222.33 ± 1.15	207 ± 9.24	207 ± 9.24
	PF+BT15D60	40% starch	269.33 ± 1.15	220.33 ±1.15	239.33 ± 6.36	91.33 ± 5.13
	PF+BT10D60	40% starch	308	308	240	90
	PF+BT7D54.1	40% starch	290.33 ± 40.5	229 ± 22.61	245 ±28	100 ± 12.48

Mean of three determination ± standard deviation, ST-Starch, PF-Plantain flour, BT15D60-Yebeshie cassava flour 12, BT10D60-Yebeshie cassava flour 10, BT7D54.1- Yebeshie cassava flour 1

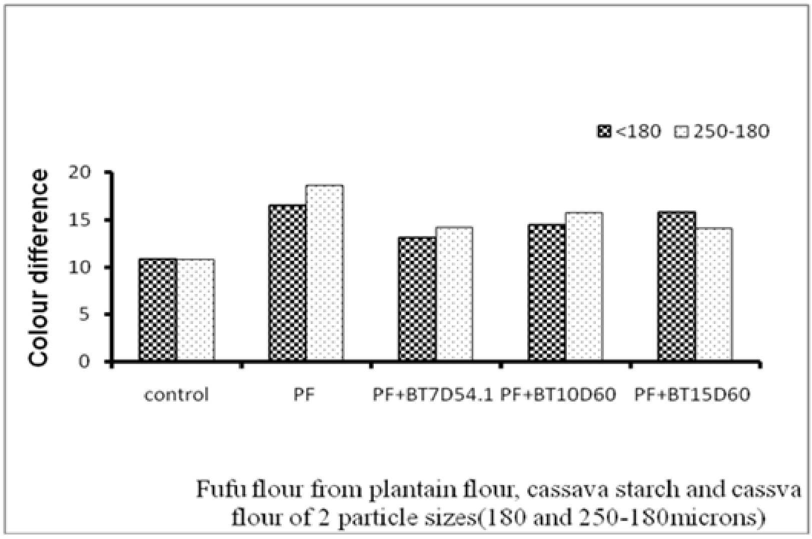

Figure 1. Colour difference of 2 particle size fufu flour formulated from Cassava starch, plantain and cassava flour with 30% starch

4). This showed that the starch from this cassava had a greater ability to form a thicker paste, which gives the idea of the texture and quality of the product from which the starch could be used. The starch from the experimental cassava (065) recorded the least peak viscosity of all the varieties considered. This implied that the starch formed a non-cohesive gel. Differences in peak viscosities therefore imply differences in paste strength and attendant differences in behaviour during processing. The viscosity of all the cassava starches increased at the onset of pasting but decreased after the first holding period, which indicated the strength of the various starch pastes. The difference in viscosity at 95ºC values indicated the strength of the various starch paste and the ease of cooking of starch.

The highest viscosity at 50ºC was recorded by the starch from the high yielding (Yebeshie) cassava and the least was from the starch from the experimental cassava (*061)*. This meant that the starch from the (Yebeshie*)* had a greater setback on cooling. For domestic products like pounded starchy paste (*fufu*), a high setback is desirable (Kim *et al*., 1995). The high values of the viscosity at 50˚C indicated also that the gel did not break. The viscosity at 50ºC values for the cassava starches studied (Table 4) were greater than that recorded by Niba *et al.* (2001) which ranged from 193.3 to 252 BU. This indicated that the cassava starches from the five varieties of cassava used in this study would probably have a better ability to form a stable gel. A high setback value is useful if the starch is to be used in products such as a local pounded starchy paste (*fufu*), which require a high viscosity and paste stability at low temperature. The setback value for cassava starches were 137 ± 35.23 BU for cassava starch from experimental cassava variety (*061)* to 258 ± 12.09 for cassava starch from the high yielding cassava (Yebeshie). This implied that the Yebeshie cassava if processed would have the desired characteristics wanted in fufu flour, because of its desirable pasting qualities which will form crystalline aggregates with a gelled texture when cooked.

The starch from the (Yebeshie) cassava recorded the highest peak viscosity, setback, and viscosity at 50 ˚C of all the 5 cassava starches studied (Table 4). The flour from the high yielding cassava (Yebeshie*)* also recorded the highest peak viscosity compared to all the flour samples assessed. Yebeshie cassava starch and flour pasting properties stood out greatly compared to the local (bosom nsia) variety and the experimental accessions. Cassava starch and flour from the experimental cassava variety (061) recorded the highest peak viscosity, setback and viscosity at 50 ˚C among the experimental accessions. However its 24months age made it impossible for it to be processed for cassava flour, because some of the starch had broken down and the tuber has become fibrous. The cassava flour from cassava variety *061* recorded the highest final viscosity compared to all the other cassava flours. The peak viscosities of the high yielding Yebeshie cassava flour and experimental *061* cassava flour were the same (482BU). On account of the pasting characteristics of the cassava flours and starches, the high yielding cassava (Yebeshie) was selected for the processing of cassava flour for the formulation of fufu flour, since its pasting characteristics stood out among the rest. Yebeshie cassava will therefore be suitable for producing *fufu* flour because when it is reconstituted it would have might have had smaller granules.

Generally, the cassava- plantain *fufu* flour formulated with the $BT_7D_{54.1}$ Yebeshie cassava flour and 40% starch recorded the highest cold paste value of 245 ± 28BU (Table 5). This increase may be attributed to the processing parameter used for the $BT_7D_{54.1}$ Yebeshie cassava flours compared to the drying temperature of 60˚C for the $BT_{10}D_{60}$ and $BT_{15}D_{60}$. This could have made the $BT_7D_{54.1}$ Yebeshie cassava flour to have higher starch granules which were not gelatinised. Hence the increased value of pasting parameters for almost all the cassava- plantain fufu flour formulated from it. Highly significant differences (p≤0.05) occurred in the viscosity at 50˚C values. Setback viscosity which indicates gel stability and potential for retrogradation increased as the percentage of starch increased for the cassava-plantain fufu flour formulated from either plantain flour and starch alone or starch with plantain flour and Yebeshie cassava flour for both the <180 and 250-180micron (Tables 5).

An increase in viscosity indicates the tendency of the starch particle to associate or retrograde to form a gel. The extended linear fraction of the starch (amylose) is believed to be responsible for the high setback since these fractions were freer to orient themselves (Kim *et al*., 1995). A low setback value shows that the starch gives a non cohesive paste. The setback values for the <180 micron cassava-plantain fufu flour were generally higher than those of the 250-180 micron fufu. This could be attributed to the fact that if the particle size is smaller; the surface area of the starch granules are larger, this made the starch granules more exposed to gelatinization. Results showed highly significant differences (p≤0.05) in the setback.

Conclusions

Bosom nsia cassava starch was whiter than the other samples. Yebeshie cassava flour obtained the highest L* value. The least colour difference was obtained by the *061* cassava flour. The highest L* value was obtained from the 250-180micron cassava-plantain fufu flour formulated with cassava flour $BT_{10}D_{60}$. The 250-180 microns cassava plantain fufu flour formulated with 30% starch and plantain flour combination recorded the largest colour difference. The least colour difference was recorded by 250-180 microns cassava plantain fufu flour formulated with 40% starch plantain flour and $BT_{10}D_{60}$ cassava flour. The peak viscosity, viscosity at 95º for the <180 and 250 micron cassava-plantain *fufu* flour increased as the starch percentage increased for all the formulations with starch, plantain flour and cassava flour. The viscosity at 50˚C values increased as the starch added increased for <180 and 250-180 micron cassava- plantain fufu flour formulated using starch, plantain flour and Yebeshie cassava flours. The cassava- plantain *fufu* flour formulated with the $BT_7D_{54.1}$ Yebeshie cassava flour and 40% starch recorded the highest cold paste value of 245 ± 28BU. This increase may be attributed to the processing parameter used for the Yebeshie cassava flours compared to the drying temperature of 60˚C for the $BT_{10}D_{60}$ and $BT_{15}D_{60}$.

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