Physico-functional properties and colour changes of three cultivars of plantain and their products in Ghana

Fidelis Kamaayi

Science Department, Accra College of Education, Accra

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Abstract

Plantain is widely cultivated in Africa and they are consumed after taking them through various methods of cooking. The riped and unriped pulps are used in making many delicacies. As a climacteric fruit, technology should be applied to process them to increase their shelf life and also develop new products which will be accepted by consumers.

The colour of three (3) cultivars of plantain; Apantu, Oniaba and Apem were determined using a hand-held Minolta CR-310 Tristimulus Colorimeter. In the unripe samples, Oniaba recorded the highest value of 'a' (-0.46 ± 0.2) followed by Apem (-1.06 ± 0.00) and then Apantu (-1.52 ± 0.1). The degree of yellowness was highest in Oniaba followed by Apem and Apantu.

In the firm ripe samples, Apem was the lightest/whitest followed by Oniaba and then Apantu. The value of 'a' was highest for Oniaba followed by Apantu and then Apem.

In the boiled samples, the redness was highest in Oniaba, Apantu and Apem.

All the cultivars were processed into two types of flours; fresh dried and milled (FDM) and fresh boiled dried and milled (FBDM). The 'L' values for FDM ranged between 60 and 63 whilst those of FBDM was 51. The 'b' values for the FBDM (24 – 26) were higher than those of FDM (11 – 13).

The colour of reconstituted slurry of FDM and FBDM were determined. The water absorption capacity at 70ºC was higher for Oniaba FDM and Apantu FBDM.

Oniaba had the highest peak viscosity whilst Apem had the lowest. Break down viscosity ranged from 29 to 228 BU for Oniaba and Apantu respectively.

Index Terms: Peak viscosity, Breakdown viscosity, Setback, Visco-amylograph

I. INTRODUCTION

Plantain (Musa *paradisiaca*) is one of the foods consumed worldwide by many people and it serves as a food security crop. In 2010 the annual production of plantain in Ghana was 3,537,735 metric tonnes (SRID, 2010). It is mostly cultivated in the forest zones and some of the indigenous cocoa farmers intercrop it with the cocoa seedlings.

Both the unripe and riped pulp are used in making variety of dishes in African and in Ghana in particular. The riped pulp is sometimes consumed raw by people who live in farming communities. The stem is cut in pieces and is used with charcoal to clean the teeth of children and adults. Users claim that it makes their teeth white.

Plantain as a climacteric food ripen very fast and easily undergo senescence. It cannot be stored in the fresh unripe form for a long period. It is imperative for scientists to process it into a shelf-stable low-moisture flour using less capital-intensive technologies that will reduce their postharvest losses, add value and make the commodities available throughout the year. Technologists have to also use technology to turn plantain into new products.

In fresh foods, such as fruits and vegetables, consumers depend on the color to determine their level of maturity and/or freshness. If the color of a food product does not match consumer expectations, they may perceive its taste and flavor differently (Barrett et al., 2010). Browning is observed in many plants during maturation, handling, storage, and post-harvest processing and affects the nutritional quality and sensory properties of food products due to changes in color and taste (Martinez and Whitaker, 1995), this leads to reduction in consumer acceptability. Food color is a criterion of quality and acceptance for consumers. The main sources of food browning during processing are chemical discoloration caused by copper, iron, manganese, traces of heavy metals, natural pigments (anthocyanins, carotenoids, chlorophylls, etc.), as well as reactions like the Maillard reaction, which corresponds to the condensation of reducing sugars with amino acid groups occurring at high temperatures (Utomo et al., 2008), the caramelization of sugars and the enzymatic oxidation of phenols into brownish compounds (Manzocco et al., 2000).

Consumer acceptability of products include its color, and other sensory attributes.

The aim of this paper is to determine the changes in color of the plantain pulp and products, and the physico-functional properties of plantain flour.

II. MATERIALS AND METHODS

Collection of Plant Materials

Three cultivars of Plantain, namely false horn plantain, intermediate plantain and French plantain as known locally as *Apantu*, *Oniaba* and *Apem* respectively. The samples were collected from the Agricultural Research Center of University of Ghana, Legon at Kade in the Eastern Region of Ghana.

Sample Preparation

The matured samples were prepared as described by Kamaayi et al., (2020).

Laboratory analysis

Colour measurements of the unprocessed samples

The method according to Adeniji *et al.,* (2006) was followed with slight modifications. The colour of plantain pulp and the plantain flour were quantitatively determined with the aid of a hand-held Minolta CR-310 Tristimulus Colorimeter (Minolta Co. Ltd., Osaka, Japan). The plantain samples were washed in a plastic bowl with potable water to remove dirt and peeled manually with the aid of stainless kitchen knife. The pulps were sliced longitudinally and the instrument was used to measure the colour.

This was done on all the unripe, firm ripe and fully ripe cultivars.

Colour measurement of boiled samples

Three fingers each of the unripe cultivars were washed, unpeeled and placed in water and boiled at 100 ^{o}C for 5 minutes on a hotplate. The cooked samples were allowed to cool and the peels were removed with the aid of a stainless kitchen knife. The pulps were sliced longitudinally and the instrument was used to measure the colour.

Colour measurements of flour samples

Two flours fresh dried and milled (FDM) and fresh boiled dried and milled (FBDM) were made using the method by (Kamaayi et al., 2020). The colour of the flours were measured. About 35 g flour was placed in a petri dish. The nosecone and sensor of the colour meter was placed at the middle of the flour and pressed down firmly and flatly against the surface of the sample before and during the measurement to prevent external light. The displayed measurement result is a specific calculation made using the sample reflectance. The data obtained was displayed on the Liquid Crystal Display of the colour meter. The corresponding figure was compared to Colour-Tec CIE LAB Colour Chart and the degree of lightness, redness and yellowness read off. Three different samples from each cultivar were examined and the readings averaged to obtain the means.

Physico-functional Properties of plantain flour

Water Absorption capacity of the plantain pulp flour. Water absorption capacity determination was based on the method described by Sefa-Dedeh *et al*., (1978) with minor modifications. Five (5) g of the flour sample was weighed into a 50 ml pre-weighed centrifuge tube and 30 ml of distilled water (at 27°C) was added, mixed thoroughly by shaking, vortexing and inverting the tube. The mixture was allowed to stand for 30 minutes, inverting the sealed tube after every 10 minutes. The mixture was then centrifuged at 3000 rpm for 15 minutes and the amount of water absorbed was calculated as the increase in weight of the slurry formed after decanting the supernatant. The experiment was carried out in triplicate. The procedure was repeated using distilled water at 70°C.

Determination of pasting characteristics of the plantain flours

The pasting characteristics were determined by using a Brabender Visco-Amylograph (Model No. 802525, Duisburg, Germany). An aqueous suspension of 30.5g Plantain flour (dry weight basis) in 420ml of distilled water was heated from 50ºC to 95ºC at a rate of 1.5ºC/min by means of a thermoregulator. At 95ºC the sample was held constant for 20 min (first holding period) while being stirred continuously. The paste was cooled to 50ºC at 1.5ºC/min and held at that temperature for 15 min (second holding period). Pasting temperature, peak (maximum) viscosity at each stage and the peak temperature were taken from the Amylograph curves. From these measurements the setback viscosity, retrogradation tendency and paste stability at 95 and 50ºC were computed (Champange *et al.*, 1999).

Statistical analysis

The results were analysed using Analysis of Variance (ANOVA) for mean differences among the cultivars. A Graphpad Prism version 17 was used to analyse the data.

III. RESULTS AND DISCUSSION

Colour measurement of unprocessed plantain

Apantu was significantly different ($P < 0.05$) from Oniaba and Apem in their lightness values (L) but there was no significant difference ($P < 0.05$) between Oniaba and Apem (table 1). This was expected because data from work done by (Kamaayi et al., 2020), Apem recorded the highest total phenolic content followed by Oniaba and Apem. The colour of Plant parts are imparted by phytochemicals (carotenoids, flavanols, polyphenols etc). and from that work Apem had the highest total phenolic content and when this is juxtaposed with the colour index for lightness 'L' it was the lowest followed by Oniaba and Apantu. As the lightness diminishes then the impact of other colours will be manifested. From table 1.0, Oniaba recorded the highest value of 'a' (-0.46 ± 0.2) followed by Apem (-1.06 ± 0.00) and then Apantu (-1.52 ± 0.1). Since all the values are in the minimum, it implies that there was traces of green in all the samples studied and this was expected because green is a mixture of blue and yellow but the yellow colour was dominant.

The 'b' axis ranged from yellow (+b) to blue (−b) and from table 1.0, all the values were positive indicating that they were all yellow. The degree of yellowness was highest in Oniaba followed by Apem and Apantu. The colour of the pulp mostly reflects the maturity of the plantain at harvest. If the pulp is more whitish/lighter or pale, then it represents an immature pulp but if it is more yellowish, then the pulp is more matured. It can therefore be deduced from table 1.0 that the samples that were used for the study were all matured since the values for 'b' were all positive.

On the other hand, in the firm ripe samples in table 1.0, Apem was the lightest/whitest followed by Oniaba and then Apantu. The value of 'a' was highest for Oniaba followed by Apantu and then Apem. Thus Oniaba contained more pigments of red followed by Apantu and Apem. In general, there was an increase in the degree of yellowness from the unripe to the firm ripe sample. It means that as the pulps ripens the pulp turn into more yellowish-red. The degree of ripeness was higher in Oniaba followed by Apem and Apantu had the least.

Considering the fully ripe samples in table 1.0, Oniaba was the lightest/whitest and Apem was the least. All the samples had distinguishable lightness statistically ($P < 0.05$). The value of 'a' in the fully ripe sample recorded its maximum. The 'a' value for Apantu and Apem were positive indicating that they were more yellowish-red than Oniaba. The degree of yellowish-redness was higher in Apem, Apantu and Oniaba. The degree of yellowness was high and in the positive region of 'b' indicating that all the samples were yellowish. When the value of 'b' of the unripe sample were juxtaposed with that of the fully ripe, the fully ripe had higher values and this is indicative that the fully ripe samples were very yellowish-red and this is the accepted colour for fully ripe samples by consumers. Another difference between the unripe and the fully ripe samples had to do with the texture of the pulp. The fully ripe samples were softer at hand-feel than the unripe samples. Maturation does not end with harvesting but the pulp continues to mature until senescence. The starches had been converted to glucose and there was a gradual breakdown of the structure of the cells that held the pulp together, thus making the pulp softer.

Effect of boiling on the colour of Plantain pulp

In the boiled plantain samples, the 'L' values were less than fifty (50) which shows that the samples were not white but rather they were darker. All the plantain samples recorded a similar ($P < 0.05$) amount for 'L' about 47, in table 1.0. The redness was highest in Oniaba, Apantu and Apem. In the degree of yellowness, 'b', Oniaba recorded the highest followed by Apem then Apantu. Boiling had an effect on the lightness/whiteness as well as the yellowness of the plantain samples. The effect could be due to gelatinization of the starches in the boiled plantain samples.

The differences in colour of the various samples were due to the cultivar type.

Table 1.0: Colour measurement for boiled and ripening stages of the Plantain samples

Cultivar	Colour Measurement											
	Unripe			Firm ripe			Fully ripe			Boiled		
	L	a	b	L	a	b	L	a	b	L	a	b
Apantu	54.66	-1.52	22.24	51.90	-0.43	25.63	56.97	0.67	34.37	47.42	-1.98	28.80
	±0.33[a]	±0.11[a]	±0.34[a]	±0.59[a]	±0.14[a]	±0.76[a]	±0.87[a]	±0.34[a]	±1.70[a]	±1.10[a]	±0.11[a]	±0.45[a]
Oniaba	52.87	-0.46	25.50	58.29	-0.27	34.32	57.94	-1.22	34.36	47.55	-0.06	33.69
	±0.68[b]	±0.21[b,c]	±0.53[b]	±0.78[b]	±0.06[a]	±0.49[b]	±0.10[a]	±0.22[b]	±0.95[a]	±0.73[a]	±0.02[b]	±0.17[b]
Apem	52.72	-1.06	24.68	63.00	-1.96	32.34	55.87	1.16	34.48	47.31	-2.48	28.87
	±0.31[b]	±0.09[a,c]	±0.18[b]	±0.33[c]	±0.09[b]	±1.00[b]	±0.03[b]	±0.02[c]	±0.04[a]	±0.08[a]	±0.17[a]	±0.46[a]

Values are reported as Mean± SE. Post hoc test was by Tukey's. Values with different letters in the same column are significantly different at $P < 0.05$. (n=3)

Considering the fresh, dried and milled (FDM) flour samples of the plantain, Apantu was the whitest (63.20) followed by Apem (62.30) and finally Oniaba (60.70) in table 2.0. Significant differences ($P < 0.05$) existed between Apantu and Oniaba and also between Oniaba and Apem. When the 'L' values of the FDM were compared with that of the unripe samples, FDM had higher values. The difference in the whiteness was due to the treatment (drying and milling) the unripe samples were taken through. The 'a' values were negative throughout all the samples. Although Apem had the highest value followed by Apantu and Oniaba there was no significant differences ($P < 0.05$) between any of the sample. The 'b' values however recorded positive values and this is an indication that the degree of yellowness was visible. Oniaba was more yellowish than Apantu and Apem.

On the other hand, in the fresh, boiled, dried and milled (FBDM) flour samples, the degree of lightness was reduced. When the 'L' values were compared with either the unripe samples or the FDM, the FBDM were having lesser values giving rise to higher 'b'. The yellowness of the FBDM were maintained or fixed due to the boiling but 'L' values of the FDM were bleached and thus had higher values. Apantu was higher than Oniaba but there was no significant difference ($P < 0.05$) between Apantu and Oniaba when analysis was done using t-test. All the 'a' values were also negative with no significant difference between them. Inasmuch as there was no significant difference between the 'a' values, there was a significant difference in the 'b' values. Oniaba recorded 26.8 which was higher than that of Apantu (24.10) in table 2.0.

Table 2.0: Colour measurement of flour samples of plantain

Cultivar	FDM +			FBDM #		
	L	a	b	L	a	b
Apantu	63.20± 0.38 [a]	-0.90±0.03[a]	11.40±0.04[a]	51.60±0.41	-1.03±0.04	24.10±0.36
Oniaba	60.70 ±0.30 [b]	-1.00±0.01[a]	13.00±0.20[b]	51.30±0.19	-1.07±0.08	26.80±0.34
Apem	62.30± 0.85 [a]	-0.89±0.04[a]	11.50±0.14[a]			

Values are reported as Mean± SE. FDM-fresh, dried and milled plantain pulp, FBDM-fresh, boiled, dried and milled. L represents colour lightness (0 = black and 100 = white). The 'a' scale indicates in the maximum the red (+a) and in the minimum the green colour (−a) while the 'b' axis ranged from yellow (+b) to blue (−b). Values in the same column with different letters are significantly different at $P < 0.05$. +- analysis was done using one way ANOVA, #- analysis was done using unpaired t-test.

Color of reconstituted Plantain slurry

In table 3.0, the colour of reconstituted slurry from FDM and FBDM were taken. In the FDM slurry, the lightness was generally low. The 'L' values were all less than 40. Apem had the least value of 34.2± 0.09 and the highest was Apantu (38.07 ± 0.06). It is worth noting that all the 'a' values are positive but all the previous measurements were negative. The 'a' scale indicates in the maximum the red (+a) and in the minimum the green colour (−a) and so the component of red colour was dominating in the FDM slurry product. The colour of the reconstituted slurry were very dark due to enzyme activity.

The degree of lightness in the FBDM fufu in table 3.0 was in the range of that for the FDM slurry but the Oniaba recorded a higher value than Apantu. The values of 'a' were also positive but they were smaller as compared with the FDM slurry. Similarly, Oniaba had the highest value followed by Apantu. The colour of the FBDM slurry was also yellowish-red but the yellow component dominated.

Table 3.0: Colour measurement of reconstituted slurry from FDM and FBDM

Cultivar	FDM slurry+ (Mean ± SE)			FBDM slurry # (Mean ± SE)		
	L	a	b	L	a	b
Apantu	38.07 ± 0.06[a]	3.26 ± 0.05[a]	7.10 ± 0.13[a]	35.18 ± 0.18	0.89 ± 0.04	13.39± 0.40
Oniaba	35.57 ± 0.01[b]	3.84 ± 0.04[b]	9.64 ± 0.04[b]	38.14± 0.25	0.16 ± 0.05	16.19± 0.49
Apem	34.2 ± 0.09[c]	2.96 ± 0.02[c]	6.78 ± 0.08[a]			

FDM-fresh, dried and milled plantain pulp, FBDM-fresh, boiled, dried and milled. Values are presented as Mean ± SE. L represents colour lightness (0 = black and 100 = white). The 'a' scale indicates in the maximum the red (+a) and in the minimum the green colour (−a) while The 'b' axis ranged from yellow (+b) to blue (−b). Values in the same column with different letter superscripts are significantly different at $P < 0.05$. +- analysis was done using one way ANOVA, #- analysis was done using unpaired t-test.

Physico-functional properties of plantain flour.

Water absorption capacity of the flour samples.

Two temperatures were selected for the water absorption capacity. The first temperature was 27ºC and the second 70ºC also referred to as hot swollen starch temperature. The water absorption capacity of the samples ranged from 10 to 17.

At 27ºC, (figure 1.0) Oniaba FDM had the highest water absorption capacity (14) and this was followed by Apantu FBDM (13). Apem FDM recorded the least water absorption capacity (10). At 70ºC, Apantu FBDM and Oniaba FDM recorded the highest water absorption capacity (17). Apem FDM recorded the least water absorption capacity of 9.72. Analysis of variance for water absorption capacity of the flours produced from various cultivars showed that water absorption capacity of the flours was significantly ($p<0.05$) affected by the interaction of temperature of water used and the type of flour. As the temperature increases, the starch granules swells and they are able to take on more water molecules (Baah et al., 2005). However, the absorption amount depends on the starch content and the type of starch as well as the cultivar (Dadzie B. K., 1995).

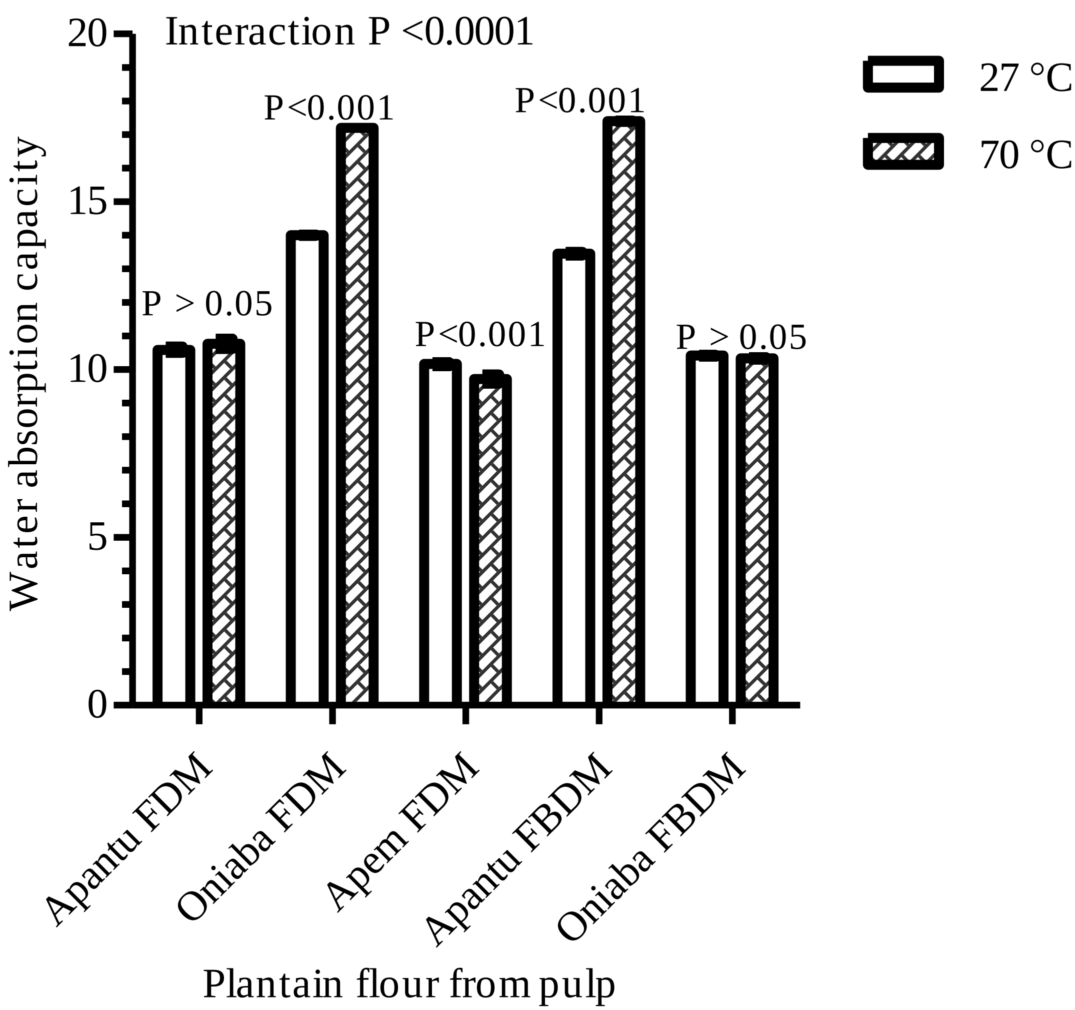

Figure 1.0: Water Absorption Capacity of the plantain flour

Pasting characteristics of Plantain flours

Paste viscosity is among the most important parameters used to ascertain the suitability of flours and starch for certain end uses. It helps in the selection of a cultivar for use in the industry as a thickener, binder or for any other use. The pasting characteristics of the plantain cultivars are summarized in table 4.0.

Starch when heated increases in viscosity as a result of the swelling of the starch granules and in their difficulty in moving past one another. Plantain absorbs water during cooking, which results in softening of the pulp. The amount of water absorbed depends on the duration of cooking, starch content and the cultivar (Dadzie B. K., 1995).

Gelatinization temperature is defined as the temperature where 98percent of the starch granules undergo birefringence loss when microscopically viewed with a Kofler hot stage microscope (French, D., 1984). The gelatinization temperatures ranged from 76.7±0.30 to 78.95±0.75ºC. Apantu recorded the least and Apem the highest. Although there were slight variations in their magnitude, however, they were not significantly different. At the gelatinization temperature, the starch starts to absorb water and swell (Godswill et al., 2019). Gelatinization of starch improves and increases the availability of starch for hydrolysis by the enzyme amylase. It is also employed in cooking and food industries to make starch digestible and also to thicken/bind water in sauce and soup (Godswill et al., 2019).

Peak viscosities of the samples ranged from 1115 to 1325 BU. Oniaba had the highest peak viscosity whilst Apem had the lowest. However, there were some variations in the magnitude of their peak viscosities. Generally, for starches, high viscosity is desirable for industrial uses, for which a high thickening power at high temperatures is required (Kim *et al.*, 1995). These high values in peak viscosity are probably due to the presence of interfering non-starch components, and also as a result of amylose activity in starch, which have the tendency to cause changes in viscosity. Starch produces a viscous paste when heated in the presence of water, and this viscosity accounts for the application of starch in textiles, paper, adhesives and food industries (Adeniji et al., 2010).

From the viscosity at 95ºC, Apantu had the highest (1305 BU) and Apem (950 BU), the lowest (table 4.0). When the viscosity at 95ºC was maintained for 30 minutes, Oniaba and Apem recorded increases in viscosities except Apantu which had some reduction in its viscosity. The increases were Oniaba (from 1105 to 1201 BU) and Apem (from 950 to 1061 BU); the decrease in Apantu was from 1305 to 1257 BU.

When the temperature was decreased from 95ºC to 50ºC there was an increase in the viscosities of all the cultivars (figure 4.0). The viscosity increase was highest in Oniaba (1630BU) followed by Apantu (1555BU) and Apem (1400BU). As the temperature was held at 50ºC for 30 minutes, there was a further increase in the viscosities of the cultivars. Apantu was highest (1783BU), Oniaba (1659BU) and the least was Apem (1479BU).

Break down viscosity ranged from 29 to 228 BU for Oniaba and Apantu respectively. Significant differences existed amongst the cultivars studied.

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Break down viscosity is the measure of the tendency of swollen starch granules to rapture when held at high temperatures and continuous shearing (Patindol *et al.,* 2005) and it is indicative of the stability of the starch on heating. Break down was significantly higher in the other cultivars studied than Oniaba which makes Oniaba very stable during heating. Aryee *et al.,* (2006) reported that low paste stability is an indication of very weak cross-linking within the starch granules. This means that such starches cannot be used for products where starch stability is required at very high temperatures, because they will break down. Pasting properties are dependent on the rigidity of starch granules, which in turn affect the granule swelling potential (Sandhya Rani & Bhattacharaya, 1989) and amount of amylose leaching out in the solution (Morris, 1990).

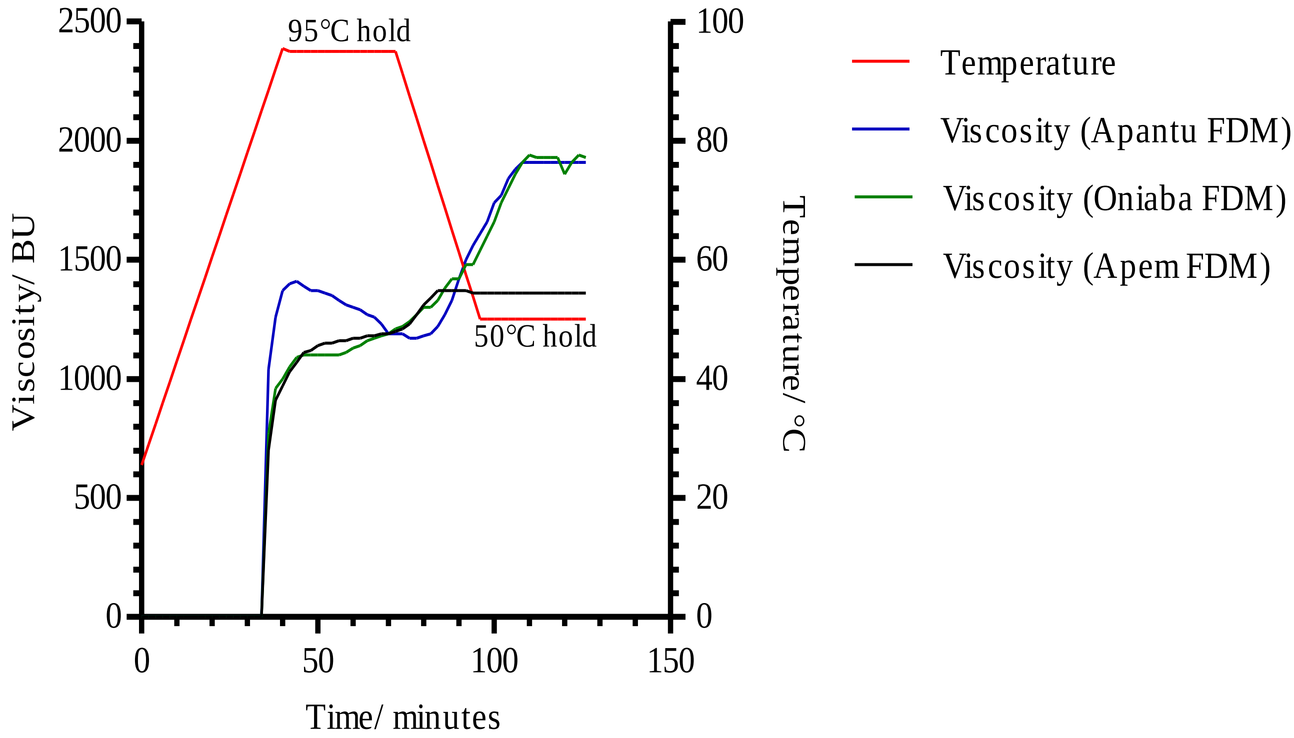
Table 4.0: Pasting characteristics of the flours prepared from the plantain cultivars.

Cultivar	Gelatinization temp.ºC	Viscosity at 95ºC (BU)	Viscosity at 95ºC hold (BU)	Peak viscosity (BU)	Viscosity at 50ºC (BU)	Viscosity at 50ºC hold (BU)	Setback (BU)	Break down (BU)
Apantu	76.7±0.3[a]	1305±65[a]	1257±60.53[a]	1325±85[a]	1555±55[a]	1783±83[a]	48.47±4.47[a]	228.0±28.00[a]
Oniaba	78.7±0.1[b]	1105±55[b]	1201±86.79[a]	1285±95[a]	1630±230[a]	1659±259.3[a]	95.54±31.79[b]	29.29±3.40[b]
Apem	78.95±0.75[b]	950±20[c]	1061±76.32[b]	1115±85[a]	1400±30[a]	1479±111.8[a]	111.3±56.32[c]	81.84±11.30[c]

Values are reported as Mean± SE. Post hoc test was by Tukey's. Values with different letters in the same column are significantly different at P < 0.05.ns – no significant difference. (n=3)

Setback (which is the measure of the paste hardening on cooling) ranged from 48 to 111 BU. Apem registered the highest setback value which was significantly different ($P < 0.05$) from the other studied cultivars. This indicates that Apem recovered most of its amylose content during cooling than all the other studied cultivars with Apantu being the least (Jane and Chen, 1992) which indicates that the flour gives a non-cohesive paste (Kim *et al.*, 1995).

This means that such starches cannot be used for products in which starch stability is required at low temperatures, such as adhesives, fillings and products that require refrigeration. High set back value is associated with a cohesive paste and has been reported (Oduro et al., 2000) to be significant in domestic products such as pounded yam, which requires high set back, high viscosity and high paste stability.



BU= Brabender Units

Figure 2.0: Pasting profile curves from the Brabender Visco-amylograph

Figure 2.0 shows a time-viscosity plot of the pasting of the plantain flour from the studied cultivars generated from Brabender Visco-amylograph. Viscosity increased to a peak and either dropped or leveled whilst cooking and increased on cooling. There was a continuous rise in viscosity of Apantu and Oniaba though the temperature was reduced to 50°C and held for about 30 minutes. The viscosity of Apem leveled off as the temperature was reduced to 50°C and held there for the same time. From figure 2.0, all the cultivars had a similar gelatinization temperature until 95°C when Apantu reached its peak viscosity. Apantu recorded the highest peak viscosity followed by Apem and finally by Oniaba. However, there was no significant difference amongst any of the cultivars.

IV. CONCLUSION

1. The colour of the unprocessed cultivars were more pale with higher L values ranging from 51 to 63 than the boiled samples with L value of 47. The FBDM flour products had lower values of L compared to those of FDM with higher values. The FBDM were more yellowish than the FDM products.
2. The reconstituted flour into slurry had a texture that looked more like a local dish in Ghana called fufu. The colour of the slurry made from FDM (7 to 9) was less yellowish as compared with FBDM (13 to 16). However, slurry from FBDM was not as well constituted as that of FDM. ApantuFDM is the best cultivar for thick slurry and this followed by Oniaba but in terms of yellowness, Oniaba was better than Apantu.
3. Water absorption capacity was generally high at 70°C and this was observed in Apantu FBDM. At 27°C the water absorption capacity was highest for Oniaba FDM and Apem FDM was the least.
4. There was significant difference ($P < 0.05$) among the three cultivars in Setback and breakdown viscosities.

Appendix

Samples of the flours

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Author biography

Fidelis Kamaayi is a science teacher. He has taught Chemistry and aspects of Physics at the Senior High School and the College of Education in Ghana. He holds B. Sc. Chemistry, Post graduate Diploma in Education and an M. Phil. Food science degree. Areas of research interests include; Food chemistry, food toxicology and organic chemistry.

For any correspondence: fide20088@gmail.com