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Quality attributes of *fufu*: Instrumental and sensory measurement

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A B S T R A C T

Texture is one of the key desirable sensory attributes of *fufu*, a cassava-based staple of most Ghanaians. Cassava starch and plantain puree were blended in the ratios of 20:80, 25:75, 30:70, 35:65, and 40:60, respectively. To optimize the processing parameters for cassava starch-plantain puree *fufu*, the texture attributes of the reconstituted *fufu* were assessed and characterized using instrumental and sensory methods and compared with "Neat" *fufu*. The result of the instrumental test on texture showed that *fufu* samples with 20% cassava starch and 80% plantain puree are most desirable while the percentage of starch between 25 and 40% gave higher values which indicated hardness. Overall, the starch content did not have any significant effect on adhesiveness, smoothness and springiness of the *fufu*. The sensory analysis showed that 22 out of 30 assessors prefer *fufu* made from plantain puree and cassava starch in terms of softness and smoothness despite the browning nature of the *fufu*. In general, plantain puree-cassava starch *fufu* had high values for peak viscosity, final viscosity, setback, peak time and peak temperature than "Neat" *fufu*. These findings suggest the need to improve upon the colour of plantain puree in *fufu* preparation for total acceptability by consumers.

Introduction

Fufu, a puree made from boiled cassava and plantain by pounding, is a staple food for a majority of Ghanaians. The difficulty in preparing *fufu* through pounding which is energy consuming is gradually fading out in the homes of most career men and women. Processors are increasingly aware that the traditional pounding of *fufu* put many consumers off for reasons bordering on hygiene and sanitation especially if these are prepared by commercial food vendors. The aforementioned has resulted in the development of a shelf-stable form of *fufu* ("Neat" *fufu* powders, freshly dried-milled cassava

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and/or plantain) with an extended shelf life that could be stored by processors, traders and consumers over a longer time period.

Interestingly, processors have developed flours with high plantain content for consumers with a preference for plantain *fufu*. Plantain is known to have available starch of 56.29% and 17.50% of resistant starches [19] but lacks the viscoelastic/pasting properties that are required in typical plantain-cassava pounded *fufu*. However, the textural characteristics of pounded plantain (usually not smooth and elastic) are improved by adding cassava [18]. Starch is the main component of the cassava roots and plays a vital role in the use of cassava as a food and industrial crop [7]. The starch is expected to behave as texture modifier and hence should modulate or control the pasting properties of the resulting *fufu.*

Hence the production of *fufu* from plantain puree and cassava starch with the right proportion will give a desired texture that will be appealing to consumers. The goal of the study is to produce and apply starch as an additive to plantain puree to produce *fufu* of consumer acceptability.

Materials and methods

Source of materials

Fresh roots of cassava and plantain were obtained from Mampong Agricultural Research Station in the Ashanti Region through Ministry of Food and Agriculture, Kumasi. The cassava variety used was *Afisiafi* and was harvested at tenth (10th) months after planting. The plantain variety used was *Apantu*.

Starch preparation

The cassava was peeled, sliced and washed. Then 16 kg of the sliced cassava was milled in a commercial miller. The resulting mixture was then passed through a cheesecloth. The pulp on top of the sieve was washed with about 3000 mL of distilled water to get all the starch out. The filtrate was divided equally into three plastic buckets and allowed to settle overnight. Then, the liquid was discarded and the light yellow layer was manually scraped off the starch, using a spatula. Distilled water was added to the precipitate and allowed to settle. This was repeated for three times. The precipitate (starch) was then removed from the buckets and solar dried for three days and milled to obtain a fine cassava starch powder.

Plantain puree preparation

Twenty fingers of plantain were peeled and each cut longitudinal into two and the seeds removed. The plantain was then grated into smaller sizes. 400 g of the grated plantain were put into a Binatone blender (BLG 401-28G, China) and 600 mL of water was added and blended for 2 min.

Proximate analysis

The proximate analysis of cassava, starch and plantain was determined according to AOAC [2].

Physicochemical and functional properties

Water binding capacity of the starch was determined according to the method of Diniz and Martin [9]. Samples (2 g) of cassava starch were dissolved with 40 mL of distilled water in a graduated centrifuge tube and vortex for 30 s to disperse the starch. After a holding period of 30 min at room temperature, dispersions were centrifuged at 3000 rpm for 25 min. The supernatant was filtered with cheesecloth and the volume of released fluid was accurately measured. The difference between initial and the final weight of the sample was calculated. The results were reported in duplicate as volume (mL) of water absorbed per gram of cassava starch sample.

Solubility and swelling power determinations were carried out based on a modification of the method by Leach et al. [14]. One gram of sample (cassava starch) was dissolved with distilled water to a total volume of 40 mL using a weighed 50 mL graduated centrifuge tube. The suspension was stirred just sufficiently and uniformly to avoiding excessive speed since it might cause fragmentation of the starch granules. The slurry in the tube was heated at 85 °C in a thermostatically regulated temperature water bath for 30 min with constant stirring. The tube was then removed, wiped dry on the outside and cooled to room temperature. It was then centrifuged at 2200 rpm for 15 min. The supernatant was decanted into a pre-weighed moisture can. The solubility was determined by evaporating the supernatant in a thermostatically controlled drying oven at 105 °C and the residue and sediment paste was weighed. The swelling power was calculated as the weight of sediment paste per gram of flour used.

Five grams of sample (cassava starch) was weighed and mixed with 50 mL of distilled water to obtain a slurry. The pH was then determined using a Fisher Science Education pH meter (Hanna instrument, Piccolo ATC pH meter, Canada).

Experimental design

Design Expert software version 7.0 [8] was used to design the formulation of the plantain puree-cassava starch *fufu*. The constraints for *fufu* preparation was 40 g upper limit and 20 g lower limit for cassava starch and 80 g upper limit and 60 g lower limit for plantain puree.

Fufu preparation

Different portions of plantain puree and cassava starch (Supplementary Table 1) were constituted into a paste and homogenized in a blender (Binatone, Model No. BLG 401-28G, China) and poured into a microwavable bowl with cover. For each formulation, the mixture was microwave (Whirlpool microwave oven JT 356, Whirlpool House UK) for 5 min. After microwaving a thick paste (*fufu*) of consistent appearance was formed. It was then covered with foil to prevent it from becoming dry. They were kept in a food flask prior to evaluation.

Evaluation of fufu texture with Fruit Pressure Tester

Fruit Pressure Tester (FT 327, Italy) was improvised and used to assess the texture of the various formulations. The Fruit Pressure Tester is a worldwide recognized small tool used to detect the firmness of a fruit. It measures the penetration and squashing of fruit pulp using a tip of 1 cm square. The tip of the Fruit Pressure Tester was changed to a cylindrical metal of diameter 8 cm in order to be used to determine the firmness of the *fufu* formulations. The *fufu* was put into a plastic container into which the tip of the improvised Fruit Pressure Tester could fit. The tester was used to penetrate the *fufu* in the container and readings were recorded which indicate softness or hardness. The values for the various formulations were fed back into the software design for analysis.

Sensory evaluation of fufu texture for optimum response

Sensory Texture Profile Attribute (STPA) was carried out on all the formulations. The method described by Bourne and Szczesniak [5] was adopted with slight modification. In their method, the texture analysis or assessment was done manually not orally and it is known as the non-oral method. Sensory evaluation of formulated *fufu* was conducted using a fifteen (15) trained panel members who were regular *fufu* consumers on the Kwame Nkrumah University of Science and Technology campus, Kumasi-Ghana. The panellists were asked to score for adhesiveness, hardness, smoothness and springiness using a 5 point hedonic scale where; 1 = least, 2 = less, 3 = moderate and 4 = very and 5 = extreme. The data obtained for the sensory evaluations was fed into the software design and analysed.

Validation of formulated plantain puree-cassava starch fufu

After optimization of the data (40 g upper limit and 20 g lower limit for cassava starch and 80 g upper limit and 60 g lower limit for plantain puree), 80 g of plantain puree and 20 g of cassava starch (optimum response) was used in *fufu* preparation. The plantain puree and cassava starch were reconstituted and homogenized in a blender (Binatone) and was poured into a microwavable bowl with cover. The mixture was microwave (Whirlpool microwave oven JT 356, Whirlpool House UK) for 5 min to obtain *fufu* of consistent appearance. It was then covered with foil to prevent it from becoming dry, kept in a food flask before subjecting it for evaluation.

Assessment of formulated fufu with "Neat" fufu using paired preference test

The formulated *fufu* was compared with "Neat" *fufu* with a constituent of 60% plantain, 30% potato granules, 10% cassava and colour; E 102 and E 110. Its directions for preparation were followed as instructed on the package. The samples were coded and served with light soup. The evaluation was conducted with a thirty (30) panel members who were regular *fufu* consumers. *Fufu* sample made from 80 g plantain puree and 20 g starch *fufu* sample and the "Neat" *fufu* samples were presented to each panellist at room temperature in partitioned and well-lit booths for assessment. The samples were coded 429 (represent the *fufu* made from pureed plantain and starch) and 924 (represent the "Neat" *fufu*) to assess attributes such as softness, smoothness, smell, taste and colour.

Pasting properties of plantain puree and cassava starch formulation and "Neat" fufu powder

The pasting properties of the samples were determined using Brabender Viscograph (Brabender OHG, Kulturstr.51-55, D-47055 Duisburg Germany) at Food Research Institute, Accra-Ghana. The ICC-Standard No.110/1(1976) and ICC-Standard No. 130 [12] were the methods used. About 40 g "Neat" *fufu* sample and a mixture of plantain puree and cassava starch (20% plantain puree and 80% cassava starch) were separately suspended in 420 mL distilled water to prepare slurry in a large beaker. The suspension of the flour was mixed thoroughly and poured into the rotating stainless measuring bowl of the Brabender Viscograph. The test was run at a speed of 75 rpm with a measuring range of 1000 cmg. The temperature profile of the analysis was programmed to commence measurement at a temperature of 50 °C with heating at the rate of 3 °C/min up to a temperature of 95 °C. The temperature of the sample was held constant for 15 min and cooled at the rate of 3 °C/min to a temperature of 50 °C. This temperature was also held constant for 15 min. The pasting characteristics were then determined by reading the following: the time, temperature and viscosity at the beginning of gelatinization, maximum

Table 1
Proximate analysis of cassava, cassava starch and plantain.

Parameters	Cassava (%)	Cassava starch (%)	Plantain (%)
Moisture	50.1 ± 0.06^a	8.57 ± 0.24^b	54.36 ± 0.01^c
Crude protein	1.03 ± 0.01^a	0.85 ± 0.01^b	1.51 ± 0.00^c
Crude fat	0.56 ± 0.01^a	0.53 ± 0.05^a	0.57 ± 0.02^a
Crude fiber	1.11 ± 0.05^a	1.01 ± 0.01^b	0.52 ± 0.02^c
Ash	1.09 ± 0.01^a	1.22 ± 0.16^a	0.72 ± 0.02^b
Carbohydrate	46.21 ± 0.01^a	87.82 ± 0.30^b	42.32 ± 0.02^c

Means in row with different superscripts letters are significantly different ($P < 0.05$).

Table 2
Functional and physical properties of unprocessed cassava starch.

Parameter	Water binding	Swelling power	Solubility	pH
Cassave starch	81.23%	27.47	11.39%	8.87

viscosity, the start of holding period, the start of the cooling period, end of the cooling period, and at the end of final holding period as well as the breakdown and set back viscosities.

Results and discussion

Proximate analysis

The moisture content of the fresh cassava was 50.1% as shown in Table 1. This was higher than what was reported by Emmanuel et al. [11] (33.14–45.86%). However, it was lower than 56.5–68.80% which was reported by Richardson [21]. The differences in moisture content might be due age and varietal differences.

There was a significant difference in moisture content for all the samples examined (Table 1). Plantain had the highest moisture content of 54.36% followed by cassava, 50.1%. The high moisture content has the ability to influence the amount of water need in cooking and this is necessary for formulation since less moisture (water) will be required to prepare the *fufu*. Crude protein, fat and fibre were generally low for all the samples compared to other studies [4,6,10,20] and this could be attributed to a varietal difference, maturity or age of harvesting. The carbohydrate content of plantain (42.32%) was low compared to the values obtained by Odenigbo et al. [15], 80.55–82.44% and Adebayo and Abdou [1]; 91.96–92.70%. This implies that the plantain variety will have less starchy and hence cannot provide the viscoelasticity needed in '*fufu*' hence the need for texture modifier, cassava starch.

Functional and physical properties of cassava starch

The pH of the starch was 8.87 which indicated that no fermentation had taken place. pH is an important parameter in determining the quality of flour and pH of 4 or less indicate a level of starch breakdown which imparts sour taste and characteristics aroma to food. Since the pH of the starch sample in this study was more than 4, it will not impart undesirable flavour and aroma to the *fufu*. The value (8.87) observed in this study as shown in Table 2 was comparable to what was reported by Mensah (unpublished) which was 8.28.

The swelling power of cassava starch was 27.47 and this was comparable to the range values of 17.2–28.0 which were reported by Appea-Baah et al. [3]. However, Mensah (unpublished) also reported a value of 10.28 which was lower than what was reported in the study.

The solubility of *Afisiafi* cassava flour ranged between 8.1 and 17.1% in a research work by Appea-Baah et al. [3]. The value observed in this study was 11.39% which was within range.

Sensory evaluation

Instrumental assessment of fufu texture

The result of the instrumental test on texture that was conducted on the *fufu* samples by the use of fruit tester showed that *fufu* samples with starch between 25 and 40% gave higher values which indicated hardness. In a research work which was done by Oduro-Yeboah et al. [17], cassava-plantain flour with formulation 50 g of cassava, 50 g of plantain and 40 g of starch increased the hardness of their *fufu* sample in both the instrumental and sensory texture profile attribute. Increase in hardness of *fufu* was observed as the addition of starch increases with decreasing plantain puree. However, formulations with more than 35% starch and 65% plantain puree had their texture to remain constant.

Table 3
Results of paired preference test.

Samples	Softness	Smoothness	Smell	Taste	Colour
429	22	22	21	23	5
924	8	8	9	7	25

Table 4
Pasting properties of Plantain puree – cassava starch *fufu*, and "Neat" *fufu* powder.

Sample	Peak viscosity (BU)	Holding strength (BU)	Breakdown (BU)	Final viscosity (BU)	Setback (BU)	Peak time (min)	Pasting temperature (°C)
Plantain puree and starch	350	33	89	177	−84	30:15	72.6
"Neat" *fufu* powder	232	88	98	103	−31	29:35	70.6

Sensory test on fufu formulations

The force required to move the material that adheres to the mouth during eating (adhesiveness) is the same for all the formulations since there is no significant difference in the values obtained (0.33–0.46 N). These values are comparable to those reported (0.30–1.12 N) by Oduro-Yeboah et al. [17]. Bourne and Szczesniak [5] reported that moderate adhesiveness is a desirable feature of paste-like foods. The effect of starch on adhesiveness and smoothness of the *fufu* were non-significant at $p > 0.05$.

The rate at which a deformed material goes back to its original state after the applied force is removed (springiness) was reported to be 0.35–0.40 mm for *fufu*. These values are lower compared to those reported by Oduro-Yeboah et al. [17]; 0.85–0.90 mm. This implies the product is less susceptible to deformity and hence may be more stable in terms of springiness than its counterpart flour used in making *fufu*. Irrespective of the amount of starch added to the puree, springiness remained almost the same.

Values for hardness ranges from 0.33–0.53 N and a significant difference were observed when the starch content was 40% and plantain puree 60%. Therefore, the force required in compressing *fufu* between the tongue and the palate was observed to be the same for cassava starch and plantain puree within the ranges of 20–35 g and 80–65 g, respectively. The values (1.35–1.72 N) obtained in the work by Oduro-Yeboah et al. [17] are higher and significant differences exist between the values and project values. It is evident from the results that *fufu* from plantain puree and starch is less hard than that from the flour though moisture content during preparation may play a role.

Consumer preference test

A panel of 30 assessors was to choose between the two samples which one they preferred in terms of the attributes of softness, smoothness, smell, taste and colour. The results showed that 22 out of the 30 assessors selected sample 429, the plantain and starch *fufu*, as the one they preferred in terms of softness and smoothness (Table 3).

Twenty-one out of the 30 assessors selected sample 429 as their preferred choice in terms of smell and 23 assessors also selected 429 in terms of taste. The reason for selecting sample coded 429 with respect to the smell could be due to the high amount of plantain used in the *fufu* preparation. Colour recorded the least value for sample 429 and this was due to the addition of colours E102 and E110 to mask the browning reaction in sample 924. In general, sample coded 492 despite its colour had a good taste, easy to swallow and good mouth feel. For a panel of 30, the minimum number of identical responses required to determine that a difference exists at 5% significance level ($P = 0.05$) is 21.

Pasting properties

The pasting characteristics of the plantain puree-cassava starch *fufu* and "Neat" *fufu* flour are shown in Table 4, Figs. 1 and 2. The pasting temperature of the "Neat" *fufu* and plantain puree-cassava starch were not too different.

Setback values for "Neat" *fufu* (31) was quite lower than that of the plantain puree-cassava starch *fufu* (84) which meant that "Neat" *fufu* was of less cohesiveness than plantain puree-cassava starch *fufu*. Kim et al. [13] reported that paste with high setback produced good cohesiveness. It has been reported by Sanni et al. [22] that setback pasting property has a correlation with the texture of *fufu* flours and that low setback of *fufu* paste indicates high stability. The peak time which is the time at which viscosity peaks were almost the same for both samples.

Peak viscosity for both plantain puree-cassava starch *fufu* and "Neat" *fufu* were 350 BU and 232 BU, respectively. Breakdown value was 89 BU for plantain puree-cassava starch *fufu* and 98 BU for "Neat" *fufu*. High breakdown values implied that there was less granule rapture which made the *fufu* from plantain puree-cassava starch more resistant to breakdown in viscosity and hence its paste more stable. Oduro et al. [16] in their research work on pounded yam reported that starch with low paste stability or breakdown shows weak cross-linkage among the granules.

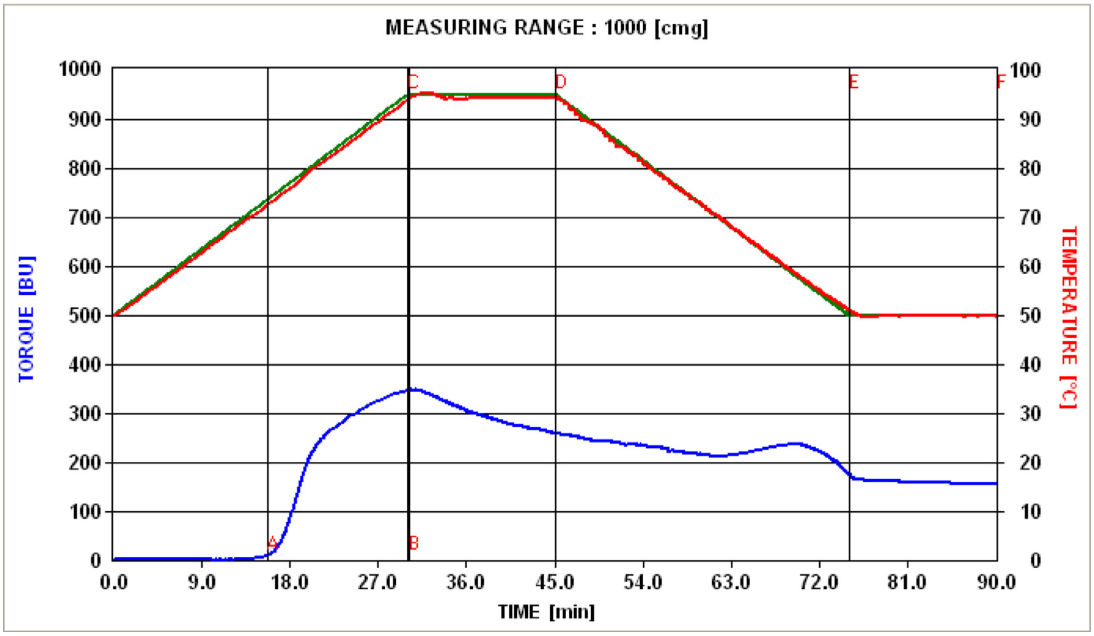

Fig. 1. Paste viscosity of plantain puree-cassava starch *fufu* as determined by a Brabender Visco-amylograph.

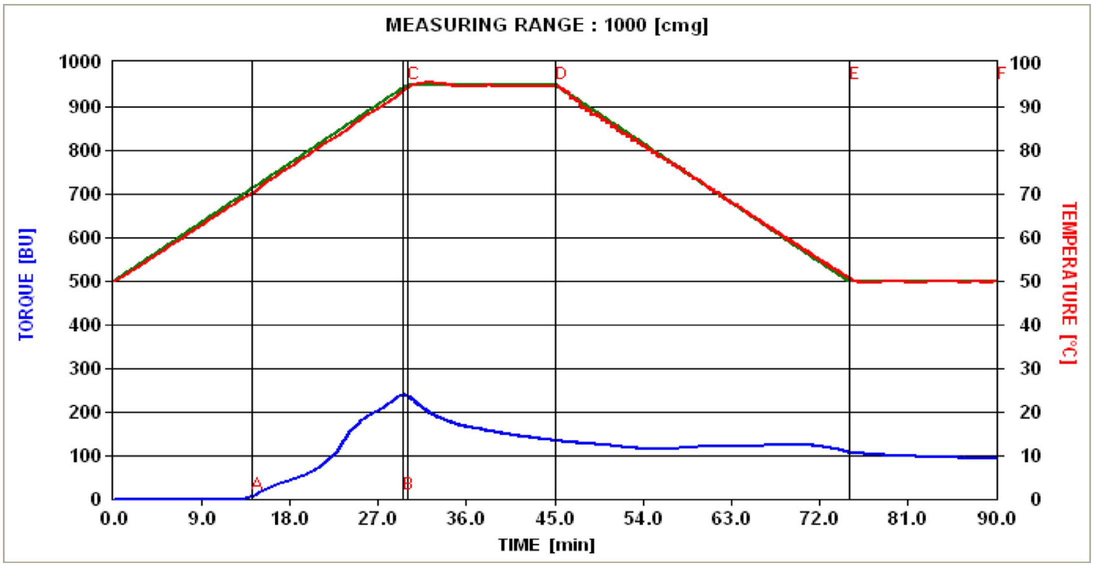

Fig. 2. Paste viscosity of “Neat” *fufu* flour as determined by a Brabender Visco-amylograph.

In general, plantain puree-cassava starch *fufu* had high values for peak viscosity, final viscosity, setback, peak time and peak temperature than “Neat” *fufu*. This confirms what Oduro et al. [16] reported that domestic products such as pounded yam *fufu* require high setback, high viscosity and high paste stability.

Conclusions

Starch content did not have any significant effect on adhesiveness, smoothness and springiness of the *fufu* except for hardness when the starch content was 40% and plantain puree 60%. The instrument test on the *fufu* formulations indicated that as the amount of starch increases, hardness also increase. It is therefore important not to underestimate texture of food when all other food quality parameters are good. Improving on the colour of plantain puree in *fufu* pxreparation will influence consumer acceptability of the product.

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None.

Conflict of interests

None.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.sciaf.2018.e00005.

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