

Effect of Soil Amendment on the Functional and Pasting Properties of False Horn Plantain Flour

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Abstract— *There is growing public perception that fruits from fertilized plantain plants have their organoleptic qualities reduced during food preparations. Such perception has the potential consequence of lowering production levels of the commodity in Ghana. To ascertain the veracity of this perception, a study was conducted between July 2012 and March 2015 to determine the effects of different rates of poultry manure, cocoa pod husk and NPK as soil amendments on nutritional composition, physical characteristics and functional properties of plantain pulp flour. The experimental design was a Randomized Complete Block with three replications. Flours from plantain with amended soils recorded moisture contents (8.41 % to 12.08%) which were within the acceptable levels for flours. The flour with the lowest moisture content was produced from plantain with CPH amendment (8.41%). The protein content of false horn plantain flour was however low (3.39 % to 5.27%). The plantain flour starch was not influenced by any of the soil amendments. On the other hand, flour produced from plantain with NPK+PM amendment had low bulk density and low water absorption capacity. Similarly, the false horn plantain flour had lower swelling power values compared to other flours. Flours from plantain with CPH amendment had lower oil absorption capacity. Flour from plantain with PM amendment was more likely to cook faster than the flour from the plantain with the other amendments. Flours from plantain with NPK+CPH amendment would form a more stable paste because of its lower breakdown value. In conclusion, the plantain flours were comparable to known food flours and therefore could be applicable as thickening agents and also find usefulness in fufu powder preparation and baking.*

Keywords— *plantain, soil amendment, flour, pasting, functional properties and manure.*

I. INTRODUCTION

The consumption of plantain is all year round whilst its production is seasonal and hence the need to reduce post-harvest losses through the processing of fruits into forms with reduced moisture content. Plantain production has, for some time now, experiencing an increasing production with a correspondent increase in surplus since 2001

(Dankyeet *al.*, 2007). It is assumed that in 2015, there will be about 912,000 Mt surpluses (MoFA SRID, 2014). These surpluses would have to be processed, exported or it will end up at the refuse dump (Dankyeet *al.*, 2007). This is due to the highly perishable nature of plantains as result of high metabolic activity leading to fast deterioration mostly after harvest (Demirel and Turhan, 2003).

For the efficient use of plantain flours as an ingredient for the food industry it is important to investigate the effect of soil amendments to determine its impact on their chemical, nutritional composition, shelf life as well as their functional properties. Therefore, it is plausible to characterize the nutritional and chemical composition, as well as their physicochemical, physical and functional properties of plantain flours in order to make any recommendation for its usage in the food industry. It is also important to note that some companies in the manufacturing of instant plantain fufu flour import flours to Ghana in spite of the surpluses recorded in plantain production over the years (Dankyeet *al.*, 2007). The conversion of plantain into flour which has the desired functional properties could contribute to reducing if not totally eliminating the import of flour into the country. Nonetheless, the preparation of flour from cooking banana is a surest means of value addition as well as extending the shelf life and enhancing transportation (Adeniji and Empere 2001).

Functional properties are the characteristics of food which dictate their behaviour, quality and acceptability during processing, storage, and preparation (Ishmealet *al.*, 2011). Plantains are high in carbohydrate (31 g/100 g) and have relatively low fat content (0.4 g/100g). Notwithstanding, they are important sources of vitamins and minerals (Adenijiet *al.*, 2006), notably iron (24 mg/kg), potassium (9.5 mg/ kg), calcium (715 mg/kg), vitamin A, ascorbic acid, thiamin, riboflavin and niacin. Unripe plantain flours are rich in dietary fiber (8.82%) and resistant starch (16.2%), micronutrients which enhance the reduction of blood sugar level. They are, however, low in fat and oil as well as protein (Ayodele and Erema, 2011). The flour is used in confectionery and bakery industries in the treatment of intestinal disorders. They are also used in the preparation of infant diets (Adenijiet *al.*, 2006)

Plantains require high amounts of nutrients for optimum growth and fruit production but these nutrients are often supplied in part by the soil (Lahav, 1995). This is one of the reasons why in the West and Central African regions, the crop is predominantly cultivated in the home gardens where it receives continuous supply of organic matter and nutrients from household refuse (Baiyeriet al., 2007). Animal manure is a source of nutrients and organic matter, which could improve soil bio-physical conditions (Munoz et al., 2004) for sustainable food production.

Improvement in soil fertility greatly influences the physical characteristics of both the plant and the fruit. Soil amendments strategy which seek to increase the nutritional status of the soil will therefore trigger a corresponding increase in the yields of crops grown on such soils (Ndukweet al., 2014).

Although it is known that organic and inorganic fertilizer levels affect nutrient composition of plantain fruit pulp (Ndukweet al., 2014), little is known about how they influence functional properties of plantain pulp flour which is widely used in production of fufu flour and other food products. However, the effects of a particular soil amendment strategy on the flour quality of fruits of false horn plantain (*Apantu pa*) ought to be determined, hence the need for this investigation.

II. LITERATURE REVIEW

Effect of fertilizer on the quality characteristics of Produce

In the experiment conducted by Premsekhar and Rajashree (2009) to determine the influence of different organic manures on the growth, yield and quality of okra. It came out that, organic manures performed better by producing quality fruits with less fibre content. Application of farm yard manure at 20 t /ha recorded fruits with less crude fibre content and less moisture content. It was noted that, application of farm yard manure might have caused accumulation of nutrients and dry matter in fruits than synthetic fertilization which resulted in better quality of fruits grown on soils amended with farm yard manure.

In other experiment, Kipkosgeiet al. (2003) researched on the effect of farmyard manure and nitrogen fertilizer on vegetative growth, leaf yield and quality attributes of black nightshade (*Solanum villosum*). It was revealed that, the β -carotene content in the edible portions increased with increasing levels of fertilizers. This was attributed to Nitrogen facilitating the formation of chloroplasts, which are rich in β -carotene. Results also showed that farm yard manure increased the vitamin C content of edible leafy portions of *Solanum villosum* whereas inorganic nitrogen fertilizers decreased vitamin C content.

Quality Indicators of Flour

In the cooking sense, flour is in a form of powder which is derived from cereal, grains, roots and tuber and other seeds. It is the major ingredient used in the baking industries for the preparation of varieties of food products (Appiah et al., 2011). In the Middle East, North Africa, Europe and the Americas, wheat flours form integral part of their diet and are widely used in the preparations of breads and pastries. Good quality flours have higher gluten content which are able to produce lighter and softer baked products by embedding small gas bubbles. The amount of protein (gluten) in flour predicts its bread-baking quality for plain white flour Appiah et al. (2011).

FUNCTIONAL PROPERTIES

Matil (1971) defined functional property as the properties that affect the quality and acceptability of food as well as the characteristics that governs the behaviour of nutrients its composition when altered during storage, processing and preparation into various forms. Important functional properties that influences the suitability and usage of starchy staples such as plantain include; swelling power, water and oil absorption capacity, bulk density, solubility etc.

PASTING PROPERTIES

Otegbayo et al., (2006) stated that, during the heating and cooling of starch series of processes follow gelatinization which include granule rupture and subsequently polymer alignment due to mechanical shear which finally result in pasting.

Flours are normally cooked into paste before eating, therefore the determination of pasting characteristics of flours are very essential in predicting quality index and the behavior of paste during and after cooking (Etudaiyeet al., 2009).

III. METHODOLOGY

The experiment was conducted on the research field of Council for Scientific and Industrial Research Institute located (Horticultural Department Kwadaso Kumasi) at Kenyasi in the BrongAhafo Region of Ghana. The experiment was established as a demonstration field for farmers within the catchment area. The experiment which lasted for a period of two years commenced in 2012 and ended in 2014. This was done to demonstrate the influence of soil amendment on the yield and performance of two plantain groups that is, the False Horn and French Horn which are locally known as *Apantu pa* and *Apem pa* respectively. The area falls within latitude 7° 03' .631'' North and longitude 2° 29' .424'' west.

The flour obtained from the plantain was subjected to laboratory analysis. The laboratory work investigated the influence of soil amendments on the flour that was prepared from the false horn plantain.

The experiment was set up in the Randomized Complete Block Design (RCBD) with three replications.

Data were collected on samples at three (3) different laboratories. The laboratory of CSIR (Abuakwa), Department of Horticulture laboratory (KNUST) and the Food Research laboratory (Accra).

Preparation and Application of Treatments

The poultry manure was kept for period of three (3) months to allow decomposition and elimination of heat. The manure was applied (top dressing) to each stand with a planting distance of 2m within rows and 3m between rows. Each plot had a total plant population of fifteen (15) and occupied an area of 6 x 8m².

Cocoa Pod Husk was subjected to open air drying for a period of three (3) months and it was further crushed in a sack using wooden pistils into smaller particles of about 2cm. Cocoa Pod Husk was also applied (top dressing) to each stand.

The land was divided into three blocks, with each block made up of six plots. Each plot received different soil amendment including the control (no treatment). The treatments administered on the various plots comprise 10kg/stand (16660kg/h) of Poultry Manure(PM), 5kg Poultry Manure and NPK (0.065kg+0.045kg,0.18kg)/stand (108kgN+75kgP+300kgK/h and 8330kg/h PM), 10kg Cocoa Pod Husk/stand (16660kg/h), 5kg cocoa pod husk and NPK (0.065kg+0.045kg,0.18kg)/stand (108kgN+75kgP+300kgK/h and 8330kg/h CPH), NPK (0.13kg+0.09kg,0.36kg)/stand (216kg/h N,150kg/h P, 600kg/h K).

SAMPLE COLLECTION AND PREPARATION

For the purpose of this study, the false horn variety (Apantu pa) was used due to its popularity in flour preparation. Fresh firm and matured but green plantain fruits were harvested from the various plots for use in the flour preparation. Following the recommendations of Baiyeri and Ortiz (2000). Finger samples were collected from the second hand of the proximal end of the bunch. The fruits were sliced to 5mm diameter using a grater after they have been washed and peeled.

Preparation of False Horn Plantain Flour

Sliced plantain pulp was placed in an oven (Wagtech-Model GP120SSE300HYD) and dried at 60°C for 24 hours till it turned crispy. This was done by spreading out slices in layers of 1cm thick on stainless-steel shelves in a tray-drying accessory of the oven. Dried slices were then cooled and milled in a hammer miller for three (3) times till a fine powder was obtained. Flour samples were packaged in high density polyethylene for laboratory analysis. At the laboratory, flour samples were screened through a sieve with 0.25 mm diameter of hole (Model BS 410) before the various analyses were carried out.

Moisture

Two grams (2 g) each of the samples were weighed in triplicates and dried for 24hours at 60°C in an oven (Wagtech-Model GP120SSE300HYD) to a constant weight. Samples were removed, allowed to cool and weighed. The moisture content calculated and expressed as a percentage of the mass of sample taken by repeating the procedure of weighing and drying of each sample (AOAC 1990).

Protein

The Micro-Kjeldahl method of protein determination was used in the determination of the percentage of protein in the various sample (AOAC, 1990). Methods involved in the protein determination are two (2).

Digestion

Two grams (2 g) of sample was weighed unto a filter paper pre-folded like an envelope and introduced in to the kjeldhal flask in triplicates. Anti-bumping agents and half spoonful of selenium base catalyst were added. The flask was shaken to get the samples thoroughly wet immediately about 25ml of concentrated H₂SO₄ was added. The heater turned on when the flask was placed on the distillation rack and the sample digested until the solution became clear. Cooling of the flask was allowed at room temperature to obtain a clear solution. The digested sample was transferred into 100 ml volumetric flasks and top up with distilled water to the 100ml mark.

Distillation and Titration

Two drops mixed indicator was added, when twenty-five of 2% boric acid was pipetted into a 250ml Erlenmeyer flask followed by 18 ml of 40% NaOH. The conical flask and its contents was placed under the condenser in a position that left the tip of the condenser completely submerged in the solution. The digested sample of ten millilitres (10ml) was poured into the steam jacket. The stopcock was closed to drive the liberated ammonia gas directly in to the collection flask and steam forced from the decomposition chamber by shutting the stop cock on the steam tap outlet. Distillation continued until the boric acid turned bluish green, before distillation was stop. The distillate titrated against 0.1N H₂SO₄ to a faint pink endpoint and the set up was then disconnected afterwards. Similar method was used to prepare a blank in which a similar piece of filter paper minus sample was used. The percentage nitrogen was multiply by the appropriate conversion factor of 6.25 to obtain the percentage protein.

Starch Determination

The Starch content was obtained by adopting the method of Lintner but with slight modification. Triturate 2.5g of flour with 20ml of water, and 40ml hydrochloric acid (sp.gr.1.15) added in small portions. Wash the mixture into a 200ml flask with hydrocholic acid (12% w/w HCL) add 10ml of 5% phosphotungstic acid to precipitate proteins and make the volume up to 200ml with 12% hydrochloric acid. Shake, filter and measure the optical

rotation of the filtrate in a 200-mm tube. Multiply the reading by 1.912 to get the percentage of starch directly.

Pasting Characteristics

American Association of Cereal Chemist Approved Method 22.10 (AACC, 1983) with slight modifications was used to determine the pasting characteristics of plantain flour samples which were in triplicates (moisture content ranging between 7.5 and 13.65 and corrected to 14%). A Brabender viscoamylograph (Viscograph PT-100) from Food Research Institute, Accra was used to study all the pasting properties of the flour at 75 rpm and a torque of 700 g equivalent to 100 Brabender units (BU) (Demiateet *et al.*, 2001). Under a constant stirring speed, the slurry was heated from 25–95°C at a uniform rate of 1.5°C/min. Monitoring was continuously done on the torque. Cooling took place under a controlled rate of 1.5°C/min (Damardjati and Luh 1987) to 50°C after torque was formed. The cooked paste viscosity of 14% slurries in 420 ml water was measured. Pasting parameters including beginning of gelatinization, maximum/peak viscosity, end of final holding, break down and set back were recorded and expressed as Brabender Units (BU) (Demiateet *et al.*, 2001).

Swelling Power and Solubility

Based on a slight modification of the method of Appiah *et al.* (2011) solubility and swelling power were determined. One (1 g) of flour was transferred into a 50ml capacity graduated centrifuge tube. A total volume of 40ml was obtained by adding deionized water. In order to avoid fragmentation of starch granules, the suspension was stirred just sufficiently and uniformly avoiding excessive speed. The sample in the centrifuge tube was heated at 85°C in a thermostatically controlled temperature water bath (Grant type) for 30 min with constant stirring. The tube was cooled to room temperature after it had been removed and wiped dry. It was centrifuged for 15 min at 2200 rpm. The supernatant was evaporated and the residue weighed to ascertain the solubility. The sediment paste was weighed and the percentages of swelling power and solubility were then calculated. Determinations were done in triplicate.

Water and Oil Absorption Capacities

With slight modification of the method of Appiah *et al.* (2011), water absorption capacity was ascertained. 1.0 g of the sample in a beaker was topped up with 10mL of distilled. A Rota mixer 7023 was used for mixing the suspension for 3 min. The supernatant obtained was measured in a 10 mL graduated cylinder by centrifuging the suspension at 5000 rpm for 30min. The density of water was taken as 1.0 g/ml. The difference between the initial volume of water added to the sample and the volume of the supernatant was used to calculate the water absorbed.

The same methodology was adopted for oil absorption except that oil was used instead of water. The density of the oil used was 0.9095g/ml.

The volume of water or oil on the sediment was measured. Oil and Water absorption capacities were calculated in millilitres of oil or water absorbed per gram of flour respectively.

Bulk Density

Water absorption capacity was determined using the method of Appiah *et al.* (2011). 50.0g of the flour sample was weighed into a 100ml graduated measuring cylinder. The cylinder was then gently tapped repeatedly on the laboratory bench till a constant volume was obtained. The volume was then noted.

The bulk density (g/cm³) was calculated as weight of flour (g) divided by flour volume (cm³).

That is Bulk density (g/ cm³) = weight of sample (g) /volume of sample after tapping cm³.

IV. RESULTS AND DISCUSSION

QUALITY CHARACTERISTICS OF PLANTAIN FLOUR

Moisture Content

There were significant differences ($P \leq 0.01$) in the moisture content of the plantain flour among the various amended soils. Flour produced from plantain without any soil amendment (control) recorded the highest moisture content (12.08 %), significantly different from the other amendments except NPK+CPH amendment soil. Flour produced from plantain with CPH amended soil recorded the lowest moisture content (8.41%).

Ishmael *et al.*, (2011) and Onwuka and Onwuka, (2005) however, reported moisture contents of 61.10% and 61.6%, respectively which were comparatively higher than the findings in the present study. The lower pulp moisture content found in this study is an indication of the higher dry matter content of the pulp which is known to have an influence on the energy content due to the high carbohydrate content associated with high dry matter (Gowen, 1995). The moisture content of the flour was within the recommended range of 10% to 14% for flours (Akubor and Badifu, 2004). Appiah *et al.* (2011) reported moisture content of 8.53% to 9.11% for flours obtained from breadfruit cultivars which were slightly lower than what pertained in the current study.

Higher moisture content in flours have been reported to enhance spoilage through creating favourable condition for microbial proliferation as well as enhance enzymatic deterioration (Odure *et al.*, 2009). Since the flours in the present study had acceptable moisture content they are expected to have longer shelf life.

Protein content

There were also significant differences ($P \leq 0.01$) in the plantain flour protein between the various amended soils.

Flour produced from plantain with NPK amendment recorded the highest protein content (5.27 %), significantly different from the flours from NPK+PM amendment and the control which recorded the lowest protein contents of 3.39 and 3.44, respectively (Table 1). All the other amendments produced flours with protein content similar to that from the NPK amended soil.

This could be due to the readily availability of nitrogen and phosphorus needed for protein synthesis from the NPK as against the slow release of these same elements by the organic amendments. In the present study, the protein in the flour recorded from soils amended with NPK was higher than those quoted by previous researchers such as Ishmael (2011) (3.06%) and Onwuka and Onwuka (2005) (2.8%). The differences could be due to the type of fertilizer applied and the condition of the soils used for the plantain cultivation. In spite of these differences, the protein content of false horn plantain flour was generally low and as such required fortification

with other high protein foods to boost the nutritional content of the flour as indicated by Zhao *et al.* (2004).

Starch Content

For starch content, flour produced from plantain without any soil amendment recorded the highest (51.33 %), significantly different from all the other amendments (Table 1). Flour produced from plantain with NPK+PM amended soil recorded the lowest starch content (30.67 %) although similar to those from NPK+CPH and PM amended soils.

From the present study, the findings are indicative that the flour starch is not influenced by any soil amendments. Starch characteristics such as swelling power, solubility pattern, pasting behaviour are important for improved quality of food products and could be useful for the development of composite blends from small scale industrial level as value-added products (Ikegwuet *al.*, 2010).

Table.1: Effect of soil amendments on protein and starch content of plantain flour

Treatment	Protein (%)	Starch (%)
NPK	5.27	40.33
PM	4.41	36.67
CPH	3.53	41.33
NPK+PM	3.39	30.67
NPK+CPH	3.76	32.00
CONTROL	3.44	51.33
LSD(0.01)	1.779	8.857
CV	17.99	9.17

FUNCTIONAL PROPERTIES OF FALSE HORN PLANTAIN FLOUR

There were no significant differences ($P \geq 0.01$) between the soil amendments with regards to the functional properties of the plantain flour. The functional properties assessed were bulk density, oil absorption capacity, water absorption capacity, solubility and swelling power. Bulk density ranged from 0.79g/cm³ to 0.84g/cm³. Oil absorption capacity ranged from 1.82ml/g to 10.73ml/g whereas water absorption capacity ranged from 1.37ml/g to 2.05ml/g. Solubility power ranged from 7.77% to 9.96% while swelling power ranged from 9.49% to 10.45%.

Bulk Density of Plantain Flours

There were no significant differences ($P > 0.01$) between the various soil amendments with regards to the bulk density of the flour. The bulk densities ranged from 0.79g/cm³ to 0.84g/cm³ with soil amended with PM recording 0.84g/cm³ and NPK+PM recording 0.79g/cm³. Ismael *et al.*, (2011) recorded a bulk density of 0.63g/cm³ for false horn. The disparities in the values could be due to an interplay of several factors, such as environmental conditions during production, the fertility status of the soil

and the method of processing the plantain into flour. Comparatively, the bulk density of fermented maize flour was reported to be 0.55g/cm³ (Akubor and Badifu, 2004 and Mbataet *al.*, 2009). According to Bhattacharya and Prakash (1994), the bulk density of foods increases with increasing starch content. Furthermore, Okezie and Bello (1988)

stressed that high bulk density of food material is important in relation to its packaging. Ijarotimi and Ashipa (2005) documented that, higher bulk density is essential in the sense that it offers greater packaging advantage as greater quantity of flour may be packed within a constant volume. Oladele and Aina (2007) also describe bulk density as the measure of the heaviness of a flour sample. Mbataet *al.*, (2009) indicated that weaning food should have low water absorption capacity and low bulk density in order to produce a more suitable and nutritious weaning food. Consequently, the flour produced from plantain with NPK+PM amendment might be suitable for preparing weaning food formulations.

Water Absorption Capacity of Plantain Flours

Water absorption capacity (WAC) for false horn plantain flour varied from 1.37ml/g to 2.05ml/g. Flours obtained from plantain grown on soils without any amendment

(control) recorded 2.05ml/g for WAC whiles flour from CPH amendment recorded the lowest WAC value of 1.37. Elmoneimet *al.* (2005) indicated that water absorption capacity gave an indication of the amount of water available for gelatinization. Low water absorption capacity is desirable for making thinner gruels. Desikachar (1980) indicated that a high water absorption capacity of flours increases its viscosity (consistency) when mixed with water, resulting in a thick paste but does not allow free-flow of the meal (Mosha and Lorri 1987).

Oil Absorption Capacity of False Horn Plantain Flour

False horn plantain flours had oil absorption capacity (OAC) ranging from 10.72g/g to 1.82g/g. Flour produced from plantain on soil amended with NPK+CPH recorded the oil absorption capacity of 10.72g whereas flour from plantain with CPH amendment recorded oil absorption capacity of 1.82g. The oil absorption capacity values recorded in the present study were higher than the 1.30g/g recorded by Mepbaet *al.*, (2007). The variation could be due to the varietal differences of plantain used as well as the stage of maturity of the fruits harvested. In a study on breadfruit flour, an oil absorption capacity range of 0.38g/g to 1.13g/g was obtained (Appiah *et al.*, 2011). Also, Udensi and Okoronkwo (2006) reported oil absorption capacity value of 2.2g/g for mucunabean. Generally, flours with lower oil absorption capacity have higher flavor retention abilities (Oladele and Aina, 2007). Consequently, flours from plantain with CPH amendment could have a high potential of retaining flavour and therefore could be desirable in food product formulation. Adejuyitanet *al.*, (2009) explained that the lower oil absorption capacity could be due to low hydrophobic proteins which show superior binding of lipids. For flours with high oil absorption capacities, such as that observed in the flour from plantain with NPK+CPH amendment, they could be useful in food formulation where oil holding capacity is needed for instance in the sausage making, soups and cakes (Aremuet *al.*, 2006).

Swelling Power of False Horn Plantain

Swelling power of false horn plantain flour ranges from 10.45 to 9.49. Ishmealet *al.*, (2011) documented similar swelling power values (7.14 to 10.28) for false horn plantain flour. The swelling power values of plantain flour are comparable to those for soybean-fortified yam flour (6.8-9.6) (Jimo and Olatidoye, 2009). However, plantain flour exhibited a better swelling capacity than cassava and this could be due to the small particle sized plantain starch which is highly digestible in nature (Ojinnakaet *al.*, 2009).

In comparison to the flour of other crops, there appeared to be no consistent trend as in some cases the swelling power values are lower (tigernut - 2.47, Oladele and Aina 2007); breadfruits cultivars - 4.84 to 6.23 (Appiah *et al.*, 2011) whiles in other cases the values are higher (cereal

starches - 24 to 42 (Tester and Morrison, 1990). The swelling power test provided a suitable predictive method for identifying flours capable of producing high quality noodles (McComicket *al.*, 1991). The false horn plantain flours in the present study had lower swelling power values and as such might not be suitable for noodle production.

Also in the present study, solubility percentage strongly affected the swelling power of the plantain flour, an indication that as the solubility of the flour increased the swelling power also increased leading to an improved water absorption capacity of the flour (Etudaiyeet *al.*, 2009). Johnson *et al.* (2001) indicated that higher solubility also permitted better digestibility.

EFFECTS OF SOIL AMENDMENTS ON THE PASTING PROPERTIES OF DERIVED PLANTAIN FLOUR

Gelatinization Temperature

There were significant differences ($P \leq 0.01$) between flours produced from the various amended soils with regards to temperature at the beginning of gelatinization (Table 2). Flours produced from plantain with NPK+PM amendment and the Control recorded the highest temperature at the beginning of gelatinization (77.47°C and 77.45°C respectively), which differed significantly from flours produced from PM amended soils which recorded the least temperature (75.45°C). However, the temperature figure obtained from flours produced by PM amended soils was not significantly different from NPK, CPH, and NPK+CPH which recorded temperatures of 77.22°C, 76.73°C and 77.10°C respectively.

Time Taken to Reach Peak Viscosity

There were significant differences ($P \leq 0.01$) between the flours produced from the various amended soils with regards to the time taken to reach peak viscosity (Table 2). Flours produced from soils amended with NPK+CPH and the control recorded the highest time taken to reach peak viscosity (1912.50 sec. and 1881.70 sec. respectively), which was significantly different from flours obtained from NPK amended soils which recorded the least time (1065.00 sec.).

Beginning of Gelatinization Time

There were significant differences ($P \leq 0.01$) between the flours produced from plantain grown on the various amended soils with regards to the time taken for the beginning of gelatinization. Flours produced from plantain grown on NPK+PM amended soil (1150.00 sec) and the control (1150.80 sec.) recorded the highest time for 'Beginning of gelatinization' which were significantly different from PM which recorded the least time (1065.00 sec.) (Table 2). The time recorded by flour produced from PM amended soils was not significantly different from NPK, NPK+CPH, and CPH which recorded time of 1141.70 sec., 1137.50 sec. and 1125 sec., respectively.

Table.2: Effect of soil amendment on beginning of gelatinization temperature, time and time taken to reach peak viscosity of false horn plantain flour

Treatment	Beginning of gelatinization temperature (°C)	Beginning of gelatinization time (sec.)	Time taken to Reach Peak Viscosity (sec.)
NPK	77.22	1141.70	1675.80
PM	75.45	1065.00	1811.70
CPH	76.73	1125.00	1791.70
NPK+PM	77.47	1150.00	1859.20
NPK+CPH	77.10	1137.50	1912.50
CONT.	77.45	1150.80	1881.70
LSD(0.01)	1.829	77.072	77.072
CV	1.50	4.30	0.85

Higher gelatinization temperatures (81.87°C; 94.6°C) have been reported for breadfruit flours by Appiah *et al.*, (2011) and by Oladele and Aina (2007) from other studies. Mira *et al.* (2005), explained that such higher gelatinization temperatures could be the result of delayed or restricted swelling and amylose leaching. Lower gelatinization temperature, on the other hand, is indicative of lower cooking temperature and shorter cooking time (Otegbayo *et al.*, 2006). Appiah *et al.*, (2011) reported that, flours with shorter cooking time is advantageous as it might reduce energy consumption (fuel) as well as reduce the cost and time of processing. From the present study therefore, flour from plantain with PM amendment is more likely to cook faster than the flour from the plantain with NPK+PM amendment.

Viscosities (Maximum, Final, Breakdown and Setback)

Flours from plantain with CPH amendment recorded the highest maximum viscosity (401.33BU) whereas flours from plantain with NPK amendment recorded the least viscosity of 354.33BU. Zakpaa *et al.*, (2010) reported a maximum viscosity of 677 BU for false horn plantain flour which is higher than the value in the present study. Also in an earlier study, maximum viscosities have been reported for Potato (3000 BU), Maize (77.5 BU), Wheat (300 BU) and Cassava (966 BU) (Ciacco *et al.*, 1997). The differences in values could be attributed to pasting

characteristics which depend on granule size and amylose content. Larger granules have a lower surface area to volume ratio and therefore the association between hydrogen bond and granules are very weak, hence increased swelling (Zakpaa *et al.*, 2010). Maximum viscosity is an important feature of starch flour since it gives an indication of the ability of the flour to form a thick paste during cooking which is the result of the swelling power of the starch (Adebowale *et al.*, 2005; Opata *et al.*, 2007). Kim *et al.*, (1995) indicated that starch with high viscosity is desirable as thickening agents in industry and in food systems.

Breakdown Viscosity

The breakdown values for false horn plantain flour ranged between 51.00 BU (NPK+CPH) to 93.00 BU (NPK) in the present study (table 3). The breakdown values generally indicate the difference between peak viscosity and minimum viscosity and show the degree of drop during heating and the extent of starch granule disintegration (Adebowale *et al.*, 2005). Higher breakdown in viscosity suggests lower ability of sample to withstand heating and shear stress during cooking. Therefore, starch samples with lower breakdown will have better ability to withstand heating and shear stress giving more stable cooked paste (Zobel, 1984). From the present study therefore, flours from plantain with NPK+CPH amendment would form a more stable paste.

Table.3: Effect of soil amendment on breakdown and setback of false horn plantain flour

Treatment	Breakdown viscosity (BU)	Setback viscosity (BU)
NPK	93.00	7.50
PM	79.00	-93.17
CPH	90.33	-14.83
NPK+PM	82.67	-70.67
NPK+CPH	51.00	-86.83
CONT.	71.17	35.83
LSD(0.01)	18.646	76.249
CV	15.08	129.70

Start of Cooling and End of Cooling

There were significant differences ($P \leq 0.01$) in start of cooling viscosity between the flours produced from plantain under the various soil amendments (Table 4). All the amendments and the control recorded significantly higher start of cooling viscosity values than that from the NPK amendment which recorded the least start of cooling

viscosity value (Table 4). The end of cooling viscosity values also differed significantly ($P \leq 0.01$) between the flours produced from plantain under the various soil amendments (Table 4). Flour produced from plantain without amendment (control) recorded the highest viscosity at the end of cooling, significantly different from flour from NPK+PM and PM amendments.

Table.4: Effect of soil amendment on start of cooling and end of cooling on false horn plantain flour

Treatment	Start of cooling viscosity (BU)	End of cooling viscosity (BU)
NPK	261.33	268.67
PM	303.00	210.00
CPH	311.00	295.83
NPK+PM	309.50	238.83
NPK+CPH	317.67	255.00
CONT.	303.00	331.00
LSD(0.01)	23.083	87.808
CV	4.83	20.75

Start of Holding and End of holding

There were significant differences ($P \leq 0.01$) between the flours from the various amended soils with regards to the viscosity at the start of holding (Table 5). Flour produced from plantain amended with CPH recorded significantly higher start of holding viscosity values than the other amendments except that from the NPK + PM amended soil (Table 5). The least start of holding viscosity was recorded by NPK amended soil.

The end of holding viscosity values also differed significantly ($P \leq 0.01$) between the flours produced from plantain under the various soil amendments (Table 5). Flour produced from plantain without soil amendment (control) recorded the highest viscosity at the end of holding, which was not significantly different from flour from CPH amended soils.

Table.5: Effect of soil amendment on start of holding and end of final holding on false horn plantain flour

Treatment	Start of holding viscosity (BU)	End of final holding viscosity (BU)
NPK	349.50	227.50
PM	378.00	182.33
CPH	399.67	263.33
NPK+PM	387.00	213.17
NPK+CPH	359.00	198.00
CONT.	360.00	303.83
LSD(0.01)	14.777	67.626
CV	2.50	18.41

REGRESSION RELATIONSHIPS BETWEEN SOME AGRONOMIC PARAMETERS, FUNCTIONAL AND PROXIMATE PROPERTIES OF PLANTAIN FLOUR

There was a significant relationship between the swelling power of plantain flour and its solubility. The swelling power of the flour was positively affected by the flour's solubility. Solubility of the flour accounted for 88 % of the variation in the observed swelling power (Eqn 1).

Swelling Power = $7.08157 + 0.29512$ (solubility %); $R^2 = 0.88$; $p = 0.018$; $n = 10$ (Eqn 1).

There was also a significant relationship between the oil absorption capacity of the flour and the pulp weight of the plantain fruit. The oil absorption capacity of the flour was positively and significantly affected by the plantain fruit pulp weight such that 91 % of the variation in the oil absorption capacity of the flour was explained by the pulp weight of the plantain fruit (Eqn 2).

Oil Absorption Cap. = 0.02732 (Pulp Weight) – 3.23967 ; $R^2 = 0.91$; $P = 0.012$; $n = 10$ (Eqn 2).

Similarly, there was a significant relationship between the starch content of the flour and the pulp weight. The starch content of the flour was positively and significantly

affected by the fruit pulp weight such that 70 % of the variation in the starch content of the flour was explained by the fruit pulp weight (Eqn 3).

Starch Content = 27.8127 + 3.76498 (pulp weight); $R^2 = 0.70$; $p = 0.046$; $n = 10$ (Eqn 3).

There was a significant relationship between the maximum viscosity of the flour and the oil absorption capacity of the flour. The maximum viscosity of the flour was positively and significantly affected by the oil absorption capacity of the flour. However, only 25 % of the variation in the maximum viscosity of the flour was explained by the oil absorption capacity of the flour (Eqn 4).

$Y(\text{max. viscosity}) = 372.501 + 1.33796(\text{oil absorption})$; $R^2 = 0.25$; $p = 0.035$; $n = 10$. (Eqn 4).

There was also a significant relationship between the maximum viscosity of the flour and the starch content of the flour. The maximum viscosity of the flour was positively and significantly affected by the starch content of the flour. However, only 26 % of the variation in the maximum viscosity of the flour was explained by the starch content of the flour. (Eqn 5).

$Y(\text{max. viscosity}) = 423.169 - 1.19374(\text{starch})$; $R^2 = 0.26$; $p = 0.030$; $n = 10$. (Eqn 5).

V. CONCLUSION

Flours from plantain obtained from amended soils recorded moisture contents which were within the acceptable levels for flours. The flour with the lowest moisture content was produced from plantain with CPH amendment. The protein content of false horn plantain flour was, however, lower and as such required fortification with other high protein foods to boost the nutritional content of the flour.

The starch from plantain flour was not influenced by any of the soil amendments. On the other hand, flour produced from plantain on soil amended with NPK+PM had low bulk density and low water absorption capacity and therefore might be suitable for preparing weaning food formulations. Contrarily, the false horn plantain flours had lower swelling power values and as such might not be suitable for noodle production.

Flours from plantain with CPH amended soil had lower oil absorption capacity which suggested that it would have a high potential of retaining flavour and therefore could be desirable in food product formulations. Similarly, flour from plantain with PM amendment was more likely to cook faster than the flour from the plantain with the other soil amendments. Flours from plantain with NPK+CPH soil amendment would form a more stable paste because of its lower breakdown value which will

ensure its ability to withstand heating and shear stress and give more stable cooked paste.

Generally, the Plantain flour compared favourably with known food flours and therefore could be applicable as thickening agents and also find usefulness in fufu powder preparation and baking.

VI. RECOMMENDATIONS

1. Further studies could be done with other combinations of organic and inorganic fertilizers.
2. Soils amended with cocoa pod husk, poultry manure, NPK fertilizer and their combinations could be adopted as it is effective in enhancing the quality of plantain flour.
3. Sensory studies (texture, colour, and aroma) need to be conducted on the plantain flours emanating from the amended soils.

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