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EFFECTS OF SOIL AMENDMENTS ON AGRONOMIC CHARACTERISTICS AND FUNCTIONAL PROPERTIES OF FALSE HORN PLANTAIN (APANTU PA)

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EFFECTS OF SOIL AMENDMENTS ON AGRONOMIC CHARACTERISTICS AND FUNCTIONAL PROPERTIES OF FALSE HORN PLANTAIN

(APANTU PA)

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BY FREDERICK DANSO

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DECLARATION

I hereby declare that this submission is the result of my own work and that it has not been submitted either in part or whole for any other degree elsewhere. Works by other authors have been duly acknowledged.

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DEDICATION

This work is dedicated to my lovely wife Doreen Oduro Antwi for unflinching love, support and patience. My parents Theresa Adoma and John Asante Danso, My grandfather's Kwadwo Mensah Boansi, Adu Okofo Boansi and Pro. Martin Oteng

Ababio (Family Head) for their inspiration which has propelled me this far.

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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. Selected agronomic data as well as the organoleptic qualities data were collected. Soils amended with NPK+PM and NPK+CPH recorded the highest bunch yields (17.78 mt ha^{-1} and 17.22 mt ha^{-1}, respectively) whiles soil amended with NPK recorded the highest finger weight (427.33 g) and pulp thickness (3.98 cm). 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.

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CHAPTER ONE

1.0 INTRODUCTION

Plantain (*Musa AAB*) is very popular crop and it is ranked the third most important after yam and cassava in the food crop sector in Ghana (FAO, 2006). The contribution of plantain to the Agricultural Gross Domestic Product amount to closely 13%. The annual consumption of the crop stands at 101.8kg per person (FAO, 2006). Its consumption is higher than other starchy foods with the exception of cassava.

Ghana is ranked the second largest producer of the crop in Africa after Uganda. However, it is the largest producer in West Africa (FAO, 2010). The total annual production stands at 3.786 million tonnes (SRID-MOFA, 2014)

The importance of plantain as food security crop cannot be overemphasized. The crop have variety of usage at various stages of ripeness. Nwaichi *et al* (2014) reported that when an unripe plantain is cooked, and pounded, a meal called *fufu* is obtained, which can be eaten with soup. Ripe plantain is used for fritter preparations. Unripe plantain cooked and pounded together with yam has smooth texture and is known as 'fufu', and is more elastic than cocoyam or yam pounded alone (Ohimain, 2014). Amala a popular dish in Nigeria is prepared from the past of plantain and yam flour which is usually served with soup (Karim *et al* 2015).

The highly perishable nature of plantain is attributed to high moisture content which in tend increases metabolic activity after harvest (Demirel and Turhan, 2003). Nonetheless the preparation of flour from cooking banana was a surest means of value addition as well as extending the shelf life and enhancing transportation (Adeniji and Empere 2001).

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.

Functional properties are the characteristics of food which dictate their behavior, quality and acceptability during processing, storage, and preparation (Ishmeal *et 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 (Adeniji *et 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
(Adeniji *et 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 (Baiyeri *et 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.

Although it is known that organic and inorganic fertilizer levels affect nutrient composition of plantain fruit pulp (Ndukwe *et 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. Hence this study.

The demand of nutrient by a growing crop generally varies through the growing season, with the highest uptake during the period of most rapid plant growth. Timing of nutrient application, therefore, ensures the supply of the nutrient within the peak periods where they become most needed by the crops. This will also prevent the risk of nutrient losses which is supplied to the crop at time when plants are not in need thereby preventing fertilizer wastage. Magdoff (1995) reported the necessity of synchronization of plantavailable soil nutrients vis-a-vis crop nutrient demand for optimum plant growth and prevention of excess nutrient leakage with its attendant environmental ramifications. Thus, the need for external inputs of nutrients, especially for commercial plantain production. This could either be organic materials (such as animal waste, which is mostly in the form of feacal matter, compost manure and farmyard manure) or inorganic
fertilizers.

There is therefore the need to adopt the requisite soil management strategies that will help increase the yield of fruits in plantain. 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.

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 (Dankye *et 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 (Dankye *et al*., 2007). This is due to the highly perishable nature of plantains as result of high metabolic activity leading to fast deterioration even 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 their chemical, nutritional composition, shelf life as well as their functional properties. It is also important to note that some companies in the manufacturing of instant plantain fufu flour import flours to Ghana inspite of the surpluses recorded in plantain production over the years (Dankye *et 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. 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 (Ndukwe *et al*., 2014).

The size of the bunch and fruit, pulp to peel ratio, number of hands and fingers are some of the physical attributes that are greatly improved. In other to make an informed decision on the appropriate soil amendment strategy, the effect of soil amendment on functional and pasting qualities of the flour ought to be ascertained.

1.2 OBJECTIVE OF THE RESEARCH

The main objective of the study was to determine the influence of various soil amendments on the growth, yield and postharvest qualities of false horn plantain

(Apantu Pa).

1.2.1 Specific Objectives

The specific objectives were:

1. To assess the effect of different soil amendments on the growth and yield of false horn plantain (Apantu Pa.)
2. To determine the influence of soil amendments on the nutritional composition of plantain fruits.
3. To assess the influence of soil amendments on functional properties of plantain pulp flour.
4. To determine pasting characteristics of flours of plantain produced from different soil amendments.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 REVIEW OF TAXONOMY OF PLANTAIN AND BANANA

Plantains (musa spp.L.) are giant perennial herbs that thrive in the more humid parts of the tropics. They are commonly divided into dessert bananas, cooking bananas and plantains, and beer bananas. Dessert bananas are palatable when eaten raw after ripen, however, the other bananas are generally processed by cooking or fermentation before consumption. The plantains are specific type of cooking banana, whose fruit remains starchy during ripeness. They are distinct with the characteristic orange- yellow colour of the compound tepal in flowers and a distinguished orange-yellow colour of fruit pulp at ripeness. Fruits are long and slender, angular-to-pointed, and unpalatable when raw (Simmonds 1966; Swennen 1990a).

Plantain and banana evolved from intra- and interspecific hybrids of the two diploid wild species musa acuminate colla and Musa balbisiana colla. The genus musa which belongs to the eumusa series (Simmonds and shepherd 1955; Simmonds 1966), genomic and ploidy constituents vary among the different groups and cultivars of bananas which are designated by A and B to denote the genomes of M. acuminate and commonly categorized as AAA dessert bananas. The AAA highland cooking and beer bananas of East African origin, the AAB plantains, and the ABB cooking bananas. Thus the term
"plantain" in the narrow sense, refers to only the AAB cultivars of bananas that are eaten only when cooked.

2.2 MORPHOLOGY OF PLANTAIN

A plantain plant consists of basically the roots, pseudo-stem, leaves and inflorescence. The roots system is made up of primary, secondary and tertiary roots. The roots that developed to form the Secondary roots are those of primary roots, whereas the secondary roots developed into what is known as the tertiary roots. The primary roots have the explorer roots and the feeder roots. The explorer roots are basically for anchorage and are thicker than feeder roots. Feeder roots are responsible for water and nutrients absorption and usually grow from explorer roots Swennen and Oritz (1997).

Pseudo-stem is the cylindrical structure growing from the corm and carrying the foliage. The pseudo-stem is not wood because plantain crops are giant herbs, not trees. It consists of tight packing of overlapping leaf sheaths Swennen and Oritz (1997).The pseudo-stem offers support for the leaves and inflorescence. The function of the pseudostem is purely connective and provides vascular connection between roots, leaves on one hand and the inflorescence on the other.

The inflorescence, also known as the bunch, is the collection of the plantain fingers (fruits) on a fruit stalk. There are types of inflorescence, and this depends on the type of variety.

2.3 GROUPS OF PLANTAIN

There are four (4) main groups of plantains. They are mostly differentiated by; completeness of inflorescence and male bud at maturity, presence of neutral flowers and , number of hands, and number as well as the weight of fingers (Swennen and Oritz 1997).

The four main groups are; French plantain, French horn plantain, False Horn Plantain and True Horn Plantain.

- The French plantain has a complete inflorescence at maturity. This variety can grow to a maximum height of about 2.5 m and pseuodostem circumference of 600 mm. It produces between 30-38 leaves before fruit initiation and takes 12 months to attain full bunch maturity. The bunch could carry as many as 6-12 hands and 60-170 small fingers (Swennen and Oritz, 1997).

- The False Horn plantain variety has smaller number of hands as compared to the French plantain nonetheless larger fingers. The False Horn bunch can carry as many as 5-12 hands and 25-80 fingers. There are neutral flowers and no male bud at maturity. It has incomplete inflorescence.
- The French horn plantain also has an incomplete inflorescence, no male bud but many neutral flowers at maturity. French horn plantain usually has 7-8 number of hands and fingers of 30-85.
- The True Horn plantain variety usually has 1-5 hands. The fingers are few in number, 1-50. The True Horn plantains are longer and stouter than the False Horn plantains (Swennen and Oritz, 1997).

2.4 TYPES OF PLANTAIN CULTIVARS IN GHANA

Out of the four main groups of plantain, three (3) are present in Ghana; they are the False horn plantain, True horn and French plantain (Ampofo *et al.*, 2013). There are also hybrids of plantains in Ghana. The hybrids were developed to be resistant to the major diseases affecting the three main groups. Some of the hybrids are FHIA-21, FHIA-01, FHIA-03 and FHIA-25 (Dankyi *et al*., 2007).

The False horn plantain, True horn plantain and French plantain are considered as local landraces and they have various varieties in the country. Locally *Apantu* and *Apem* are the names given to the False horn plantain and the French plantain respectively (Ampofo, *et al*., 2013).

In 2005, majority of farmers planted the local races. The local races had an adoption rate of 87.1% and the hybrid plantain had 12.9%. The False horn plantain had 73%, French plantain had 12.1% and the True horn plantain had 2.0 %. *Apantu pa* and *Asamienu* were the only varieties planted for the False horn and True horn plantain respectively. *Apem pa* contributed 10.9% out of 12.1% for the French plantain whiles *Apemhemaa* hybrid plantain contributed 9.7% out of the 12.9% for the hybrid plantain (Ampofo *et al*., 2013).

2.5 PLANTAIN CONTRIBUTION TO GHANA'S ECONOMY

Plantain contributes 9% of the Agricultural Gross Domestic Product and it comes second to roots and tubers which are currently ranked first. Cereals and other crops are ranked third and fourth with 7% and 2% respectively. This obviously underpins significant contribution of plantain to Ghana's economy.

Table 2.1: Contribution of various crops to Agricultural GDP

Sub Sector	Contribution to Agricultural GDP
Crops (Total)	64
Roots and Tubers	46
Plantain	9
Cereals	7

Others	2

Source: SRID, MoFA 2006

2.5.1 Importance and Benefits of Plantain Production and Consumption

Plantain cultivation is more lucrative to farmers as results of its low labour requirement for production as compared to maize, rice, cassava, and yam (Marriot and Lancester, 1983). Its production forms part of the non-traditional sector of the rural economy, where it is predominantly used by cocoa farmers to shade cocoa as well as mulch in the reduction of moisture during the dry season. It is also an essential component of the diet and generates considerable employment to agricultural households. With regards to job creation, traditional mechanized or inter-crop cultivation of one hectare of plantain generates 1.68, 0.39 and 0.19 permanent direct jobs per ha per year. In view of this, it is estimated that one hectare of plantain generates an average of 0.75 permanent direct and indirect jobs (Martinez Rodriguez and Saavedra Rodriguez, 2001). Table 2.2 shows the production of plantain in relation to other crops in Ghana.

The world production of plantain stands at 33million metric tonnes and it is grown in 52 countries (FAO, 2005). Plantain is an important staple crop, supplying up to 25% of the carbohydrates for approximately 70 million people in the humid zone of sub-Saharan Africa. Africa alone produce 50% of the world total plantain. Plantain account for nearly one quarter of the total world production of banana and plantain (Swennen, 1990). Plantain pulp is low in protein with estimated values of 4g per kg in green unripe finger and 9g per kg in the fully ripe finger. A higher level of about 72g per kg is found in the peels, which makes the peel a suitable feeding stuff for ruminants, especially in ripe form (Izonfuo and

Omuaru, 1988). Plantain peel is richer in minerals such as potassium, calcium, magnesium, phosphorus, copper and iron, except sodium, when compared to the pulp, at all stages of physiological ripeness, with increasing levels of potassium, calcium and iron as the fruits ripens (Izonfuo and Omuaru, 1988).

When processed into flour, it is used traditionally for preparation of wide range of dishes (Trejo-González *et al.,* 2014).

Plantains have a high content carbohydrate (31 g/100 g) but low fat content (0.4 g/100g). They are good sources of minerals and vitamins (Akissoe *et al.*, 2001), notably iron (24 mg/kg), potassium (9.5 mg/ kg), calcium (715 mg/kg), vitamin A, thiamin, ascorbic acid, riboflavin and niacin. Unripe plantain flour is rich in dietary fiber (8.82%) and resistant starch (16.2%), micronutrients and helps in the reduction of blood sugar level, nevertheless low in protein and fat (Ayodele and Erema, 2011).

In Ghana for instance, *fufu* (a mixture of boiled green plantain and cassava, pounded into thick dough), *ampesi* (boiled fruit) and eto (boiled and mashed plantain) are the main household dishes usually eaten with soup or stew (Wormenor, 2015). Torgal *et al.* (2008) reported the production and utilization of flour from unripe cooking banana and plantain. Two parts of the flours may be reconstituted in one part of boiling water, and mixed thoroughly with a wooden spatula over the heating medium to produce a thick dough, called ‘amala’, which is a traditional dish commonly eaten with vegetable soup in Western Nigeria among the Yorubas. The utilisation of flour from unpeeled green plantain in poultry feed, and concluded that no ill or toxic effects could be observed in the chicks fed with the flour (Adeniji and Tenkuona 2008).

Table 2.2 Plantain production compared to other crops in Ghana ('000Mt)

Crop	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Maize	1013	938	1400	1289	1158	1171	1189	1220	1470	1620	1872
Plantain	1932	2074	2279	2329	2381	2792	2900	3234	3338	3563	3538
Cassava	8107	8966	9731	10239	9739	9567	9638	10218	11351	12231	13504
Millet	169	134	159	176	144	185	165	113	194	246	219
Rice (paddy)	215	253	280	239	242	237	250	185	302	391	492
Rice (milled)	129	152	168	143	145	142	150	111	181	235	295
Sorghum	280	280	316	338	287	305	315	155	331	351	324
Cocoyam	1625	1688	1860	1805	1716	1686	1660	1690	1688	1504	1355
Yam	3363	3547	3900	3813	3892	3923	4288	4376	4895	5778	5960
Total	16833	18032	20093	20371	19704	20008	20555	21302	23750	25919	27559

Source; SRID, MoFA 2010

Note: Milled rice is estimated to be 60% of paddy

2.5.2 Supply and Demand of Plantain

Generally there is a positive correlation between the population and national consumption. The increase in the population triggers a correspondent increases in the consumption of plantain. The available national consumption of plantain and its production status are illustrated Table 2.3. 85% is the biological production that is assumed as available for human consumption. This justifies as a major stable crop for both the present and generations ahead. The increasing surplus production since 2001as illustrated in table 2.4 should be converted into flours which have a variety of usage to curtail wastage.

Table 2.3: Per capita consumption of some selected food crops

	Kg/head/year					
Commodity	1980	1985	1990	1995	2000	2005
	(Roots and Tubers)					
Cassava	145.2	146.3	148.0	149.7	151.4	152.9
Yam	44.2	43.8	43.3	42.8	42.3	41.9
Cocoyam	-	-	54.0	55.0	56.0	40.0
Plantain	82.2	82.5	83.0	83.5	84.0	84.8
	Cereals					
Maize	38.4	39.2	40.3	41.4	42.5	43.8
Rice (milled)	12.4	12.7	13.3	13.9	14.5	15.1
Millet	8.5	9.4	5.1	12.6	9.0	6.4
Sorghum	13.0	14.4	9.3	21.7	14.8	10.1

Source: SRID, MoFA 2010

Table 2.4: Estimated domestic plantain supply and demand

Year	Total domestic production (‘000Mt)	Production available for human consumption (‘000Mt)	Per capita consumption (kg/Annum)	Estimated national consumption (‘000Mt)	Surplus (‘000Mt)	Population (Millions)
2000	1943.9	1,652.3	88.8	1562.4	89.9	18.6
2001	2073.9	1,762.8	93.2	1587.6	175.2	18.9
2002	2,300.0	1,995.0	100.2	1629.6	325.4	19.4

2003	2329.0	1,979.7	100.2	1663.2	316.5	19.8
2004	2,381.0	2,023.9	101.8	1764.0	259.9	21.0
2010	3,538.0	3,007.0	84.8	2,054.1	953.0	24.2
2012	3,557.0	3,023.0	84.8	2,197.2	825.8	25.9

Source: MoFA (SRID/ Facts& Figures 2010, 2012) various reports.

2.6 EFFECT OF ORGANIC MANURE ON GROWTH, YIELD AND QUALITY OF CROPS

Experiment conducted by Premsekhar and Rajashree (2009) to determine the influence of different organic manures on the growth, yield and quality of okra. It was revealed that, all the organic manure used had positive impact on the yield and growth characteristics exhibited by the okra. They attributed this to the fact that the chlorophyll content in the leaves were significantly improved when organic fertilizer applied. The application of farm yard manure at 20 t/ha did better than the other treatments in terms of plant height, number and yield of fruits per plant increased. They explained that, the application of farm yard manure, which contained appreciable quantities of magnesium might have induced the synthesis of chlorophyll which in tend enhanced the rate of photosynthesis. Hence the higher yield observed. They attributed the increased yield to factors such as; the ability of the organic manures in the improvement of the physical and biological properties of the soil which resulted in better supply of nutrient and the increased solubilisation effect of plant nutrients leading to an increase in the uptake of NPK. They also said that farm yard manure helped the soil to improve its water holding capacity. For the quality characteristics, 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, Kipkosgei *et 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*). Incorporation of various concentrations of farm yard manure significantly improved the vegetative parameters such as plant height, plant width (girth), number of branches as well as number of leaves per plant. The above parameters improved with increasing levels of farm yard manure incorporated into the soils. The significant impact of farm yard manure compared with the inorganic N was observed in the improvement of the rooting system, girth and height of plants, number of bearing branches of the plants. This was attributed to the higher levels of N P K in farm yard manure compared to Calcium Ammonium nitrate. They also mentioned the possibility of lower leaching rate of nutrients due to improved soil texture, structure, water holding capacity as well as CEC associated with soils amended with farm yard manure. The ß-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 ß-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.

In an experiment to determine the growth and yield of roselle as affected by farmyard manure and intra-row spacing. It was revealed that plant height was significantly influenced by manure application. Plants that received higher dose of manure produced taller plants.

It was also found that manure application significantly increased the seed yield of roselle. This was attributed to the role of manure in increasing plant vigour (Tukur *et al.*, 2009).

Akparobi (2009) studied the effect of different level of farmyard manures on the growth and yield of *Amaranthus cruentus.* The amaranthus treated with the highest level of manure attained the highest plant height than those that received no manure. This was attributed to the optimum amount of manure which decreased the number of days required to attain full maturity, and increased the plant height of amaranthus. Farm yard manure increased the soil organic matter content and provided adequate soil nutrients. The result also showed that the increasing the quantity of manure applied triggered a corresponding increase in number of leaves produced per plant. The least average number of leaves per plant was produced by amaranthus that received no manure during the period under study. He reported that this was due to low organic matter content of the soil since amaranthus required soils with high organic matter content to enable it produce high leaf number and larger leaf surface area. He stated that low rates of fertilizer gave the least leaf number and leaf surface area per plant when compared to other higher level of fertilizer application in *Amaranthus*. The result also showed that fresh and dry weight per plant increased with increase in quantity of manure applied. Plants grown on soils amended with 35 t/ha manure recorded the higher fresh and dry weight as compared to those grown on soils amended with 25 t/ha, 15 t/ha, and 0 t/ha manure respectively. This was attributed to the fact that manure decreased the number of days from planting to first harvesting, increased the number of harvests before senescence since manure increased the organic matter content of the soil and improved the rate of growth as well as the production of fresh weight of *Amaranthus.*

In other research conducted by Gambo *et al*. (2008) to determine the effects of farmyard manure, nitrogen and weed interference on the growth and yield of onion, two field trials were conducted during dry seasons under irrigation. The results came out that, increasing rates of farmyard manure increased bulb yield of onion with the highest values at 30 tons/ha though this was not significantly different. The results showed that there is the tendency for higher onion bulb yield with higher application rate of farmyard manure. They reported that organic manure is a supplier of N, P and K in the soil, which also increased the phosphate solubilising bacteria in the rhizosphere, thereby increasing the nutrient status of the soil, resulting in increased yield. Seran *et al.* (2010) also accepted that, manure application increases the nutrient status of soil, with a correspondent increase in yield.

2.6.1 Effect of Poultry Manure on Soil Fertility

Poultry manure is an important source of plant nutrients and soil conditioner. The exchangeable bases in all the soil types increased with application rate, hence indicating positive effects on the nutrient status of the soil. Similarly, Dikinya and Mufwanzala, (2010) reported a significant increase in N and P when poultry manure was added to the soil. Adeleye *et al* (2010) reported that increase in soil and plant nutrients content were due to the application of cocoa pod ash and poultry manure because they contained macro and micronutrients. According to Adekiya and Agbede *et al.* (2009) poultry manure improved soil nutrient status by increasing soil organic carbon, total N, available P as well as exchangeable K, Ca and Mg. Ewulo *et al.* (2008) reported an increase in soil nutrient contents due to the application of poultry manure. Aluko and Oyedele (2005) reported that poultry manure improved soil moisture and was attributed to the mulching effect of organic matter and improvement in moisture retention as a result of improved soil structure, texture and aeration.

2.6.2 Effect of Poultry Manure on Growth and Yield of Crops

In an experiment conducted to evaluate the effect of plant nutrient source and weeding regime on the growth and yield of onion, poultry manure significantly produced the highest number of leaves per plant among the different sources of organic manure. It was also observed that poultry manure produced larger bulb size and the highest bulb yield than other fertilizer sources (Tukur *et al.,* 2009). The superiority of poultry manure over the other organic sources of plant origin with respect to number of leaves per plant, bulb size and bulb yield was attributed to the high nutrient content and its ability to release adequate nutrients to the plants, leading to the development of adequate leaf area index, which is necessary for assimilate production and translocation to sinks.

Dauda *et al.* (2008) investigated the efficacy of different levels of poultry manure on the growth and yield of watermelon (*Citrullus lanatus*). The results indicated that poultry manure application significantly enhanced growth and yield. They attributed the significant performance of watermelon over the control in growth parameters and yield to the fact that poultry manure contained essential nutrient elements associated with promotion of high photosynthetic activities and thus promotes vegetative growth. Increased number of fruits and average weight was attributed to the ability of poultry manure to promote vigorous growth, which is associated with increase physiological and meristematic activities in the plants as a results of the supply of plant nutrient and improved soil properties, thereby, enhancing the synthesis of more photo-assimilates, which is used in the production of fruits.

Hence, an increase in fruit number and size. Aliyu (2003) reported that poultry manure supplies nutrients, which enhance vigorous growth and increase yield.

Awodun (2007) carried out a study to find out the effect of poultry manure and NPK fertilizer on the growth, leaf nutrient content and yield components of Telfaria (*Telfaria occidentalis* Hook F) at two sites in Akure, Nigeria. The treatments applied were 0, 2, 4, 6 t ha-1 poultry manure and 250 kg/ha NPK 15-15-15 fertilizer. Application of 250 kg/ha of NPK fertilizer gave the highest number of leaves and stem girth at the two sites. He attributed this to high and fast release of nutrients in the NPK as against the use of the poultry manure. In an experiment involving the use of poultry litter for vegetable production, the level of poultry litter application affected carrot yield significantly.

Adekiya and Agbede (2009) found that application of poultry manure resulted in better growth and yield of tomato than NPK fertilizer alone. It improved the performance of tomato and its nutrient status. The finding that all levels of poultry manure performed better than the NPK fertilizer alone was attributed to the fact that poultry manure supplied more nutrients than NPK fertilizer. The poultry manure could have supplied micronutrients which are essential for tomato growth and yield. Stephenson *et al.* (1990) and Oladotun (2002) indicated that poultry manure contains micro and macro nutrients such as, Cu, Mn, Zn, Bo, Fe, N, P, K, S, Ca, and Mg. An experiment was conducted on single application of cocoa pod ash, poultry manure and their residual effects on soil chemical properties, nutrient content and yield components of maize. It was reported that the poultry manure increased grain yield than cocoa pod ash due to the lower C/N ratio of the poultry manure which ensured quicker release of N and P (Adeleye *et al*, 2010).

2.6.3 Effect of Cocoa Pod Husk on the Fertility of the Soil

Cocoa pod husk remains a major treat to farm sanitation but are important source of soil nutrient essential for the cultivation of a wide variety of crops (Adeyanju et al., 1975; Egunjobi, 1975; Oladokun, 1986). Close to 60% (wet basis) of cocoa pod is made up of husk. However it is assumed that 8,000,000 tons of the husk are discarded annually (Oyewole 2012).

Agyarko and Asiedu reported that, the application of these agricultural wastes significantly ($p \leq 0.05$) increased the soil pH (H_2O), Exchangeable Cations, ECEC, Base Saturation, NH_4^+,-N, NO_3 – N and Available P over the control. Whereas the sole CPH amended soil, gave the highest K (0.46me/100g soil) among the treatments. This trend, they observed, might have arisen from the higher P, Ca and Mg content in the PM and the higher K content in the CPH used in the soil amendment. Onwuka *et al*. (2007) also reported that CPH has high levels of K and hence capable of enhancing soil nutrients levels especially in situations where K is lacking.

Agbor *et al*. (2012) also reported on the ameliorating potential of CPH and Plantain peels on crude oil polluted soils. Their investigations showed that, there was significant reduction ($p \leq 0.05$) in the total petroleum hydrocarbon of CPH-amended soils. This result indicated that the TPH degraded in cocoa pod husk (CPH) amended soil was higher compared to that of plantain peels (PP) and the combination of cocoa pod husk and plantain peels (1:1) amended soil. However in all the amended soils, high concentration (500g) of the agro-wastes showed a significant reduction ($P < 0.05$) in TPH than the lower concentration

(400g) of the agro-wastes. This observation is in support of the earlier findings of Moyin-Jesu (2008), who reported also that cocoa pod husk increases magnesium, pH, nitrogen, phosphorus, potassium, calcium and organic matter content of the soil, when he assessed its use in enhancing the fertility of the soil for the growth and performance of coffee seedlings (*Coffee arabica*). Agbor *et al*. (2012). From his results suggested that cocoa pod husk and the combination of cocoa pod husk and plantain peels possess bio-utilizing potentials than plantain peels alone.

2.6.4 Effect of Cocoa Pod Husk on Growth and Yield of Crops

The use of organic sources of fertilizer would reduce farmers' expenditure in purchasing inorganic fertilizers thereby saving money for other farm activities. Cocoa pod husk used as soil amendment has proven to be effective in reducing soil fertility when it was tested on some crops. There was a significant ($P>0.05$) increase in the growth and fruit yield (177%) when cocoa pod husk was used as soil amendment Odedina *et al.* (2007).

Ajayi *et al*. (2007) also reported that cocoa pod husk enhanced the growth of kola (*Cola nitida*) because of the high levels of nitrogen and phosphorus it contains. Ayeni (2008) in his research to investigate the application of cocoa pod ash and NPK fertilizer on the yield of tomatoes reported that, the highest level of combinations (C5F100 and C10F100) had the highest agronomic parameters. C10F100 had highest number of leaves, leaf area and fruit yield. He reported that the least amount of N, P and K found in tomato leaves planted on the control suggested that cocoa pod husk supplied sufficient amount of NPK to the soil. In addition, soils amended with cocoa pod husk and its combination with NPK recorded high levels of soil organic matter, N, P and K as compared with those grown on the soils without any amendment which had lower SOM, N, P and K thus translating into relatively lower leaf N, P and K content. The reduced level of NPK fertilizer combined with cocoa pod ash became more effective in the increment of tomato fruit yield as compared to the single application of cocoa pod ash and NPK fertilizer. Combination of NPK and cocoa pod ash fertilizer significantly improve soil fertility.

The combined effect of cocoa pod ash and NPK fertilizer on the improvement of soil fertility was confirmed by the findings of Ayeni (2010) that N, P and K strongly influenced the growth and yield of tomato. Tripathi *et al.* (2004) reported the indispensability of N and P, thus, they are indispensable on the better performance of tomato.

2.6.5 Effect of NPK on Soil Fertility

Inorganic fertilizers are used in modernized agriculture for various reasons. Notable among them include; correction of known plant nutrient deficiencies, to provision of high levels of soil nutrient, which aid plants in over-coming stress conditions by maintaining optimum soil fertility as well as improving quality of crops. To sustain optimum net returns on crop productivity adequate supply of fertilizer becomes very important. (Leonard, *et al* 1986). It is therefore essential to ensure that soil fertility is not a limiting factor in crop production.

The continuous usage of chemical fertilizer has not been beneficial under intensive system of agriculture since it is often associated with reduced crop yield in the long term.

Some of its negative effect includes soil acidity and nutrient imbalances (Ojeniyi, 2000). Repeated application of inorganic fertilizers results in soil degradation which is induced by the loss of organic matter as results of continuous cropping. The response of crop to fertilizer applied is as a result of the organic matter content of the soil (Hayners and

Naidu 1998).

2.7 EFFECT OF SOIL AMENDMENT ON THE YIELD OF PLANTAIN.

Decline in the yield of *Musa* species could be partly due to low soil organic matter and associated poor soil fertility, hence the need for incorporation of external nutrient to boost the level of yields. Best practices in fertilizer application includes correct rate of application, correct timing and place.

Nonetheless, maintaining soil fertility through appropriate crop management practices on the farmers' field goes a long way to sustain the yields of a *Musa* species. Continued land degradation and rapid population growth pose serious threat to soil fertility management especially in the tropics (Scherr and Yadav 1996). For sustaining and improving yields input of external nutrient source cannot be over emphasized (Lal, 2006). In a research conducted by Zake *et al*. (1996), they compared different methods of applying coffee husks, where they concluded that the most effective option was the combination of applying half dose to the subsoil within the root zone and the half on the surface. These application methods improve soil fertility, root system and yield of banana and plantain. Improved root growth, yield of plantain as well as the reduced susceptibility of plantain has been associated with the beneficial effect of mulching (Banful *et al.*, 2000). Baiyeri and Tenkouano (2008) reported that manure placement might have improved significant plant growth and biomass yield which presupposed the effectiveness of manure in releasing nutrients and making it available for plant roots for absorption, utilization and eventually growth.

The nutritional requirements of Bananas just like plantain are high and they are partly supplied by the soil (Lahav, 1995). Lots of research have recommended various

combination of inorganic fertilizers for plantain production in both Nigeria and Ghana (Ndubizu, 1981; Obiefuna, 1984; Baiyeri, 2002; Swennen, 1990). However, the expensive nature of inorganic fertilizers makes it inaccessible to subsistence farmers (Brandjes *and* Agromisa 1989). Organic manure are readily available, cheaper and constitute a valuable source of organic matter and nutrients which can obviously improve soil physical conditions (Munoz et al., 2004). Improving the bio-physical condition of the soil must go hand in hand with increasing the levels of organic matter content which in effect will sustain productivity. Hence, the application of manure or compost or both may increase soil nutrients and organic matter, with long lasting residual effects on soil properties and sustainable crop yields (Eghball *et al.*, 2004).Some soils supporting plantain production in Ghana and West Africa as whole, to a large extent are of low productivity (Sanginga and Woomer, 2009 Swennen, 1990). The rampant decline in
yields of plantain are attributable to constraints in dwindling soil fertility. (Irizzarry *et al*., 1989; Swennen, 1990).

Fertilizer application and mulching of plantain with organic materials which constitute good agronomic practices should be adopted to enhance the productivity of the plant (Swennen, 1990). Nevertheless, in tropical soils, nutrient like potassium which very essential to plantain growth are always in limited supply (Yayock *et al.*, 1988). The addition of potassium to the soil takes several forms; either through direct application of inorganic fertilizers, manure or ash and return of crop residues. The production of plantain under intensive and continuous system, inorganic fertilizers becomes the most appropriate option for the supply of plant nutrient.

2.8 GROWTH AND YIELD INDICES

2.8.1 Harvest Index

An important trait in the determination of yields in crops is the ratio of fruit weight to total plant weight. The increment in these ratio is an essential in plant harvest index. The vegetative parts of the plant above the surface of the soil as well as the fruit weight sums up the total plant weight. Hay, (1995) describes plant harvest index as the economic yield by the total plant yield. Accumulation of photosynthate between the vegetative part of the plants and the fruits reviews the harvest index. However improvement of harvest index relies on the allocation of carbons in fruit production. Morphological changes are evident during maturation. Morphological changes that take place during fruit maturation includes increase in stem girth relative to length, fruit weight, bunch weight, number and weight of fruits, and pulp to peel ratios. Skin colour, size, shape, angularity and the nature of the styler end are some of the visual changes that occur concomitantly with other physiological changes such as aroma, texture and taste. The variety, breed or cultivar type to a large extent determines the characteristics of fruits during maturation (Strosse *et al*., 2006; Falade and Oyeyinka, 2014).

2.9 PLANTAIN MATURITY INDICES

Determination of maturity standards are more pronounce in plantain compared to banana. Maturity in plantains are determined by several distinct internal and external characteristics. Notable among them are age of the bunch, length of the fruit, fruit diameter, angularity of the fruit, and the colour of the peel. The diameter of the fruits depicts the maturity status of the finger. The diameter is determined through the measurement of the fruit at its middle section with a pair of calipers (Kader and Rolle, 2004). Recording the bunch age is another way of determining maturity in plantain. Though cumbersome, this can be done by recording the time from when the bunch becomes visible.

2.9.1 Method of Harvesting

The normal standard way of harvesting plantains is to cut partly through the pseudostem approximately 2 m from the ground. The weight of the bunch induces the pseudostem to bend. This allows for the cutting of the bunch which is now within the reach of the farmer (Kader and Rolle 2004).

2.10 FLOUR PRODUCTION

2.10.1 Pre-Drying Operations

Harvesting and handling procedures prior to drying are very essential in enhancing the quality of the final products. According to Brenndorfer *et al*. (1985), pre-drying procedures may include cleaning, grading, sorting and sizing, peeling, (coring, pitting, trimming), cutting (slicing), blanching, use of additives, sulphuring, salting or sugaring.

The sequence and specific procedures depends on the crop to be dried.

2.10.2 Drying Operations

There are two basic sequence involved in drying operations, namely: movement of moisture from the interior part to the surface and evaporation of moisture from the surface. Evaporation rate is dependent on the difference between the saturated vapour pressure of water at the surface temperature, and the partial vapour pressure of the water in the adjacent air. In practical terms the warmer the air the greater the difference between saturated vapour pressure (Ps) - actual vapour pressure (Pa) and hence the greater the rate of evaporation; the more humid the air the smaller the Ps-Pa and hence a lower rate of evaporation

(Brenndorfer *et al*., 1985). Drying can be done by various means including the use of solar and oven dryers.

2.10.3 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 forms 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. Jackfruit seed flour has high carbohydrate, especially fibre and other nutritional content (Jinshui *et al*., 2002). The seeds are thus blended into flour and mix with other flours in baking (Verheij, 1991). The amount of protein (gluten) in flour predicts its bread-baking quality for plain white flour Appiah *et al.* (2011).

2.11 FUNCTIONAL PROPERTIES

Matil (1971) defined functional property as the properties that affect the quality and acceptability of food as the characteristics that governs the behavior of nutrients composition are altered during storage, processing and preparation into various forms.

2.11.1 Bulk density

Bulk density is defined as the ratio of weight of flour to flour volume in grammes per centimeter cube, (Subramanian and Viswanathan, 2007). It is a measure of heaviness of a flour sample. Bulk density is directly proportional to starch content of flour (Oti and

Akobundu, 2007) and increases with increase in starch content (Bhattachrya and Prakash, 1994). Therefore, in the food processing industries, knowledge of bulk density provides an idea of the amount of starch in the food material and also how the individual particles of the flour can arrange themselves in a compact manner. Bulk density helps in determining suitable packaging materials and requirements of the flours as it relates to the load the sample could carry if allowed to rest directly on one another (Appiah *et al*., 2011). It gives a measure of the mass relative to the space occupied by the food substance. High values are indicative of high cost of packaging (Oluwatooyin *et al*., 2002) as more materials would be required.

There significant differences ($p<0.05$) in the bulk densities of starch samples stated by Ojinnaka *et al*. (2009) when they studied the effects of starch modification on sensory, cookies qualities as well as functional properties of cocoyam. This was noted when the starch samples were subjected to acid and enzyme modification treatment. The highest bulk density (0.75g/ml) was recorded by samples treated with acid and enzymes whereas the least values (0.62g/ml) were recorded by native starch. Increases in starch content triggers a correspondent increase in bulk densities of flour samples (Bhattacharya and Prakash, 1994). The outcome of the research reviewed that, the bulk densities of modified starches will be most appropriate for energy foods whereas that of the native starch will be appropriate for developing foods that require more protein. Also high density of protein substances are influential on the packaging of the food sample (Okezie and Bello, 1988). Meanwhile, products that exhibit higher bulk density are more likely to exhibit better packaging properties than those with low bulk density. Mouth feel and flavor are known to be related to bulk density of food products. Etudaiye *et al.*, (2009) also documented that particle size distribution of flour samples are a true reflection of bulk density which is also affected by moisture content of the flour.

2.11.2 Solubility

The indication of water penetration ability of granules of starch reflects its solubility. In the manufacturing of confectionaries goods, absorption and retention of water to increase swelling power of starches could be achieved through the modification of starches (Ikegwu *et al*, 2010). Increased solubility is enhanced by swelled starch granules which is also facilitated by the increased leaching of solubilized amylose molecules. (Tumaalii and Wooton, 1988). On the other hand, Doublier *et al.* (1987) and Shamekh *et al.* (1994) demonstrated that removal of lipid from oat starch triggered an increment in solubility.

Pomeranz, (1991) in his research indicated that, high amount of fat and protein which might form inclusion complexes with amylose are probably responsible for the strong bonding forces as a results of the solubility and swelling power of flour.

There were no significant differences recorded for solubility values for cocoyam starch samples. These values ranged from 10.00 to 26.67% (Ojinnaka *et al*. 2009).

In another research by Bremiller (1993), increased solubility of starches could be attributed to starch modification. High swelling power and swelling volume could be due to low solubility of good quality starch with high starch content (Bainbridge *et al*., 1996). Gel food and aqueous emulsions preparation, maximum solubility of protein is useful for flours with good nitrogen solubility (Akinyele *et al.*, 1986). In food preparations where maximum solubility of protein is desired, as in aqueous emulsions and gel food preparations, flours with good nitrogen solubility are useful (Akinyele *et al.*, 1986). Associative binding forces within starch granules are the evidence for the existence of solubility and swelling power (Aryee *et al.,* 2006).

2.11.3 Swelling Power

The ratio of weight paste to the weight of the dry flour sample defines the swelling power of the flour (Crosbie, 1991). In heating granules, the index of water absorption determines the swelling power (Loos *et al*., 1981). Dengate (1984) stated that swelling power shows basically the exudation of amylose resulting from the swelling of granules. Also in initiating changes in hydration related properties, starch granule swelling marks the beginning of the first stage (Aguilera, *et al*. 1991).

Swelling takes place when aqueous suspension of starch granules are heated and their structures hydrated. King (2005) and June *et al*. (1991) reported that starch granules in suspension swell when heated, the granules continue to swell so long as the temperature is raised, water molecules become attached to liberated hydroxyl groups since hydrogen bonds are continuously disrupted. Usually the higher the swelling power, the more

soluble the flour is in a solution.

According to Galvez and Resurreccion (1993), the classifications of starches are; highly restricted swelling, high swelling, moderate swelling and restricted swelling. At temperature of 95^{0}C high swelling starches have swelling power of approximately 30% or higher. When the starch is cooked in water, there is an enormous swelling of their granules making their internal bonds to swell and becoming fragile toward shear. At the swelling power range of 16 to 20% at temperature of 95^{0}C restricted swelling starch takes place.

There significant differences among pretreated starch samples as elucidated by Ojinnaka *et al*. (2009) native starch recorded the least swelling index whereas acid treated starches registered the highest swelling index (Ojinnaka *et al*., 2009). Various modifications gave rise to variations amongst the swelling indices as indicated in the results. The differences in molecular organization reflects the differences in swelling power (Adebowale *et al*., 2005).

2.11.4 Water Absorption Capacity

Water absorption capacity of flour is defined as the differences in weight of the flour before and after water absorption, (Abbey and Ibeh, 1988). Improvement in food consistency depends on the ability of starch or flour to absorb water and swell. To give to improve yield, consistency and give body to the food water absorption capacity becomes handy. In foods such as sausage, custard and dough water absorption capacity is an essential functional property (Adebowale *et al*., 2005).

Water absorption capacity is specific for each type of starch, and it depends on several factors such as amylose: amylopectin ratio, intra and inter molecular forces and size of granules, (Rahman *et al*., 1999). The higher the water absorption capacity the smaller the size of the granules (Singh *et al*., 1991). Precious processing methods such as heating and akali processing, composition and protein source are some of variables that determines water absorption capacity (Ikegwu *et al*., 2010). The shape and size of protein molecule, temperature, pH and ionic strength are the some of the functions of water absorption capacity. According to Etudaiye *et al*. (2009) water absorption capacity is increased during heating as gelatinization of carbohydrates and swelling of crude fiber are most likely to occur. Edema *et al*., (2005) reported that, the amount of water available for gelatinization is a reflection of the water absorption capacity of flour. In aqueous food formulation, specifically those involving handling of dough such as processed cheese, sausages and bread dough, water absorption capacity becomes very essential indicator of whether protein could be incorporated (Osungbaro *et al*., 2010).

Oluwatooyin *et al.,* (2003) measured the oil and water absorption capacities as well as least gelation concentration of white and red sweet potatoes varieties. Meanwhile their water absorption capacity was improved through parboiling (173% and 175 for white and red potatoes respectively). This becomes important when potato flour is desired as a thickener, parboiling enhances the stability of colour of potato and stop enzymatic as well as the anti-nutritional activity of the flour. It was also noted that both varieties of red and white potatoes starch had the similar water absorption capacities. Hence, the not parboiled form of sweet potato flour may be used effectively in food processing systems as a binding agent. However, similar gelation properties were shown as the starches did not show any significant differences in their water absorption capacity. In general, water absorption capacity of the white and red varieties of potatoes were similar, notwithstanding, the white variety was slightly higher

Water absorption capacity (75%) was found be higher in unripe plantain flour sample as compared to the firm ripe plantain flour (60%) (Idoko and Neajiaku 2013). They further emphasize that, water absorption capacity of the unripe plantain flour was as a result of high amount of hydrophilic carbohydrates in the samples. This they suggested the flours suitability in product formulation such as bakery products where hydration is needed to improve handling characteristics.

Odoemelam, (2000) suggested that, flours with high water absorption capacity is an indication of the possible presence of some hydrophilic polar amino acids or proteins residue in the four. In another research conducted by Kaur and Singh (2005), they suggested that flours with high levels of hydrophilic constituents, such as polysaccharides, have higher water absorption capacity. Increase in water absorption capacity may be due to effect of water adsorption via existing polar binding sites distributed over the protein surface, and molecular rearrangement leading to the exposure of more polar binding sites. The compactness of the molecular structure is an indicative of the water absorption capacity, as lose structures of starch polymers have higher water absorption capacity compared to compact structures (Sanni *et al.* 2006).

2.11.5 Oil Absorption Capacity

The difference in weight of flour before and after oil absorption is described as oil absorption capacity of the flour (Giami *et al.*, 1994). In food formulations oil absorption capacity is very essential functional traits. The mouth feel as well as the flavor of food products are improved through the products' oil adsorption capacity. In addition, flavor retaining capacity of flour is an indication of oil absorption capacity (Narayana and Narasimga, 1982), therefore it very important in food formulations (Odoemelam, 2000).

Meanwhile in research conducted by Appiah *et al.* (2011) on the oil absorption capacity of breadfruit, they obtained values ranging from 0.50 ml/g to 1.25 ml/g. They reckoned that the figures recorded for their studies were comparatively lower than the figures (2.8ml/g) in a similar research conducted by Odoemelam (2005) for the same breadfruit species. In other instance, oil absorption capacity recorded by *Artocarpus spp* (Appiah *et al.*, 2011) had figures higher than mucuna bean (2.2g/g) reported by Udensi and Okoronkwo (2006). In effect flours produced from *A. camansi* and *A. heterophyllus* may have lower flavor-retaining ability than the other flours due to the lower oil absorption capacities figures (0.5ml/g).

In other research conducted by Oluwatooyin *et al*. (2003) where they compared the oil absorption capacities of the flours and starches of red and white potatoes, there were no significant differences between parboiled and native flours and again between flours and starches of both white and red varieties. The parboiled red variety potatoes flour recorded lower oil absorption capacity compare with the red native potato flour which recorded higher figures. There was a 25% reduction of oil absorption capacity of red potato flour which can be attributed to parboiling. Consequently, toasted wheat flour as well as native and toasted African breadfruit kernel recorded higher oil absorption capacities (148% and 91%, 96% respectively) compare with those recorded by both red and white sweet potato products. This he attributed to the lower protein content of sweet potato preparations (4.38-8.75%) as compared to African breadfruit kernel (17%) and toasted wheat flour (10%). The reason for this, they attributed to high levels of protein in both toasted wheat flour (10%) and African breadfruit kernel (17%) compared to lower protein content of sweet potato preparations (4.38-8.75%).

2.12 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 sheer 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 (Etudaiye *et al*., 2009).

2.12.1 Gelatinization

When starch is heated in the presence of sufficient quantity of water, its granules swell, and the crystalline organization in starch decomposes (Donovan, 1979) to form amorphous regions. This molecular disordering and disintegration is known as gelatinization and is manifested by irreversible changes in properties (Rojas-Molina *et al.*, 2007). Series of changes take place during the heating of a starch-water system, these include; enormous swelling, increased viscosity, translucency and solubility. These changes are known as gelatinization (Ikegwu *et al*, 2010). Water first enters the amorphous growth rings, causing these regions to swell (Jenkins and Donald 1998). After a sufficient amount of water enters the amorphous regions, a large amount of swelling occurs, providing sufficient stress through connectivity of molecules from the amorphous growth ring to the semi-crystalline lamellae, resulting in the disruption of starch crystallites, which is showed by the loss of crystallinity. Huang *et al.* (2007) however, indicated that amylopectin molecules are involved. Gelation of protein also take place in flour pastes and is very essential for the preparation of puddings, jams and sauces that require jelling and thickening. Some kinds of proteins form gels through interactions with polysaccharide gelling agents such as starch and gelatin (Nunoo, 2009).

2.12.2 Role of Starch

According to Adebowale *et al*. (2005) starches are the principal food reserve polysaccharides in plants and are of both nutrition and economic benefit in human diets. Starches with their wide applications and importance have generated demand in the food industry. Starches are normally converted to lot of important materials through biochemical and chemical techniques (Eliasson and Gudmundsson, 1996). Starches play useful roles in food preparation and food industries because it affects the physical properties of many foods and it has many uses such as thickening, water binding, emulsion stabilizing and gelling. Starches are obtained from various plant sources in view of this, they have their own peculiar characteristics that enable them to tolerate a wide range of processing techniques as well as various storage, distribution and final preparation conditions (Daniel and Weaver, 2000; David and William, 1999; Buleon *et al*., 1998).

According to Hoover *et al*. (1991) starch granules can be separated into two distinctly different components, amylose and amylopectin. Various physical treatment can be employed to alter the molecular arrangement of starch granules. Adebowale *et al*. (2005) reported that physical treats can change certain starch properties. Starch characteristics such as solubility pattern and swelling power, pasting behaviour and physico-chemical properties are very necessary for improved quality of food products and can be utilized for the development of composite blends from small scale industry level as value-added products (Ikegwu *et al*, 2010)

2.14 SIGNIFICANCE OF PASTING PROPERTIES

2.14.1 Pasting/Gelatinization Temperature

Pasting temperature is the temperature at which the paste gel during cooking. Shimelis *et al*. (2006) stressed that, the minimum temperature required for sample cooking, energy costs involved and other components stability are strongly influenced by pasting temperature. It has implications on the formula components of food and the products stability and also indicates energy loss (Etudaiye *et al.,* 2009). Gelatinization temperature has been known to be dependent on the granule size of starch; smaller granules are more resistant to rupture and loss of molecular order (Rincon and Padilla, 2004). High gelatinization temperature of starches indicates that the starch granules resist swelling.

Cooke and Gidley (1992) reported that, stronger crystalline structures or more molecular orders are true reflection of higher pasting temperatures. Higher pasting temperatures may be linked to the presence of stronger bonding forces with the granules interior bonds (Opata *et al.*, 2007). Ikegwu *et al*. (2009) attributed high pasting temperature to amylopectin's high crystalline nature which is known to resist gelatinization compared with amorphous amylase.

2.14.2 Peak/Maximum Viscosity

Peak viscosity is the highest viscosity achievable during cooking of flour pastes. It is the maximum viscosity developed by a starch-water suspension during heating (Adebowale *et al*., 2005). Before the physical breakdown of starch, peak viscosity provides an indication of the ability of the starch granules to swell freely. It is a useful distinguishing factor of a given starch from given species (Rincon and Padilla, 2004). Variation in the peak viscosity could be attributed to the presence of amylose in the starch (Oledinma *et al.*, 2009).

Relatively high peak viscosities of starches are indicative that the starches may be conducive for food products requiring high gel strength and elasticity (Ikegwu *et al.*, 2010). According to Opata *et al. (*2007) peak viscosity is linked to the ease of cooking and indicative of the strength of pastes which form gelatinization during processing in food applications. Ghiasi *et al.,* (1982) documented that, the removal of water from the exuded amylose by the granules as they swell may be attributed to an increase in viscosity with rising temperatures. The action of protein and fat stabilizers which prevent water from coming into contact with the granules culminating in a decrease in the swelling of starch granules might be due to low starch viscosity. (Opata *et al*., 2007).

Jacobs *et al.,* (1995) indicated that, viscosity development in starch paste during heating can be attributed to the formation of tightly packed array of swollen and deformable granules and the leaching of amylose According to the authors, the rigidity of starch granules are more resistant to shearing in the sense that, rigidity of granule increases due to insufficient gelatinization resulting in higher viscosity of paste. Increases in swelling power and solubility lead to a correspondent increase in viscosity because better starch dispersion in aqueous systems and water absorption are achieved due to hydrophilic substituting groups that allow the retention of water molecules because of their ability to form hydrogen bonds (Acona *et al*., 1997).

On the other hand higher peak viscosity of pastes implies ability to form thicker pastes on cooking due to higher swelling power of starches (Otegbayo *et al*., 2006). Sandhu and Singh (2007) showed that there is a significant negative correlation (r = -0.86) between protein content and peak viscosity of corn flour. Amylopectin increases peak viscosity due to high water binding capacity of the starch granules while oxidized amylose result in low peak viscosity indicating low water binding capacity of the starch (Ikegwu *et al*., 2009).

2.14.3 Setback

The difference between the hot paste viscosity or trough and the final viscosity, gives the setback value. Setback is the measure of paste stability after cooking. During cooling of the mixture, a re-association between the molecules of starch takes place on a greater or lesser extent at the setback phase. Setback viscosity gives an indication of retrogradation or reordering of starch molecules during heating. Hence, its affects re-ordering or retrogradation of the starch molecules. It is also associated with syneresis. Low set back values indicate high stability (Etudaiye *et al.*, 2009) of paste and greater resistance to retrogradation (Sanni *et al.*, 2004) and syneresis. The general term for the behavior of recrystallization of gelatinized starches on cooling and storage which is followed by gel hardening and the leakage of water (syneresis) from the starch gel is termed as retrogradation (Nunoo, 2009). Peroni *et al*. (2006) indicated that flours with low setback may have low values of amylose which have high molecular weight. Decrease in viscosity on cooling shows the absence of setback or retrogradation (Aryee *et al.*, 2006). Flours which give a non-cohesive paste is a clear indication of low setback value (Kim *et al.*, 1995). For products in which starch with high stability is required at low temperatures, (such as adhesives) starches of this nature will not be conducive or useful. Bajner (2002) observed that the addition of stearic acid to maize starch resulted in reduced viscosity on cooling due to setback.

Increase in setback may be attributable to higher starch concentrations encouraging the formation of a more ordered structure, which in turn trapped enough water, forming stronger gels with higher viscosities. This phenomenon may increase the tendencies for retrogradation accompanied by syneresis (Nunoo, 2009). The lower the retrogradation, the higher the setback value, during cooling of the products made from the flour (Ikegwu *et al*, 2010). For starches used as food ingredient in the processing and preservation industries, setback viscosity is an important factor that should be put into consideration, because the quality of food and physical properties deteriorate due to retrogradation as time passes. Kim *et al*. (1995) has indicated the association of setback values with cohesiveness of paste in potato. Oladele and Aina (2007) have attributed low setback and breakdown (i.e. good stability to heating and mechanical shear) viscosities of tiger nuts to their high fat contents (32.13%-35.43%).

2.14.4 Hot Paste Viscosity

Carnali and Zhou, (1996) stated that, the additional breakdown of granules due to stirring which reflects the stability of the hot paste is an indication of the hot paste viscosity at 95^{0}C. The tendency of the paste to breakdown during cooking is a measure of the hot past viscosity. Gebrie-Mariam *et al (*1998) documented that, the mixed effect of swollen starch granules, dispersed colloidal starch molecules, granule fragments, dispersed molecules of starch, rate of amylose exudation, and competition between exuded amylose and remaining free water has been attributed to hot paste viscosity (Gebrie-Mariam *et al*., 1998).

Very weak cross-linking within the starch granules is attributable to high paste stability. For products where starch stability is required at very high temperatures, starches of that nature cannot be used, since they will breakdown easily (Aryee *et al.,* 2006). Lower breakdown of hot paste is attributable to a starch maintaining its structural integrity under shear and heat implying such starch could be appropriate for used in food products that require continuous heating such as those for children and the aged (Gebrie- Mariam *et al*., 1998)

2.14.5 Cold Paste

According to Carnali and Zhou (1996) the cold paste viscosity at 50^{0}C is an indicator of stability of the cold paste. As the temperature of the paste decreases, increase in cold paste viscosity is an indication of the elements present in the paste. Rincon and Padilla (2004) reported that the extent of increase in viscosity on cooling hot starchy paste is governed by the starch tendency to retrogradation and is mainly attributed to the affinity of hydroxyl groups of one molecule for another. Gel formation occurs when amylose molecules which is randomly dispersed orient themselves in a parallel fashion to form aggregates of low solubility. Increase in viscosity on cooling is attributable to high retrogradation tendency of the amylose fraction (Rincon and Padilla, 2004).

2.14.6 Breakdown

Low breakdown is indicative of good paste stability. Food products such as soups and sauces, which undergo loss of viscosity and precipitation as a result of retrogradation, smaller tendencies to retrograde is an added advantage (Adebowale and Lawal, 2003a). Higher breakdown values of pastes imply that there is less granule rupture in a starch implying stability of paste (Farhat *et al*., 1999). Oduro *et al.* (2000) explained that starches with low paste stability or breakdown show weak cross-linkages among the starch granules. During cooking the higher the breakdown in viscosity, the lower the ability of the sample to withstand heating and shear stress (Ikegwu *et al*., 2009)

2.14.7 Final Viscosity

The change in the viscosity after holding cooked starch at 50°C represents the final viscosity. It gives an idea of the ability of a material to form gel after cooking. The stability of the cooked paste in actual use and the particular quality of starch gives an indication of the final viscosity. The ability to form paste or gel after cooling are also an indication of the final viscosity. (Ikegwu *et al*, 2010). In addition it is the most predominantly used indicator to determine a particular starch-based food sample quality (Sanni *et al*., 2006). Increased final viscosity on cooling is indicative of a starch forming firm gel after cooking and cooling. It can be an essential indicator in predicting and defining the final textural quality of pounded yam with regards to its springiness (Otegbayo *et al*., 2006). Variation in the final viscosity might be as a result of modification of the native amylose (Ikegwu *et al*., 2009).

2.14.8 Peak Time (Time Taken to Reach Peak Viscosity)

Peak time is the time at which the peak viscosity occurs (Lawal *et al*., 2004). During cooking the time it takes the paste to gel represents peak time.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 EXPERIMENTAL SITE AND LABORATORY LOCATIONS

The experiment was conducted on the research field of Council for Scientific and Research Institute located (Horticultural Department Kwadaso Kumasi) at Kenyasi in the Brong Ahafo 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 7^0 03’.631’’North and longitude 2^0 29’.424’’ west.

The experiment comprised field and laboratory work**.** The field work sort to find out the influence of soil amendments on growth and yield of plantain whereas 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).

3.2 SOURCE OF POULTRY MANURE AND COCOA POD HUSK

Poultry manure was obtained from a commercial poultry farmer in the Kumasi Metropolis. Cocoa Pod Husk was also obtained from a local farmer in Kenyasi.

3.2.1 Preparation and Application of Treatments

The poultry manure was kept for period of three (3) months to allow decomposition and elimination of heat. Poultry 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 x8m^2.

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). These treatments were administered on a previously analyzed soil to ascertain its true nutrient status.

3.3 DATA COLLECTED FROM EXPERIMENTAL FIELD

3.3.1 Plant Height

The height of plants during harvesting was taken with the aid of tape measure. The height was taken by measuring the pseudosterm from the base to the point of emergence of the bunch stalk.

3.3.2 Stem Girth

The circumference of the pseudosterm is taken with the aid of measuring tape. The girth was taken by measuring the circumference of the plant 50cm above the base.

3.3.3 Number of Suckers

The number of suckers (plantlets) that has emerged from the parent plant was counted during harvesting.

3.3.4 Weight of Bunch

The bunch weight was taken with aid of spring balance. The bunch weight includes the hands (which is made up of the fingers) and the stalk.

3.4 DATA COLLECTED AT THE LABORATORY

3.4.1 Number of Hands and Fingers/Fruits

The number of hands and fingers of each of the samples were counted at the CSIR laboratory (Horticultural Department Kumasi) and also at the Department of Horticulture laboratory.

3.4.2 Average Finger/fruit Weight

One finger was taken from each of the four hands of the bunch and weighed. The weight of the four fingers were divided by four (4) to determine the average finger weight of that particular bunch.

3.4.3 Average Finger/Fruit Length

Four (4) fingers taken from each of the hands were measured with the aid of tape measure. The average finger length was determined by adding up the four finger length and dividing by four.

3.4.4 Average Finger Girth/ Circumference

With the aid of caliper, one finger from each of the four (4) hands was used in determining the average finger girth. The mid-section of the finger was measured as the girth of the finger. The values generated from the four fingers were added up and divided by four to arrive at the average finger girth.

3.4.5 Average Peel Thickness and Peel Weight

Four fingers selected from each hand were peeled and the peels are weighed on a scale. The thickness of the peels was also determined with the aid of calipers. In both cases the values for the four fingers are added up and divided by four to arrive at the various averages.

3.4.6 Pulp Thickness and Pulp Weight

Each of the four fingers are peeled and weighed on a scale to determine their weight. The thickness of the four pulp are also taken at the mid-section of the pulp with the aid of a caliper. The averages are noted by dividing the values obtained by four.

3.4.7 Pulp to Peel Ratio

The average of pulp weight of a particular sample was divided by the average of that peel weight of that sample to obtain the pulp to peel ratio.

3.5 COLLECTION OF SOIL SAMPLES

Two groups of soil samples were taken and analyzed. The first soil samples were taken at different locations on the experimental site at a depth of 0 – 20cm before application of treatments. The samples were bulked and analyzed for available nitrogen, phosphorus, potassium, organic carbon, organic matter, exchangeable cations, C/N ratio and pH of the soil. The final soil samples were taken from the different treated plots at harvest at (0 – 20cm) and analyzed for available nitrogen, phosphorus, potassium, organic carbon, organic matter, exchangeable cations, C/N ratio and pH of the soil.

3.6 SOIL CHEMICAL ANALYSIS

Soil samples were taken at a depth of 0-20cm at the beginning of the experiment and at harvest. These samples were taken to the laboratory to determine their chemical properties. The samples were dried and sieved using a 2mm mesh sieve. The following properties were determined.

3.6.1 Organic Carbon

The Walkley-Black wet combustion procedure (Nelson and Sommers, 1982) was used to determine organic carbon.

3.6.2 Soil pH.

This was measured in 1:1 soil to water suspension by the use of a glass Electrocalomel electrode (Mclean, 1982) pH metre.

3.6.3 Total Nitrogen

The Macro Kjeldahl method described by Bremner and Mulvaney (1982) was used. A 10g soil sample (< 2mm in size) was digested with a mixture of 100g potassium sulphate, 10g copper sulphate and 1g elenium with 30mls of concentrated suferic acid. This was followed by distillation with 10ml boric acid (4%) and 4 drops of indicator and 15mls of 40% NaOH. It was then titrated with Ammonium sulphate solution. Based on the relation that 14g of nitrogen is contained in one equivalent weight of NH3, the percentage of nitrogen in the soil was calculated as follows:

$$\% \text{ Nitrogen } \frac{14\times(A-B)\times N\times 100}{1000\times 1}$$

Where,

A = Volume of standard acid used in the titration.

B = Normality of the standard acid.

3.6.4 Potassium

The flame photometre method was used to determine the amount of potassium with ammonium acetate as the extractant (Simard 1993).

3.6.5 Available phosphorous

The Bray-2 P method was used for the determination of phosphorus with dilute acid fluoride as the extractant (Ziadi and Tran 2007).

3.6.6 Exchangeable Bases (Ca, Mg, K, Na)

The exchangeable base cations were extracted using ammonium acetate (NH_4OAc) at pH of 7.0.

Magnesium and Calcium were determined by using the method of EDTA titration (Moss, 1961) while sodium and potassium were determined by using the flame photometer method.

3.7 ANALYSIS OF CHEMICAL COMPOSITION OF TREATMENTS

Poultry Manure and Cocoa Pod Husk were subjected to chemical analysis at the laboratory to ascertain their true nutritional content before applying them to the soil. They were analyzed for percentage Nitrogen, Phosphorus, Potassium, Calcium and Magnesium.

3.8 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 from the proximal end of the bunch. The fruits were sliced to 5mm diameter using a grater after they were washed and peeled.

3.8.1 Preparation of False Horn Plantain Flour

Sliced plantain pulp were placed in an oven (Wagtech-Model GP120SSE300HYD) and dried at 60oC 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.

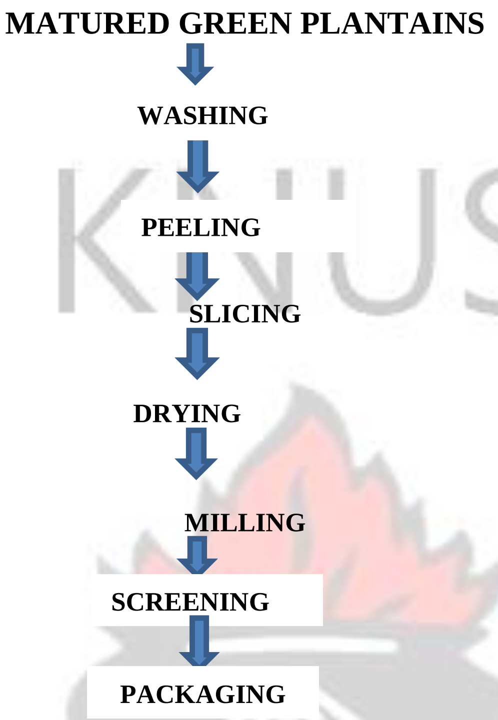

Figure 3.1: Flow chart for the production of plantain flour

3.9 PROXIMATE ANALYSIS

3.9.1 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).

3.9.2 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).

3.9.2.1 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 conc. H_2SO_4 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.

3.9.2.2 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 milliliters (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 H_2SO_4 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.

3.9.3 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.

3.9.4 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) (Demiate *et al.,* 2001). Under a constant stirring speed, the slurry was heated from 25–95^0 C at a uniform rate of 1.5^{0}C/min. Monitoring was continuously done on the torgue. Cooling took place under a controlled rate of 1.5C/min (Damardjati and Luh 1987) to 50^{0}C after torgue 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) (Demiate *et al.,* 2001).

3.10 SELECTED FUNCTIONAL PROPERTIES OF FLOUR

3.10.1 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 other to avoid fragmentation of starch granules, the suspension was stirred just sufficiently and uniformly avoiding excessive speed. The sample in the centrifuge tube ^{o} 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.

3.10.2 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 top up with 10mL of distilled. A Rota mixer 7023 was used for missing 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 milliliters of oil or water absorbed per gram of flour respectively.

3.10.3 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/cm^3) was calculated as weight of flour (g) divided by flour volume (cm^3).

That is Bulk density (g/ cm^3) = weight of sample (g) /volume of sample after tapping cm^3.

3.11 DATA ANALYSIS

Data from the field and laboratory were analyzed using statistix 9 student version for the analysis of variance. Least Significant Difference (LSD) was used for the separation of means at a probability level of 0.05 and 0.01 for the field and laboratory work respectively.

CHAPTER FOUR

4.0 RESULTS

4.1 CHEMICAL CHARACTERISTICS OF POULTRY MANURE AND COCOA POD HUSK

Nitrogen(N), phosphorus(P), potassium(K), calcium(Ca) and magnesium(Mg) content of the manure used were 3%, 1.30%, 1.20%, 0.70% and 0.45% respectively. On the other hand, cocoa pod husk had 1.20%, 0.15%, 1.00%, 0.15%, and 0.10% which were recorded for N, P, K, Ca and Mg respectively.

Table 4.1: Chemical properties of poultry manure and cocoa pod husk

Properties %	**Poultry manure**	**Cocoa pod husk**
Nitrogen(N)	3	1.20
Phosphorus(P)	1.30	0.15
Potassium(K)	1.20	1.00
Calcium(Ca)	0.70	0.15
Magnesium (Mg)	0.45	0.10

4.2 CHEMICAL PROPERTIES OF SOIL BEFORE AND AFTER APPLICATION OF AMENDMENTS

There were significant differences ($P \leq 0.05$) in the pH value for the various amended soil as compared to the initial soil status (Table 4.2). Soils treated with CPH recorded the highest pH (7.01) which was significantly different from the initial soil status as well as the other soil amendments. However soils treated with NPK recorded the lowest pH value of 6.47.

The percentage organic carbon differed significantly (P≤0.05) among the various amended soil as well as the initial soil status (Table 4.2). Soils amended with CPH and PM recorded the highest percentage organic carbon (2.65 and 2.61, respectively) compared with the other amended soil and the initial soil status. The un-amended soil (control) recorded the lowest percentage of organic carbon (1.86 %). There were no significant difference (P≤0.05) among treated soils and the initial soil status with regards to the percentage total nitrogen (Table 4.2). The percentages ranged from 0.44
(NPK+CPH) to 0.23 (Initial soil condition and un-amended soil).

The C/N ratio differed significantly (P≤0.05) among the various amended soils as well as the initial soil status (Table 4.2). The initial soil status recorded the highest C/N ratio of 10.78, significantly different from the other amended soils. However, NPK+PM and NPK+CPH recorded the lowest C/N ratio of 5.40.

The value of K+ differed significantly (P≤0.05) among the various amended soils as well as the initial soil status (Table 4.2). NPK recorded the highest figure of 0.85 for K+ which was significantly different from the other amended soils and also the initial soil status. However, initial soil status recorded the least value of 0.30 for K+.

For available P significant difference (P≤0.05) were observed in the figures recorded by the various amended soils (Table 4.2). Soils treated with NPK and poultry manure (PM) recorded the highest values of 24.70mg/kg and 23.90mg/kg respectively which differed significantly from the other soil amendments as well as initial soil status. Also the control and initial soil status recorded the lowest available P values of 10.40mg/kg and

11.87mg/kg, respectively.

The CEC differed significantly (P≤0.05) among the various amended soils as well as the initial soil status (Table 4.2). Initial soil status recorded the highest CEC value (19.70cmol/kg) which was significantly different from the control which recorded the lowest CEC value of 11.57cmol/kg. The CEC recorded by NPK (14.75cmol/kg) and NPK+CPH (14.54cmol/kg) were not significantly different from each other.

Table 4.2: Chemical properties of soil before and after the application of the amendments

	pH	%organic carbon	%Total Nitrogen	C/N ratio	K+ cmol/kg	Av. P (Bray 2) mg/kg	CEC cmol/kg
	Initial soil chemical properties						
	6.80	2.48	0.23	10.78	0.30	11.87	19.70
	Soil chemical properties after treatment application						
NPK	6.47	2.15	0.36	6.00	0.85	24.70	14.75
PM	6.81	2.61	0.32	8.20	0.51	23.90	12.05
CPH	7.01	2.65	0.41	6.50	0.79	12.80	16.37
NPK+PM	6.78	2.25	0.42	5.40	0.52	15.10	15.18
NPK+CPH	6.68	2.36	0.44	5.40	0.75	13.60	14.54
CONT.	6.66	1.86	0.23	6.40	0.38	10.40	11.57
LSD(0.05)	0.150	0.100	0.650	0.080	0.060	0.840	0.250

4.3 EFFECTS OF SOIL AMENDMENT ON GROWTH AND YIELD OF FALSE HORN PLANTAIN

The height of plants differed significantly ($P \leq 0.05$) with respect to soil amendments (Table 4.3). Soils amended with PM recorded the tallest plant height of 299 cm whereas the control registered the shortest height of 257 cm. Soils amended with PM, NPK+PM, NPK, NPK+CPH were not significantly different from each other. However these treatments were significantly different from the control. Also CPH and control were not significantly different from each other.

The number of fingers per bunch differed significantly ($P \leq 0.05$) between the various soil amendments. Soils amended with NPK+PM recorded the highest number of fingers (33) whereas soils which had no soil amendment (control) recorded the least number of fingers (25). However the other soil amendments were not significantly different from the control.

On the other hand, growth parameters such as stem girth, number of suckers and number of hands did not show any significant differences ($P \leq 0.05$) between the various soil amendments. Stem girth ranges from 55.33cm to 59.00cm. Number of suckers also ranges from 8 to 6. Whereas number of hands ranges from 6 to 8.

The weight of bunches were significantly ($P \leq 0.05$) influenced by soil amendments (Table 4.4). Soils amended with NPK+PM recorded the heaviest bunch weight 17.22 Mt ha^{-1} whereas soils without any amendment (control) recorded the lowest bunch weight of 12.22 Mt ha^{-1}. However, bunch weights recorded from soils amended with NPK+PM were not significantly different from the other amended soils. There were significant differences ($P \leq 0.05$) between the soil amendments with regards to the finger weight (Table 4.4). Soils amended with NPK recorded the heaviest fingers (427.33g), significantly ($P \leq 0.05$) different from all the other soil amendments. Soils without amendments (control) and soils amended with poultry manure registered the lowest values of 258g and 269g respectively. For the pulp thickness, significant differences ($P \leq 0.05$) were also observed between the various soil amendments. Soils amended with NPK recorded the highest pulp thickness (3.98 cm), significantly different from CPH, NPK+CPH, PM and Control which registered the lowest values of 3.5 cm, 3.48 cm, 3.07 cm and 3.24 cm, respectively.

On the other hand, there were no significant differences ($P \geq 0.05$) among amended soils concerning pulp weight, peel weight, peel thickness and pulp to peel ratio and moisture content of the pulp. Pulp weight ranged from 156.43g to 183.5g. Peel weight ranged from 100g to 119.5g. Peel thickness ranged from 0.26cm to 0.48cm and Pulp to peel ratio ranged from 1.34 to 1.59. Pulp moisture content ranged from 55.72% to 58.11%.

Table 4.3: Effect of soil amendment on growth and yield parameters of false horn plantain.

Treatment	Plant height(cm)	No. of fingers
NPK	288.0	28.3
Poultry Manure (PM)	299.0	30.7
Cocoa Pod Husk (CPH)	279.7	31.3
NPK+PM	288.7	33.3
NPK+CPH	284.3	29.7
No amendment (Control)	257.0	25.3
LSD	30.58	7.86
CV	5.94	14.50

Table 4.4: Effects of soil amendments on some yield parameters of false horn plantain

Treatment	Bunch weight(Mt/h)	Average finger wgt(g)	Pulp thickness
NPK	14.17	427.33	3.98
PM	16.11	258.00	3.07
CPH	15.83	330.33	3.50
NPK+PM	17.78	332.00	3.72
NPK+CPH	17.22	321.00	3.48
CONT.	12.22	269.00	3.24
LSD(0.05)	4.930	45.133	0.399
CV	17.42	7.68	6.27

4.4 POSTHARVEST QUALITY CHARACTERISTICS OF PLANTAIN FLOUR

4.4.1 Moisture, Protein and Starch Content of false horn plantain flour

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

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. All the other amendments produced flour with protein content similar to that from the NPK amendment.

For starch content, flour produced from plantain without any soil amendment recorded the highest starch content (51.33 %), significantly different from all the other amendments. 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 amendments (Table 4.5).

Table 4.5: 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

4.5 FUNCTIONAL PROPERTIES OF FALSE HORN PLANTAIN FLOUR

There were no significant differences (P≥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/cm^3 to 0.84g/cm^3. 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% whiles swelling power ranged from 9.49% to 10.45%.

4.6 PASTING PROPERTIES OF FALSE HORN PLANTAIN FLOUR

4.6.1 Beginning of Gelatinization

There were significant differences (P≤0.01) in the time it took for gelatinization to begin between the flours produced from plantain under the various soil amendments. Flour produced from plantain amended with CPH recorded the highest value for beginning of gelatinization (11.50 BU), which differed significantly from NPK+CPH which recorded the least value (9.17 BU) (Table 4.6).

4.6.2 Maximum Viscosity

There were significant differences (P≤0.01) in maximum viscosity between the flours produced from plantain under the various soil amendments. Flour produced from plantain amended with CPH recorded the highest value for maximum viscosity (401.33BU), significantly different (P≤0.01) from the other amendments, except NPK+PM which was similar (Table 4.6). The least maximum viscosity was recorded by flour from plantain amended with NPK which was not different from that of the control.

Table 4.6: Effect of soil amendment on beginning of gelatinization and maximum viscosity of false horn plantain flour

Treatment	Beginning of gelatinization(BU)	Maximum viscosity(BU)
NPK	9.83	354.33

PM	10.50	382.50
CPH	11.50	401.33
NPK+PM	10.17	392.50
NPK+CPH	9.17	368.67
CONT.	10.50	366.83
LSD(0.01)	2.020	13.200
CV	12.43	2.22

4.6.3 Start of Cooling and End of Cooling

There were significant differences (P≤0.01) in start of cooling viscosity between the flours produced from plantain under the various soil amendments (Table 4.7). 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 4.7). The end of cooling viscosity values also differed significantly (P≤0.01) between the flours produced from plantain under the various soil amendments (Table 4.8). 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 4.7: 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

4.6.4 Start of Holding and End of holding

There were significant differences (P≤0.01) between the flours from the various amended soils with regards to the viscosity at the start of holding (Table 4.8). 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 amendment (Table 4.8). The least start of holding viscosity was recorded by NPK amendment.

The end of holding viscosity values also differed significantly (P≤0.01) between the flours produced from plantain under the various soil amendments (Table 4.8). Flour produced from plantain without amendment (control) recorded the highest viscosity at the end of holding, which was not significantly different from flour from CPH amendments.

Table 4.8: 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

4.6.5 Breakdown

There were significant differences (P≤0.01) between the flours from the various soil amendments with regards to the viscosity at the breakdown stage (Table 4.9). Flours produced from plantain amended with NPK and CPH recorded the highest viscosity values at the breakdown stage whereas the NPK+CPH recorded the least value (51.00BU). Viscosity values recorded by flour from NPK and CPH amendments were not significantly different from those from PM (79.00BU) and NPK+PM (82.67BU) amendments.

4.6.6 Setback

For setback viscosity, significant differences (P≤0.01) were observed between the flours produced from the various soil amendments. The control recorded the highest setback viscosity value (35.83BU), significantly different from viscosity values of flours produced from the other amendments, except NPK. The least setback viscosity value was obtained from flour with PM amendment.

Table 4.9: 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

4.6.7 Beginning of Gelatinization Temperature

There were significant differences (P≤0.01) between flours produced from the various amended soils with regards to temperature at the beginning of gelatinization (Table 4.11). Flours produced from plantain with NPK+PM amendment and Control recorded the highest temperature at the beginning of gelatinization (77.47^{0}C and 77.45^{0}C respectively), which differed significantly from flours produced from PM amended soils which recorded the least temperature (75.45^{0}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^{0}C, 76.73^{0}C and 77.10^{0}C respectively.

4.6.8 Beginning of Gelatinization Time

There were significant differences (P≤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 4.11). 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.

4.6.9 Time Taken to Reach Peak Viscosity

There were significant differences (P≤0.01) between the flours produced from the various amended soils with regards to the time taken to reach peak viscosity (Table 4.11). 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 NPK which recorded the least time (1065.00 sec.).

Table 4.10: 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 (^{0}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

4.7 RELATIONSHIP ANALYSIS AMONG AGRONOMIC AND POSTHARVEST PARAMETERS

4.7.1 Correlation Relationship among some of the Yield Parameters of False Horn Plantain

There was a strong significant positive correlation between finger girth and pulp thickness (r= 0.70) (Table 4.12). Moderate positive significant correlations also existed between pulp: peel ratio and pulp weight (r = 0.50) as well as pulp: peel ratio and pulp thickness (r = 0.52).

Table 4.11: Correlation relationships among some yield parameters of false horn plantain

Correlation variables	Correlation coefficient (r)	Probability level
Pulp to peel ratio and pulp thickness	0.52	0.02
Pulp to peel ratio and pulp weight	0.50	0.03
Average finger girth and pulp thickness	0.70	0.00

4.8 REGRESSION RELATIONSHIPS BETWEEN SOME AGRONOMIC PARAMETERS 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(max. viscosity) = 372.501 + 1.33796(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(max. viscosity) = 423.169 – 1.19374(starch); $R^2 = 0.26$; p = 0.030 ; n = 10. (Eqn 5).

CHAPTER FIVE

5.0 DISCUSSION

5.1 CHEMICAL PROPERTIES OF SOIL BEFORE AND AFTER AMENDMENTS APPLICATION

Initial soil analysis revealed that the soil pH was 6.8 but decreased slightly at the end of the study for most of the amended soils. The pH decreased to 6.5 (NPK), 6.7 (control), 6.7 (NPK+CPH) and 6.8 (NPK+PM). For PM and CPH however, the pH increased to 6.81 and 7.01, respectively. This increase is as result of the high content of calcium in both the poultry manure and cocoa pod husk (Boateng *et al.*, 2007; Ayeni *et al.*, 2008 a,b ; Ajayi *et al.,* 2007 a,b). Plantain does very well in soils with slightly acidic to slightly alkaline soils (Tropical Horticulture, 2010). Amending the soil with poultry manure and cocoa pod husk increased the soil organic matter content to levels reported by several authors to be good for high production of plantain (Agbede *et al*., 2008; Kartika and Susila, 2007 and Agboola and Corey, 1973). Such high organic matter levels would ensure the retention of nutrients in the root zone particularly N and P (Schroth *et al*., 2002), and moisture as well as an increased stability of the soil aggregates (Grant 1989) thus improving on the availability of the nutrients in most of the amended soils for uptake by the plantain roots.

As found in the present study, all the amended soils had higher levels of N, P, K, O.C and CEC than the control where there was no amendment, an indication that the amendments had contributed to an improvement in the fertility status of the soils. Similar findings were reported by Moyin-Jesu and Adeofun (2008). All the soils including the control recorded C/N ratios which were within the optimum acceptable level (Golueke, 1991).

The soils that recorded low C/N ratios were indicative of the fast decomposition of organic material with a resultant release of nutrients for plant uptake. Considering the established critical level of K+ (0.20cmol kg^{-1}) as reported by Akinrinde and Obigbesan, (2000) and Adeleye *et al.* (2010), all the soil amendments increased the availability of potassium in the soil. Similarly, the P content of the amended soils were much higher than the critical levels of 8-10 mg kg^{-1} as reported by Akinrinde and Obigbesan, (2000) and Adeleye *et al.*

(2010) and Agboola and Corey, (1973). Consequently plant root growth and other plant processes that utilize phosphorus would be enhanced in the amended soils.

5.2 EFFECTS OF SOIL AMENDMENTS ON GROWTH AND YIELD OF FALSE HORN PLANTAIN

All the amendments resulted in taller plantain plants relative to the control where no amendment was applied. This could be attributed to the high nutrient content contained in the amended soils which provided the needed nutrients required for metabolic activities such as chlorophyll synthesis and photosynthesis (Premsekhar and Rajashree, 2009; Oladotun, 2002). According to Dauda *et al.* (2008) poultry manure for example has the ability to promote vigorous growth and increase physiological and meristematic activities in the plants due to the supply of plant nutrients.

The bunch weights of plantain from the amended soils were heavier than the control. The high nutrient content of the soils, particularly of potassium might have accounted for the increased bunch weight compared to the control. Zake *et al.* (1996) reported that optimum K fertilization is beneficial to plantain as the crop has a high affinity for the nutrient. Potassium Fertilization enhances vegetative growth and sustains high bunch production (Banful *et al.*, 2008).

5.3 EFFECTS OF SOIL AMENDMENTS ON THE PROXIMATE

COMPOSITION OF PLANTAIN FLOURS

5.3.1 Protein and Starch Content of Flour

Except the NPK amended soils which resulted in significantly higher protein content (5.27%) of the flour, all the other amendments produced flour with similar protein content as the control. This could be due to the ready 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 the NPK amendment 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).

From the present study, the findings are indicative that 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 valueadded products (Ikegwu *et al.,* 2010).

5.3.2 Moisture Contents of False Horn Plantain Pulp and Flour

The moisture content of plantain pulp was not significantly different from each other. 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 (Butt *et al.*, 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 (Oduro *et al*., 2009). Since the flours had acceptable moisture content they are expected to have longer shelf life.

5.4 EFFECTS OF SOIL AMENDMENTS ON THE FUNCTIONAL PROPERTIES OF PLANTAIN FLOURS

5.4.1 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/cm^3 to 0.84g/cm^3 with soil amended with PM recording 0.84g/cm^3 and NPK+PM recording 0.79g/cm^3. Ismael *et al.,* (2011) recorded a bulk density of 0.63g/cm^3 for false horn. The disparities in the values could be due to an interplay of several factors including 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/cm^3 (Akubor and Badifu, 2004 and Mbata *et al.*, 2009). According to Bhattacharya and Prakash (1994), the bulk density of foods increase 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 since 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. Mbata *et 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.

5.4.2 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. Elmoneim *et 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 increase 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).

5.4.3 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 from plantain with NPK+CPH amendment recorded the oil absorption capacity of 10.72g whereas flour from plantain with CPH amendment recorded the 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 Mepba *et 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). Udensi and Okoronkwo (2006) reported oil absorption capacity value of 2.2g/g for mucuna bean. Generally, flours with lower oil absorption capacity have higher flavor retention abilities (Oladele and Aina, 2007). Consequently, flours from plantain with CPH amendment would have a high potential of retaining flavour and therefore could be desirable in food product formulation. Adejuyitan *et 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 (Aremu *et al.,* 2006).

5.4.4 Effect on Swelling Power of False Horn Plantain

Swelling power of false horn plantain flour ranges from 10.45 to 9.49. Ishmeal *et 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 soybeanfortified 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 (Ojinnaka *et 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 noodle-quality flours (Morris *et al.*, 1997; McComick *et 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 (Etudaiye *et al.*, 2009). Johnson *et al*. (2001) indicated that higher solubility also permitted better digestibility.

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

5.5.1 Gelatinization Temperature

The gelatinization temperature of the flours ranged from 75.45^{0}C to 77.47 ^{0}C. Flours obtained from soils amended with NPK+PM recorded the highest temperature while flours from PM amended soils produced the lowest gelatinization temperature. Higher gelatinization temperatures (81.87^{0}C; 94.6^{0}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 as well as reduce the cost 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.

5.5.2 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 studies, 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 on 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.

The breakdown values for false horn plantain flour ranged between 51.00 BU (NPK+CPH) to 93.00 BU (NPK) in the present study. 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.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 CONCLUSIONS

The findings of the study suggested that soil amendments had an impact on the growth, yield and postharvest qualities of flour derived from the plantain, parameters as well as, moisture content, starch, protein and pasting properties of false horn plantain.

Plantain grown on the amended soils exhibited better growth than the control. On yield parameters, soils amended with NPK+PM and NPK+CPH recorded the highest bunch yields whiles soil amended with NPK recorded the highest finger weight and pulp thickness.

Flours from plantain with 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 low and as such required fortification with other high protein foods to boost the nutritional content of the flour.

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 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 amendment 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 amendments.

Flours from plantain with NPK+CPH 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 flours compared favourably with known food flours and therefore could be applicable as thickening agents and also find usefulness in fufu powder preparation and baking.

6.2 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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Appendix II: Analysis of Variance

Rep= Replication

Trt= Treatment

Growth and Yield Data

Analysis of Variance Table for Average Finger Length

Source	DF	SS	MS	F	P
Rep	2	13.3611	6.68056		
Trt	5	43.6111	8.72222	3.91	0.0317
Error	10	22.3056	2.23056		
Total	17	79.2778			

Grand Mean 25.389   CV 5.88

Analysis of Variance Table for Number of Fingers

Source	DF	SS	MS	F	P
Rep	2	127.444	63.7222		
Trt	5	113.111	22.6222	1.21	0.3706
Error	10	186.556	18.6556		
Total	17	427.111			

Grand Mean 29.778   CV 14.50

Analysis of Variance Table for Plant height

Source	DF	SS	MS	F	P
Rep	2	1928.11	964.056		
Trt	5	3005.11	601.022	2.13	0.1450
Error	10	2825.89	282.589		
Total	17	7759.11			

Grand Mean 282.78 CV 5.94

Analysis of Variance Table for Bunch Weight

Source	DF	SS	MS	F	P
Rep	2	6.242	3.1208		
Trt	5	63.507	12.7015	1.73	0.2154
Error	10	73.434	7.3434		
Total	17	143.183			

Grand Mean 15.556 CV 17.42

Analysis of Variance Table for Average Finger Weight

Source	DF	SS	MS	F	P
Rep	2	684.8	342.4		
Trt	5	54495.6	10899.1	17.71	0.0001
Error	10	6154.6	615.5		
Total	17	61334.9			

Grand Mean 322.94 CV 7.68

Analysis of Variance Table for Pulp Thickness

Source	DF	SS	MS	F	P
Rep	2	0.07795	0.03898		
Trt	5	1.58102	0.31620	6.57	0.0059
Error	10	0.48095	0.04809		
Total	17	2.13992			

Grand Mean 3.4992   CV 6.27

Postharvest Parameters

Analysis of Variance Table for Moisture Content of Flour

Source	**DF**	**SS**	**MS**	**F**	**P**
Treatment	5	55.3446	11.0689	18.91	0.0000
Error	30	17.5559	0.5852		
Total	35	72.9005			

Grand Mean 10.154   CV 7.53

Analysis of Variance Table for Protein Content of Flour

Source	**DF**	**SS**	**MS**	**F**	**P**
TRT	5	8.2339	1.64679	3.24	0.0444
Error	12	6.1081	0.50901		
Total	17	14.3420			

Grand Mean 3.9667   CV 17.99

Analysis of Variance Table for STARCH Content of Flour

Source	**DF**	**SS**	**MS**	**F**	**P**
TRT	5	848.278	169.656	13.45	0.0001
Error	12	151.333	12.611		
Total	17	999.611			

Grand Mean 38.722   CV 9.17

Analysis of Variance Table for Bulk Density

Source	**DF**	**SS**	**MS**	**F**	**P**
Trt	5	0.00343	6.870E-04	1.38	0.2988
Error	12	0.00597	4.979E-04		
Total	17	0.00941			

Grand Mean 0.8207   CV 2.72

Analysis of Variance Table for Oil Absorption Capacity

Source	DF	SS	MS	F	P
Trt	5	197.390	39.4779	0.85	0.5414
Error	12	558.292	46.5243		
Total	17	755.682			

Grand Mean 3.3222   CV 205.31

Analysis of Variance Table for Solubility Power

Source	DF	SS	MS	F	P
Trt	5	11.2366	2.24733	1.63	0.2247
Error	12	16.4942	1.37452		
Total	17	27.7308			

Grand Mean 8.6844   CV 13.50

Analysis of Variance Table for Swelling Power

Source	DF	SS	MS	F	P
Trt	5	1.81138	0.36228	1.38	0.2979
Error	12	3.14400	0.26200		
Total	17	4.95538			

Grand Mean 9.7989   CV 5.22

Analysis of Variance Table for Water Absorption Capacity

Source	DF	SS	MS	F	P
Trt	5	1.42752	0.28550	1.46	0.2738
Error	12	2.35053	0.19588		

Total	17	3.77805

Grand Mean 1.7317   CV 25.56

Analysis of Variance Table for Beginning of Gelatinization

Source	**DF**	**SS**	**MS**	**F**	**P**
Treatment	5	18.2222	3.64444	2.23	0.0770
Error	30	49.0000	1.63333		
Total	35	67.2222			

Grand Mean 10.278   CV 12.43

Analysis of Variance Table for Breakdown

Source	**DF**	**SS**	**MS**	**F**	**P**
Treatment	5	7052.8	1410.56	10.2	0.0000
Error	30	4137.5	137.92		
Total	35	11190.3			

Grand Mean 77.861   CV 15.08

Analysis of Variance Table for Gelatinization Temperature

Source	**DF**	**SS**	**MS**	**F**	**P**
Treatment	5	17.3647	3.47294	2.62	0.0444
Error	30	39.8050	1.32683		
Total	35	57.1697			

Grand Mean 76.903   CV 1.50

Analysis of Variance Table for Maximum Viscosity

Source	**DF**	**SS**	**MS**	**F**	**P**
Treatment	5	9268.3	1853.67	26.4	0.0000
Error	30	2103.7	70.12		
Total	35	11372.0			

Grand Mean 377.67   CV 2.22

Analysis of Variance for Gelatinization Time

Source	**DF**	**SS**	**MS**	**F**	**P**
Treatment	5	31558	6311.67	2.68	0.0407
Error	30	70692	2356.39		
Total	35	102250			

Grand Mean 1128.3   CV 4.30