The Physicochemical Characteristics Of Plantain (Musa Paradisiaca) And Banana (Musa Sapientum) Pseudostem Wastes

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ORIGINAL ARTICLE

The Physicochemical Characteristics Of Plantain *(Musa Paradisiaca)* And Banana *(Musa Sapientum)* Pseudostem Wastes

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U.D. Akpabio, D.S. Udiong and A.E. Akpakpan: The Physicochemical Characteristics Of Plantain *(Musa Paradisiaca)* And Banana *(Musa Sapientum)* Pseudostem Wastes

ABSTRACT

The physicochemical properties of plantain *(Musa paradisiaca)* and banana *(Musa sapientum)* pseudostem wastes have been determined. It was found that the average moisture content for both samples were very high while the concentrations of solubles in both cold and hot water were moderate, the concentrations of the solubles of the pulverized pseudostems in 1:2v/v ethanol-benzene solution mixture were higher than those of 18% NaOH. The mineral elements detected in the leaf-fold and the core of both *Musa paradisiaca* and *Musa sapientum* pseudostem wastes were Na, K, Cr, Mg, Zn, Fe, Cu, and P. Pb was present in trace concentrations in only the banana leaf-folds. The phytochemical composition in mg/100g for the plantain and banana pseudostem wastes were: oxalates (66.28±2.01, 41.56±2.55); phytates (3.78±0.05, 3.23±0.33); tannins (7.99±0.26, 6.55±0.33); and cyanogenic glycosides (1.47±0.14, 1.44±0.33) respectively. Flavonoids, saponins and alkaloids were present in both varieties, but steroids were absent. The values of lignin ranged between 2.28 and 7.30% pseudostems, the carbohydrate between 39.71 and 62.21 mg/100g for plantain and 42.13 and 93.82 mg/100g for banana pseudostems while the pentosan content for both ranged between 6.67 and 11.73 mg/100g. Generally, plantain, pseudostems waste contains higher values of the phytochemicals than the banana pseudostems except the pentosen content; both contain high amount of carbohydrate which can be exploited for the preparation of pulp for paper making and for production of cellulose derivatives and sugar.

Key words: Physicochemical characteristics, *Musa paradisiaca and Musa sapientum* pseudostem wastes,

Introduction

Plantain and banana plants are among the most important staple food crops in humid forest zone of West and Central Africa. This is due to the contribution of the crops to food security, employment and diversification of income sources in rural and urban areas, hence contribution to the gross national product (GNP) (Nkendah and Akyeampong, 2003). Banana is the world's second most important fruit crop after oil palm. It is grown in 130 countries worldwide, world production stood at 71 million metric tones of banana, while plantain is grown in 52 countries with world production of 33 million metric tones per year (FAO, 2004). Plantains are of less importance than banana in terms of world trade in the genus but in West and Central Africa about 70 million people are estimated to derive more than one quarter of their food energy requirement from plantains (Robinson, 1996; Swennen and Ortiz, 1997).

The plantain *(Musa paradisiaca)* and banana *(Musa sapientum)* pseudostem wastes are abundant and widely available as a lignocellulosic material. Maloney (1978) stated that lignocellulosic materials are the most abundant polymers on earth which are obtainable as the original biomass. Lignocellulosic materials are mainly constituted from three natural polymers namely: cellulose, lignin and hemicelluloses in varying proportions depending upon the specific plant in which they occur (Casey, 1980).

The use of lignocellulosic materials as a base for the production of chemicals is very small in relation to the amount generated annually. This, according to Maloney (1978), is because it has been less expensive to derive carbon based chemicals from fossil fuels, especially natural gas and petroleum.

Wood and wood wastes have a complex carbohydrate–lignin structure, requiring severe chemical reaction conditions to reduce it to simple chemicals such as methanol, ethanol, furfural and phenols (Maloney, 1978). Ethanol can be obtained from wood by acid hydrolysis of the cellulose to hexose sugars and subsequent fermentation of the sugars into ethanol (Maloney, 1978). Fermentation ethanol can be produced by the action of the yeast, *Saccharomyces cereviscae* on sugars obtained from corn, grain, fruit, molasses, sulfite spent liquor and whey (Elder, 2002).

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Traditionally, cellulose comes from wood but there are also locally available non-woody agricultural wastes, which may be used as sources of cellulose. Such sources are the pseudostem of plantain *(Musa paradisiaca)* and banana *(Musa sapientum)*, straw from grains, sisal, etc. (Akpabio, 1991, Quame, 1985). Studies have also shown that cellulose acetate and paper can also be made from plantain pseudostem wastes (Akpabio, 1988). Musa species are particularly suitable for extracting the cellulosic materials because of its less complex structure and low lignin content (Akpabio, 1991).

The aims of the study are to determine the physical and chemical composition of *Musa paradisiaca* and *Musa sapientum* pseudostem wastes in other to ascertain it suitability or otherwise for preparation of pulp for paper making, preparation of cellulose derivatives and sugar(glucose).

Materials And Methods

Materials:

The materials for this research are the pseudostems of plantain *(Musa paradisiaca*) and banana (*Musa sapientum*).The pseudostems were collected after the matured fruits of the plants were harvested from some gardens in Abak and Uyo Local Government Areas of Akwa Ibom State, Nigeria. Plates 1 and 2 show the full matured plants while Plates 3 and 4 show their transverse sections, and plate 5 shows the Musa species filaments. The pseudostems were cut into 10 cm portions and conveyed to the Central Laboratory, University of Uyo for further preparation and analysis.

Sample preparation:

The pseudostems of both plantain and banana were separated into two parts, the outer folded leaf sheaths and the central core portion which is the stalk of the fruit inflorescent. The folded leaf sheaths are hereinafter referred to as the leaf-folds while the central core portion, the stalk of the inflorescent, as the core. The leaf-folds and the core portions were further cut into chips of 1 cm by 1 cm and using locally made pestle and mortar they were beaten moderately. After beating, a lot of water was released from the pseudostems and using a clean dry white cloth, the water was squeezed out from the fibrous pseudostems and core. The leaf-folds and core were further dried in the oven at a temperature of $100 \pm 5^{o}C$ for 48 hours and cooled in a desiccator until a constant mass was obtained. The oven dried pseudostems and the core was ground with a manual grinder until the pseudostems and core portions became pulverized.

Methods:

Determination of physical characteristics:

Moisture content based on oven-dried and air-dried pseudostem wastes was determined by A.O.A.C. (1990) method. The following solvent soluble extractives were also determined: hot and cold water solubles (Onwuka, 2005), alkali slubles in 1% and 18% NaOH (TAPPI, 1990) and 1:2 ethanol-benzene solution mixtures (TAPPI, 1990). The basic density of the samples was determined by weighing and volume measurement of the sample, using the formula:

$$\text{Basic density} = \frac{\text{mass of oven-dried sample}}{\text{volume of water displaced by green sample}} \quad \text{(Casey, 1980).}$$

Determination of Mineral Elements Composition (A.O.A.C. 1990):

The method adopted for the determination of mineral elements composition was the A.O.A.C. (1990) recommended methods. The procedures included digestion of ashed samples; preparation of stock solution of the elements and the determination of the concentration of the elements using a calibration curve obtained by plotting the concentration of the pure elements against their absorbance readings from Atomic Absorption Spectrophotometer. The metal elements were determined by the approved A.O.A.C. (1990) methods. These were Cd, Ca, Cr, Cu, Fe, Pb, Mg, Zn, As, Na and K. The concentration of phosphorus in the pseudostem wastes was determined by colorimetric method (James, 1984).

Determination of Toxicants Levels in Samples:

Spectroscopic and titrametric methods were used to determine the levels of phytochemicals in the plantain *(Musa paradisiaca)* and banana *(Musa sapientum)* pseudostem samples. The phytochemicals determined in the samples were: total oxalates, phytates, hydrocyanic acid, flavonoids, saponins, alkaloids, steroids and tannins.

The phytochemicals determined in the samples are oxalates (Dye, 1956) phytates (McCance and Widdowson, 1935) and HCN (A.O.A.C. 1990). The others were flavonids, saponins, alkaloids (A.O.A.C. 1990) steroidal nucleus (Shoppee, 1964), tannin (Pearson, 1976) while pentosan was determined by first converting the pentosan into furfural and secondly by adding orcinol iron (III) chloride mixture to furfural, from which the amount of xylan was determined from the absorbance of the furfural orcinol reagent mixture at 630nm measured with spectrophotometer.

Acid insoluble or Klanson lignin was determined with 72% H_2SO_4 (TAPPI, 2006). The total carbohydrate content was determined by dinitrosalicylic (DNS) method (Browning, 1963) while qualitative test for carbohydrate was done with Fehling's solution (Furniss *et al.*, 1981), preparation of glucose and (sugar) was done by saccharification (ie acid hydrolysis using conc. H_2SO_4) Okon, (2005).

Results And Discussion

The parameters determined for both the leaf-fold and the core of the pseudostem wastes were the moisture content, the solubles in water, sodium hydroxide and 1:2 v/v ethanol-benzene solution mixture; the mineral elements detected were Na, K, Cr, Mg, Zn, Fe, Cu and P; Pb was present in trace concentration in only the banana leaf-folds, phytochemicals identified were the oxalates, the phytates, hydrocyanic acid, tannins, flavonoids, saponoids and alkalites.

Physical Properties:

The moisture content is significant to the deterioration of wastes from plant materials (e.g wood, pseudostem waste); it also gives information on the dry matter present in the given sample. The moisture creates

Plate 1: *Musa paradisiaca* (plantain) with matured fruit

Plate 2: *Musa sapientum* (banana) with matured fruit

Plate 4: Transverse Section of *Musa paradisiaca* (plantain) pseudostem

Plate 5: Transverse Section of *Musa sapientum* (banana) pseudostem

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Plate 5: *Musa* species filaments

Table 1: Physical parameters of *Musa paradisiaca* and *Musa sapientum* pseudostems wastes

Physical parameters	*Musa paradisiaca*			*Musa sapientum*		
	Leaf-folds	Core	Aver-age	Leaf-folds	Core	Aver-age
Moisture content (oven dried) (%)	92.25	92.60	92.43	93.40	93.50	93.45
Moisture content (air dried) (%)	78.60	79.30	78.95	80.00	82.60	81.30
Solubles in cold water (%)	20.70	28.50	24.60	27.50	23.20	25.35
Solubles in hot water (%)	33.90	35.50	34.70	20.70	26.30	23.50
Solubles in cold 1 % NaOH (%)	19.10	27.80	23.45	27.90	28.60	28.28
Solubles in hot 1 % NaOH (%)	16.70	34.50	25.60	16.60	23.50	20.05
Solubles in cold 18 % NaOH (%)	36.70	39.20	37.95	37.50	38.00	37.75
Solubles in hot 18 % NaOH (%)	35.30	31.70	33.50	33.20	30.00	31.60
Solubles in 1:2 ethanol-benzene Solution (%)	46.50	38.80	42.65	44.30	40.50	42.40
Basic density (g/cm^3)	0.24	0.21	0.22	0.22	0.19	0.20

Table 2: The concentrations of mineral elements in the *Musa paradisiaca* and *Musa sapientum* pseudostem wastes.

Elements (mg/100g)	*Musa paradisiaca* Pseudostem (mg/100g)			*Musa sapientum* Pseudostem (mg/100g)		
	Leaf-folds	Core	Average	Leaf-folds	Core	Average
Iron	23.41±0.15	18.93±0.20	21.17±0.25	17.95±0.01	27.93±0.30	22.94±0.30
Zinc	10.67±0.25	82.21±0.15	46.44±0.21	8.03±0.14	31.79±0.45	19.91±0.47
Magnesium	24.94±0.22	18.96±0.25	21.95±0.33	08.03±0.30	50.11±0.50	79.07±0.58
Phosphorus	32.58±0.15	31.20±0.34	31.89±0.37	9.35±0.46	19.45±0.25	14.40±0.52
Copper	3.70±0.01	9.52±0.12	6.61±0.12	3.42±0.01	5.43±0.01	4.43±0.01
Calcium	20.43±0.40	30.04±0.10	25.23±0.41	8.83±0.32	13.59±0.15	11.21±0.35
Sodium	18.60±0.12	24.00±0.55	42.60±0.64	25.20±0.55	21.60±0.10	23.40±0.55
Potassium	30.60±0.10	36.30±0.12	33.45±0.15	32.40±0.10	26.70±0.42	29.55±0.43
Lead	Nd	0.03±0.01	0.02±0.01	Nd	Nd	-
Arsenic	Nd	Nd	-	Nd	Nd	-
Chromium	Nd	Nd	-	Nd	Nd	-
Cadmium	Nd	Nd	-	0.04±0.02	Nd	0.02±0.14

Nd = Not detected

Each value is a mean of three determinations ± standard deviation.

Table 3: Phytochemical composition of *Musa paradisiaca* and *Musa sapientum* pseudostems

Phytochemical	*Musa paradisiacal*			*Musa sapientum*		
	Leaf-folds (mg/100g)	Core (mg/100g)	Average mg/100g	Leaf-folds (mg/100g)	Core (mg/100g)	Average mg/100g
Oxalate	52.28±2.01	60.28±0.10	56.28±2.01	46.42±2.55	36.70±0.20	41.56±2.55
HCN	0.86±0.02	2.08±0.14	1.47±0.14	1.78±0.30	1.10±0.01	1.44±0.30
Tannin	5.86±0.18	10.12±0.20	7.99±0.26	8.90±0.15	4.20±0.30	6.55±0.33
Phytate	3.45±0.05	4.12±0.02	3.78±0.05	3.88±0.30	2.58±0.15	3.23±0.33
Flavonoids	+	+		+	+	
Saponins	++	++		+	+	
Alkaloids	++	+++		+	++	
Steroids	-	-		-	-	

+++ = Highly present ++ = Moderately present

+ = Present in trace amount – = Absent or not detected

Table 4: Lignin, pentosan, carbohydrate and sugar (glucose) composition of *Musa paradisiaca* and *Musa sapientum* pseudostems

	Lignin Composition		Pentosan mg/100g	Carbohydra-tes mg/100g	Sugar content mg/100	
	(I) Acid insoluble lignin (%)	(II) Phloroglu-cinol detection				
M.paradisiaca leaf-folds	3.15	+	11.73	39.71	26.44	
M. paradisiaca core	2.28	+	8.42	62.21	28.60	
Average	2.72		10.07	49.46	27.52	
M.sapientum leaf-folds	7.30	++	10.80	42.13	31.53	
M. sapientum core	2.55	+	6.67	93.82	29.76	
Average	4.93		8.89	67.97	30.65	

++ = Moderately present, + = present in trace amount

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an enabling environment for microorganisms to break down the biomass components into water and carbon (IV) oxide.

The results (Table 1) shows that banana pseudostem stem wastes contained moisture slightly greater than plantain pseudostem the core in each sample having a value slightly higher than the leaf-folds. In each case the dry matter in pseudostem waste was less than 10% green sample and about 20% dried samples. This low content of dry solid matter in the two pseudostem wastes was confirmed by the low basic density 0.22g/cm^3 for plantain and 0.20g/cm^3 for banana.

The solubles in 1:2 ethanol-benzene solution mixture were the highest compared with those in sodium hydroxide (18%) and water while the lowest occurred in water. The reason for the different is that 1:2 ethanol benzene being polar and non- polar solution mixture was able to extract both the polar and non-polar components while (18% NaOH) sodium hydroxide and water extracted only the polar components of the pseudostem wastes.

Mineral Element Compositions:

The mineral elements detected were, Fe, Zn, Mg, P, Cu, Ca, Na, K, lead and Cd. These elements must have come from the absorption of minerals from the soil during growth period. Some of the elements are essential to growth processes in plants e.g Zn (Wardlaw, 1999); Mg and P (Ramlingam, 2003), Cu (Wardlaw, 1999), Ca and K contents are quite high; the lead content was very low and occurred only in the core of the banana pseudostem waste.

Phytochemical Composition:

The phytochemical composition of both *Musa paradisiaca* and *Musa sapientum* pseudostem wastes which include total oxalates, hydrocyanic acid, tannins, phytates, flavonoids, saponins, alkaloids, and steroids are recorded in Table 3, steroids were not detected. The total oxalate of *Musa paradisiaca* pseudostem waste was higher than that of *Musa sapientum* but did not exceed the lethal dose of 2.5g per kg weight (Oke, 1996). The results showed low contents of hydrocyanic acid, tannins, and phytates, these were list during processing of the pseudostem waste into sugar and biofuel. Other phytochemicals flavonoids, saponins and alkaloids were present at moderate levels. Some of the phytochemicals served as the protectants for the pseudostem and some were useful during the growth period of the plants.

The lignin content was low (Table 4) and smaller than the amounts in hardwood and soft woods (Casey, 1980). The carbohydrates content was higher in banana pseudostem than in plantain pseudostem wastes while the pentosan contents were similar in the two samples.

Conclusion:

The results showed that the green plantain and banana pseudostem wastes contain high amount of carbohydrate which can be converted into sugar (glucose) by saccharification and fermentation into alcohol (biofuel), it can also be used in the paper making and in the preparation of cellulose derivatives; both samples have very high moisture content. It is therefore suggested that in order to avoid carrying water to the factory and to reduce the wit of transportation, the green pseudostem wastes should first be cut into pieces and sun-dried for several days before transporting them to the factory for processing.

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