pp 52 - 66

Effect of ripening on the Chemical Composition of Green locally Cultivated Banana Cultivars (Musa Spp.) Peel

Ayo, J.A.[1,2], Ochefu, A.[1] and Agbatutu, A.[1]
[1]Department of Biological Sciences,
Kwararafa University, Wukari, Nigeria
[2]Department of Food Science and Technology,
Federal University Wukari, Wukari, Nigeria.
Corresponding Author:jeromeayo@yahoo.com, jeromeayo@gmail.com

Abstract
The study investigated the Effect of ripening on the proximate, minerals, vitamins and photochemical composition of green locally cultivated banana cultivars peels. The matured unripe green banana fruits were collected from Ussa, Ussa LGA, Taraba State, Nigeria. The proximate, minerals, vitamins and photochemical composition of banana cultivars peels were determined using standard methods. The moisture, protein and carbohydrate content of the peel of unripe green banana decreased from 8.64 to 8.43, 5.47 to 5.23 and 73.04 to 72.42%, respectively, while the ash, fats and fibre content increased from 4.55 to 5.23, 5.35 to 5.57 and 2.96 to 3.13%, respectively, on ripening. The vitamin C, vitamin E, starch and lignin content of the peel of the green cultivar decreased from 0.08 to 0.11, 106.83 to 95.03, 1.07 to 0.97 and 5.84 to 5.55mg/100g, respectively, while the sugar increased from 0.95 to 1.09mg/100g on ripening. The green cultivar peel flour showed a significant decrease, p=0.05, in calcium(0.65 to 0.58mg/100g), potassium(4.63 to 4.36mg/100g), iron(0.28 to 0.23mg/100g) and zinc(0.4 to 0.3mg/100g), respectively, with relative increase in the phosphorous(0.35 to 0.37mg/100g) content on ripening. Ripening decreased the phenol (0.73 to 0.64mg/g), flavonoid (1.70 to 1.41mg/g), carotinod (5.05 to 3.35mg/g) and sterol (0.18 to 0.16mg/g) content of the green cultivar peel flour. The study has shown that ripening has generally improved the vitamins and the sugar content of the ripe banana peels.

Key words: Banana peel, ripening, locally cultivated and chemical composition.

Introduction

Since the dawn of human civilization plants have made large contributions to facilitate human health and well being (Singh *et al.,*2012). The stage of maturity of plants greatly affects the concentrations of nutrients in plants (Izonfuo and Omuaru 1988) , thus it is very important to choose suitable stage of harvesting (Yu *et al*., 2004). Medicinal potentials of most common plants have been extensively studied and compiled but the lack of information regarding the potential of these plants at varying stages of development makes these plants to be highly underutilized.

During the process of growth and development of fruit, series of developmental transitions are undergone. These processes involve coordinated changes in a number of catabolic and anabolic reactions (Duhan *et al.,* 1992), which leads to the synthesis or degradation of wide range of bioactive compounds. Hence, fruits at varying maturity levels may possess vivid bioactive compounds, which need to be studied so as to provide maturity indices for its usage as a source of food or medicine. It has also been proven that ethno-botanically derived compounds have potential bioactive compounds and they, therefore, provide greater potential for product development (Chanda *et al*., 2011).

Increased vegetable utilization and consumption are critical to alleviate world-wide incidence of nutritional deficiencies. Investigations have shown that some plants contribute to increased intake of some essential nutrients and health-promoting phytochemicals. Phytochemicals are present in virtually all of the fruits, vegetables, legumes (beans and peas), and grains we eat, so it is quite easy for most people to include them in their diet (Onuegbu, *et al*., 2011).

In Nigeria, fruits can be harvested at all stages of development (from immature to overripe) and can be used as a source of food in one form or the other. Some fruits are picked when they are mature but not yet ripe (Sitti and Mamogkat 2013). The stage of maturation at which any fruit is harvested also influences the fruit's green-life or its ability to be stored for long periods (DFID, 1995).

The peels of plantain can be dried and made into meal which can be used to substitute up to 70 – 80% of the grain in pig and dairy diets with little change in performance (Sharrock, 1997. The meals are also used in poultry diets but when in high level tends to depress growth and reduces feed efficiency. Plantains and bananas are known to contain bioactive compounds (phytochemicals) such as alkaloids, flavonoids, tannins and phenolic compounds (Atindehou *et al*.,2002, Edeoga *et al*., 2003). According to Akinmoladun *et al.*, 2007) , knowledge of the chemical composition of a plant together with its antioxidants activity will give a fair estimate of its therapeutic potential furthermore.

The banana peel being a key source of many functionally important bioactive compounds that are still underutilized, and very little scientific effort has been put to identify its functionality in terms of application to food and nutraceuticals. This biomaterial can potentially offer new products with standardized compositions for various industrial and domestic uses (Essien *et al*., 2005

Ripening is a natural process that brings a series of biochemical changes which are responsible for the change of color, pigment formation, starch breakdown, textural changes and aroma development and finally abscission of fruits. Ripening is a process in fruits that causes them to become more palatable. In general, a fruit becomes sweeter, less green and softer as it ripens. Nutritional changes upon ripening are very complex and depend on a number of factors, including light and temperature. It is important to realize that this is occurring in the mature fruit tissue and very little phloem activity occurs in a mature fruit that can ripen off the plant.

Banana peel has been fairly researched into including unripe plantain pulp which is a good source of resistant starch(RS), dietary fiber(DF), and polyphenols. Composition, digestibility and application in bread making of banana flour, current use of banana and plantain peels (Happi-Emaga *et al*., 2011. Ripening influences banana and plantain peels composition and energy content, antioxidant source, and in cellulose nanofibers (Annaduari *et al*., 2004). Adsorption of heavy metals from water using banana and orange peels(Essien et al., 2004). Flour of banana (Musa spp) peel as a source of antioxidant phenolic compounds. Isolation and characterization of cellulose nano-fibers from banana peels, plantain peels was

used as a source of antioxidant DF to prepare cookies.,

From the ongoing it is clear that knowledge of the constituents of any plant at each usable stage of development is necessary for better understanding of when it will be used to achieve desired result. Keeping in view the importance of the banana peel as a potential source of many functionally important biochemical compounds, it would be interesting to understand the detailed changes in biochemical compositions at various stages of development. As the fruit advances to maturation stage, the composition of both the pulp and peel changes significantly (Emaga *et al.,* 2007). Therefore, the present study was undertaken to evaluate the changes in biochemical compositions with advancement in fruit maturity and the best stage for obtaining the particular compound of interest at its maximum quantity.

The peel of bananas constitutes 40% of the total weight of fresh bananas, and yet, it has been underutilized and discarded as waste. But these wastes are either uneconomically utilized or disposed of, thereby causing serious pollution problems. This may be due to the ignorance regarding the benefits of commercial application (Khawas *et al*., 2015).

The major wastes of plantain and banana processing in Nigeria are their peels (generated as a result of mechanical removal of the two outer coverings of plantain and banana pulps subsequent to their processing. Ripe banana is very perishable and subject to fast deterioration after harvesting, more susceptible to mechanical injuries and increasing the losses further due to spoilage. In all stated uses, there is little or no account of reuse or recycling of the waste peels, except for some insignificant use as animal feed(Babayemi *et al*., 2009). This will be unconnected with lack of scientific information as to the composition of varied species of banana peel at different stages of development particularly in the developing countries where the same fruit is been cultivated in abundance

During the process of growth and development of fruit, series of developmental transitions are undergone. These processes involve coordinated changes in a number of catabolic and anabolic reactions(Duhan *et al*., 1992), which leads to the synthesis or degradation of wide range of bioactive compounds. Hence, fruits at varying maturity levels may possess vivid bioactive compounds, which need to be studied so as to provide maturity indices for its usage as a source of food or medicine. The end-use of banana and plantain peel depends on its chemical composition, which is affected by the fruit's ripeness. It has also been proven that ethno-botanically derived compounds have potential bioactive compounds and they therefore provide greater potential for product development(Chanda *et al*., 2011).

Peels are the major by-products of all fruits and vegetables obtained during processing; however, some studies show that these are good sources of polyphenols, carotenoids, and other bioactive compounds, which in turn, possess various beneficial effects on human health (Zhang *et al*., 2005. Banana peel extract contains higher antioxidant compounds and thus, promising a more intense utilization of the peels in food and nutraceuticals. However, potential application of the banana peel depends on its chemical composition as well as its physicochemical and functional properties(Emaga *et al*., 2007).

In a bid to encourage the bioconversion of the peels of these crops into useful products, this study was set up to investigate bioactive composition of the peels of unripe and ripe banana peel. The revelation of the bioactive composition of banana peel will unveil its potential usage, add to waste management of the peel, encourage its use in fortification or enrichment of food and encourage commercial production of banana. The aim of this study is to investigate the "Effect of ripening on the proximate, minerals, vitamins and photochemical composition of locally cultivated green banana cultivars peels

Materials and Methods

Materials

Material Collection: The matured unripe locally cultivated green banana cultivars used for this study was bought from Ussa in Ussa Local Government, Taraba State, Nigeria . Green cultivar was identified as *Saba* Banana {*Musa acuminata x balbisiana* (ABB Group) cv saba} using Porcher and Barlow (2002) Banana botanical classification chart..

Material Preparation: The green banana fruits

were cleaned and divided into two and one portion was wrapped in jute bag and stored at room temperature to ripe. The other portion was washed and the peels removed manually (using stainless knife). The peels were sliced and further reduced into smaller pieces to enhance drying, spread on wire gauze and dried at 50°C (using hot air oven) The dried unripe peels (green) were milled (Kenwood Blender), packed in polyethylene) and stored in the refrigerator until use.

The other portion kept for ripening were observed to ripe after four days. The peels of the ripe banana cultivars were removed manually, sliced, pulverize (by slight pounding), spread on wire gauze and oven dried at 50°C. The dried peels were milled, packed (polyethylene) and stored under refrigerator until use.

Methods

Determination of proximate composition

Moisture content: The method described by AOAC (2012) was used. 2.0 g of the banana peel flour were weighed into previously weighed crucibles and dried at 95 – 100°C for two hours in an oven. The samples were removed, cooled in a desiccator, weighed and returned into the oven again for an hour. The samples were then brought out and cooled in a desiccator before weighing. This was repeatedly done until a constant weight was obtained with three consecutive weighing. The percentage of moisture was determined from the results of the weighing.

Ash content: Ash content of the banana peel flour was determined in triplicates as described by Onwuka (2005). About 2.0 g of finely ground samples obtained after moisture determination were weighed into porcelain crucibles. The samples were charred on a heating mantle inside a fume cupboard to get rid of the smoke. The samples were then transferred into a muffle furnace and gradually heated to a temperature of 550°C for 8 h until a clear grey ash was obtained and then after which the samples were cooled in a desiccator and weighed. The percent ash was determined from the results of the weighing.

Crude fibre: Crude fibre content of the banana peel flour was determined using the method of Nelson (1994). About 2.0 g of sample was weighed into a round bottomed flask and 100 cm^3 of 0.25 M was added and the mixture boiled for 30 min. The solution was quickly filtered under suction. The insoluble matter residue was washed several times with hot water until it was acid free. It was quantitatively transferred into the flask and 100 cm^3 of 0.3 M NaOH solution was added and the mixture boiled again under reflux for 30 minutes before it was quickly filtered. The residue was washed with boiling water until it was base free; It was dried to constant weight in the oven at 100°C, cooled in a desiccator and weighed (C1). The weighed residue (C1) was then incinerated in a muffle furnace at 550°C for two hours, cooled in the dissicator and weighed (C2). The loss in weight on incineration divided by the original weight of sample multiplied by 100 gave the percent crude fiber.

Crude Fats: Crude fats contents of the banana peel flour were determined using the method of AOAC (2012). A previously cleaned and dried 500 cm^3 round bottomed flask containing a few anti-bumping granules was weighed (W1) and 300 cm^3 of petroleum ether was poured into the flask fitted with soxhlet extraction unit. The extraction thimble containing 20.0 g of the sample was fixed into the round bottomed flask and a condenser connected to the soxhlet extractor. Cold water circulation was put on, the heating mantle switched on and heating rate adjusted until the solvent was refluxing at a steady rate. Extraction was carried out for six hours, the solvent was recovered and the crude fats extract obtained was dried in an oven at 70°C for an hour. The round bottomed flask with lipid extract was cooled and then weighed. Crude fats content was calculated and expressed in percentage.

Protein: Crude protein content of the banana peel flour was determined using Kjeldahl method as described by Mendham(2006). Five gram(5.0 g) of the dried sample was weighed into a 500 cm^3 Kjeldahl flask. 10.0 g of K_2SO_4 and 0.7 g of Ca_2SO_4 (both as catalyst) was added followed by 40 cm^3 of 98% H_2SO_4. The mixture was gently boiled for over two hours to obtain a clear digest solution. 50 cm^3 of the digest was poured into a distillation flask. 20 cm^3 of water and a few anti-bumping granules were added. 100 cm^3 of 10% NaOH solution was poured into the funnel of the distillation

flask. 100 cm3 of 0.1 M HCl was poured into a receiving conical flask with the funnel tap was opened. The flask was heated to gentle boiling and distillation continued for about 40-45 minutes (or until about 150 cm^3 of liquid had distilled out). A few drops of mixed indicator (methyl red-bromocresol green) was added and titrated against 0.1 M NaOH solution. A blank titration was carried out with an equal measured volume of 0.1M HCl acid. Results were expressed as percent nitrogen.

Carbohydrate: The total carbohydrate contents in the banana peel samples were determined using the method of difference (Onwuka, 2005). Thus percentage available carbohydrate was obtained as: % carbohydrate = 100 – (% moisture + % ash + % crude protein + % lipid extract + % crude fibre).

Determination of Vitamins© & E)

Total ascorbic acid content of the banana peel flour was measured following the DNPH method (Kapur *et al*., 2012). 5 grams of fresh sample was extracted with 20 mL of 5% Meta phosphoric acid using a homogenizer in an ice bath. The extract was filtered using whatman # 01 filter paper and a clear sample was taken. 0.2 mL of 0.02% indophenol solution was added with 0.4 mL of sample extract and incubated for 2-3 minutes until it became a stable reddish-pink color. After that, 0.4 mL of 2% thiourea and 0.2 mL of 2% DNP solution were added and then incubated 3 hours at 37ºC in a hot water bath. Then, 1 mL of 85% sulfuric acid was added and then incubated at room temperature for 30 minutes. The absorbance was determined at 540 nm using a UV visible spectrophotometer (Shimadzu, UV-1601, and Japan). A standard curve was prepared using standard ascorbic acid with concentrations of 20,40,60,80 and 100 mg L-1.

Determination of total starch: Starch content of the banana peel flour was determined following phenol-sulphuric acid method of Onwuka (2005)About 50 g of starch was extracted with hot 80% ethanol to separate the sugar. About 1.0 ml of the sugar extract was pipetted into a test tube and diluted to 2.0 ml with distilled water. About 1.0 ml of 5% phenol was added and the tube was allowed to stand for 10 min. The mixture was vortexed and allowed to stay for another 20 min. Absorbance was read at 490 nm. A standard curve was plotted using 0–100 µg glucose. A standard solution of glucose was prepared by dissolving 10 mg of glucose solution in 100 ml distilled water. About 0.20, 0.40, 0.60, 0.80 and 1.00 ml of standard glucose solution was pipette into a test tube and treated following the procedure for sugar extract. The amount of sugar in the dilution factor and weight of sample was taken into consideration. Starch was calculated using the formula:

Starch (%)=0.05×A×1/M. Weight of sample×0.9

where A = absorbance, M = slope of curve.

Determination of sugar content: Total sugar content in the samples was measured following the sulfuric method (Dubois *et al*., 1956). 1 gram of fresh pulp sample was extracted with 10 mL of 80% ethanol using a homogenizer in an ice bath. The homogenate was filtered using whatman #04 filter paper. 1 mL of 5% fresh phenol solution was added with 1 mL of sample extract and 5 mL of 98% sulfuric acid was added thereafter. The absorbance of the resulting brownish-yellow colored solution was determined at 490 nm using a UV visible spectrophotometer (Shimadzu, UV-1601 and Japan). A standard curve was prepared using the same procedure with a series of D - glucose, at 10, 20, 40, 60 and 80 µg mL-1.

Determination of mineral composition of banana peels

An amount of 2 g of fruit peels was dried in an air oven at 105 °C for 3 hours. The dried sample was next charred until it ceased to smoke. The charred sample was then ashed in a muffle furnace at 550°C until a whitish or greyish ash was obtained. The ash was treated with concentrated hydrochloric acid transferred to a volumetric flask and made up to 100 mL before submission to atomic absorption spectrophotometry (AAS).

For AAS, a SHIMADZU atomic absorption flame emission spectrophotometer model AA-670 IF with an air-acetylene flame, and wavelength respectively set to 422.7 nm for calcium, 279.5 nm for manganese, 248.3 nm for iron and 213.9 nm for zinc determination was used. Stock solutions (1000 ppm) of calcium, manganese, iron and zinc were used to prepare

working standard solutions with at least 4 concentrations within the analytical range. To eliminate phosphorus interference, lanthanum chloride was added to working standard solutions of calcium and to the test ash solution destined to calcium determination so that the final solutions contained 1% La. Concentration of each mineral contained in test solutions was calculated from the standard curve prepared.

Determination of Photochemicals

Phenolics content: Total phenolics content of the banana peel flour were analyzed for total phenolics content according to the Folin-Ciocalteu method (Trease and Evans 1996).. An amount of 2 g of peels paste was extracted with 20 mL of ethanol 80% for 1 h. The mixture was centrifuged at 3000 g for 10 min and the supernatant collected. To a volume of 100 µL of fruit peels extracts, were added 1.150 mL of distilled water and 250 µL of the Folin-Ciocalteau solution. After 6 min, 2.5 mL of a solution of sodium carbonate 7% were added and the volume was adjusted to 6 mL with distilled water. The mixture was allowed to stand for 90 min. Optical density was measured at 760 nm using a spectrometer. The calibration curve was obtained using gallic acid as standard and the concentration ranged from 20 to 600 mg/mL. The results were expressed as gallic acid equivalents/100 g of sample.

Carotenoids content: Carotenoids content of the banana peel flour was determined according to the method described by Krishnaiah *et al*. (2009). A measured weight of banana was homogenized in methanol using a laboratory blender. A 1:10 (1%) mixture was used. The homogenate was filtered to obtain the initial crude extract, 20 ml of other was added to the filtrate and mixed well and then treated with 20 ml of distilled water in a separating funnel. The ether layer was recovered and evaporated to dryness at low temperature (35-50°C) in a vacuum dessicator.

The dry extract was then saponified with 20 ml of ethanoic potassium hydroxide and left over in a dark cupboard. The next day, the carotenoid was taken up in 20 ml of ether and the washed with two portions of 20 ml distilled water. The carotenoid extract (ether layer) was dried in a dessicator and then treated with light petroleum (petroleum spirit) and allowed to stand overnight in a freezer (-10°c). The precipitated steroid was removed by centrifugation after 12hours and the carotenoid extract was evaporated to dryness in a weighed evaporation dish, cooled in a dessicator and weighed. The weight of carotenoid was determined and expressed as a percentage of the sample weight.

$$\text{Percentage carotenoid content} = \frac{\text{weight of sample}}{\text{weight of sample taken}} \times 100$$

Flavonoids content: Flavonoids content of the banana peel flour was determined using the method described by Bohm and Kocipal, (1994). Five grams (5g) of acha-carrot composite biscuit sample was boiled for 30 min under reflux. It was allowed to cool and then filtered through a Whatman No. 42 grade filter paper. A measured volume of the extract was treated with equal volume of ethyl acetate starting with drop. The flavonoid precipitate was recovered by filtration using a weighed filter paper. The resulting weight difference was recorded as the weight of flavonoid in the sample.

$$\text{Percentage flavonoid content} = \frac{\text{weight of residue}}{\text{weight of sample taken}} 100$$

Steroids content: The steroid content of the banana peel flour was determined using Igbokwe *et al* (2016) method. A measured weight of aerial yam flour sample was dispersed into 100 ml distilled water and homogenized in a laboratory blender. The homogenate is filtered and the filtrate is eluted with normal ammonium hydroxide solution (pH 9). 2 ml of the eluate is put into test tube and mixed with 2 ml of chloroform. 3 ml of ice-cold acetic anhydride is added to the mixture in the flask and 2 drops of concentrated H_2SO_4 are added to cool. Standard sterol solution is prepared and treated as described above. The abundance of standard and prepared sample is measured in a spectrophotometer at 420nm.

Tannin: Tannin content of the banana peel flour was quantitatively determined as reported in the manual of food quality control (Trease and Evans 1996). 0.5 g of the slurry was weighed

into a conical flask and mixed with 10 cm^3 of distilled water, shaken and allowed to stand for 1hour. About 1 cm3 of the extract was pipetted into another test tube, and was followed by addition of 5 cm3 distilled water. Two drops of $FeCl_2$ in 0.1M HCl was added, shaken to mix properly and about four drops of potassium ferrocyanide was also added. Absorbance of a portion of the mixture was read at 620nm on a using UV-Visible spectrophotometer. The concentration of tannin was calculated and expressed as percent tannin in the sample.

Statistical Analysis

One-way analysis of variance (ANOVA) was conducted on each of the variables and the least significant difference (LSD) test at significant level $p<0.05$ was performed using SPSS 23 version software for windows to compare the difference between treatment means. Results were expressed as the mean± standard deviation of the triplicate.

RESULTS

Proximate composition of Unripe and Ripe Green peel flour

The proximate compositions of the peels of unripe and ripe green banana are shown in Table 1. The moisture, protein and carbohydrate content of the peel of unripe green banana decreased from 8.64 to 8.43, 5.47 to 5.23 and 73.04 to 72.42%, respective, while the ash, fats and fiber content increased from 4.55 to 5.23, 5.35 to 5.57 and 2.96 to 3.13%, respectively, on ripening. The ripening effect is significant, p = 0.5.

Table 1: Proximate composition of Unripe and Ripe Green banana cultivar peel flour

Sample	Moisture	Ash	Fats	Protein	Fibre	CHO
GUB	8.64±.01b	4.55±.02d	5.35±.01c	5.47±.02a	2.96±.02c	73.04±.02a
.GRB	8.43±.0c	5.23±.01b	5.57±02b	5.23±.02c	3.13±.01b	72.42±.02c

*GRB – Green Ripe banana peel flour, GRU-Green Unripe Banana peel flour, CHO -Carbohydrate

Vitamins and Starch/sugar composition of Unripe and Ripe Green Peel flour

The effect of ripening on the peel of the green banana cultivars on the vitamins (A and C), carbohydrate (starch and sugar) and lignin were shown in Table .2 . The Vitamin C, Vitamin E, starch and lignin content of the peel of the green cultivar decreased from 0.08 to 0.11, 106.83 to 95.03, 1.07 to 0.97 and 5.84 to 5.55mg/100g, while the sugar increased from 0.95 to 1.09mg/100g on ripening. The observed effects were significant, p=0.05.

Table 2: Vitamins and Starch/sugar Composition of Unripe and Ripe Green Banana cultivar Peel flour

Samples	Vitamin C (mg/100g)	Vitamin E (mg/100g)	Starch (%)	Sugar (%)	Lignin (%)
GRU	.08±.02ab	95.03±1.29c	1.07±.02b	.95±.01bc	5.84±.5
GRB	.11±.03b	106.83±3.54b	.95±.01c	1.09±.01ab	5.22±.3

*GRB – Green Ripe banana peel flour, GRU-Green Unripe Banana peel flour,

Mineral composition Unripe and Ripe green Banana Peel flour

The result of the effects of ripening on the mineral composition of peel flour of green banana cultivar is shown in Table .3 . The result observed for the green cultivar peel flour showed a significant decrease in calcium(0.65 to 0.58mg/100g), potassium(4.63 to 4.36mg/100g) and iron(0.28 to 0.23mg/100g) and zinc(0.4 to 0.3mg/100g)with relative increase in the phosphorous(0.35 to 0.37mg/100g) content on ripening.

Phytochemical composition of green banana peel flour

The photochemical composition of peel flour of green cultivar of banana is summarizes in Figure 1 . Ripening decreased the quantity of phenol (0.73 to 0.64mg/g), flavonoid (1.70 to 1.41mg/g), carotinod (5.05 to 3.35mg/g) and sterol (0.18 to 0.16mg/g) content of the green cultivar peel flour.

Table 3: Mineral composition of ripe and unripe green banana peel flour (mg/100g)

Samples	Ca	Mg	K	P	Fe	Zn
GRU	.65±.010a	.31±.01b	4.63±.06a	.35±.01b	.28±.03a	.04±.00a
GRB	.58±.00b	.31±.014b	4.36±.10b	.37±.01a	.23±.01c	.03±.00b

*GRB – Green Ripe banana peel flour, GRU-Green Unripe Banana peel flour.

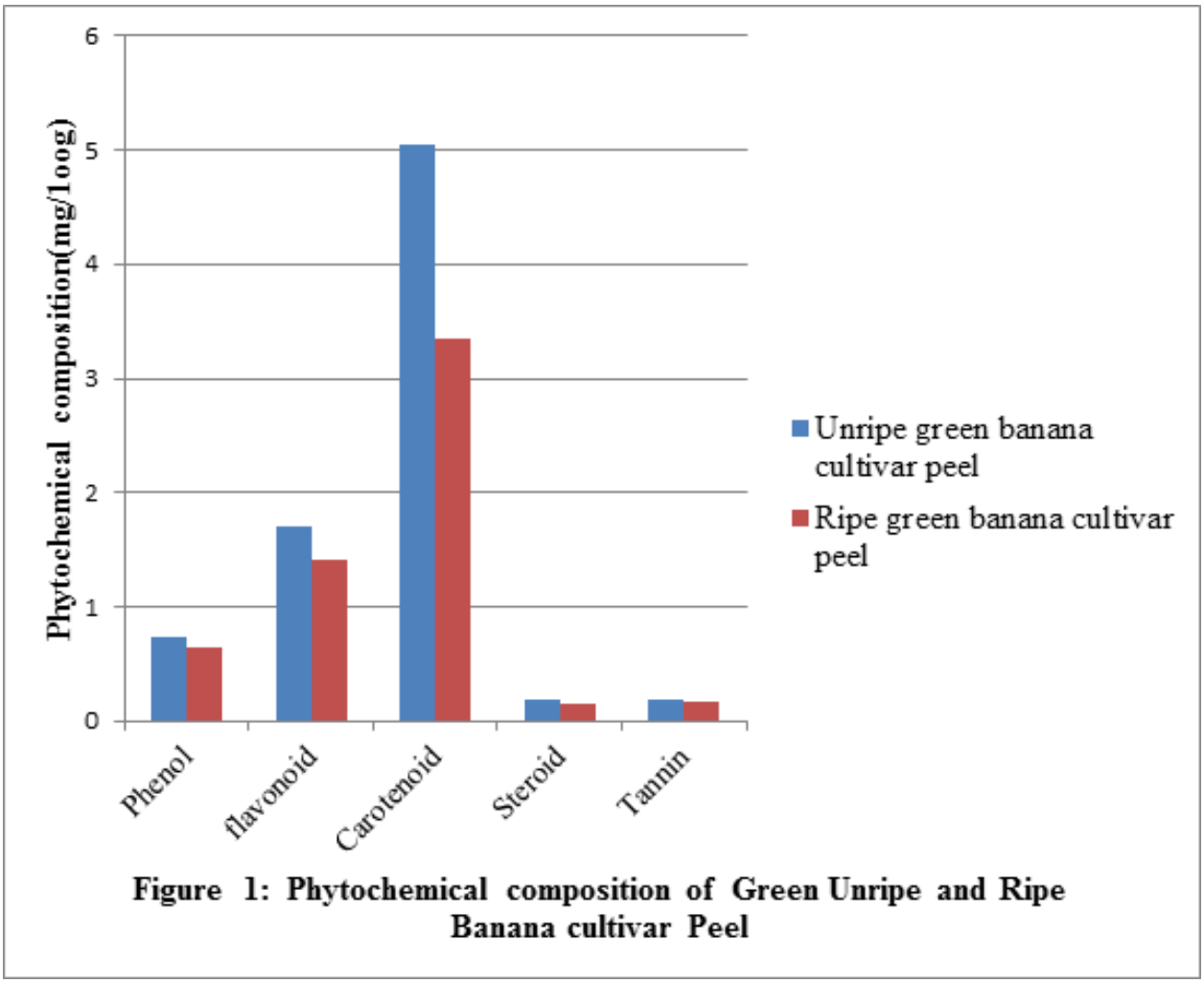

Figure 1: Phytochemical composition of Green Unripe and Ripe Banana cultivar Peel

Discussion

Proximate Composition of unripe and ripe banana peel

The decrease in the moisture content with ripening as observed for the green (Table 1) cultivar agreed with the findings of Khawa *et al*., (2014). In previous study of culinary banana pulp, the moisture content increased with the stages of maturity (Khawa *et al*., 2014), which is opposite from the present finding. The plausible reason behind this may be that the moisture from the peel is transferring to the pulp and as a result, a decreasing trend in moisture content with maturity has been observed. Furthermore, several authors have also stated that carbohydrates are utilized during breathing and osmotic transfer from the peel to pulp, increasing the water content of the pulp which caused a variation in the osmotic pressure between the peel and the pulp (Feenandes *et al*., 1997). The finding of Emaga *et al*.(2007)in the case of different varieties of banana peel supports the results under studies.

The crude protein content of unripe green cultivar banana peels decreased on ripening. The decrease in protein content agreed with the findings of Adamu *et al* (2017). The protein in the banana peel are enzymes involved in the maturation of the fruit(Zhang *et al.,* 2012). During fruit ripening, the breakdown and synthesis of protein occurs: amino acids are recycled. But during the beginning of ripening the actual concentration of protein increases (Singh *et al.,* 2012). A slight decrease in the protein content at stage of ripening could be attributed to the utilization of protein in the gluconeogenes is (Goswaami *et al*., 1996).

The crude fat content in the peel of the

green cultivar of banana recorded an increasing trend and it varied significantly, p=0.5. This may be due to the continuous synthesis of fatty acids during metabolism, and the lipid content also varies drastically. The increasing trend in the crude fat concentration with fruit development has been reported by various authors in the cases of different fruits, which supports the current findings(Siddika *et al*., 2013).

The crude fibre content of the peel of the green cultivar increased. Unripe banana peel presented an increase in the crude fibre in banana peel during fruit ripening which agreed with the findings of Happi-Emaga *et al*., (2007). Researchers have shown that crude fibre content in the peel depends on various factors such as cultivar and ripening stage(Happi-Emaga et al., 2007). Zhang *et al*., (2005) reported that peels of banana and plantain could be a good source of dietary fibre of low cost for use in foods, but the characterization of fiber components from green banana and plantain peels should be determined(Happi-Emaga *et al*., 2007). The values of crude fiber found in the present study is on the higher side which suggests that the culinary banana peel can be a good source of fiber and can help in alleviating digestion problems, for example, constipation, and improve general health and well-being(Anhwange *et al*., 2008). Apart from this, the culinary banana peel can also be a potential source for making poultry and cattle feed due to it being an excellent source of fiber(Adeniji *et al.*, 2008)

The amount of the ash content in the peel of culinary bananas varied with growth and maturity (Zhang *et al*., 2005). These studies showed an increased an increase in the ash content of the peels of both the green cultivar. The changes in the ash content did not vary much among the cultivars at ripening. Ash content, which is generally an inorganic material, is directly or indirectly associated with the absorption capacity of mineral salts at different developmental stages. The ash content in present study is comparatively less than the values reported (12.8%) by Emaga *et al*., (2007) this may correlate to the absorption of mineral salt by the plant and soil condition.

The ripening process decreased the carbohydrate content of the peel of both green banana cultivar. This variation might be due to the degradation of starch at different developmental stages (Sakyi *et al*., 2008). The carbohydrate content in the present study is comparatively higher as compared 59% carbohydrates present in the *Musa sapientunm* peel(Anhwange *et al*., 2008) and this variation may be attributed to the variety used in the present study.

Starch, sugar and Vitamins(C and E) of unripe and ripe banana peel

The starch decreased with ripening of green banana cultivar. The decreasing trend of starch with advancement in maturity has also been reported by Emaga *et al*., (2007) in the case of banana peels. The reducing trend in starch content with maturity may correlate to the accumulation of carbohydrates during maturation which causes the hydrolysis of starch and sugar storage during maturation. Various enzymes involved in the starch degradation during ripening are amylase, glycosidase, phosphorylase, invertase, and sucrose synthase, etc., which further help in the accumulation and formation of soluble sugars (Cordenunsi *et al*., 1995). The onset of ripening was attended with a pronounced decrease in the starch (Raji 1974).

The relative high starch content in the banana peel could provide more information on determining the structure–function relationship and suggest some applications of the peel. Peels of banana and plantain could be a good source of DF of low cost for use in foods, but the characterization of fiber components from green banana and plantain peels should be determined (Happi-Emaga *et al.,* 2007). Green plantain peels contain 40% (wet weight basis) starch that is transformed into sugars after ripening. Green banana peels contain much less starch (about 15%) when green than plantain peels, while ripe banana peels contain up to 30% free sugars (Happi Emaga *et al*., 2011).

During maturation, the sugar contents of the peel of banana gradually increased. The increasing trend of sugars content for the cultivar with advancement in maturity and ripening is in line with the report of Adisa and Okey (1987). The increase in the sugar content evinced the degradation of starch to sugar with maturity(Khawas *et al*., 2014). According to the reports of Emaga *et al* (2007), the major TSS found in the peel of bananas are mainly glucose and fructose with a slight amount of sucrose. In

the present study, the amount of sugar of ripen peel studied was higher than the unripe peel. Therefore, the ripe banana peel may be a better source of fructose than glucose, as fructose is a non-reducing sugar.

Lignin content of the peel of the green banana cultivar in these studies decreased during ripening. The decreased observed agreed with Happi-Emaga *et al*., (2008. This decrease trend of lignin may correlate to the lignifications of cell wall constituents which result in decrease in other dietary fiber fractions(Punna *et al*., 2004).

The growing cell wall is dynamically modified by enzymes that change the structure of pectins and hemicelluloses, thereby altering their interactions with each other and with cellulose. Growth cessation is correlated with reduced expression of genes that promote wall loosening and changes in the matrix polysaccharides that lead to a less extensible cell wall (Cosgrove *et al.* 2014)

Banana fruits contain various antioxidant compounds in both pulp and peel tissues, such as vitamin C, vitamin E, β-carotene and flavonoids. The pink cultivar con tain relatively higher Vit C content. The vitamin C content of the green peel banana cultivar increased from 0.08 to 0.11mg/100g on ripening. Osman *et al*.(1998) obtained increasing ascorbic acid content with ripening, with highest level at the fully ripened stage, as similarly obtained in the present study.

The increase in ascorbic acid content with ripening has been attributed to the increase in lipid peroxidation considering that fruit ripening which is an oxidative phenomenon that requires turnover of active oxygen species(Jimenez *et al*., 2002). The vitamin E increased from 95.00 to 106.83 mg/100g for green banana cultivars. Under this condition, antioxidant compounds including ascorbic acid and vitamin E usually increased during ripening(Mosa and Khalil 2015).

Minerals content of unripe and ripe banana peel flour

The study indicates insignificant decrease of calcium(Ca), potassium(K), zinc(Zn) and magnesium(Mg) as unripe banana ripens. Minerals play a key role in various physiological functions of the body, especially in the building and regulation processes. Fruits are considered as a good source of dietary minerals (Ismail *et al.,* 2011). Calcium is an important constituent of bones and teeth and it is actively involved in the regulation of nerve and muscle functions (Soetan *et al*., 2010). According to Leterme *et al.* (2006), several factors like variety, state of ripeness, soil type, soil condition, and irrigation regime may cause variation in the mineral and trace elemental contents in different types of fruits as well as within different parts of the same fruit.

The calcium content of the green banana peel decreased on ripening of the cultivars. The observed decrease of calcium content in this study agreed with the findings of O'Conell (2001). Thus the relative high amounts of calcium in the peel of unripe banana as observed in this study, suggest the importance of these peels to diabetics. Calcium is an important component of intracellular processes that occur within insulin responsive tissues like skeletal muscle and adipose tissue. Alteration in calcium flux can have adverse effects on insulin secretion which is a calcium-dependent process(O'Connell 2001).

The study showed that unripe banana peels contain significantly higher amounts of Mg than ripe plantain peels for both cultivars under study. Magnesium is a cofactor of hexokinase and pyruvate kinase and it also modulates glucose transport across cell membranes(O'Connell 2001).

The high amount of potasium(K) in the peel samples investigated are considered of comparative advantage. This is because intake of diets with higher Na to K ratio has been related to the incidence of hypertension(Chen, 2010). The phosphorous content of the banana cultivars could be advantageous to consumers. Phosphorus is involved in several biological processes such as: bone mineralization, energy production, cell signaling and regulation of acid-base homeostasis.

Findings from this study indicate that unripe plantain peel contains higher quantities of zinc(Zn) . Zinc plays a key role in the regulation of insulin production by pancreatic tissues and glucose utilization by muscles and fat cells(Eleazu, 2013). Zinc is particularly necessary in cellular replication and the development of the immune response. Zinc also plays an important role in growth; it has a recognized action on more than 300 enzymes by

participating in their structure or in their catalytic and regulatory actions(Salgueiro *et al*., 2002). Iron carries oxygen to the cells and is necessary for the production of energy, synthesis of collagen and the proper functioning of the immune system.

The large variation in all of the micronutrients observed during fruit development may be attributed to preferential absorbance, and this may be due to the cultivar and/or soil, climate, agricultural practice, and the quality of water for irrigation(Rop *et al*., 2010). Most of the minerals are very crucial in many of the enzymes activities, protecting the cells from attacks by free radicals, the regulation of glucose homeostasis, etc(Anhange *et al*., 2008). The results revealed that the unripe banana peel contains a higher amount of mineral salts comparing to the ripe(Khawas *et al*., 2014), and hence, the culinary banana peel could be a good feed material for cattle and poultry.

Photochemical composition of unripe and ripen banana peel

Banana is rich in phyto-nutrients hence has nutritional value(Happi Emaga *et al*., 2011; Onwuka *et al*., 1997). The peels could be good source of bioactive compounds but as major waste products of various fruits are essentially discarded. Generally, nutrient content and antibacterial activity determination are basic steps to developing novel nutraceuticals (*Musa paradisiaca*) peels and leaves. The possible contribution of these samples, notably the peels, to food supply could be high(Ighodaro 2012). Plantains and bananas are known to contain bioactive compounds (phytochemicals) such as alkaloids, flavonoids, tannins and phenolic compounds(Atindehou *et al.*, 2002, Edeoga *et al.,* 2003).

Generally, a higher phytochemical content were observed for the green banana cultivar both at ripen and unripe stage. The decrease in the phenol content of the green banana cultivar (Figure 1) agreed with findings of Someya *et al.*, (2002). In humans, phenolic compounds have been reported to exhibit a wide range of biological effects including anti-bacterial, anti-inflammatory and antioxidant properties(Han *et al.,* 2007). In general, phenolic content, particularly tannins which are responsible for astringency taste of unripe fruits, decreased with ripening mainly due to polymerization rendering them insoluble and undetectable to taste.

The plausible explanation behind this variation has been explained by Kiyoshi and Wahachiro (2003) that during the early ripening stage, 60% of the polyphenolic compounds have a molecular weight above 2×10^5. With advancement in ripening, this higher molecular weight disappears slowly, resulting in a decrease in astringent property. On further ripening, only those 40% of polyphenols with a molecular weight below 2×10^5 remain, and the polyphenols content decreased which are in line with our results. The decreasing trend of polyphenols in the banana peel with growth is also reported by Sundaram *et al.,* (2011).

The culinary banana peel is an excellent source of polyphenols, and is generally involved in defense against radiation or aggression by pathogens(Ashraf *et al.,* 2011). Polyphenols may contribute to the bitterness, astringency, color, flavor, odor, and oxidative stability (Pandey, 2009) and are an important group of antioxidants, having the ability to absorb free radicals (Delfanian, 2015).

The decrease in the flavonoid content of the green banana cultivar agreed with the findings of Cao *et al*., (1997) and Choi *et al*.,(2012). As maturity progressed, the biosynthesis of flavonoids occurs which is regulated by coordinated transcriptional control of the enzymes resulting in the decreasing level of flavonoids with respect to maturity. Many flavonoids are found to have strong antioxidants and being capable of effectively scavenging the reactive oxygen species (AOS) because of their phenolic hydroxyl groups. Flavonoids, the most potent ant oxidative compounds of the plant phenolics, potentially occurred during the early stages of the culinary banana peel development. The maximum amount gradually decreased with a minimum value at ripening. Many flavonoids are found to have strong antioxidants and being capable of effectively scavenging the reactive oxygen species (AOS) because of their phenolic hydroxyl groups(Cao *et al*., 1997).

The decrease in the tannin content with the advancement of growth reduces the astringency property. The astringency property gets reduced as the culinary banana attains maturity, and this property is related to insolubilization and polymerization of polyphenols with other constituents of pulp

(Khawas *et al*. 2014). The tannins content of the peel, which act against the availability of proteins in the rum, decreases with ripening as a consequence of a migration of the polyphenols from the peel toward the pulp and the phenolic oxidative degradation by polyphenol oxidases and peroxidases(Bugaud *et al*., 2009).

An astringent and bitter plant polyphenolic compound that binds and precipitates proteins and other organic compounds, including amino acids and alkaloids, are known as tannins. The decrease in the tannin content with the advancement of growth reduces the astringency property. The astringency property gets reduced as the culinary banana attains maturity, and this property is related to insolubilization and polymerization of polyphenols with other constituents of pulp (Khawas *et al*., 2014). The tannins content of the peel, which act against the availability of proteins in the rumen, decreases with ripening as a consequence of a migration of the polyphenols from the peel toward the pulp and the phenolic oxidative degradation by polyphenol oxidases and peroxidases(Bugaud *et al*., 2009).

Conclusion

Ripening is a process consists of a set of biochemical and physical changes which gives an edible fruit. Softening of the texture, yellowing of peel, reduction of astringency and increase of sweetness (increase in sugar content) are major organoleptic changes which were noted in banana ripening. These changes occur as a result of series of biochemical changes in peel and flesh of banana fruit as revealed by the study.

The results revealed the culinary banana peel to be a potential source of many important nutritional and bioactive compounds. Phenols, flavonoids and scavenging activity were at their minimum at the ripening stage. Hence, the present study favorably justifies that the culinary banana peel particularly at matured and unripe stage has enormous potential for commercial application as a source of nutritional and bioactive compounds which can add a higher value to this locally important crop if added to other food products.

Researches on the chemical and photochemical composition of other banana cultivars (local and hybrid) should be encouraged to allow the selection of the best cultivars for multiplication by agronomists and distribution by agricultural economists to the local farmers. Also the bioactive components of banana cultivars at the various stages (immature, mature, ripe and over ripe) need to be investigated to enlighten the producer / farmers as to the best stage of harvest depending on the usage (food products).

References

Adamu, A.S., Ojo, I.O. and Oyetunde, J.G. (2017). Evaluation of Nutritional values of ripe, unripe, boiled and roasted plantain pulp and peel. *European Journal of Basic and Applied Sciences*. Vol.4 (1): 9-12.

Adeniji, T.A., Barimalaa, I.S., Tenkouano, A; Sanni, L.O and Hart A.D (2008). Antinutrients and Heavy Metals in New Nigerian *Musa* Hybrid Peels with Emphasis on Utilization in Livestock Production. *Fruits*, 63(2): 65–73.

Adewale, I.O; Adefila, A and Adewale, T.B (2013). Changes in Amylase Activity, Soluble Sugars and Proteins of Unripe Banana and Plantain during Ripening. *Annual Review & Research in Biology;* 34:678-685.

Adisa, V.A and Okey, E.N (1987). Carbohydrate And Protein Composition of Banana Pulp And Peel As Influenced By Ripening And Mold Contamination. *Food Chemistry*, 25(2), 85–91.

Ashraf, A.M; Maah, J.M; Yusoff, I; Mahmood, K and Wajid A (2011). Study of Antioxidant Potential of Tropical Fruits. International *Journal of Bioscience, Biochemistry and Bioinformatics,* 1(1), 53–57.

Akinmoladun, A.C; Ibukun, E.O; Afor, E; Akinrinlola, B; Onibon, T.R; Akinboboye, O.A; Obuotor, E.M and Farombi, E.O (2007), Chemical Constituents and Antioxidant Activitity of Alstonia boonei, *African Journal of Biotechnology* 6 (10): 1197- 1201.

Anhwange, B.A (2008). Chemical Composition of *Musa Sapientum* (Banana) Peels. *Journal of Food Technology* 6(6): 263–266.

Annadurai, T; Muralidharan, A.R; Joseph, T; Hsu, M.J; Thomas, P.A and Geraldine, P

(2012). Antihyperglycemic and antioxidant effects of a flavanone, naringenin, in streptozotocin-nicotinamide-induced experimental diabetic rats. *J Physiol Biochem*. 68:307–318.

AOAC (Association of Official Analytical Chemists) (2012). Official Methods of Analysis of the Association of Official Analytical Chemists 17th Ed. Published by the Association of Official Analytical Chemists International, Suite 400 2200 Wilson Boulevard, Arlington, Virginia USA.

Atindehou, K.K; Kone, M; Terreaux, C; Traor, D; Hostettmann, K and Dosso, M (2002), Evaluation of the antimicrobial potential of medicinal plants from the Ivory Coast. *Phytotherapy Research* 16 (5): 497- 502.

Babayemi, O.J; Khadijah, T.D; Abideen, A.K and Davies, O.N (2009). Determination of potash alkali and metal Contents of ashes obtained from peels of some varieties of Nigeria grown Musa species. *Bioresources* 5: 1384-1392.

Bohm, B.A and Kocipal, A.R (1994). Flavonoid and condensed tannins from the leaves of Vaccinum raticulatia and Vaccinum caloyimum. *Journal of Pacific Science*, 48:458-463.

Bugaud, C; Alter, P; Daribo, M.O and Brioullet, J.M (2009). Comparison of the Physicochemical Characteristics of a New Triploid Banana Hybrid, FLHORBAN 920, and the Cavendish Variety. *Journal of the Science of Food and Agriculture*, 89, 407–413.

Cao, G; Sofic, E and Prior, R.L (1997). Antioxidant and ProOxidant Behaviour of Flavonoids: Structure Activity Relationships. *Free Radical Biology and Medicine*, 22(5), 749–760.

Chanda, S; Kaneria, M and Nair, R (2011). Antibacterial activity of Psoralea corylifolia L. seed and aerial parts with various extraction methods, *Res. Journal of Microbiology*, 60: 124-131.

Chen, X.H; Xia, L.X; Zhou, H.B and Qiu, G.Z (2010). Chemical composition and antioxidant activities of Russula griseocarnosa sp. . *J Agric Food Chem* 58: 6966-6971.

Choi, S.H; Ahn, J.B; Kim, H.J; Im, N.K; Kozukue, N; Levin, C.E and Friedman, M. (2012,). Changes in Free Amino Acid, Protein, and Flavonoid Content in Jujube (*Ziziphus Jujube*) Fruit During Eight Stages of Growth and Antioxidative and Cancer Cell Inhibitory Effects by Extracts. *Journal of Agricultural and Food Chemistry* 60, 10245–10255.

Cordenunsi, B.R and Lajolo, FM (1995). Starch Breakdown During Banana Ripening: Sucrose Synthase and Sucrose Phosphate Synthase. *Journal of Agricultural and Food Chemistry*, 43(2), 347–351.

Daniels, J (2016). Constituents of six Malaysian medicinal plants. *Journal of Medicinal Plant resources*, 3 (2): 67-72.

DuBois, M; Gilles, K.A; Hamilton, J.K; Rebers, P.A and Smith, F (1956). 'Colorimetric Method for Determination of Sugars and Related Substances' *Analytical Chemistry,* 289(3):350 – 356.

Duhan, A; Chauhan, B.M and Punia, D (1992). Nutritional value of some non-conventional plant food of India, *Plant Foods Human Nutrition*, 42: 193-200.

Edeoga, H.O; Okwu, D.E and Mbaebie, B.O (2003), Mineral and nutritive value of some Nigerian medicinal plants, *Journal of Medicinal and Aromatic Plant Science* 25: 689-694.

Eleazu, C.O; Iroaganachi, M and Eleazu, K.C (2013). Ameliorative potentials of cocoyam (Colocasia esculenta L.) and unripe plantain (Musa paradisiaca L.) on the relative tissue weights of streptozotocin-induced diabetic rats. *Journal of Diabetes Research* (2013): 1-8.

Emaga, T.H; Andrianaivo, R.H; Wathelet, B; Tahnago, J.T and Paquot, M (2007). Effects of the Stage of Maturation and Varieties on the Chemical Composition of Banana and Plantain Peels. *Food Chemistry* 103(2): 590–600.

Essien, J.P; Akpan, E.J and Essien, EP (2005). Studies on Mould Growth and Biomass Production Using Waste Banana Peel. *Bioresource Technology*, 96(13): 1451–1455.

Fernandes, K.M; Carvalho, V.D and Cal-Vidal,

J (1979). Physical Changes During Ripening Of Silver Banana. *Journal of Food Science*, 44(4), 1254–1255.

Goswami, B and Borthakur, A (1996). Chemical and Biochemical Aspects of Developing Culinary Banana (*Musa* ABB *Kachkal*. " *Food Chemistry*, 55(2):169–172.

Han, X; Shen, T and Lou, H (2007). Dietary polyphenols and their biological significance, *International Journal of Molecular Science*, 8: 950-988.

Happi Emaga, T; Bindelle, J; Agneesens, R; Buldgen, A; Wathelet, B and Paquot, M (2011). Ripening influences banana and plantain peels composition and energy content. *Trop. Anim. Health Prod.*, 43 (1): 171-177.

Happi-Emaga, T; Herinavalona-Adrianaivo, R; Wathelet, B; TchangoTchango, J and Paquot, M (2007). Effects of the stage of maturation and varieties on the chemical composition of banana and plantain peels. *Food Chemistry*, 103, 590–600.

Igbokwe, C.J; Akubor, P.I and Mbaeyi-Nwaoha, I.E (2016). Effect of processing on thechemical composition, phytochemical contents and functional properties of yellow leshed aerial yam (*DioscoreaBulbifera*) Flour, *Journal of Food Science*. 4(4):1-4.

Ighodaro, O.M (2012). Evaluation study on Nigerian species of Musa paradisiacal Peels: Phytochemical screening, proximate analysis, mineral composition and antimicrobial activities. *Researcher*.4(8):1-4. 15.

IPGRI (1996). Descriptors for banana (Musa spp.). Documentation and Information management, International plant genetics Researches Institute, IPGRI, Rome (ITA). 55p.

Ismail F, Anjum MR, Mamon AN and Kazi T G (2011). Trace metal contents of vegetables and fruits of Hyderabad retail market, *Pakistan Journal of Nutrition*, 10, 365– 372.

Izonfuo WAL and Omuaru VOT (1988)," Effect of Ripening on the Chemical Composition of Plantain Peels and Pulps (Musa paradisiaca)", *Journal of the Science of Food and Agriculture* 45:333-336.

Kapur, N; Murphy, E; Cooper, J; Bergen, H and Hawton, K (2008). Psychosocial assessment following self-harm: results from the multi-centre monitoring of self-harm project. *Journal of Affective Disorders* 106: 285–293.

Khawas, P; Das, A.J; Sit, N; Badwaik, L.S and Deka, S.C (2014). Nutritional Composition of Culinary *Musa* ABB At Different Stages of Development. *American Journal of Food Science and Technology*, 2(3), 80–87.

Khawas, P; Dash, K.K; Das, A.J and Deka, S.C (2015). Drying Characteristics and Assessment of Physicochemical and Microstructural Properties of Dried Culinary Banana Slices. *International Journal of Food Engineering,* 11(5), 667–678.

Krishnaiah, D; Devi, T; Bono, A and Sarbatly, R (2009). Studies on photochemical constituents of six Malaysian medicinal plants. *Journal of Medicinal Plant resources*, 3 (2): 67-72.

Leterme P, Buldgen A, Estrada F and Londono AM (2006). Mineral content of tropical fruits and unconventional foods of the Andes and the rain forest of Colombia, *Food Chemistry,* 95, 644-652.

Mosa, Z.M and Khalil, A.F (2015). The effect of banana peels supplemented diet Mounts TL (2000). The Chemistry of Components, 2nd Edn. Royal Society of Chemistry

O'Conell, B (2001). Select vitamins and minerals in the management of diabetes,"*Diabetes Spectrum,* 14: 133-148.

Onwuka, G.I.(2005). Food analysis and instrumentation: theory and practice. Naphathali prints, Nigeria, 95-96.

Osman, A; Syafirin, N; Saad, N and Mohamed, S (1998). Comparing the physico-chemical characteristics of Mas, Rasthali and Berangan bananas at 3 stages of maturity. First National Banana Seminar, Awana Genting, UPM, Serdang (MYS).

Porcher, M.H and Barlow, S (2002), Sorting Musa names, The University of Melbourne.

Raji, K. LalMeera, G. and Krishna, P.S (1974). Biochemical aspects of the developing

and ripening banana. Phytochemistry (13)11:2365-2370.

Rop, O; Sochor, J; Jurikova, T; Zitka, O; Skutkova, H; Mlcek, J; Salas, P; Krska, B; Babula, P; Adam, V; Kramarova, D; Beklova, M; Provaznik, I and Kizek, R (2010). Effect of Five Different Stages of Ripening on Chemical Compounds in Medlar (*Mespilus Germanica L.*) *Molecules,* 16(1), 74–9.

Sakyi-Dawson, E; Asamoah-Bonti, P and Annor, G.A (2008). Biochemical Changes in New Plantain And Cooking Banana Hybrids At Various Stages of Ripening. *Journal of The Science Of Food Agriculture* 88(15), 2724–2729.

Salgueiro, M.J; Zubillaga, M.B; Lysionek, A.E; Caro, R.A; Weill, R and Boccio, J.R.(2002), The role of zinc in the growth and development of children, *Nutrition,* 18, 510519.

Siddika, A.M; Khatun, S; Khan, M.M.H and Pervin. F (2013). Changes In: Contents of Some Chemical Compositions and Activities of Hydrolytic and Oxidative Enzymes of *Coccinia Cordifolia* L. Fruits. *Journal of Bioscience*, 21, 35–41.

Singh, R, Dar SA and Sharma P (2012). Antibacterial activity and toxicological evaluation of semi purified hexane extract of Urtica dioica leaves. *Res. Journal of Medicinal Plant*, 66: 123-135.

Someya, S; Yoshiki, Y and Okubo, K (2002). Antioxidant compounds from bananas (Musa Cavendish). *Food Chemistry*, 79, 351–354.

Trease, G.E and Evans, W.C (1996). Pharm acognosy . Macmillan publishers ltd. Pp 213.

Yu, P; Christensen, D.A and Mckinion, J.J (2004). In situ rumen degradation kinetics of timothy and alfalfa as affected by cultivar and stage of maturity *Canadian Journal of Animal Science,* 84: 255- 263.

Zhang, L.L; Feng, R.J and Zhang, Y.D (2012). Evaluation of different methods of protein extraction and identification of differentially expressed proteins upon ethylene-induced early-ripening in banana peels. *Journal of the Science of Food and Agriculture*, 92, 2106– 2115.

Zhang, P; Whistler, R.L; BeMiller, J.N and Hamake, B.R (2005). Banana starch: Production, physicochemical properties, and digestibility – A review. *Carbohydrate Polymers*, 59, 443 –458.