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NUTRIENT, SECONDARY METABOLITE AND PHYSICOCHEMICAL CONSTITUENTS OF SELECTED PLANT PEELS

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Food scarcity has been a major scourge to majority of third-world countries as many plant food materials are being lost to spoilage or are diverted into livestock breeding. This study was aimed at evaluating the nutrient, physicochemical and antioxidant properties of flours of the peels of selected tuber crops (potato, plantain and yam). Standard procedures were used in determining the nutrient, antioxidant and phytochemical constituents of the peel flours. The proximate composition revealed that moisture and ash content of the samples showed no significant difference ($p>0.05$). However potato peel flour had a significantly ($p<0.05$) higher concentration of fat (1.13±0.06 %) and carbohydrate (59.72±0.02 %), while plantain peel flour had higher ($p<0.05$) protein (2.14±0.01%) and crude fiber (77.87±0.06 %) content. The peels showed appreciable amount of mineral composition (mg/100 g), although potatoes peel flour had significant ($p<0.05$) amount of phosphorus, sodium, potassium and magnesium. The Na^+/K^+ was significantly low in plantain peel flour (0.0057±0.25). The water absorption capacity was significantly higher ($p<0.05$) in yam peel flour (49.33±0.58 %), while gelatinization temperature was higher ($p<0.05$) in plantain (80.50±0.50 ℃). The result for antioxidant properties showed that yam and plantain peel flour had the highest ($p<0.05$) total phenol (57.86±0.56 mg/100g) and flavonoid (7.18±0.28 mg/100 g) contents respectively. The nutrient, mineral, antioxidants as well as low anti-nutrient content of tuber peels present them worthy for animal-feed production and plant solid waste management.

Keywords: Nutrient, Antioxidant, Peels, Tuber crops, Phytochemicals

Nutrient, Secondary Metabolite and Physicochemical Constituents of Selected Plant Peels

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Abstract

Food scarcity has been a major scourge to majority of third-world countries as many plant food materials are being lost to spoilage or are diverted into livestock breeding. This study aimed at evaluating the nutrient, physicochemical and antioxidant properties of flours of the peels of selected tuber crops (potato, plantain and yam). The proximate composition revealed that moisture and ash content of the samples showed no significant difference ($p>0.05$). However, potato peel flour had a significantly ($p<0.05$) higher concentration of fat (1.13±0.06%) and carbohydrate (59.72±0.02 %), while plantain peel flour had higher ($p<0.05$) protein (2.14±0.01%) and crude fiber (77.87±0.06 %) content. The peels showed appreciable amount of mineral composition (mg/100g), although potatoes peel flour had significant ($p<0.05$) amount of phosphorus (255.15±0.58), sodium (382.077±0.84), potassium (644.83±0.12) and magnesium (150.58±0.07). The Na^+/K^+ was significantly low in plantain peel flour (0.0057±0.25). The water absorption capacity was significantly higher ($p<0.05$) in yam peel flour (49.33±0.58%), while gelatinization temperature was higher ($p<0.05$) in plantain (80.50±0.50^{0}C). The result for antioxidant properties showed that yam and plantain peel flour had the highest ($p<0.05$) total phenol (57.86±0.56mg/100g) and flavonoid (7.18±0.28mg/100g) contents respectively. The anti-nutrient composition of the tuber peel flours showed that oxalate (0.67±0.03mg/kg), phytate (0.34±0.01 mg/kg) and cyanide (0.38±003mg/kg) contents were very low in plantain peel flour. The nutrient, mineral, antioxidants as well as low anti-nutrient content of tuber peels present them worthy for animal-feed production and plant solid waste management.

Keywords: Nutrient, Antioxidant, Peels, Tuber crops, phytochemicals

INTRODUCTION

Many developing countries of the world have been faced with a major challenge of food scarcity which results from factors such as the diversion of food materials into animal and livestock breeding, food spoilage, natural disasters, floods and frost. The competition for these limited food resources between humans, livestock and the biofuel industry has resulted in inaccessibility and inflation of prices of these food resources (Baksi *et al.,* 2020). Grains, tubers, legumes and vegetables constitute a large portion of food resources that have been greatly limited by the challenge of food scarcity. Researchers are for this reason relentlessly working on considering alternative environmentally suitable food by-product options, such as the peels of tubers like potato, plantain and yam. The skin of potato, plantain or yam is normally peeled-off and discarded during processing. It can be obtained by lye-peeling, steam-peeling or abrasion-peeling, depending on the desired product (Ovando *et al.,* 2019). Abrasion peeling is made from chips, while steam peeling is made from frozen and dehydrated potato goods. A large number of by-products have resulted from the increasing production of yam, potato and plantain processed commodities.

Some by-products of potato, yam and plantain processing are unsuitable for foodstuff. The World Health Organization estimates that 40-50 % of the by-products are not suitable for human use (Charmley *et al.,* 2016). Two forms of by-products include cull products which constitute whole products not meant for human use, and potato, yam and plantain process waste derived from production of potatoes. On the one hand, peels constitute the bulk of processed waste that poses disposal problem to the food industry, in particular as wet peels are prone to a high rate of microbial degradation. On the other hand, they include a variety of phenolic compounds, glycoalkaloids and cells which can be used for natural antioxidants, steroid hormone, as well as dietary fiber. These peels comprise pharmacologically fascinating components, there is hence enthusiasm for its production (Ovando *et al.,* 2019). Synthetic animal and human dietary food additives are not popular any more, but natural functional compounds are a potential alternative. The use of byproducts also reduced waste and so made production more sustainable (Schieber *et al.,* 2011). This study examines the available nutrients and other phytochemicals of potato, plantain and yam peel flour as nourishment for animals and man. As the world's population expands, food insecurity remains a worry to large population in low-income countries. In 2021 roughly 33 % of crops had been transformed into animal feed due to problems like as food shortages and a lack of awareness about the nutritional qualities of diverse food crops (FAO, 2021). In order to resolve the problem, we need to examine the flour produced from the peels of many traditional food crops (plantains, yams and potatoes), as well as their mineral and nutritional make-up and other physicochemical qualities.

Nigerian roots and tuber production grew from 90.7 million tons in 2013 to 117 million tons in 2020 (FOA, 2020). In this way, more by-products will be available. Consequently, the difficulties to be solved are food shortages and the under-uses of *peels* generation from the peelings of the above-mentioned crops. This study attempts to avail the nutrient contents and physicochemical properties of the peels which may redefine consumption and food shortages in the population of the country, minimizing food insecurity and starvation. Therefore, the objectives of the study were to investigate the proximate, mineral, physicochemical, secondary metabolites and anti-nutrient composition of potatoes, plantain and yam peels.

MATERIALS AND METHODS

Sample Collection

The yam *(Dioscorea alanta),* potato (*Ipomoea batatas)* and plantain *(Musa acuminate)* tubers used for this study were obtained from the Kure Ultramodern Market, Minna, Bosso LGA, Niger state, Nigeria in January, 2021.

Chemicals

All chemicals used for the various experimental works were of analytical grade and prepared according to the standard procedures as described in the various methods.

Sample preparation

The yam, potatoes and plantain were washed and peeled; the peels were placed separately in trays. The peels were left to dry for 7-14 days at room temperature after which they were blended and poured into an air-tight container.

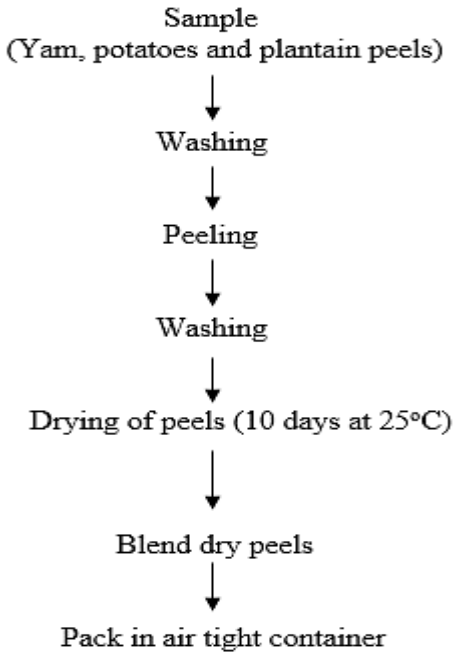

Figure 1: Flow chart on the production process of plants peel flour

Proximate Analysis

The proximate analysis was carried out according to the methods outlined by the Association of Official Analytical Chemists (AOAC, 2000).

Determination of Moisture Content

A crucible was dried to a constant weight in an air oven at 105 ºC and the crucibles were cooled in a desiccator and weighed (W_1). 2.0g of the sample was weighed into the crucible and weighed (W_2) and dried in the oven at 105 ºC to a constant weight (W_3).

$$\text{Moisture (\%)} = \frac{\text{Loss in weight on drying (g)}}{\text{Initial weight of sample}} \times 100$$

$$= \frac{W2 - W3}{W3 - W1} \times 100$$

Where,

W_1= Weight of empty crucible

W_2= Weight of crucible + sample before oven drying

W_3 = Weight of crucible +sample after oven drying

3.3.2 Determination of Ash Content

Clean crucibles were ignited in a Muffle Furnace at 550 ºC for 1h, cooled in a desiccator and was weighed (W_1). 2.0g of the sample into the crucible, was weighed (W_2) and transferred into the Muffle Furnace (550 ºC) for 8h. The Furnace was allowed to cool to 200 ºC; the crucible was transferred into a desiccator and cooled to a constant weight (W_3).

$$\text{Ash (\%)} = \frac{\text{Weight of ash (g) x 100}}{\text{Weight of sample}} \times 100$$

$$= \frac{W3 - W1}{W2 - W1} \times 100$$

Where,

W_1= Weight of empty crucible

W_2= Weight of sample in the crucible before incineration/ashing

W_3 = Weight of sample in the crucible after incineration/ashing

3.3.3 Determination of Crude Lipid Content

A circular petroleum etcher of 250cm3 was cleaned and dried at room temperature before the petroleum ether (40–60ºC) was filled with 200cm3. This was utilized for a Soxhlet Extractor unit. Weighting a thimble without fat (W1), adds 10g of stuff and weighs (W2). In the extraction chamber, with forceps, the thimble was inserted and cold water circulated via the condensers. The heating mantle of the apparatus was activated and the heating rate was set at 40–60ºC until the solvent flowed at an 8-hour steady pace. The thimble was removed, cooled, then dried (50° C) and finally weighed again (W3)

$$\text{Lipid (\%)} = \frac{\text{Weight of lipid extracted (g)}}{\text{Weight of sample}} \times 100$$

$$= \frac{W2 - W3}{W2 - W1} \times 100$$

Where,

W_1= Weight of thimble

W_2= Weight of thimble + sample before extraction

W_3 = Weight of thimble + sample after extraction

Determination of Crude Protein

In a 100 cm3 Kjeldahl digestion flask, 1.0 g of the catalyst combination (K2SO4 + anhydrous CuSO4) was applied to 2.0 g of the sample. The addition of 25 cm3 of concentrated H2SO4 and its heating to 500 ^{0}C provided a translucent solution. Before the solution was transferred to a 100cm3 volumetric flask, it was cooled and diluted to the required concentration using distilled water.An aliquot of the 10cm3 of the diluted digestion has been combined in and distilled with the 10cm3 NaOH solution of 40 % in a Markham semi-micro nitrogen distiller. The ammonia was in a conical flake of 100cm3 with 10cm3 of 4% boric acid and 2 drops of a methyl red indicator. Distillation remained until the rose colour of the indicator greenish and then titration was taken to 0.1M HCl until the end point had been indicated by a shift in colour from greenish to pink. The volume of acid and a blank acid used for distillation were recorded and each sample was tripled.

$$\text{Nitrogen (\%)} = \frac{(V1 - VO)\ M \times 14 \times 100 \times 100}{2 \times 1000 \times 10}$$

Crude protein (%) = 6.25 × Nitrogen (%)

Where V_O = Volume of HCl required for the blank

V_1 = Volume of HCl required for 10ml sample

M = Concentration of HCl (0.1M)

14 = Atomic weight of nitrogen

100 = Total volume of digest

100 = % conversion

10 = Volume of distillate used

1000 = Conversion to dm^3

2 = Atomic weight of sample taken in gram

6.25 = conversion factor. Proteins contain 16% nitrogen, therefore 100/16 = 6.25

Determination of Total Carbohydrate Content

The carbohydrate content was determined by subtracting the summed-up compositions (%) of moisture, protein, lipid, fiber and ash contents from 100 (Otitoju, 2009).

Total carbohydrate = nitrogen free extract (NFE) is calculated by difference:

Total Carbohydrate (%) = 100 – (% Protein + % Lipid + % Ash + % Moisture)

Mineral Analysis

The elemental analysis of Na, Ca, and K was determined using flame photometry (A.O.A.C, 1984) and digestion. Place 1.0g of the sample in a 100ml beaker. Mix the wet digestive mix in 10ml (concentrated HNO_3 and PCA in a 3:1 ratio). The beakers' contents were cooked in a smoke cupboard on hot plates, leave a colorless liquid behind. Samples have been transferred to a 50mL volumetric flask following mineralization and distilled water used to label it in the same manner that the actual samples were digested, reference standards were digested for the samples' constituents, blanks and repeats. The digested samples have been aspired with an FP902 PG INSTRUMENTS Flame Photometer. Mg and P were measured with a spectrophotometer for atomic absorption (AAS).

Analysis of Physical Properties

pH

10 g of every sample of flour is blended with 100 mL of water distilled to measure the pH values of the flour. The blend is left at room temperature for 30 minutes. The pH readings are then measured by a pH meter which has already been standardized with pH 4.0 and pH 7.0 buffer solutions.

Swelling Capacity and Solubility Index

The Anyasi et al approach, which mixed roughly 1 g of flour with 15 ml of distilling water in a centrifuge pipe and warmed it at 80°C for 30 minutes with continuous rattling, was used to test the swelling capacity and solubility index of the flour samples. The tubes were removed and the temperature in the room cooled. The materials were centrifuged for 15 minutes after cooling at 2200 rpm. It was decanted and the weight of the pure estimated. The swelling power obtained supernatant was decanted into a pre-weighted evaporation platform dried into the oven to consistent weight and evaluated the solubility index.

Water Absorption Capacity

The Onwuka method has been used to determine flour water absorption capacity. 1 g of flour samples were weighed and scattered in 10 ml of water in a conical graded centrifuge tube. The mixture was shaken for 1 minute at room temperature. The material was permitted to settle 30 minutes before centrifugation at 5000 g for 30 minutes. Directly from the centrifuge tube, the free water volume was estimated. Water density (1 g/ml) was increased by the amount of water absorbed, resulting in g/100 g.

Bulk density

The wang and kinselle method (1976) was used to determine this, modified by (Ashogbon and Akintayo, 2013). The sample was poured into a 10ml measuring cylinder with a graded capacity (W1) by taping the cylinder bottom numerous times on the laboratory bench until no more powder level had contracted after the 10ml mark was filled. The weight is obtained by the measuring cylinder (W2).

Bulk density (g/ml) = weight of sample/volume occupied

Gelatinization temperature

Two g of each flour sample was placed in a 10ml conical bottle of water and then put on a heat plate with a thermometer in it. The temperature at which the flour sample gelled was constantly agitated for 30 seconds (Onwuka, 2005).

Antioxidant Properties

Total Phenol

Singleton *et al.* (1999) approach used the total phenol concentration of the flour samples. In a nutrient, 0.01 g each was distilled in 10mL of water and 0.5mL with a 2.5mL of 10% Folin-Ciocalteu with a 2 mL of 7.5 % sodium carbonate was then neutralized. The reaction blend was incubated at 450°C for 40 minutes. The Shimadzu UV-1800 twin beam was used to test 765nm UV absorption. A standard garlic acid was used to generate the calibration curve.

Total Flavonoids

Total flavonoid levels were evaluated using the *peels* sample method (Chang *et al.,* 2002). 0.5mL of each sample were entered and incubated at room temp for 30 minutes on a test tube containing 1.5 ml of 100% methanol, 0.1 ml 10% aluminum chloride, 0.1 ml of one ml of sodium acetate and 2.8 ml of distilled water. The absorbance was measured at 415nm using a twin Shimadzu UV-spectrophotometer, UV-1800. The standard quercetin was used to develop the calibration curve.

Estimation of beta carotene content

Approximately 1 g of each sample has been mined, sometimes shaken, with 10 mL of 95 *%* hot ethanol during 30 minutes. To get 85% ethanol to this extract, it was filtered, measured and distilled water by the formula:

$$\text{Volume required to bring to } 85\% = \frac{\text{Volume of extract measured X } 95\%}{85\%}$$

The ethanol extract was regularly agitated with 3 mL petroleum ether during a separating funnel, until the petroleum ether was colorless. 5 mL of 85% ethanol was shaken by a petroleum ether extract in order to remove xanthophylls that had entered the oil ether extract. The oil extract volume was measured and diluted to an ultimate 10 ml with petroleum ether. The absorbance was measured at 452 nm using petroleum ether as a blank. Beta carotene concentration (mg/100g) was estimated on the calibration curve of standard beta carotene.

Cyanide content

The standard AOAC (2005) method was used. For each specimen four grams (4 g) were dissolved using a mixture of 40 ml distilled water and 2 ml of orthophosphoric acid. The sample was merged, covered and kept at room temperature for 12 hours in order to release the entire bonded hydrocyanic acid. Before it was transferred to the distillation flask, a drop of octyl alcohol (anti-foaming) was added to the finished combination. After it was connected to other distillery systems,

the flask was distilled. About 45 ml of the distillate were harvested in a receiving flask containing 4 ml of distilled water and 0.1 g of pellets of sodium hydroxide. The distillate was then transferred to a volumetric flask of 50 mL, using distilled water to produce the mark. A conical conical flask was measured with 20 mL of diluted distillate, and a flake was added with 1.6 mL of 5% potassium iodide solution, which was then titrated against 0.02 M AgNO3 solution. The blank was also titrated until the endpoint was indicated by a weak but permanent turbidity.

Cyanide (mg/kg) =13.5 (vo -vb)/m

Where, Vo = Titre value of sample,

Vb =Titre value of the blank,

m = mass of sample (g)

phytic acid content

The Phytin approach was used as stated by Reddy and Pierson (1994) for the Young and Greaves (1940) and revised by Sokrab (2014). For three hours in 100 ml of 2 % HCl two gram (2 g) finely ground materials had to be soaked and then filtered. The filter (25 mL), together with a 5 mL of 0.03 % NH_4SCN solution, was then filled to a 100 mL conical flask. Afterwards the acidity was corrected with 50 ml of water. After the ferric chloride solution titration of 0.005 mg of $Fe3^+$ per ml of $FeCl_3$ was estimated for a phytate level of mg/100 grams, the equivalent was generated and the phytate content of mg/100 grams computed.

Phytic acid = Titre value *1.19

X=phytin p (mg/g)

% phytic acid = v* 8.24/1000 * 100/weight of sample

Where, V = Titre value

Oxalate content

Day and Underwood (1986) technique were used to carry out the analysis. One gram of the sample was weighed in a 100 mL conical bottle. Added 75 mL 3 M H_2SO_4, stirred with the magnet stirrer for 1 hour and filtered it intermittently with Whatman No 1, and collected 25 mL of the Filtrate and titrated hot (80-90 ^oC) against 0.1 M $KMnO_4$ for a minimum period of 30 seconds.

*Oxalate (mg/g)=Vt * 0.9004*

Where, Vt = Titre value.

RESULTS

Proximate composition

The proximal composition of samples is quantitatively estimated in Table 4.1. The samples had no significant ($p>0.05$) difference in moisture and ash content, but ranged between 1.17±0.29 % - 2.00±0.50 % and 0.50±0.00 % - 1.00 %, respectively. The flour of Plantain peel contains significantly ($p>0.05$) higher fiber (77.87±0.06 %) and protein (2.14±0.01 %) than the rest of the other samples. The crude fat of yam peel (0.17±0.06 %) was significantly ($p<0.05$) lower

compared with other samples. The carbohydrate content (59.72±0.02 %) of potato peel flour were significantly ($p>0.05$) higher than that of other samples.

Mineral composition of selected plant peels

The mineral composition of potato, plantain and yam flour is shown in Table 4.2. The result showed that the peeling peels of potatoes are significantly ($p<0.05$) higher, with the exception of calcium significantly ($p>0.05$) greater in yam peel flour (156.13±0.07 mg/100 g) than Phosphorus (255.15 ±.58 mg/100 g), Sodium (382.07 ±0.84 mg/100 g), Potassium (644.83 ± 0.12 mg/100 g), and Magnesium (150.58 ± 0.07 mg/100 g). The results also revealed that plantain peels included the minimum mineral content (552.57 ± 0.06 mg/100g) excluding potassium. In the yam peel flour (0.72±0.01 mg/100 g) and the lowest in plantain peels (0.0057±025 mg/100 g) Na^+/K^+ was considerably higher ($p<0.05$).

Physical properties of samples peel flour

Table 4.3 describes the physical characteristics of peel flour samples. No significant ($p<0.05$) difference was reported on the solubility index, while the solubility index (64.00 ± 46.00 %) for plantain peel flour was reported to be greater than in other samples. In comparison to the other samples, yam peel flour ($p>0.05$) had considerably higher water absorption water absorption (49.33 ± 0.58 %) and pH (5.72 ± 0.10). The potatoes peel flour (66.17 ± 0.01 %) was significantly ($p>0.05$) greater in swelling capacity and the least in plantains (55.63 ± 0.12 %).Plantain peel flour was at a higher temperature of gelatinization ($p>0.05$) than other peelings tested (82.50 ± 0.50 °C). The mass density of yam peel (0.05 +0.60 ± 0.02 g / ml) and potato peel (0.15 ± 0.01 g/ml) have been significantly greater

Antioxidant of selected plant peels flour

The antioxidant level of each sample was observed in Table 4.4. Total phenol in yam was significantly ($p<0.05$) higher (57.86±0.56 mg/g) and plantain (45.17±0.77 mg/g) was found to be considerably the lowest. The flavonoid content of yam (5.45±0.44 mg/g) in comparison to potatoes (6.59±0.36 mg/g) and plantain peel flour (7.18±0.28 mg/g) was shown to be significantly ($p<0.05$) lower. Beta carotene concentration was significantly ($p>0.05$) higher in plantain peel flour (13.92±0.19 mg/100g).

Anti-nutrient properties of selected plant peels flour

The anti-nutrient effects of peels samples are shown in Table 4.5. Oxalate content was markedly higher ($p>0.05$) for potatoes (9.74±0.07 mg/kg) than for the lowest value for plantain peal (0.67±0.03 mg/g). Phytate was significantly ($p<0.05$) low in peel flour of potatoes (0.33±0.33%) and plantain peel flour (0.34±0.01%). The level of the plantain peel flour (0.655±0.65 mg/kg) was significantly ($p< 0.05$) higher than that of the other samples.

Table 4.1: proximate composition of flours from potatoes, plantain and yam peels

Parameters (%)	Potatoes	Plantain	Yam
Moisture content	$2.00±0.50^a$	$2.00±0.87^a$	$1.17±0.29^a$

Ash content	0.50±0.00[a]	1.00±0.00[a]	0.50±0.00[a]
Crude fiber	35.77±0.06[a]	77.87±0.06[c]	39.63±0.06[b]
Crude protein	0.89±0.01[a]	2.14±0.01[c]	1.99±0.01[b]
Fat content	1.13±0.06[b]	0.83±0.35[b]	0.17±0.06[a]
Carbohydrate	59.72±0.02[c]	16.18±0.02[a]	56.27±0.06[b]

Values are Mean ± Standard Deviation of triplicate determinations. Values with different Superscripts on same row are significantly different ($p<0.05$).

Table 2 Mineral Content of Flour Samples

Parameters (mg/100g)	**Potatoes**	**Plantain**	**Yam**
Phosphorus	255.15 ± 0.58[c]	2.37 ± 0.02[a]	78.36 ± 0.03[b]
Sodium	382.07 ± 0.84[c]	3.17 ± 0.03[a]	218.27 ± 0.12[b]
Potassium	644.83 ± 0.12[c]	552.57 ± 0.06[b]	303.53 ± 0.12[a]
Calcium	144.13 ± 0.03[b]	3.57 ± 0.06[a]	156.09 ± 0.07[c]
Magnesium	150.58 ± 0.07[c]	5.26 ± 0.03[a]	68.29 ± 0.16[b]
Na^+/K^+	0.56±0.12[b]	0.0057±0.25[a]	0.72±0.01[c]

Values are Mean ± Standard Deviation of triplicate determinations. Values with different Superscripts on same row are significantly different ($p<0.05$)

Table 3: Physical properties of Selected Plant Peels

Parameters	**Potatoes**	**Plantain**	**Yam**
Water absorptivity (%)	37.67 ± 0.58[a]	40.67 ± 0.58[b]	49.33 ± 0.58[c]
Solubility index (%)	25.67 ± 10.50[a]	64.00 ± 46.00[a]	57.67 ± 34.50[a]
Swelling capacity (%)	66.17 ± 0.01[c]	55.63 ± 0.12[a]	61.33 ± 0.12[b]
pH	3.70 ± 0.17[a]	4.55 ± 0.13[b]	5.72 ± 0.10[c]
Gelatinization temp (^oC)	78.50 ± 0.50[a]	82.50 ± 0.50[b]	78.10 ± 1.04[a]
Bulk density (g/ml)	0.51 ± 0.01[a]	0.53 ± 0.00[a]	0.60 ± 0.02[b]

Values are Mean ± Standard Deviation of triplicate determinations. Values with different Superscripts on same row are significantly different ($p<0.05$)

Table 4: Antioxidant Properties of the Tubers Peel Flour

Parameters	Plantain	Yam	Potatoes
Total phenol (mg/g)	45.17 ± 0.77^{a}	57.86 ± 0.56^{c}	51.67 ± 0.78^{b}
Flavonoid (mg/g)	7.18 ± 0.28^{b}	5.45 ± 0.44^{a}	6.59 ± 0.36^{b}
Beta-Carotene (mg/100g)	13.92 ± 0.19^{c}	7.33 ± 0.21^{b}	5.65 ± 0.23^{a}

Values are Mean ± Standard Deviation of triplicate determinations. Values with different Superscripts on same row are significantly different ($p<0.05$).

Table 5: Anti-nutrient properties of flour from potatoes, plantain and yam peels

Parameters	Potatoes	Plantain	Yam
Oxalate (mg/kg)	9.74 ± 0.07^{c}	0.67 ± 0.03^{a}	1.97 ± 0.03^{b}
Phytate (%)	0.33 ± 0.03^{a}	0.34 ± 0.01^{a}	9.92 ± 0.08^{b}
Cyanide (mg/kg)	0.59 ± 0.05^{b}	0.37 ± 0.03^{a}	0.65 ± 0.05^{b}

Values are Mean ± Standard Deviation of triplicate determinations. Values with different Superscripts on same row are significantly different ($p<0.05$).

Discussion

The analysis of proximate composition gave information on the basic chemical composition of the plants' peels flour. The moisture content is an index of water activity which many foods contain. The observed moisture content of the plants' peels was low compared to 11. 75 % reported for fresh yam peel (Shittu *et al.,* 2014). The variation in moisture content could be due to different processing methods and the difference in specie, low moisture content favors the preventive properties, it guards against microbial attack and thus an increase in storage life (Adeyeye and Ayejugo 2014). The protein content of yam and plantain peel flour were within the standard range (2-10%) reported by (WHO, 2020), however the low crude protein observed in potatoes peel was higher than that reported in banana peel 0.71 % (Anhwange *et al.,* 2019). This indicated that these by-products could support growth and movements in both livestock and human, it can also serve as body's defense. The low lipid content obtained from this study is similar to the report from the finding (Angwange *et al.,* 2019) for banana peel 1.17 %, this is reasonable due to the fact that excess fat intake leads to an implication in the etiology of certain cardiovascular diseases such as aging and cancer (Anha *et al.,* 2016). Therefore, these by-products can be recommended as part of weight reducing diet. The high fiber content revealed in the present study was higher than 9-15 % stated earlier by (Akinmutimi *et al.,* 2016) and then that obtained that for beans coat (26 %) as reported by Shittu *et al*. (2014), This plant peels may be considered for those suffering from elevated cholesterol level, (Ekumakana, 2018), because fiber reduces absorption of cholesterol, it guards against metabolic disorders such as hypertension and diabetes mellitus (Mensah et al., 2018). The high carbohydrate content of potatoes and yam peel flour was in consonance with the findings reported for potatoes peel (59.67%) by Ganiyu (2016), similarly high level of

carbohydrate was recorded for cassava peel 56.07% (Ashifat *et al.,* 2016) this gave an indication that these by-products could serve as good source of energy for animals and human. The proximate composition gave several nutrient compositions of these plant peels flour which are necessary for the breeding of animals and will reduce the risk of food insecurity affecting many under developed and developing countries.

The study established the presence of high mineral contents such as potassium, calcium, sodium, magnesium and phosphorus. Yam contained high calcium content compared to beans coat 154.00mg/100g (Mansah *et al*., 2018). Calcium is necessary for strong bones RDA value is 600-1400mg/kg (FAO, 2019), however yam peel flour sodium content was lower compared to (280mg/100g) reported for oil beans seed (Oyeleke *et al.*, 2014), while plantain peel flour was within the standard sodium value 2.5-7.2 mg/100g (WHO, 2019). Excess consumption of sodium leads to hypertension (NRC, 2019). The potassium of samples are higher compared to 40 mg/100g reported for plantain bract (Adeolu, 2017) but lower compared to 1443mg/100g reported for mung bean (Habibullah, 2017), this is a good indication that these by-product is good to enhance the maintenance of osmotic pressure and acid-base equilibrium potassium are high. The Na^+/K^+ of all sample peels were below the hazard ratio (1mg/100g) FAO (2020) that could cause death, 0.75 mg/100g could result to high risk of cardiovascular diseases (Chen, 2017). Potassium is important in the maintenance of fluid and blood volume, plantain peels contained high potassium which reduces the risk of stroke and also reduces blood pressure. Phosphorus helps in body build and maintain bones and teeth, it also serves a major role in the formation of DNA and RNA (genetic make-up), which ensures proper maintenance of cells and tissues and their repair and replacement as they age. Magnesium was low in plantain peel flour compared to (16.08 mg/100g). Magnesium is necessary for strong bones and teeth. This implies that these by-products can slightly contribute to the amount of dietary minerals. Minerals perform several essential functions which are important for the existence of organisms.

The physical properties from this study showed that, the water absorption capacity of the samples were high compared to citrus peels (16.7 %) reported by Chau and Huang (2017) and similar to plantain peel (40.54%) reported by Brown (2015). It is suggested that good water retention capacity could be attributed to better water accessibility of the surface capillaries and increase in the surface area. Water absorptivity could be attributed to the presence of carbohydrate and fiber and it is also very critical function of protein (Adeyeye and Aye, 2021). The swelling capacity of samples were high compared to Irish potatoes peel fiber (18.28 %) reported by Devin der Dhingra (2012), this is mainly dependent on insoluble dietary fiber and soluble dietary fiber ratio, particle size, extraction condition and sources (Jamie *et al.,* 2017). High swelling capacity result in high surface tension strength and water could interact with molecular components through hydrogen or dipole forms (Ayadi *et al.,* 2019). The bulk density of sample peel flour are high compared to cocoyam peel (0.41 g/ml) which was observed by (Oladeji *et al*., 2013), this indicates that the plants peel flour in this study are suitable for animal feed and also an added value which is the production of food for allergic infants and persons with gastro intestinal disorders. Bulk density is also important for determining package requirement, material handling and application in wet processing in food industries.

Antioxidants are substances that can prevent or slow down damage of cells that are usually caused by free radicals, unstable molecules that are produced total phenol, flavonoid and beta carotene. Total phenol content of yam and potatoes peel flour were found higher compared to *Silene*

swertiifolia (47.34mg/100g) studied by Roya (2016) Phenolic compound are agents that acts as free radical terminators and their bioactivities may be related to their ability to inhibit lipoxygenase and scavenge free radicals, they contribute to nutritional value in terms of modifying colour and taste.. Flavonoid contains was higher in samples peel flour compared to pigeon-pig beans (4. 21 mg/g) reported by Funmilayo (2019). Flavonoid contains hydroxyls which are responsible for scavenging effect (Das and Pereira, 2020), sample peels slightly contributes to antioxidant properties needed by animals and possibly humans. Beta-carotene detected in tubers peel sample are higher compared to 4.9 mg/100g in orange peel (Sarbaswarup *et al.,* 2019) but lower compared to banana peels (15.05 mg/100g) reported by Angwange *et al.* (2019). Beta-carotene is converted by the biological cells to vitamin A and improves lung strength of the elderly, essential for healthy skin and good vision. The anti-nutrient factors limit the use of many plants for consumption because of their deleterious effects in humans and animals (Kubmaraa *et al.,* 2018). This antioxidant properties proves that these by products are very essential and can prevent some complications if animals are feed with them.

Anti-nutrient prevents absorption of minerals, fortunately the anti-nutrient properties were found to be low compared to other plant products, the reduction of anti-nutrient in food when they are above safe level by animals and human consumers can be achieved by different hydrothermal treatments which enhances nutritional quality increasing digestion (Adeniji *et al.,* 2017). Potatoes and plantain contain low phytic acid compared to banana peels (0.74 %) reported by Akinmutimi and Anakebe (2018), yam which had the highest of phytic acid content was found lower compared to stripped black African yam beans (11.41 %) observed by Gniyu (2016). The cyanide content of the samples peels are lower compared to (0.72mg/kg) beans flour (Fumilayo, 2019). The toxicity cyanide of samples can be reduced by washing and sieving (FAO, 2020). The low level of anti-nutrients in these samples proved that this the rate at which the consumption of this product could affect the consumer is very low there by proving them good enough for consumption my animals there by reducing to the barest minimum the rate at which food are consumed by animals and the increase in the availability of food for human consumption.