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COMPARATIVE ASSESSMENT OF THE NUTRITIONAL PROFILE OF PROCESSED FLOURS FROM IRISH POTATOES, SWEET POTATOES AND TARO COCOYAM TUBERS

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ABSTRACT
The contribution of plants and their yields to human nutrition cannot be overemphasized. This study was aimed at evaluating and comparing nutritional composition of flour processed from Irish potatoes, sweet potatoes and cocoyam tubers. The Irish, sweet potatoes and cocoyam tubers were thoroughly washed with water, peeled, and grated into tiny pieces, dried and milled finely into their separate flour. Analyses of these nutrients were carried out using standard methods. Results of proximate composition showed that moisture content ranged from 70.50 ± 2.95 to 78.10 ± 0.01 %, crude ash content ranged from 0.80 ± 0.00 to 4.74 ±0.00 %, crude fat content ranged from 0.12 ± 0.00 to 0.36 ± 0.01 %, crude fibre ranged from 1.42 ± 0.0 to 1.84± 0.00 %, crude protein ranged from 0.59 ± 0.00 to 2.10± 0.05 % and total carbohydrate ranged from 92.10 ± 1.00 to 95.55 ± 0.00 %, while caloric value ranged from 375.45± 0.00 to 391.31± 0.00 Kcal. Carbohydrate fraction; glucose value ranged from 0.76 ± 0.00 to2.41± 0.00 mg/100g, sucrose value ranged from 0.08 ± 0.00 to 0.13 ± 0.00 mg/100g, sugar concentration ranged from 17.03 ± 0.00 to 24.51 ± 0.00 mg/100g, while dextrin value ranged from 0.36 ± 0.00 to 0.53 ± 0.00 mg/100g. Also, B-carotene ranged from 3.78 ± 0.01 to 17.73 ± 0.00 mg/100g, total vitamin C ranged from 3.40± 0.00 to 32.54± 0.00 mg/100g, soluble vitamins C ranged from 08.71± 0.00 to 14.30± 0.00 mg/100g, thiamine ranged from 0.08± 0.00 to 0.14± 0.00 mg/100g, riboflavin ranged from 0.03± 0.00 to 0.04 ± 0.00 mg/100g and niacin ranged from 0.48± 0.00 to 0.63± 0.00 mg/100g. The mineral element, sodium (Na) ranged from 1.91 ± 0.00 to 54.00± 0.58 mg/100g, copper (Cu) ranged from 0.17± 0.00 to 0.26 ± 0.00 mg/100g, zinc (Zn) content ranged from 0.31 ± 0.00 to 3.81 ± 0.00 mg/100g, iron (Fe) content ranged from 0.65± 0.00 to 1.35 ± 0.05 mg/100g, calcium (Ca) content ranged from 18.15± 0.58 to 28.24± 0.58 mg/100g, magnesium (Mg) content ranged from 11.22± 0.00 to 27.21 ± 0.58mg/100g, while the concentration of phosphorus (P) ranged from 5.75 ± 0.00 to 53.30± 0.58 mg/100g. The results of the study showed that Taro cocoyam flour contained these nutrients in a more acceptable amount. When compared to previous studies, it was observed that the nutritional composition of flours in the present study is more quality and healthier, mostly flours produced from Taro cocoyam. Hence, the consumption of flours made from Taro cocoyam and to some extent Irish and sweet potatoes should be encouraged.

KEYWORDS: Taro cocoyam, Irish potatoes, sweet potatoes, flour, nutritional value.

1. INTRODUCTION
The intake of roots-based food yields, from Irish potato (*Solanum tuberosum*), sweet potato (*Ipomoea batatas*), cocoyam (*Colocasia esculenta*), among others is a very known and general practice globally, specifically in developing African countries, such as Nigeria where they constitute the main source of their staple food.[1] Due to the prevailing unfavourable economic condition in most developing countries of the world, Africa and Nigeria in particular, where over 40% of the population live below poverty line, the incidence of protein-energy malnutrition among different age groups particularly children with an estimated 400 million children being reported to be malnourished worldwide is highly prevalent and on the increase on a daily basis.[2]

Irish potato, sweet potato and cocoyam are very important and cherished food crops all over the world, since they serve as vegetable and a good source of starch in the diet of human beings and animals. Irish potato, sweet potato and cocoyam are rich in starch, vitamins, minerals, and fiber.[3,4] They are very low in protein and fat, as well as phytates, which do not interfere with the absorption of minerals and vitamins.[5] Moreover, these root-based foods contain bioactive phytochemicals such as polyphenols, that exert antioxidant and anticancer effects, conferring on the plants, some biological activities, capable of promoting the crops in the disease management condition.[6,7]

Commercially, potatoes and sweet potatoes are mainly processed into starch, chips, and French fries.[8,9] However, in recent years, many countries have used Irish potato and sweet potato as staple foods; therefore, their deep-processed products, such as bread, mantou, and noodles, which satisfy the dietary habits of residents, are being studied and developed.[6,7,9,10] Because Irish potato and sweet potato are difficult to store, it is better to process them into flour, which not only maintains their nutritive composition effectively but also prolongs their supply time. The nutritional potentials of these food crops, if properly harnessed can be of immense health benefits especially in the prevention of protein-energy malnutrition and micronutrient deficiencies by providing nutrition security to the world ever-growing population. Studies have shown that replacing part of wheat flour with potato flour or sweet potato flour not only fortifies its nutritional value but also improves the properties of the flour and dough, and the texture and sensory quality of the processed products.[6,11] This study, therefore, was designed to evaluate the proximate, carbohydrates fraction, vitamin and mineral compositions of processed Irish potato, sweet potato and cocoyam flours.

2. MATERIALS AND METHODS

2.1 Collection of Samples

The cocoyam cormels, Irish and sweet potatoes tubers were purchased from Watt market, Calabar South Local Government Areas, Cross River State, Nigeria.

2.2 Sample Flour Preparation

The cocoyam, Irish and sweet potatoes tubers were thoroughly washed with water, peeled, and grated into tiny pieces using a manual kitchen grater. The samples were separately placed on a foil and weighed with a Satorious Digital Weighing Balance, Model BP210S, Germany before and after sun drying for 72 hours to obtain the wet weight and dry weight respectively. The respective dry weight sample was separately pulverized using Arthur Thomas Laboratory Mill Crypto model, USA, covered separately in a labeled white nylon and kept in the desiccator until used. They were oven air dried at a temperature of 65°C for 48 hours. After drying, they were milled finely into their separate flour after proper drying and stored in air-tight polyethylene bags.

2.3 Sample Extraction

Two hundred grams (200g) of each of the flour sample were dissolved in ethanol for 5 days while rotating at regular interval for efficient mixing of the sample with the solvent. After that, the samples were first filtered through cotton cloth and then through Whatman No. 1 filter paper which was fitted with a suction apparatus (Rocker 300). After two subsequent filtration processes through the Whatman filter paper, the solution from each sample was carefully stored for evaporation. After that, each sample was be heated at 100°C using an evaporator and the residue were carefully collected in different petri plates. Then, the petri plates were kept overnight in an incubator at 42°C. Finally, each flour sample extract was weighed and stored for further experiments.

2.4 Proximate Analysis

Proximate analysis was carried out on the three samples according to the methods of the Association of Official Analytical Chemists (AOAC, 2010) to determine the moisture content of the fresh and dry samples, crude protein, crude fat, ash, and available carbohydrate of the dry samples. Total dietary fibre was determined by enzymatic digestion, gravimetric method of AOAC (2010) – Prosky (985.29). The calorific value was calculated by multiplying the mean values of protein, fat and carbohydrate by their respective Atwater factors (4, 9 and 4 respectively) and taking the sum of the product. All data were obtained in triplicates.

2.5 Carbohydrate Analysis

Starch content was determined enzymatically, according to the method described by Cordenunsi and Lajolo.[12] Soluble sugars were extracted 3 times with 80% ethanol at 80 ^{0}C. The supernatants were combined and the ethanol was evaporated under vacuum. The soluble sugar was properly diluted in pure water and analyzed by high performance liquid chromatography with pulse amperometric detection (HPLC-PAD) (Dionex, Sunnyvale, Calif., U.S.A.), using a PA1 column (Dionex) in an isocratic run of 18 mM NaOH for 25 minutes. Total soluble sugars were given as the sum of glucose, fructose, and sucrose values. The carbohydrates in the cell wall were extracted with 10% (w/v) water at 90 ^{0}C, precipitated with 96% ethanol, hydrolyzed with 2 N H_2SO_4/121 8C for 1 h, then separated by HPLC-PAD on a PA1 column, using the same conditions described above.

2.6 Analysis of Vitamins

The ascorbic acid and niacin contents of the samples were determined according to the methods of AOAC.[13] The thiamine, riboflavin and vitamin A contents of the samples were determined according to the flourimetric methods of Onwuka[14], while beta carotene content was determined following the extraction method using acetone.[15]

2.7 Determination of Minerals

2.7.1 Digestion and Analysis for Minerals

Analysis for minerals was carried out after wet digestion using the method described by AOAC.[13] Ground samples (0.5 g) of each sample was boiled (100 ^{O}C) with 5 ml concentrated nitric acid (HNO_3) and 5 ml of 30 % hydrogen peroxide (H_2O_2) solution continuously for about 2 hours in an electric heating mantle (HP 220, LITEC Product Inc. Albany, N-Y., USA) until clear solutions were obtained. These were cooled, filtered through Whatman no 45 filter papers and then through < 0.45 millipore filter papers. Filtrates were made up to the 25-ml mark of the volumetric flasks with distilled water and then used to analyse for the individual minerals using Atomic Absorption Spectrophotometer (Buck Scientific AAS Model 210, equipped with single slot burner and air acetylene flame).

2.7.2 Preparation of Standards for Analysis of Minerals in Samples

Working standard solutions of minerals were prepared from the stock standard solutions containing 1000 ppm of each element in 2 N nitric acid solution. One gram (1 g) of the ground samples were accurately weight into a conical flask. About 25 ml of concentration Nitric acid was added to the sample. Five milliliters (5 ml) of perchloric acid was then added to the sample. The conical flask with its contents was gently heated (50-70 ^{o}C) on a Stuart hot place until the colour changed from brown to colourless. The digest was made up to 100ml with deionized distilled water. Appropriate dilutions were made for each element. Triplicate determinations were made.

Calibration and measurement of absorbance of each element against a blank at its unique wavelength was done using Atomic Absorption Spectrophotometer (A. Analyst 300, Perkin Elmer, Morwalk, Conn, U.S.A). The calibration curves were prepared separately for each element. Absorbance of each element in the filtrate was read at its wavelength from the spectrophotometer and its concentration in the sample extrapolated from the standard curve. Potassium, sodium, magnesium and calcium contents were determined by reading their absorbance at 766.5, 589.0, 285.2 and 422.7 nm wavelengths, respectively, whereas the copper, zinc and iron contents were measured at 324.8, 279.5, 213.9 and 248.3 nm wavelengths, respectively. Total phosphorus was obtained using the ascorbic acid blue color procedure of Okalebo *et al.*[16] by reading the absorbance at a wavelength of 880 nm on a Helios Gamma spectrophotometer (Helios Gamma UV-Vis Spectrophotometer, Thermo Spectronic, Cambridge, U.K.).

2.8 Statistical Analysis

All determinations were replicated thrice. All data were expressed as mean ± Standard deviation. The data was analyzed by one way ANOVA with post hoc corrected two tailed t-tests using the IBM SPSS statistic software version 22 (SPSS: Statistical Package for Social Sciences). Differences at $P< 0.05$ were considered significant.

3. RESULTS

3.1 Proximate Composition of Taro Cocoyam, Sweet and Irish Potatoes Flours

The moisture content in the three flours were significantly ($p < 0.05$) different, Irish potatoes flour recorded the highest value (78.10 ± 0.01 %), while Taro cocoyam flour recorded the lowest value (70.50 ± 2.95 %). The crude ash content in all the flour samples were significantly ($p < 0.05$) different, Taro cocoyam flour had the highest value (4.74 ±0.00 %), while sweet potatoes flour recorded the lowest value (0.80 ± 0.00 %). Among the three flours, Taro cocoyam flour recorded the lowest crude protein value (0.59 ± 0.00 %), while Irish potatoes flour had highest protein value (2.10± 0.05 %). Also, fat content, crude fibre, total carbohydrates and caloric value were significantly ($p < 0.05$) higher in Taro cocoyam flour mix compared to Irish and sweet potatoes flour (Table 1).

3.2 Carbohydrates Fractions of Taro Cocoyam, Sweet and Irish Potatoes Flours

The glucose concentration in the three flours were significantly ($p < 0.05$) different, sweet potatoes flour recorded the highest value (2.41± 0.00 mg/100g), while Taro cocoyam flour recorded the lowest value (0.76 ± 0.00 mg/100g). Sucrose concentration in all the flour samples were significantly ($p < 0.05$) different, Taro cocoyam flour had the highest value (0.13 ± 0.00 mg/100g), while sweet potatoes flour recorded the lowest value (0.08 ± 0.00 mg/100g). Among the three flours, Irish potatoes flour recorded the lowest sugar concentration (17.03 ± 0.00 mg/100g), while Taro cocoyam flour had highest sugar concentration (24.51 ± 0.00 mg/100g). Dextrin content in Taro cocoyam flour (0.53 ± 0.00 mg/100g) was significantly ($p < 0.05$) higher compared to that of sweet potatoes, which had the lowest value (0.36 ± 0.00 mg/100g) (Table 2).

Table 1: Proximate composition of Taro cocoyam, sweet and Irish potatoes flours

Sample	Moisture (%)	Ash (%)	Protein (%)	Fats (%)	Dietary Fiber (%)	Carbohydrates (%)	Energy (Kcal)
Taro Cocoyam	70.50±2.95^{a}	4.74±0.00^{a}	0.59±0.00^{a}	0.36±0.0^{a}	1.84± 0.00^{a}	92.10± 1.00^{a}	375.45± 0.00^{a}
Sweet potatoes	74.86±0.00^{b}	0.80±0.00^{b}	1.48±0.01^{b}	0.31±0.00^{b}	1.78±0.00^{b}	95.55± 0.00^{b}	391.31± 0.00^{b}
Irish potatoes	78.10±0.01^{c}	1.25±0.00^{c}	2.10±0.05^{c}	0.12± 0.00^{c}	1.42± 0.00^{c}	94.45± 0.00^{c}	389.55± 0.00^{c}

Values are presented as Mean ± Standard Deviation of triplicate determinations. Means in the same column with different letters are significantly different ($p<0.05$).

Table 2: Carbohydrates fractions of Taro cocoyam, sweet and Irish potatoes flours.

Sample	Glucose (mg/100g)	Sucrose (mg/100g)	Starch (mg/100g)	Dextrin (mg/100g)
Taro Cocoyam	0.76 ± 0.00 ^{a}	0.13 ± 0.00^{a}	24.51 ± 0.00 ^{a}	0.53 ± 0.00 ^{a}
Sweet potatoes	2.41± 0.00^{b}	0.08 ± 0.00^{b}	20.11 ± 0.00^{b}	0.36 ± 0.00^{b}
Irish potatoes	1.41± 0.00^{c}	0.11± 0.00^{c}	17.03 ± 0.00^{c}	0.42 ± 0.00^{c}

Values are presented as Mean ± Standard Deviation of triplicate determinations. Means in the same column with different letters are significantly different (p<0.05).

3.3 Vitamin composition of Taro Cocoyam, Sweet and Irish Potatoes Flours

The B- Carotene level in the three flours was significantly ($p < 0.05$) different, sweet potatoes flour recorded the highest value (17.73 ± 0.00 mg/100g), while Taro cocoyam flour recorded the lowest value (3.78 ± 0.0 mg/100g). Total vitamin C content was significantly ($p < 0.05$) different, sweet potatoes flour had the highest value (32.54± 0.00 mg/100g), while Irish potatoes flour recorded the lowest value (3.40± 0.00 mg/100g). Among the three flours, Taro cocoyam flour recorded the lowest soluble vitamin C value (08.71± 0.00 mg/100g), while sweet potatoes flour had highest soluble vitamin C value (14.30± 0.00 mg/100g). Thiamine content was significantly ($p < 0.05$) higher in sweet potatoes flour (0.14± 0.00 mg/100g) compared to Taro cocoyam flour, which had the lowest value (0.08± 0.00 mg/100g), which was not significantly ($p > 0.05$) different from that of Irish potatoes flour (0.09± 0.00 mg/100g). Riboflavin content was not significantly ($p > 0.05$) different among the three flours, though was slightly higher in Taro cocoyam and Irish potatoes flours (0.04± 0.00 mg/100g) compared to sweet potatoes flour (0.03± 0.00 mg/100g). Niacin content in Taro cocoyam flour (0.63± 0.00 mg/100g) was significantly ($p < 0.05$) higher compared to that of Irish potatoes (0.48± 0.00 mg/100g), which had the lowest value (Table 3).

3.4 Mineral composition of Taro Cocoyam, Sweet and Irish Potatoes Flours

The sodium (Na) content in the three flours was significantly ($p < 0.05$) different, sweet potatoes flour recorded the highest value (54.00± 0.58 mg/100g), while Taro cocoyam flour recorded the lowest value (1.91 ± 0.00 mg/100g). The potassium (K) concentrations in all the flour samples were significantly ($p < 0.05$) different, with sweet potatoes flour recoding the lowest value (261.06± 0.58 mg/100g), while Taro cocoyam flour recorded the lowest value (448.02 ± 0.05 mg/100g). In addition, Ca concentration was significantly ($p < 0.05$) lower (18.15± 0.58 mg/100g) in Irish potatoes flour, compared to the potatoes flours. More so, Mg concentration in the three flours was significantly ($p < 0.05$) different, with sweet potatoes flour recording the highest value (27.21 ± 0.58 mg/100g), while Taro cocoyam flour recorded the lowest value (11.22± 0.00 mg/100g). The Fe concentration was significantly ($p < 0.05$) higher in Irish potatoes flour (1.35± 0.05 mg/100g), while Taro cocoyam flour recorded the lowest value (0.65± 0.00 mg/100g). In addition, Zn concentration significantly ($p < 0.05$) differ among the three flours, with Taro cocoyam flour recording the highest value (3.81 ± 0.00 mg/100g), while Irish potatoes recorded the lowest value (0.31 ± 0.00 mg/100g). Again, Cu content in Taro cocoyam flour (0.26 ± 0.00 mg/100g) was significantly ($p < 0.05$) higher compared to that of Irish potatoes flour (0.17± 0.00 mg/100g), which had the lowest value. Finally, P concentration was significantly ($p < 0.05$) lower (5.75 ± 0.00 mg/100g) in Taro cocoyam flour, compared to sweet potatoes flour, which recorded the highest value (53.30± 0.58 mg/100g), which was not significantly ($p > 0.05$) different from that of Irish potatoes flour (52.70 ± 0.58 mg/100g) (Table 4).

Table 3: Vitamin composition of Taro cocoyam, sweet and Irish potatoes flours.

Sample	B-Carotene (mg/100g)	Total Vitamin C (mg/100g)	Soluble Vitamin C (mg/100g)	Thiamine (mg/100g)	Riboflavin (mg/100g)	Niacin (mg/100g)
Taro cocoyam	3.78 ± 0.01^{a}	15.32± 0.66^{a}	8.71± 0.00 ^{a}	0.08± 0.00 ^{a}	0.04± 0.00^{a}	0.84± 0.00 ^{a}
Sweet potatoes	17.73± 0.00^{b}	32.54± 0.00^{b}	14.30± 0.00^{b}	0.14± 0.00^{b}	0.03± 0.00 ^{a}	0.63± 0.00^{b}
Irish potatoes	6.30± 0.01^{c}	3.40± 0.00^{c}	12.80± 0.01^{c}	0.09 ± 0.00^{a}	0.04± 0.00 ^{a}	0.48± 0.00^{c}

Values are presented as Mean ± Standard Deviation of triplicate determinations. Means in the same column with different letters are significantly different (p<0.05).

Table 4: Mineral composition of Taro cocoyam, sweet and Irish potatoes flours.

Sample	Na (mg/100g)	K (mg/100g)	Ca (mg/100g)	Mg (mg/100g)	Fe (mg/100g)	Zn (mg/100g)	Cu (mg/100g)	P (mg/100g)
Taro cocoyam	1.91 ± 0.00 ^{a}	448.02 ±0.05^{a}	27.03± 0.58 ^{a}	11.22±0.00 ^{a}	0.65± 0.00 ^{a}	3.81 ± 0.00 ^{a}	0.26± 0.00^{a}	5.75 ± 0.00^{a}
Sweet potatoes	54.00± 0.58^{b}	261.06± 0.58^{b}	28.24±0.58^{a}	27.21 ±0.58^{b}	0.74± 0.00 ^{a}	0.61± 0.00^{b}	0.21± 0.00^{b}=	53.30±0.58^{b}
Irish potatoes	11.10± 0.58^{c}	398.10± 0.58^{c}	18.15± 0.58^{b}	25.71±0.58^{b}	1.35± 0.05^{b}	0.31 ± 0.00^{c}	0.17± 0.00^{c}	52.70±0.58^{b}

Values are presented as Mean ± Standard Deviation of triplicate determinations. Means in the same column with different letters are significantly different (p<0.05).

4. DISCUSSION

The result of the percentage proximate composition of the flour samples of the three different tubers; Taro cocoyam, sweet and Irish potatoes in percentage (%) is presented in Table 1. The highest moisture content was found in Irish potatoes and the result is in agreement with the earlier reports of Odebunmi *et al.*[17] who reported high moisture contents in Irish potatoes. The high moisture content in Irish potato flour suggests that it cannot be stored for long period of time after processing, compared to Taro cocoyam and sweet potatoes flours. Thus, meals from Taro cocoyam flour could have more shelf stable characteristics on storage, than the stiff made from Sweet and Irish potato flour. The high moisture contents obtained for these tubers in this study explains why post-harvest loss due to spoilage is always high for these tubers, because high moisture content enhances microbial attack. As it is common with other roots and tubers, the high moisture content in Taro cocoyam, Irish and sweet potato may have resulted in relatively low dry matter content, as observed in the present study. The ash content of the samples increased significantly ($p<0.05$) in Taro cocoyam flour, which recorded the least moisture content. The ash content obtained in this study was within the range (2.45-4.02%) of Orange Flesh Sweet Potato Flour recorded by Alexander *et al.*[18] in their study. The ash content of a food material could be used as an index for estimating the mineral constituents of the food.

In the present study, as the crude protein content of flours was less than 2% and was lower than 3.2-6.6% values of various varieties of sweet potato flour reported by Waidyarathna and Ekanayake.[19] The high protein in the previous study may be due to presence of non-protein nitrogen compounds, which are accounted for when protein is measured by Kjeldhal method and the variety of the sweet potato used in the study. However, roots and tuber crops including these tubers are not good sources of protein similar to many other tubers.[20] Since potato and cocoyam flours are generally low in protein; hence, food products from these flours should be supplemented with other high-protein products for balanced nutrition. Tubers have never been known as good source of lipids though the values recorded in the present study are higher than the 1.0 % reported by Lewu *et al.*[5] for potato and cocoyam tubers in South Africa. The reason for the decreased fats content in the flour samples in the present samples may be due to the processing of the tubers to flour, as Agiang *et al.*[21] reported that processing of food samples decrease fats content. This means that Irish potato flour is a better source of protein, compared to flours made from sweet potatoes and Taro cocoyam. Though the tubers are known to be low in protein, the higher content recorded in Irish potatoes flou r can be exploited for use in malnourished communities.

Dietary fibre has recently attracted much attendance as it is known to reduce the incidences of colon cancer, diabetes, heart disease and certain digestive tract diseases.[22] However, the amount of fibre recorded in this study is not high compared to the adequate intake (AI) values given by the Food and Nutrition Board, Institute of Medicine, National Academies which are 38 g/day for a male adult and 25 g/day for a female adult, although this is dependent on the quantity of potatoes consumed. The variation in the fibre content may be due to the difference in the maturity of tubers or the roughage. Comparing the three types of tubers, the Taro cocoyam flour had a significantly higher ash, fats and dietary fibre compared to flours made from Irish and sweet potato specie. This implies that the Taro cocoyam variety is richer in basic nutrients compared to the sweet and Irish varieties of potatoes. The variations could be due to the differences in minerals in soil, maturity and the extent of peeling. The high fiber content found in the local tubers is good for the Nigerian population as this highlights protection against some health problems.

The available carbohydrate content and caloric value were found to be high in sweet potatoes flour compared to flours from Taro cocoyam and Irish potatoes; this finding contradicts that of Oko *et al.*[23], who reported lower carbohydrate/ caloric value of some staple foods commonly consumed in Nigeria, such as semo, garri, cor n, wheat, etc. However, the results of this study are in agreement with the report of Odebunmi *et al.*[17], who reported high content of carbohydrates in sweet potato. Thus in the present study the higher value reported may be due to sugars released following degradation of oligosaccharides and sucrose present in sweet potatoes. Also, following it lower calorific value recorded in Taro cocoyam flour, the flour can be made preferable source of energy for diabetic patient and people who are on a weight loss diet. Generally, the three types of tubers examined in this study are good carbohydrate/energy source with very low protein content; this agrees with the earlier study of Matikiti *et al.*[24], who revealed that tuber and other root crops are rich in carbohydrates hence their high caloric values. This makes the tubers to be of high value both nutritionally and economically hence it is food of major importance in Nigeria.

Glucose, sucrose, starch and dextrin were the main sugars identified in the flours, and their percent compositions and concentrations varied among the type of tuber used for the flour production. Sweet potatoes flour was found to contain highest concentration of glucose and the reason for the high content of the glucose may be attributed to the present of high carbohydrates contents recorded in sweet potatoes flour in this study. Also, sucrose, sugar and dextrin were found to be higher in Taro cocoyam flour compared sweet and Irish potatoes flour. This result is in line with the report of Odebunmi *et al.*[17], who revealed that tubers, such as cocoyam, sweet potatoes, yam, cassava, Irish potatoes are excellent food sources of starch. Carbohydrates are a major class of naturally occurring organic compounds. They are the macronutrients required in the largest amounts. When eaten and broken down, carbohydrates provide the major source of energy to fuel our daily activities. Carbohydrates provide fuel for the body in the form of glucose. Glucose is a sugar that is the primary source of energy for all of the body's cells. Tubers are excellent food sources of starch, while grains that contain carbohydrates include rice, corn, wheat, barley, oats and buckwheat. Reducing sugar content represents the sum of both monosaccharide glucose and fructose.[25] Most of the carbohydrates in the flours are in the form of naturally occurring sugar, however, this may have a different effect on the body than other sugars.

Vitamins are compounds that are essential to the health of humans and vertebrates but cannot be synthesized by these animals and must therefore be obtained in the diet.[26] The B-carotene, total and soluble vitamins C, thiamine, riboflavin and niacin were present in considerably concentrations, and were significantly higher in sweet potatoes flour, compared to flours made from Taro cocoyam and Irish potatoes. The levels of B-carotene reported in this study are comparable to those of tubers reported by Moo-Huchin *et al.*[27] According to Dias *et al.*[28], B-carotene is the most widely distributed and the most important provitamin A carotenoid. Also, B-carotene is a potent antioxidant, and regulates the pathogenesis of various chronic degenerative diseases. The results of this study, which revealed that the flours are good source of B- carotene, implies that these flours maybe a good source of vitamin A, as B- carotene are the most potent provitamin A. Vitamin C is a cofactor for numerous enzymes, functioning as an electron donor. The vitamin C content in the potatoes were in line with the contents reported in the work of Gouado *et al*[29] but were higher that the vitamin C content of the flours reported by Ellong *et al.*[30] The reason for the increase of vitamin C in the present study may be due cultivar of the tubers used in this study and the method of flours processing and analysis. Vitamin C functions as an antioxidant in numerous bodily reactions. Vitamin C functions as a water soluble antioxidant, and it is also an effective antioxidant that readily scavenges reactive oxygen species (ROS) and reactive nitrogen species (RNS). As a coenzyme, it also has numerous metabolic roles. The Recommended Dietary Allowance for vitamin C is 75 mg per day for women and 90 mg for men, for nonsmokers.[31] It is important in the production of collagen (insoluble protein of connective tissue, cartilage, and bone), which plays a vital role in wound healing. Vitamin C strengthens tissue and promotes capillary integrity. Vitamin C facilitates development of Red blood cells by enhancing iron absorption and utilization. It also aids the body in utilization of folate and vitamin B_{12}.[32] In human health, vitamin C has been associated with immunity, drug metabolism and urinary hydroxyproline excretion, tissue regeneration and reduction of the incidence of cancer and blood pressure.[32]

Thiamine (vitamin B1) functions as a coenzyme in metabolism of energy nutrients via the Krebs cycle to produce energy. This role makes it crucial for normal functioning of the brain, nerves, muscles, and heart. Thiamine is also a necessary component in the synthesis of niacin and helps regulate appetite. It is a constituent of enzymes that degrade sucrose to organic acids that can ultimately dissolve tooth enamel.[32] In addition, riboflavin and niacin were found to be higher in Taro cocoyam flour compared to Irish potatoes flour. Riboflavin functions as a coenzyme in the metabolism of carbohydrate, protein, and fat to release cellular energy. Riboflavin is also essential for healthy eyes and maintenance of mucous membranes. Along with thiamine, it is necessary for synthesis of niacin.[32]

The minerals determined were Sodium (Na), potassium (K), calcium (Ca), magnesium (Mg), Iron (Fe), Zinc (Zn), Copper (Cu) and phosphorous (P) and were found to be present in considerably concentrations and were greatly varied. The sweet potato flour had the highest amount of potassium, calcium, magnesium, iron, zinc and phosphorous compared to the Irish potato and Taro cocoyam flours, while the highest amount of sodium and copper were found in the Taro cocoyam flour. The results of the present study were in line with the earlier findings of Lewu *et al.*[5], who reported higher values of some minerals in potatoes than cocoyam tubers. The results showed that the flours were rich in some minerals and this may be attributed to the high crude ash content recorded in the present study (Table 1). Minerals are important for maintaining health through their function as electrolytes, enzyme cofactors, antioxidants and structural components of bones and teeth.[33] The high concentration of these minerals could be an advantage as certain inorganic mineral elements are known to play important roles in the maintenance of the body. Globally, calcium, iron and zinc deficiencies are the most widespread forms of mineral malnutrition.[35] Potassium is an element needed to maintain the pH and electrolyte balance of human cells. Though the value obtained is lower than the RDI value (187- 5625mg/100g) for adults, the plant can still serve as a supplement. It has been documented that a K/Na ratio in a diet is an important factor in prevention of hypertension and arterosclerosis, since potassium depresses and sodium enhances blood pressure.[33] A K/Na ratio of 3-4 is considered the most adequate for the normal retention of protein during growth stage. Potassium is the principal cation in intracellular fluid, and functions in acid-base balance, regulation of osmotic pressure, conduction of nerve impulse, muscle contraction particularly the cardiac muscle, cell membrane function and Na^+/K^+-ATPase.[33] The results of this study are in line with the earlier report of Aywa *et al*.[34], who reported high levels of potassium in sweet potatoes. Calcium functions as a constituent of bones and teeth, and it is involved in regulation of nerve and muscle function, blood coagulation, and also plays a vital role in enzyme activation.[33] Sodium serves as the principal cation in extracellular fluid and this helps to control the amount of fluid around cells as well as regulate blood pressure and volume.[34]

The low sodium content recorded in the present study is an advantage due to the direct relationship of high sodiu m intake with hypertension in human.

Zinc in traces as it appears is very important for nerve function and male fertility especially for the development of testes and ovaries. Zinc stimulates the activity of vitamins, formation of red and white corpuscles.[21] Zinc is essential for the production or release of insulin, thus the high zinc content could mean that the plant can play a valuable role in the management of diabetes.[34] All these variations in the nutrients in the different flours could be attributed to crop variety, cultivation practice, climate, growing season, stage of growth, location, soil, processing and storage practices.

5. CONCLUSION

This study has provided scientific information on the proximate, carbohydrate fractions, vitamin and mineral compositions of Taro cocoyam, sweet and Irish potatoes flours. The results of the study showed that these flours, mostly that of Taro cocoyam could be potential source of nutrition, medicinal value and should be recommended for consumption as it could be used to manage cases of protein energy malnutrition which is prevalent in most developing countries of the world, like Nigeria. Also, following it lower calorific value, it can be made a preferable source of energy for diabetic patient and people who are on a weight loss diet.

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Declarations

Ethical approval

Not applicable.

Availability of data

The datasets used/or analysed during the current study are available from the corresponding author on reasonable request.

Consent of Publication

Not applicable**,** as human subjects were not used.

Availability of Data

The datasets used/or analysed during the current study are available from the corresponding author on reasonable request.

Competing of Interests

The authors declare no conflict of interest.

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Authors' Contributions

Conceptualization and design: ANI and VEA; Acquisition, analysis, and interpretation of data: ANI, JEM, VEA, ASH; Drafting, revision, and resources: ANI, EO, JEM, ASH. All the authors read the manuscript and the authors' list and consented to the publication.

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