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Research Article
Nutritional Variation in Selected Yam Species: Implication on Functional Food Goals

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Abstract

Background and Objective: There is a growing concern in many parts of Africa on the rate of spread of erstwhile unknown disease and ailments, promoting a change in the dietary pattern. The nutritive value and functional status of most of the food species are unknown. In this study, the nutritional properties and functional potential of some yam species were investigated. **Materials and Methods:** The proximate analysis was done according to the AOAC, the mineral analysis was done using AAS and the oil was characterized using GC-MS. **Results:** The Crude protein was highest in *Dioscorea alata* (19.53±0.84%) and least in *Colocasia esculenta* (14.80±0.72%) and crude fiber ranged from *4*.13±0.55% in *Colocasia esculenta*, too (1.27±0.15%) in *Dioscorea rotunda.* It has been reported scientifically the significance of crude fibre in constipation reduction, decrease in bad (LDL) cholesterol. The mineral analysis results in (mg/100 g) ranged from 70.300 mg/100 g (*D. rotundata*) to 40.260 mg/100 g (*D. alata*). The characterization of the oil extracts showed the presence of various compounds such as; Linoleic acid, an essential fatty acid needed for various physiological functions, stearic acid, palmitic acid and ascorbic acid-2,6-dihexadecanoate, it has been established that ascorbic acid supplementation increases the mRNA levels of PPARα and its target enzymes involved in fatty acid β-oxidation in visceral adipose tissues. **Conclusion:** The research work has shown that the plants could be classified as functional foods as a result of their richness nutritionally in the range of *Dioscorea alata*, *Colocasia esculenta*, *Dioscorea rotunda* and *D. alata*.

Key words: Nutritional, characterization, essential fatty acid, functional food, physiological functions, visceral adipose tissues

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Yam species are found to be rich in carbohydrate and not classified as functional foods such as Beans, nuts, whole grains, however the need to re-assess the proximate and mineral contents and characterize the oil extract for the presence of bioactive compounds in order to see if they meet part of a proponent of functional foods necessitate the research work. Food and rural livelihoods are a major concern to the populace and one of the risk factors in many developing countries associated with different diseases. In addition, it is well informed that Functional foods are foods that have a potentially positive effect on health beyond basic nutrition. Proponents of functional foods say they promote optimal health and help reduce the risk of disease. Yam species are commonly stapled tuber crops available in African content which can either be processed into yam powder or cooked, the plants are rich in carbohydrate and other mineral composition. They regenerate from tubers, dioecious and produce flowers if any [1]. The benefits of taking yam species are well documented in the literature and the health benefits are of wide ranges. It has been reported that yam species contains phenolic compounds, alkaloids and diosgenin, a steroid saponin and having anti-cancer and anti-inflammatory effect[2] and they also play a role in reducing diabetes and obesity in humans[3]. The proximate and mineral analyses of *C. esculenta* and *D. rotundata* yam species have been previously examined; the protein content of *D. Rotundata* has, *C. esculenta*, the crude fiber content of *D. rotundata* and *C. esculenta*[4]. However, the need to have broad information about the nutritional properties of *Dioscorea rotunda*, *Dioscorea alata*, *Dioscorea cayenensis* and *Colocasia esculenta* necessitated the research; vis-a-vis; proximate, metal analysis and characterisation of the oil extract for bioactive compounds present and the research findings were expected to re-design the classification of functional foods.

MATERIALS AND METHODS

Sample collection: Fresh yam samples of *Discorea rotundata*, *Discorea alata*, *Colocasia esculenta* and *Dioscorea cayenensis* were purchased from the king's market in Ado-Ekiti, Ekiti State, Nigeria on the 5th of May, 2019.

Sample preparation: Five kilograms of the tubers were washed, hand peeled and trimmed to remove defective parts. Then the tubers were grated into thin chips and dried in an air convection oven at 40°C for 30 hrs. The dried chips were powdered using a laboratory-scale grinder (Sumeet CM/L 2128945) and sifted through 300 µm sieve to obtain the yam flour. The flour samples were sealed and packed in airtight containers for further analysis[5].

Determination of proximate composition: The proximate analyses of the four samples were done[6] without modification. The crude protein content was analyzed by the Kjeldahl method, using five grams. Also, moisture content was determined by heating five grams of the sample to a constant weight in a crucible placed in an oven maintained at 105°C. The dry matter was used in the determination of the other parameters. crude fat was obtained by extracting five grams of the sample in a Soxhlet apparatus using petroleum ether (boiling point range 40-60°C). Ash was determined by the incineration of six grams placed in a muffle furnace maintained at 550°C for five hours. The crude fiber was analyzed by digesting five grams of the sample with H_2SO_4 and NaOH and incinerating the residue in a muffle furnace maintained at 550°C for five hours. The total carbohydrate was obtained by difference. Each analysis was carried out in triplicate.

Evaluation of mineral composition: Standard methods[6] were employed. The elemental constituents (Ca, Zn, Fe, Mg, K, Na) in the yam tubers were analyzed using atomic absorption spectrophotometer (AAS Buck Scientific Model 210 VGP and Flame Photometer FP 902 PG, England).

Extraction of oil from the yam flour: The conventional method of extraction involves the use of a Soxhlet apparatus. This method of extraction was designed to extract lipids. One gram of moisture-free sample was wrapped in filter paper, placed in a fat free thimble and then introduced in the extraction tube. Weighed, cleaned and dried receiving beaker was filled with petroleum ether and fitted into the apparatus. Water and heater were turned on to start extraction. After 6 siphoning, ether was allowed to evaporate and beaker disconnected before the last siphoning. The extract was transferred into a clean glass dish with ether washing and evaporated on a water bath. The dish was then placed in an oven at 105°C for 2 hrs and cooled in a desiccator.

Characterization using gas chromatography-mass spectrophotometer: GC-MS analysis of extracts of was performed using Turbo Mass GC System, fitted with an Elite-5 capillary column (30 m, 0.25 mm inner diameter, 0.25 µm film thickness; maximum temperature, 350°C coupled to a Perkin

Elmer Clarus 600C MS. Helium was used as a gas carrier at a constant flow rate of 1.0 mL min^{-1}. The injection, transfer line and ion source temperatures were 280°C. The ionizing energy was 70 eV. The oven temperature was programmed from 70°C (hold for 2 min) to 280°C (hold for 10 min) at a rate of 5°C/min. The crude extract was solubilized with chloroform and filtered with a syringe filter (Corning, 0.45 µm). Volumes of 1 µL of the crude extracts were injected with a split ratio 1:20. The data were obtained by collecting the mass spectra within the scan range 50-550 m/z. The identification of chemical compounds in the extracts was based on GC retention time; the mass spectra matched those of standards available at the NIST library.

Statistical analysis: Samples were analyzed using ANOVA in replicates of three and results were expressed by Mean±S.

RESULTS

Proximate composition: The analysis shows the protein content in the decreasing range of (19.53±0.84%) *D. alata*; (16.69±1.81%) *D. rotundata*; (16.01±1.45%) *D. cayenensis*; (14.80±0.72%) *C. esculenta.* The crude fibre ranged from (4.13±0.55%) (*C. esculenta*) to (1.27±0.15%) *D. rotundata*. The carbohydrate content of *D. cayenensis* was the highest (69.27±1.28%) and least in *C. esculenta* (52.42±0.47%) as shown in Table 1.

Mineral analysis

Mineral elements composition of *Dioscorea rotundata*, *D. cayenensis*, *D. alata* and *Colocasia esculenta*: *Dioscorea rotundata* has the highest potassium content (70.30 mg/100 g) followed by *Colocasia esculenta* (61.05 mg/100 g), *D. cayenensis* with (60.85 mg/100 g) and *D. alata* has the lowest (40.260 mg/100 g) potassium content. *Colocasia esculenta* had the highest calcium content (12.50 mg/100 g) and the *Dioscorea rotundata* had the least (8.250 mg/100 g) as shown in Table 2.

Identification of compounds in chromatogram: Some of the compounds identified in the chromatogram of *D. rotundata* included palmitic acid, stearic acid, Linoleic acid and 6-methyl-7-thioxo-4,7-dihydro-triazolo.

In the chromatogram of *D. Rotundata* (Fig. 1), some identified peak and retention time included that of peak 8,

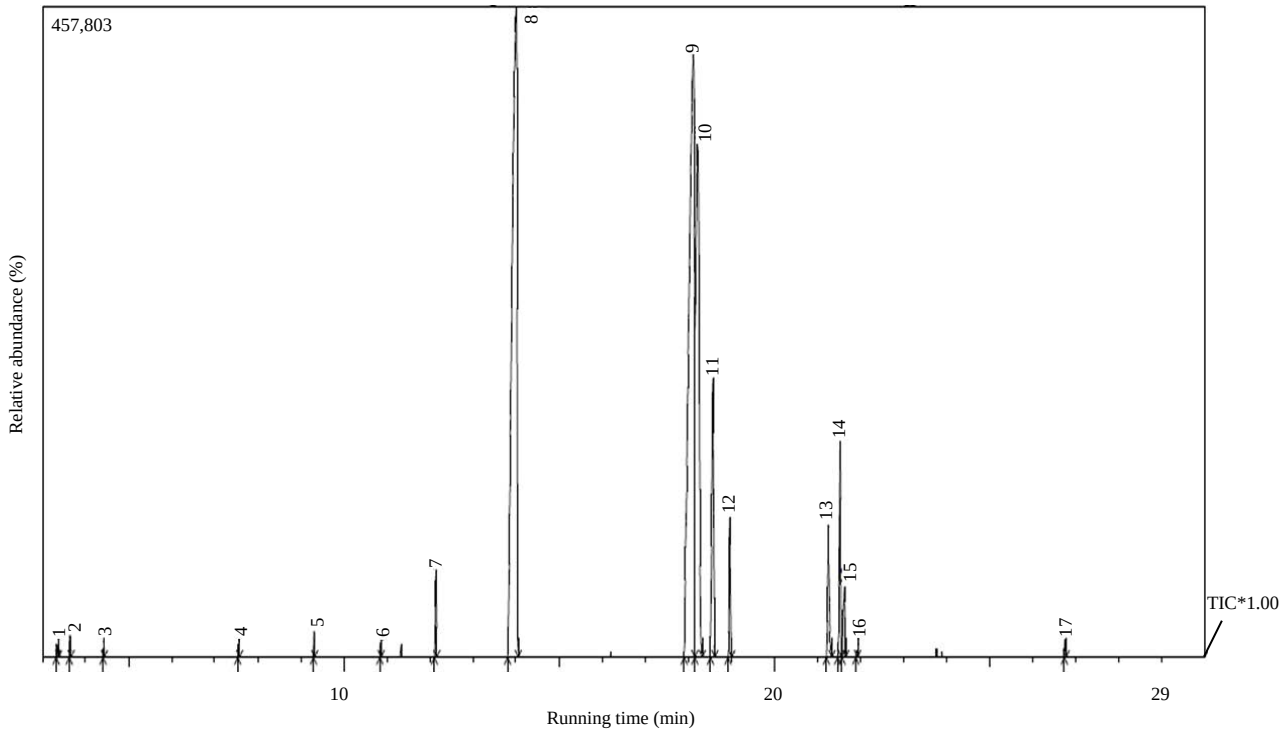

Fig. 1: Chromatogram of oil extracted from *D. rotundata*

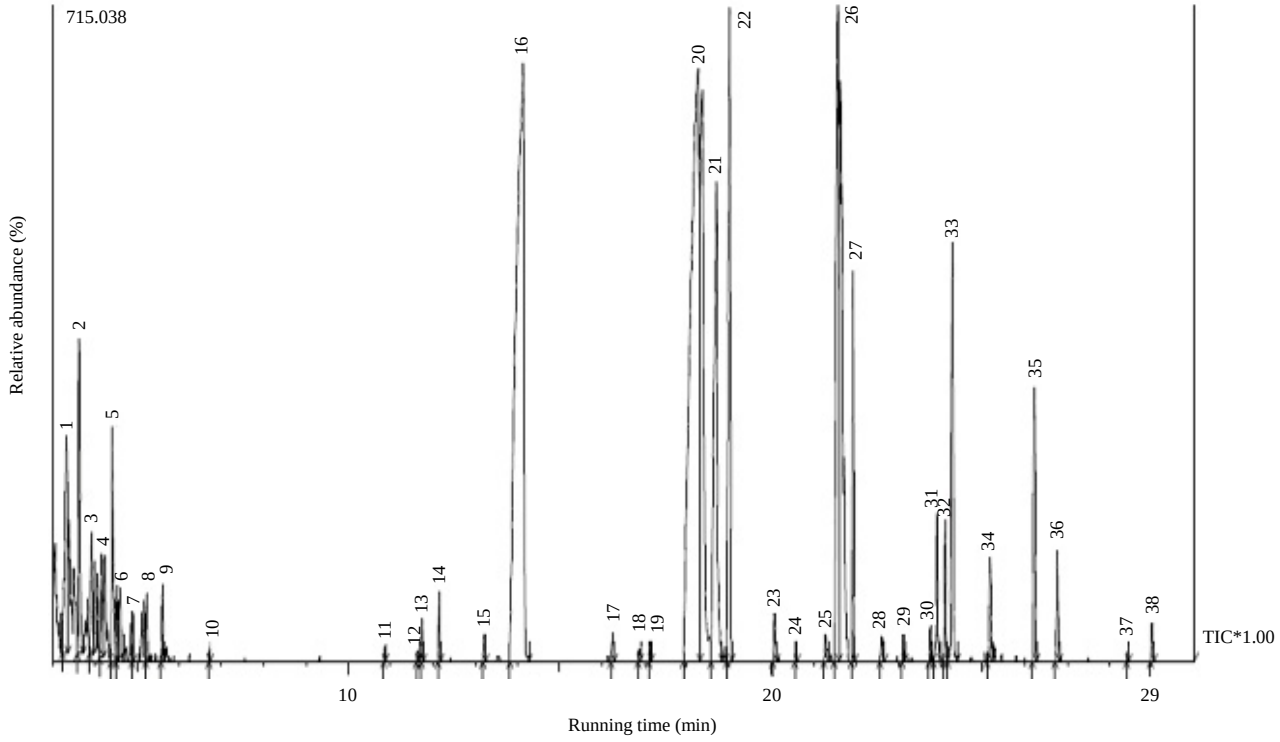

Fig. 2: Chromatogram of oil extracted from *C. esculenta*

Table 1: Proximate composition

Samples (%)	*Dioscorea rotundata*	*Colocasia esculenta*	*Dioscorea alata*	*Dioscorea cayenensis*
Moisture	6.82±0.41	11.10±0.09	5.62±0.33	3.65±0.20
Crude protein	16.69±1.81	14.80±0.72	19.53±0.84	16.01±1.45
Crude fat	8.09±0.10	11.82±0.12	6.15±0.22	4.62±0.13
Ash	6.57±0.05	5.74±0.08	7.48±0.09	4.28±0.09
Crude fiber	1.27±0.15	4.13±0.55	2.31±0.21	2.17±0.32
Carbohydrate content	60.56±1.83	52.42±0.47	58.88±0.61	69.27±1.28

Mean±standard deviation of triplicate determinations

Table 2: Mineral elements composition of *Dioscorea rotundata*, *D. cayenensis*, *D. alata* and *Colocasia esculenta* (mg/100 g)

Samples	Fe	Zn	Mg	Ca	Na	K
D. rotundata	0.041	0.062	0.620	8.250	3.510	70.300
D. cayenensis	0.038	0.011	0.912	11.600	4.250	60.850
D. alata	0.061	0.070	1.074	8.520	5.410	40.260
C. esculenta	0.038	0.076	0.782	12.500	6.060	61.05

Mg: Milligram, g: Gram

having retention time 14.005 min and identified compound of the peak was n-capric acid. Furthermore, Linoleic acid was identified on peak 10 having a retention time of 18.219 min. Other compounds identified were palmitic acid,6-methyl-7-thioxo-4,7-dihydro-triazolo and stearic acid as shown in Table 3.

The identified compounds in the chromatogram (Fig. 2) revealed the presence of Aziridine, 2-methyl at peak 18 and retention time 16.879 min, 4-Amino-4,5 (1H)-dihydro-1,2,4-triazo-5 at peak 28 and retention time of 22.610 min as shown in Table 4.

Four compounds were identified in the chromatogram (Fig. 3) of *D. cayenensis* and at various peaks and retention times, among was Aziridine, 2-methyl at peak 16 and retention time 18.967 min shown in Table 5.

The use of gas chromatography-mass spectrophotometer revealed the presence of;1H-1,2,4-Triazol-3-amine, linoleic acid, stearic acid and 1H-Indene in the chromatogram

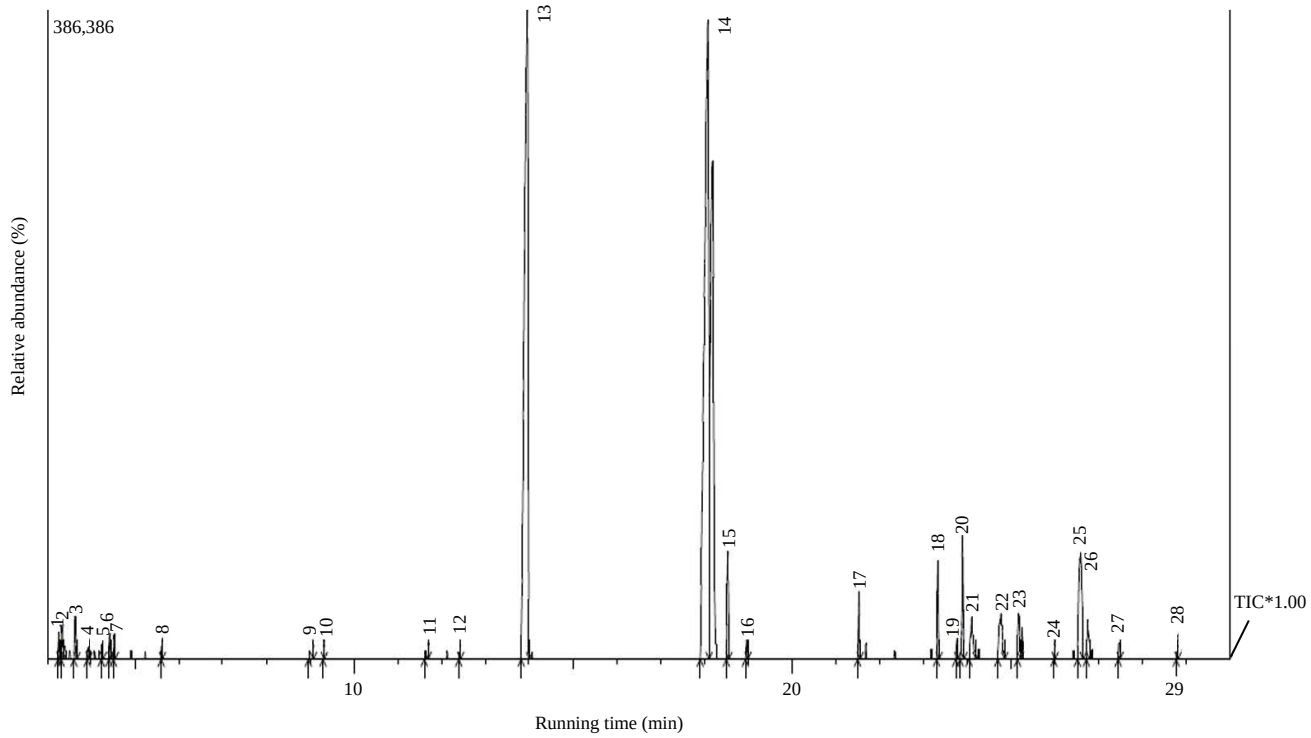

Fig. 3: Chromatogram of oil extracted from *D. cayenensis*

Table 3: Some of the identified compounds detected in the chromatogram of *D. rotundata*

Peak no.	Height (%)	Retention time (min)	Compound name
8	23.11	14.005	n-capric
9	21.40	18.118	Palmitic acid
10	18.24	18.219	Linoleic acid
11	9.91	18.573	Stearic acid
13	4.71	21.262	6-methyl-7-thioxo-4,7-dihydro-triazolo

Table 4: Some of the compounds identified in the chromatogram of *C. esculenta* included palmitic acid, stearic acid and Aziridine, 2 methyl

Peak no.	Height (%)	Retention time (min)	Compound Name
14	1.12	12.149	n-capric acid
18	0.18	16.879	Aziridine, 2 methyl
21	7.61	18.707	Stearic acid
22	10.37	18.933	Palmitic acid
28	0.40	22.610	4-Amino-4,5(1H)-dihydro-1,2,4-triazo-5

Table 5: Compounds identified in the chromatogram of *D. cayenensis included* Acetophenone and aziridine, 2-methyl

Peak no.	Height (%)	Retention time (min)	Compound name
3	1.89	3.638	Acetophenone
8	0.63	5.612	4-Isothiazolecarboxamide
16	0.87	18.967	Aziridine, 2-methyl
24	0.31	25.996	Oxalic acid

Table 6: Oil extracted from *D. alata* details

Peak no.	Height (%)	Retention time (min)	Compound name
3	1.37	4.071	1H-Indene
21	0.24	16.886	Linoleic acid
22	6.23	17.866	Stearic acid
29	1.07	23.116	1H-1,2,4-Triazol-3-amine

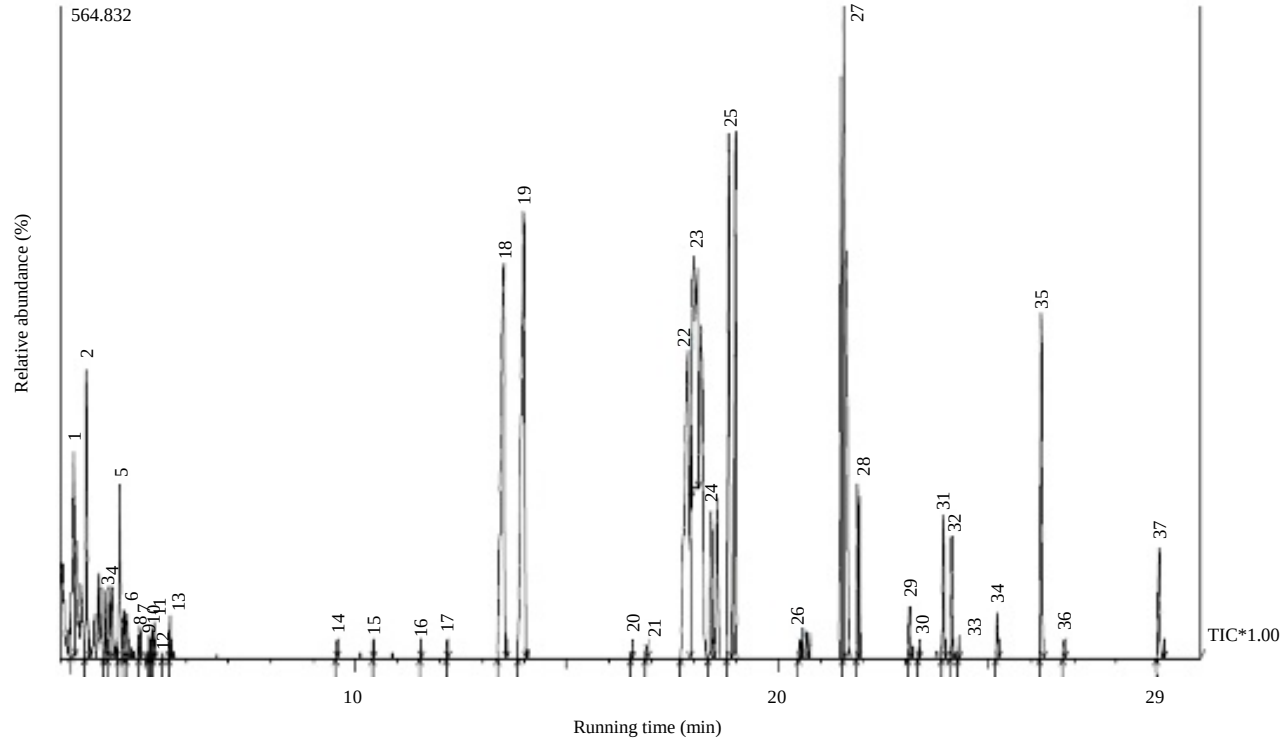

Fig. 4: Chromatogram of oil extracted from *D. alata*

compounds revealed in the chromatogram (Fig. 4) included; Linoleic acid at peak 21 and retention time 16.886 min, stearic acid at peak 22 and retention time 17.866 min, 1H-Idene at peak 3 and retention time 4.071 min as shown in Table 6.

DISCUSSION

From the results of Table 1, the proximate analysis showed the moisture content in the range; *Dioscorea cayenensis* (3.65±0.20%), *Dioscorea alata* (5.62±0.33%), *Dioscorea rotunda* (6.82±0.41%) and *Colocasia esculenta* (11.10±0.09%). The crude protein content showed that the *Dioscorea alata* was highest (19.53±0.84%)and the least was Colocasia esculenta (14.80±0.72%). From the previous study of proximate analysis of *C. esculenta* and *D. rotundata* as reported[4], the protein content of *D. rotundata* was (0.087±0.03%), *C. esculenta* (0.066±0.04%) and these values were lower than that of *Discorea bulbifera* tuber tissue for dry matter 6.35±0.87 g/100 g as reported earlier[7], moreover, the protein content of *D. dumetorum* was[8] 2.5%. Protein content *of D. rotundata was* 1.61±0.05^{c}%, *D. alata (*3.46±0.04^{a}%), *D. cayenensis* (2.13±0.06^{b}%) as also reported[9]. Moreover, the crude protein content of *D. alata* (Rajala) was (10.16±0.64^{a}%), *D. esculenta (kukulala)* (9.02±0.65^{c}%) as researched by other author[10]. These values were lower than all the protein content reported for *Dioscorea alata* (19.53±0.84%), *D. rotundata* (16.69±1.81%), *D. cayenensis* (16.01±1.45%) and *Colocasia esculenta* (14.80±0.72%).

In another development, the crude fibre content of *D. rotundata* was (0.70±0.01%), *C. esculenta* (1.00±0.01%) as reported[4] and these values were lower than that of *Discorea bulbifera* tuber tissue for dry matter 2.89±0.28 g/100 g as reported earlier[7], furthermore, crude fiber content of *D. rotundata* was (4.75±0.05^{b}%), *D. alata* (5.26±0.04^{a}%), *D. cayenensis* (4.86±0.02^{b}%)[9].

In comparison to the present study, the crude fiber contents progressed from *D. rotundata* was 1.27±0.15%, *D. cayenensis* (2.17±0.32%), *D. alata* (2.31±0.21%) and *C. esculenta* (4.13±0.55%). The crude fiber of *C. esculenta* was higher than that reported for the same yam (2.33±0.15^{a}%), the crude fiber of *D. alata* in the current study was higher than that of *D. alata* (Rajala) (2.0±0.1^{b}%)[10]. The values reported by another study[9] were higher than the values of the current study. Ash content highest value was highest in *Dioscorea alata* (7.48±0.09%) and lowest in *Dioscorea cayenens* is (4.28±0.09%). These values were higher than that of *D. rotundata* (1.60±0.00^{b}%), *D. alata* (2.18±0.03^{a}%) and

D. cayenensis (1.53±0.03^{b}%)[9]. The variation recorded in the proximate results may be due to many factors such as the age of plant, time of harvest, soil nutrients composition, the season of planting and other climatic conditions.

In another development, Table 2 Shows the minerals elements; *Dioscorea rotundata* has the highest potassium content (70.30 mg/100 g) followed by *Colocasia esculenta* (61.05 mg/100 g), *D. cayenensis* with (60.85 mg/100 g) and while *D. alata* has the lowest (40.260 mg/100 g) potassium content as shown. The potassium content, when compared to that of *D. bulbifera*[7], was lower than (176.00±1.41 mg/100 g), *Dioscorea dumetorum* Pax (17,036.00±0.25 parts per million)[11]. However, potassium values observed in this study were low when compared to the Recommended Daily Allowance (RDA) of potassium (4700 mg). Potassium is the main intracellular cation that controls osmotic pressure and is a systemic electrolyte essential for co-regulating adenosine triphosphate (ATP) with sodium. The recommended daily allowance (RDA) of potassium is (4700 mg)[12]. *Dioscorea rotundata*, has the lowest sodium content (3.51mg/100 g) while *Colocasia esculenta*, has the highest (6.06 mg/100 g). The sodium content of *D. cayenensis* and *D. alata* were (4.250 mg/100 g) and (5.41 mg/100 g), respectively. These values were lower than that of *Dioscorea dumetorum* Pax (521.00±0.00 ppm)[11]. *Dioscorea rotundata* (185.15±0.05 mg/100 g) and *C. esculenta* (270.83±0.04 mg/100 g)[7]. The RDA value of sodium is 1500 mg[12]. Sodium is the principal cation in intracellular fluids. It controls acid-base balance and is involved in the maintenance of the osmotic pressure of body fluids[13]. It is important for co-regulating ATP with potassium[12]. Magnesium is an important mineral element; an activator of many enzyme systems and it maintains the electrical potential in nerves[14]. *D. alata* and *D. cayenensis* have higher magnesium content of (1.07 mg/100 g) and (0.91 mg/100 g) than *D. rotundata* 0.62 mg/100 g and *C. esculenta* (0.78 mg/100 g). The Iron content was extremely low in all the yam samples. Values less than 0.1 mg/100 g was observed in all the samples. Iron is present in the enzyme cytochrome oxidase involved in energy metabolism. Iron is an essential trace element needed for oxidation of carbohydrates, protein and fat[14]. The RDA of iron for an adult is 15 mg, 20-300 mg for children and 40 mg for pregnant women[13]. Iron has been shown to cause oxidative damage by acting catalytically in the production of Reactive Oxygen Species (ROS) which have the potential to damage cellular lipids, nucleic acids, proteins and carbohydrates resulting in a wide range impairment in the cellular function and integrity[15]. ROS can directly attack the polyunsaturated fatty acids of the cell membranes and induce lipid peroxidation. Calcium contents in the yam samples ranged between 8.25-12.50 mg/100 g with *C. esculenta* and *D. rotundata* having the highest and lowest respectively. The RDA value for calcium in an adult male is 1000 mg[12]. Calcium content of all samples was lower than the RDA. Calcium is an important constituent of body fluids. It is a coordinator among inorganic elements particularly potassium, magnesium, or sodium where calcium is capable of assuming a corrective role when such metals are in excessive amounts in the body[16]. Zinc is among the required elements for humans. Zinc content obtained in the present work was 0.062, 0.011, 0.070 and 0.076 mg/100 g for *Dioscorea rotundata*, *D. cayenensis*, *D. alata* and *Colocasia esculenta*, respectively. The RDA of Zn is 11 mg[12]. Zinc level was low in all samples analysed. However, from the recommendation set out by NRC/NAS, the daily requirement of Zn can easily be met by supplementing this with foods high in potassium, sodium, calcium and Phosphorus. High doses of zinc can be harmful. Zinc supplements can decrease the amount of high-density lipoprotein (HDL) circulating in the blood, increasing risk of heart disease. Excess zinc interacts with other minerals, such as Cu and Fe, decreasing their absorption. In animals, zinc supplements decrease the absorption of iron so much that anaemia is produced[12]. If patients are given 150 mg of zinc per day, copper deficiency may result. Intakes of zinc only 3.5 mg/day above the Recommended Daily Allowance (RDA) decrease copper absorption[17]. Zinc contents of all the samples used in this research were below the RDA; therefore, they may not increase the risk of heart disease or decrease iron absorption nor cause copper deficiency.

In Table 3, some identified peak and retention time included that of peak 8, having retention time 14.005 min and identified compound of the peak was n-capric acid. Furthermore, Linoleic acid was identified on peak 10 having retention time of 18.219 min. Other compounds identified were palmitic acid, 6-methyl-7-thioxo-4,7-dihydro-triazole and stearic acid. Linoleic acid belongs to the class of essential fatty acid responsible for different physiological functions. Table 4 revealed the presence of Aziridine, 2- methyl at peak 18 and retention time 16.879 min, 4-Amino-4,5(1H)-dihydro-1,2,4-triazo-5 at peak 28 and retention time of 22.610 min and Palmitic acid at peak 22. *C. esculenta* had been previously characterized and 4-Methylimidazolium ion was identified having retention time of 24.318 min and % composition 1.36%, other identified compounds include; 3,5-Di-t-butyl phenol, Octadecanoic acid[18].

Furthermore, in Table 5, four compounds were identified in the chromatogram of *D. cayenensis* and at various peaks and retention times, among was Aziridine, 2-methyl at peak 16 and retention time 18.967 min. Moreover, in Table 6,

identified compounds were; Linoleic acid at peak 21 and retention time 16.886 min, stearic acid at peak 22 and retention time 17.866 min, 1H-Idene at peak 3 and retention time 4.071 min were all identified.

CONCLUSION

The high protein contents of the plants examined have vindicated that the plants are qualified to be classified as Functional foods as health benefits of protein foods have been well researched into. Also, the presence of essential fatty acids such as linoleic acid and other beneficial compounds are indicating tools for classification. The results of the research work have met the requirement to be classified as a functional food as a result of their richness nutritionally in the range of *Dioscorea alata, Dioscorea rotundata*, *D. cayenensis* and *Colocasia esculenta*.

SIGNIFICANCE STATEMENT

This study discovered the essential fatty acid which has been found to perform various physiological functions in the body, also, Triazole and Aziridine derivatives were identified which have been widely reported to have drug properties that can be beneficial for human beings. This study will help the researchers to uncover the critical areas of functional foods that many researchers were not able to explore. Thus, a new theory on functional foods may be arrived at.

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