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Research Article

The importance of nutritive parameters in the taxonomy of some corm-producing members of the family Araceae

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Abstract

This work gives detailed information of the proximate, phytochemical, Vitamin C and mineral constituents of the leaves and corms of members of family Araceae from genera *Alocasia*, *Colocasia* and *Xanthosoma* with the aim of promoting the use of these genera as food and solving some taxonomic problems. X-Ray Fluorescence was employed in determining the mineral constituents while other parameters were determined following standard methods. The result revealed high carbohydrate and moisture contents in all the taxa. The highest saponin and tannin contents were encountered in the leaves and corms of *Xanthosoma saggitifolium*. The leaves of the *Xanthosoma* taxa are rich in Vitamin C. Bulk, essential and non-essential elements were detected in all the taxa. They all had high potassium and calcium contents in their leaves and corms except in *Colocasia esculentum* var. *esculentum* where potassium was not detected in the leaves. Chromium was not detected in the leaves of *Xanthosoma saggitifolium*. Arsenic, Bromine and Rubidium were not detected in the leaves of *Alocasia macrorrhiza*, *Alocasia plumbea, Xanthosoma mafaffa* (Red) and *Xanthosoma saggitifolium*. Titanium was not detected in the leaves of the *Colocasia* and *Xanthosoma* varieties and the corms of *Alocasia cucullata*, *Alocasia plumbea*, *Colocasia esculentum* var. *esculentum*, *Xanthosoma mafaffa* (Red) and *Xanthosoma saggitifolium*. The use of nutritive parameters and phytochemicals in the taxonomy of the Araceae taxa was discussed.

Keywords: *Alocasia*; *Colocasia*; phytochemical; taxonomy; *Xanthosoma*; x-ray fluorescence

Introduction

The Arum family, Araceae is a large family of plants with diverse habits. They grow as herbs, epiphytes, climbers, vines and exhibit other growth forms as well (Croat, 1992; Mayo *et al.*, 1997). They are also found growing in different types of habitat. About 3300 species in 105 genera have been identified in the family (Mayo *et al.*, 1997) some of which are corm-producing. Many of the Araceae species also known as aroids, serve ornamental purposes while others are edible. A major caution to the edibility of these species is the presence of calcium oxalate crystals occurring as druses or raphides in the various parts of the plants which made Araceae species toxic in nature. This poisonous nature has been variously reported (Bown, 2000; Gary, 2009; Arogundade and Adedeji, 2017) and some species of Araceae have been included in the list of poisonous plants

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(Mulligan and Munro, 1990). However, human resourcefulness has made possible so many ways of using these poisonous plants as food and medicine (Bown, 2000). Detoxification methods like cooking, pounding and leaching can also be employed in order to make the aroid species edible though these methods do not degrade or destroy the raphides (Johns and Kubo, 1988). Both the leaves and corms of some of the aroids are actually part of delicacies of some indigenous people (Cable, 1984; Okeke, 1992). Aroids have medicinal value and are being used in curing different ailments. Some *Alocasia* and *Colocasia* species have been employed in curing wounds and diseases (Cambie and Ash, 1994; van Wyk *et al*., 1997; Bown, 2000). Amanze (2009) ascertained that varieties of *Colocasia* and *Xanthosoma* are rich sources of macro minerals and trace elements. Green and Oguzor (2009) analysed some of the nutritive parameters of the corms of four members of Araceae which was used, in addition to the epidermal features and starch grain structures, in delimiting the taxa.

The use of chemical constituents in explaining relationship between plants and inferring phylogeny is an important field of evidence in systematic biology. It is believed that chemical identification of specific compounds will provide a greater insight into the relationships and differences among plant taxa (Belfiore *et al*., 1997; Burkhard *et al*., 2009). The role of x-ray fluorescence (XRF) spectrometry is highly significant in this regard (Vázquez *et al*., 2002). X-ray fluorescence (XRF) spectrometry is a tool for obtaining quantitative basis in order to confirm the Linnaean systematic classification of plants. Hence, it is very useful in solving taxonomic problems. There is no known work on the application of XRF spectrometry to the taxonomy of aroids especially in Nigeria.

According to Daniel (2009), chemical data on a plant provide much information on the status of that taxon. Some of these chemical compounds are produced as secondary metabolites in plants and function in the adaptation of such plants to their environment. Examples of such metabolites include alkaloids, flavonoid, saponin, iridoids, oxalate, lectins and phenolics. These have been variously used in plant classification (Ekeke and Ndukwu, 2014; Singh, 2016; Liu *et al*., 2017). Primary metabolites on the other hand, which include but not limited to carbohydrates, lipids, proteins and nucleic acids are universal in plant kingdom. However, they can be useful as chemotaxonomic tools on the basis of their quantities (Singh, 2016). The aim of this work is therefore to provide detailed information on the proximate, phytochemical and elemental compositions of the leaves and corms of these taxa of Araceae. This will promote the use of these aroids as food and also enhance the taxonomy of the taxa which can be confusing as reported by Green and Oguzor (2009). The eight Araceae taxa used for this research are from three genera, *Alocasia*, *Colocasia* and *Xanthosoma* in the family.

Materials and Methods

Materials

The plant taxa used for this work are from three genera of Araceae. They are *Alocasia cucullata*, *Alocasia macrorrhiza* and *Alocasia plumbea* from the genus *Alocasia*; *Colocasia esculentum* var. *antiquorum* and *Colocasia esculentum* var. *esculentum* from the genus *Colocasia* and *Xanthosoma mafaffa* red variety, *Xanthosoma mafaffa* white variety and *Xanthosoma saggitifolium* from the genus *Xanthosoma*. These were collected from various parts of South West Nigeria as shown on Table 1. The young tender leaves were used for the leaf analysis while harvested corms were used for the corm analysis.

Proximate analysis

Moisture content, crude fat, crude fibre, crude protein, percentage ash and mineral contents of the leaves of all the species and corms of eight corm-producing species were determined. Vitamins C content of the samples was determined. All were carried out using AOAC methods.

Moisture content

A constant weight of each of the sample was oven dried at 102 °C for about 4 hours during which the weight was checked at specific time intervals until consecutive weighing agree within 0.05 mg. This was carried out in replicates for each sample. Percentage moisture content was calculated thus:

% Moisture content = Weight of moisture / Weight of sample × 100

Table 1. Sites and locations of collection

Sample	Place of Collection	Coordinate
Alocasia cucullata	Parks and Garden, O.A.U. Ile-Ife	N07°31.342' E004°31.834'
Alocasia cucullata	Rainbows Q Gardens, Ibadan, Oyo state	N07°24.182' E003°57.799'
Alocasia macrorrhiza	Ondo Road, Modakeke, Osun State	N07°28.986' E004°32.156'
Alocasia macrorrhiza	Ikire, Osun State	N07°22.754' E004°10.893'
Alocasia macrorrhiza	Igbara Odo, Ekiti State	N07°29.959' E005°03.996'
Alocasia plumbea	Oladapo Estate, Ondo, Ondo State	N07°06.758' E004°47.885'
Alocasia plumbea	Igbara Odo, Ekiti State	N07°30.160' E005°03.601'
Alocasia plumbea	Rainbows Q Gardens, Ibadan, Oyo State	N07°24.151' E003°57.726'
Colocasia esculentum var. *antiquorum*	Opposite Central Science Laboratory, O.A.U., Ile-Ife	N07°31.237' E004°31.720'
Colocasia esculentum var. *antiquorum*	Chapel of Grace Compound, O.A.U.T.H.C., Ile-Ife, Osun State	N07°30.365' E004°34.362'
Colocasia esculentum var. *esculentum*	Rainbows Q Gardens, Ibadan, Oyo State	N07°24.151' E003°57.771'
Colocasia esculentum var. *esculentum*	Igbara Odo, Ekiti State	N07°30.114' E005°03.993'
Xanthosoma mafaffa (Red)	Botany Department, O.A.U., Ile-Ife, Osun State	N07°31.149' E004°31.555'
Xanthosoma mafaffa (Red)	Rainbows Q Gardens, Ibadan, Oyo State	N07°24.181' E003°57.788'
Xanthosoma mafaffa (Red)	Ogotun-Ekiti, Ekiti State	N07°30.401' E004°59.427'
Xanthosoma mafaffa (White)	Ikeji Ile, Osun State	N07°28.805' E004°55.269'
Xanthosoma mafaffa (White)	Rainbows Q Gardens, Ibadan, Oyo State	N07°24.175' E003°57.794'
Xanthosoma mafaffa (White)	Bamikemo village, Ondo State	N07°18.328' E004°52.659'
Xanthosoma mafaffa (White)	Igbara Odo, Ekiti State	N07°30.160' E005°03.601'
Xanthosoma saggitifolium	Aye-Coker, Osun State	N07°17.934' E004°36.285'

Crude fat determination

Soxhlet extraction method was used. A constant weight of homogenized samples of each of the species was weighed on a filter paper (improvised thimble) and carefully wrapped. This was transferred into a Soxhlet extractor. 500 ml empty round bottom flask was weighed and recorded. The Soxhlet extractor was fitted up with a reflux condenser and down with the 500 ml round bottom flask now half filled with n-hexane. Heat was supplied to the set-up through a heating mantle. The solvent boiled gently and was left to siphon for about three hours. The condenser was then detached, the filter paper removed and the n-Hexane was distilled from the flask. The flask now containing the fat residue was dried in the oven at 100°C for 5 mins. The weight of the flask was taken on cooling.

The fat content was calculated thus:

$\% \text{ Oil extract} = Y - W/X \times 100$

Where W (g) = Weight of empty round bottom flask

X (g) = Weight of sample only

Y (g) = Weight of the round bottom flask + fat residue

Crude fiber determination

A constant weight of each of the samples was transferred into a 600 ml beaker. Added to this were 200 ml of 1.25% sulphuric acid and some burning chips. The beaker was placed on a pre-adjusted hot plate and allowed to boil for exactly 30 minutes, rotating beaker periodically to keep solids from adhering to sides. The contents were filtered and rinsed with three 50 ml portions of distilled water. After this 200 ml, 1.25% Sodium hydroxide was added and allowed to boil for another 30 minutes after which the contents were filtered and washed with three 50 ml portions of distilled water and 25 ml alcohol. The residue was then transferred into a crucible for dry ashing, after which it was weighed. The percentage crude fibre in ground (C) was calculated thus:

$C = \text{Loss in weight on ignition} - \text{Loss in weight of blank}/\text{Weight of sample} \times 100$

Percentage ash determination

A constant weight of each sample was weighed into a porcelain crucible which was ignited in a muffle furnace at 550 °C for 30 minutes for the sample to dry ash. Percentage ash was calculated thus:

$\% \text{ Ash content} = \text{Weight of ash}/\text{Weight of sample} \times 100$

Crude protein determination

A constant weight of each of the samples was weighed and poured into digestion tubes, 10 ml concentrated sulphuric acid and Kjedahl tablets were added to each tube. The samples were digested in a heater placed inside a fume chamber for about 1 - 2½ hours until a clear homogenous mixture was obtained. On cooling, 75 ml of distilled water was added to the content in the tubes. The tubes were then placed in a micro-Kjeldahl analyzer for distillation together with boric acid. During the distillation process, ammonia gas combined with the boric acid in the distillation flask. The content of the tube was then titrated against 0.1 M Hydrochloric acid to determine the percentage nitrogen which was multiplied by a conversion factor of 6.25 to obtain the crude protein present.

Phytochemical and vitamin C

Oxalate determination

A constant weight of each of the sample was weighed into 400 ml beaker and 250 ml of 1.0M H_2SO_4 was added to it. The mixture was warmed to between 80°C and 90°C. The temperature was kept constantly above 70°C. This was titrated against 0.1 M $KMnO_4$ solution. The volumes of titration were read from the top of the meniscus each time. Faint pale pink colour which persists for about 15 sec shows the end point of the

titration. The percentage oxalate ion was calculated by mass in each of the samples and the average values were reported.

Saponin determination

For each of the samples, a constant weight was weighed into a beaker, to which was added 20 ml of 20% aqueous ethanol and stirred with a magnetic stirrer for 12 hours at 55 °C. The solution was filtered and re-extracted with another 20 ml of 20% aqueous ethanol. The extracts were combined and transferred into a 250 ml separating funnel where 20 ml diethyl ether was added to it to start the purification process. The mixture was shaken properly after which the aqueous layer was recovered and the ether layer discarded. The process of purification continued until a colorless extract was obtained. The pH of the remaining aqueous solution was adjusted to 4.5 by adding 4 g NaCl to it. This was shaken successively with 60 ml and 30 ml portions of n-butanol. The combined butanol extract was washed twice with 10 ml of 5% aqueous NaCl and was evaporated to dryness in a fume cupboard to give crude saponin on weighing.

Tannin determination

A constant weight of finely ground sample of each of the taxa was measured into a beaker, to which was added 20 ml of 50% methanol; the beaker was covered with paraffin and placed in a water bath at 77 - 80 °C for one hour. It was stirred at intervals with a glass rod to prevent lumping. The extract was filtered into a 100 ml volumetric flask and rinsed with 50 ml methanol. The resulting mixture was made up to the 100 ml mark by adding distilled water. 1 ml of sample extract was then pipetted into 50 ml volumetric flask where 20 ml distilled water, 2.5 ml Folin-Denis reagent and 10 ml of 17% Sodium carbonate (Na_2CO_3) were added and mixed properly. The mixture was made up to the 50 ml mark and allowed to stand till a bluish-green coloration developed after 20 mins. Standard Tannic Acid solutions of range 0-10 ppm were treated similarly as all the samples. The absorbance of the Tannic Acid Standard solution as well as those of the samples was read after colour development on a Spectronic 21D Spectrophotometer at a wavelength of 760 nm. Percentage tannin was calculated thus:

Tannin (%) = Absorbance of sample x average gradient × dilution factor/ Weight of sample × 10,000

Ascorbic acid (Vitamin C) determination

The method of AOAC (1990) was used. Ascorbic acid in the plant samples was estimated by determining the 2, 6 - dichlorophenol (dye) strength. This involves the titration of the dye against 2 ml of blank ascorbic acid and 2 ml of 100 g standard ascorbic acid in 100 ml solution. Likewise, 20 ml of each of the plant sample extracts was made up to 50 ml with Oxalic acid (0.4%) and filtered. 5 ml of each of the extracts was then dispersed into beakers with pipette and titrated against the dye. The colour of the solution will change to rose pink to mark the end point of the titre. All analyses were carried out in replicates and the average titre values were calculated. The average blank value was calculated as well and subtracted from the average titre value gotten for each plant sample. Blank deduction was made for the correction of the titrates. The weight of the ascorbic acid in each titre value gotten was calculated thus:

Ascorbic acid (mg/100g) = (X - B) × (F/E) × (V/Y)

Where X = Average ml for sample titration; B = Average ml for blank titration;

F = Titre value of standard solution, that is, ml ascorbic acid equivalent to 1.0 ml indophenol,

E = Volume of Ascorbic acid; V = Volume of initial assay solution; Y = Volume of sample aliquot titrated.

Mineral content determination

X-ray fluorescence (XRF) was used to determine the minerals present in the samples. The leaf and tuber samples were dried, powdered and pelletized using a 13 mm dice with the aid of hydraulic press. The pellet of

each of the sample was then irradiated with X-ray in a sample chamber for 20 secs at a current of 50 μA and a voltage of 25 KV using X-ray machine; Model PX2CR, Power supply and Amplifier for XR-100CR detector.

The sample spectrum was gotten with the aid of software and each element was identified on a respective peak for quantitative analysis. The quantitative analysis was performed with the aid of software named XRS - FP which employed fundamental parameter techniques. The analysis was carried out in replicates.

The data generated from this work was subjected to paired group cluster analysis.

Results

The summary of the result of the proximate analysis of the leaves and corms of the Araceae species, varieties and cultivar studied are as shown in Tables 2 and 3 respectively.

Table 2. Proximate composition of the leaves of Araceae taxa studied

Species	% Moisture	% Ash	% Crude fat	% Fibre	% Protein	% CHO
Alocasia cucullata	10.5	1.64	2.8	1.49	3.75	79.82
A. macrorrhiza	12	1.66	0.8	3.5	6.1	75.94
A. plumbea	13.86	1.79	4.78	4.98	6.13	68.46
Colocasia esculentum var. *antiquorum*	16.34	2.16	1.8	2.5	4.79	72.41
C. esculentum var. *esculentum*	14.78	1.99	3.19	3.98	3.5	72.56
Xanthosoma mafaffa (red)	18	1.98	2	1.99	6.13	69.9
X. mafaffa (white)	11.88	1.97	0.8	1.49	4.33	79.53
X. saggitifolium	14.93	2	4.6	1.99	5.23	71.25

Proximate analysis

Moisture

Moisture content in the leaves of the taxa studied ranges from 10.5% in *Alocasia cucullata* to 18% in *Xanthosoma mafaffa* (red variety) while that of the corms ranges from 16.67% in *Alocasia macrorrhiza* to 52.33% in *Xanthosoma mafaffa* (red variety).

Ash

Ash content in the leaves of the taxa studied ranges from 1.64% in *Alocasia cucullata* to 2.16% in *Colocasia esculentum* var. *antiquorum* while that of the corms ranges from 0.98% in *Alocasia cucullata* to 2.17% in *Colocasia esculentum* var. *esculentum*.

Crude fat

Crude fat content in the leaves of the taxa studied ranges from 0.8% in *Alocasia macrorrhiza* and *Xanthosoma mafaffa* (white variety) to 4.78% in *Alocasia macrorrhiza* while that of the corms ranges from 1.0% in *Alocasia cucullata* and *Colocasia esculentum* var. *esculentum* to 4.19% in *Xanthosoma saggitifolium*.

Crude fiber

Crude fiber content in the leaves of the taxa studied ranges from 1.49% in *Alocasia cucullata* and *Xanthosoma mafaffa* (white variety) to 4.98% in *Alocasia plumbea* while that of the corms ranges from 1.49% in *Alocasia macrorrhiza* and *Xanthosoma saggitifolium* to 4.46% in *Alocasia plumbea*.

Crude protein

Crude protein content in the leaves of the taxa studied ranges from 3.5% in *Colocasia esculentum* var. *esculentum* to 6.13% in *Alocasia plumbea* and *Xanthosoma mafaffa* (red variety) while that of the corms ranges from 0.43% in *Colocasia esculentum* var. esculentum to 2.61% in *Alocasia macrorrhiza*.

Carbohydrates

Carbohydrate content in the leaves of the taxa studied ranges from 68.46% in *Alocasia plumbea* to 79.82% in *Alocasia cucullata* while that of the corms ranges from 40.55% in *Xanthosoma mafaffa* (red variety) and 77.08% in *Colocasia esculentum* var. *esculentum*.

Table 3. Proximate composition of the corms of Araceae taxa studied

Species	% Moisture	% Ash	% Crude fat	% Fibre	% Protein	% CHO
Alocasia cucullata	21.67	0.98	1	2	0.88	73.47
A. macrorrhiza	16.67	1.4	2.98	1.49	2.61	74.85
A. plumbea	26.67	0.99	1.2	4.46	0.44	66.24
Colocasia esculentum var. *antiquorum*	36.96	1.19	3.8	2	2.6	53.45
C. esculentum var. *esculentum*	17.32	2.17	1	2	0.43	77.08
Xanthosoma mafaffa (red)	52.33	1.2	2	3.48	0.44	40.55
X. mafaffa (white)	47.33	1.8	3.19	2.48	2.19	43.01
X. saggitifolium	26	2	4.19	1.49	0.88	65.44

Phytochemical and vitamin C

Tables 4 and 5 show the summary of the result of the saponin, oxalate, tannin and vitamin C contents of the taxa studied. Table 4 shows those of the leaves while Table 5 shows those of the corms.

Saponin

Saponin content in the leaves of the taxa studied are almost the same with the value of 0.25% except in *Xanthosoma mafaffa* (white) where it is 0.29% and *Xanthosoma saggitifolium* where it is 0.35%. The saponin content of the corms ranges from 0.61% in *Alocasia cucullata, Alocasia plumbea* and *Colocasia esculentum* var. *esculentum* to 0.69% in *Xanthosoma saggitifolium*.

Oxalate

Oxalate content in the leaves of the taxa studied ranges from 2.75% in *Alocasia plumbea* and *Xanthosoma mafaffa* (white) to 5.75% in *Alocasia macrorrhiza*, *Colocasia esculentum* var. *esculentum,* and *Xanthosoma mafaffa* (red) while that of the corms ranges from 5.00% in *Colocasia esculentum* var. *esculentum* to 15.00% in *Xanthosoma saggitifolium*.

Tannin

Tannin content in the leaves of the taxa studied ranges from 2.7% in *Alocasia cucullata* to 8.1% in *Xanthosoma saggitifolium* while that of the corms ranges from 5.2% in *Colocasia esculentum* var. *esculentum* to 12.45% in *Xanthosoma saggitifolium*.

Vitamin C

Vitamin C content in the leaves of the taxa studied ranges from 0.64 mg/100 g in *Alocasia cucullata* to 4.34 mg/100 g in *Xanthosoma saggitifolium* while that of the corms ranges from 0.32 mg/100 g in *Alocasia macrorrhiza* to 0.96 mg/100 g in *Xanthosoma mafaffa* (white).

Table 4. Phytochemical and Vitamin C composition of the leaves of the Araceae taxa studied

Species	Saponin (%)	Oxalate (%)	Tannin (%)	Vit. C (mg/100g)
Alocasia cucullata	0.25±0.01	5.5±0.50	2.7±0.21	0.64±0.00
A. macrorrhiza	0.25±0.01	5.75±0.25	5.87±0.00	0.64±0.00
A. plumbea	0.25±0.01	2.75±0.25	4.99±0.00	2.41±0.05
Colocasia esculentum var. *antiquorum*	0.25±0.01	3.25±0.25	2.95±0.05	0.8±0.05
C. esculentum var. *esculentum*	0.25±0.01	5.75±0.25	3.95±0.21	0.8±0.05
Xanthosoma mafaffa (red)	0.25±0.01	5.75±0.25	4.99±0.00	3.7±0.05
X. mafaffa (white)	0.29±0.01	2.75±0.25	4.16±0.00	2.57±0.05
X. saggitifolium	0.35±0.01	4.75±0.25	8.1±0.62	4.34±0.05

Table 5. Phytochemical and Vitamin C composition of the corms of the Araceae taxa studied

Species	Saponin (%)	Oxalate (%)	Tannin (%)	Vit. C (mg/100g)
Alocasia cucullata	0.61±0.01	10.5±0.50	10.19±0.21	0.48±0.05
A. macrorrhiza	0.63±0.01	8.75±0.25	7.28±0.21	0.32±0.00
A. plumbea	0.61±0.01	9.75±0.25	7.9±0.83	0.64±0.00
Colocasia esculentum var. *antiquorum*	0.63±0.01	7.25±0.25	8.1±0.62	0.8±0.05
C. esculentum var. *esculentum*	0.61±0.01	5.00±0.00	5.2±0.21	0.8±0.05
Xanthosoma mafaffa (red)	0.65±0.01	8.75±0.25	7.28±0.21	0.64±0.00
X. mafaffa (white)	0.67±0.01	6.75±0.25	11.43±0.21	0.96±0.1
X. saggitifolium	0.69±0.01	15±0.00	12.45±0.00	0.48±0.05

Mineral content

Tables 6 and 7 show the result of the mineral contents (ppm) of the taxa studied. Table 6 shows those of the leaves while Table 7 shows those of the corms.

Potassium (K)

Potassium content in the leaves of the taxa studied ranges from 17,595 ppm in *Alocasia plumbea* to 27,385 ppm in *Xanthosoma saggitifolium*. It was not detected in the leaves of *Colocasia esculentum* var. *esculentum*. In the corms, the value ranges from 11,246 ppm in *Alocasia cucullata* to 24,876 ppm in *Xanthosoma mafaffa* (white).

Calcium (Ca)

Calcium content in the leaves of the taxa studied ranges from 9,406 ppm in *Xanthosoma mafaffa* (white) to 22,860 ppm in *Alocasia plumbea*. In the corms, the value ranges from 2,497 ppm in *Xanthosoma mafaffa* (Red) to 15,704 ppm in *Alocasia cucullata*.

Titanium (Ti)

Titanium content in the leaves of the taxa studied ranges from 18 ppm in *Alocasia plumbea* to 60 ppm in *Alocasia macrorrhiza*. It was not detected in the leaves of *Colocasia esculentum* var. *antiquorum, Colocasia esculentum* var. *esculentum, Xanthosoma mafaffa* (Red) and *Xanthosoma mafaffa* (white). In the corms, the value ranges from 56 ppm in *Xanthosoma mafaffa* (white) to 176 ppm in *Alocasia macrorrhiza*. It was not detected in the corms of *Alocasia cucullata*, *Alocasia plumbea*, *Colocasia esculentum* var. *esculentum, Xanthosoma mafaffa* (Red), *Xanthosoma saggitifolium*.

Chromium (Cr)

Chromium content in the leaves of the taxa studied ranges from 27 ppm in *Colocasia esculentum* var. *esculentum* to 63 ppm in *Xanthosoma mafaffa* (white). It was not detected in the leaves of *Xanthosoma saggitifolium*. In the corms, the value ranges from 43 ppm in *Xanthosoma mafaffa* (white) to 259 ppm in *Xanthosoma mafaffa* (red).

Manganese (Mn)

Manganese content in the leaves of the taxa studied ranges from 105 ppm in *Colocasia esculentum* var. *esculentum* to 522 ppm in *Xanthosoma mafaffa* (white). In the corms, the value ranges from 191 ppm in *Xanthosoma mafaffa* (white) to 336 ppm in *Alocasia cucullata*.

Iron (Fe)

Iron content in the leaves of the taxa studied ranges from 196 ppm in *Xanthosoma saggitifolium* to 632 ppm in *Xanthosoma mafaffa* (white). In the corms, the value ranges from 720 ppm in *Xanthosoma mafaffa* (white) to 2,402 ppm in *Alocasia macrorrhiza*.

Nickel (Ni)

Nickel content in the leaves of the taxa studied ranges from 64 ppm in *Xanthosoma mafaffa* (red) to 315 ppm in *Xanthosoma mafaffa* (white). In the corms, the value ranges from 384 ppm in *Alocasia cucullata* to 1,266 ppm in *Xanthosoma mafaffa* (red).

Copper (Cu)

Copper content in the leaves of the taxa studied ranges from 62 ppm in *Alocasia cucullata* to 388 ppm in *Xanthosoma mafaffa* (white). In the corms, the value ranges from 476 ppm in *Alocasia cucullata* to 1,906 ppm in *Xanthosoma mafaffa* (red).

Zinc (Zn)

Zinc content in the leaves of the taxa studied ranges from 77 ppm in *Xanthosoma saggitifolium* to 467 ppm in *Xanthosoma mafaffa* (white). In the corms, the value ranges from 594 ppm in *Xanthosoma mafaffa* (white) to 1,545 ppm in *Xanthosoma mafaffa* (red).

Rubidium (Rb)

Rubidium content in the leaves of the taxa studied ranges from 11 ppm in *Alocasia cucullata* to 207 ppm in *Xanthosoma mafaffa* (white). In the corms, the value ranges from 133 ppm in *Alocasia cucullata* to 823 ppm in *Xanthosoma mafaffa* (red).

Molybdenum (Mo)

Molybdenum content in the leaves of the taxa studied ranges from 7 ppm in *Alocasia cucullata* and *Xanthosoma saggitifolium* to 308 ppm in *Colocasia esculentum* var. *antiquorum*. In the corms, the value ranges from 311 ppm in *Colocasia esculentum* var. *esculentum* to 1150 ppm in *Xanthosoma mafaffa* (red).

Cobalt (Co)

Cobalt content in the leaves of the taxa studied ranges from 11 ppm in *Xanthosoma saggitifolium* to 128 ppm in *Xanthosoma mafaffa* (white). In the corms, the value ranges from 269 ppm in *Alocasia cucullata* and *Xanthosoma mafaffa* (white) to 759 ppm in *Xanthosoma mafaffa* (red).

Arsenic (As)

Arsenic content in the leaves of the taxa studied ranges from 10 ppm in *Alocasia cucullata* to 81 ppm in *Colocasia esculentum* var. *esculentum*. It was not detected in the leaves of *Alocasia macrorrhiza, Alocasia plumbea, Xanthosoma mafaffa* (red) and *Xanthosoma saggitifolium*. In the corms, the value ranges from 88 ppm in *Alocasia macrorrhiza* to 323 ppm in *Xanthosoma mafaffa* (red).

Bromine (Br)

Bromine content in the leaves of the taxa studied ranges from 7 ppm in *Xanthosoma saggitifolium* to 160 ppm in *Xanthosoma mafaffa* (white). In the corms, the value ranges from 157 ppm in *Alocasia plumbea* to 694 ppm in *Xanthosoma mafaffa* (red).

Table 6. Mineral contents of the leaves of Araceae taxa studied

Leaf sample	Mineral content (ppm)													
	K	Ca	Ti	Cr	Mn	Fe	Ni	Cu	Zn	Rb	Mo	Co	As	Br
AC	20444 ±484	16594 ±354	32 ±10	32 ±6	252 ±15	309 ±14	70 ±5	62 ±4	83± 5	11 ±1	7 ±1	42 ±5	10 ±1	8 ±1
AM	20258 ±465	20348 ±389	60 ±13	50 ±8	304 ±16	274 ±13	81 ±6	106 ±6	115 ±6	12 ±1	9 ±1	63 ±6	ND	27 ±2
AP	17595 ±302	22860 ±372	18 ±7	50 ±8	282 ±16	413 ±16	87 ±6	130 ±6	148 ±6	13 ±1	9 ±1	71 ±6	ND	33 ±2
CER	18676 ±544	10224 ±328	ND	57 ±13	438 ±32	455 ±31	232 ±20	355 ±25	373 ±25	128 ±20	308 ±53	106 ±14	81 ±13	154 ±19
CEW	ND	6068 ±224	ND	27 ±6	105 ±10	256 ±13	100 ±7	132 ±8	129 ±7	37 ±5	41 ±8	65 ±6	22 ±3	26 ±3
XMR	20970 ±491	12809 ±315	ND	48 ±8	289 ±16	265 ±13	64 ±5	83 ±5	91 ±5	20 ±2	20 ±4	35 ±4	ND	22 ±2
XMW	18955 ±594	9406 ±342	ND	63 ±15	522 ±40	632 ±41	315 ±27	388 ±30	467 ±33	207 ±29	299 ±60	128± 18	46 ±11	160 ±23
XS	27385 ±400	13697 ±329	20± 8	ND	132 ±11	196 ±11	74 ±5	81 ±5	77 ±4	17 ±2	7 ±1	11 ±2	ND	7 ±1

Legend: AC - *Alocasia cucullata*; AP - *Alocasia plumbea*; AM - *Alocasia macrorrhiza*; CER - *Colocasia esculentum* var. *antiquorum*; CEW - *Colocasia esculentum* var. *esculentum*; XMR - *Xanthosoma mafaffa* (Red); XMW - *Xanthosoma mafaffa* (White); XS – *Xanthosoma saggitifolium*; ND- Not Detected

Table 7. Mineral contents of the corms of Araceae taxa studied

Corms	Mineral Content (ppm)													
	K	Ca	Ti	Cr	Mn	Fe	Ni	Cu	Zn	Rb	Mo	Co	As	Br
AC	11246 ±417	15704 ±394	ND	142 ±20	336± 28	996 ±45	384 ±26	476 ±28	1076 ±42	133 ±20	333 ±45	269 ±22	319 ±25	168 ±20
AM	17858 ±659	6759 ±330	176 ±37	237 ±35	323 ±37	2402 ±96	550 ±43	729 ±49	1118 ±61	191 ±35	489 ±95	415 ±39	88 ±19	245 ±35
AP	14685 ±490	12278 ±362	ND	152 ±21	246 ±25	866 ±43	489 ±30	559 ±32	820 ±39	210 ±26	656 ±80	341 ±26	124 ±16	157 ±20
CER	20808 ±641	4944 ±225	125 ±28	152 ±24	296 ±31	1352 ±62	562 ±38	654 ±40	1217 ±55	191 ±29	511 ±83	328 ±30	187 ±23	260 ±31
CEW	23068 ±637	4324 ±227	ND	107 ±19	248 ±26	781 ±43	442 ±31	529 ±33	848 ±42	237 ±30	311 ±58	283 ±25	195 ±22	208 ±25
XMR	18210 ±774	249 7±233	ND	259 ±43	239 ±38	1913 ±103	1266 ±79	1906 ±96	1545 ±87	823 ±87	1150 ±178	759 ±63	323 ±44	694 ±71
XM W	24876 ±636	2624 ±171	56 ±17	43 ±11	191 ±21	720 ±39	463 ±29	673 ±34	594 ±32	211 ±26	520 ±70	269 ±23	169 ±19	178 ±21
XS	19065 ±739	3018 ±239	ND	151 ±30	305 ±40	1821 ±92	1101 ±68	1562 ±80	1319 ±74	739 ±76	1054 ±155	624 ±52	312 ±39	490 ±54

Legend: AC - *Alocasia cucullata*; AP - *Alocasia plumbea*; AM - *Alocasia macrorrhiza*; CER - *Colocasia esculentum* var. *antiquorum*; CEW - *Colocasia esculentum* var. *esculentum*; XMR - *Xanthosoma mafaffa* (Red); XMW - *Xanthosoma mafaffa* (White); XS – *Xanthosoma saggitifolium*; ND- Not Detected

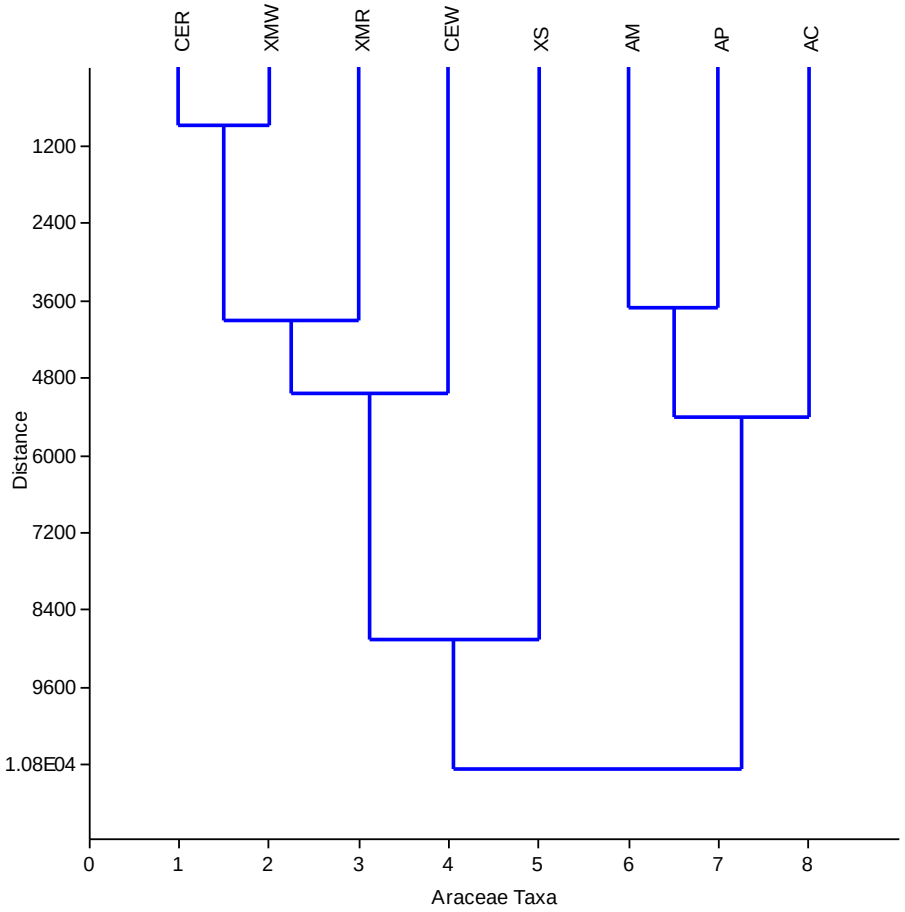

Figure 1. Paired group cluster analysis (PGCA) dendrogram of the studied taxa of Araceae based on their leaf nutritive parameters

Legend: AC - *Alocasia cucullata*; AP - *Alocasia plumbea*; AM - *Alocasia macrorrhiza*; CER - *Colocasia esculentum* var. *antiquorum*; CEW - *Colocasia esculentum* var. *esculentum*; XMR - *Xanthosoma mafaffa* (Red); XMW - *Xanthosoma mafaffa* (White); XS – *Xanthosoma saggitifolium*.

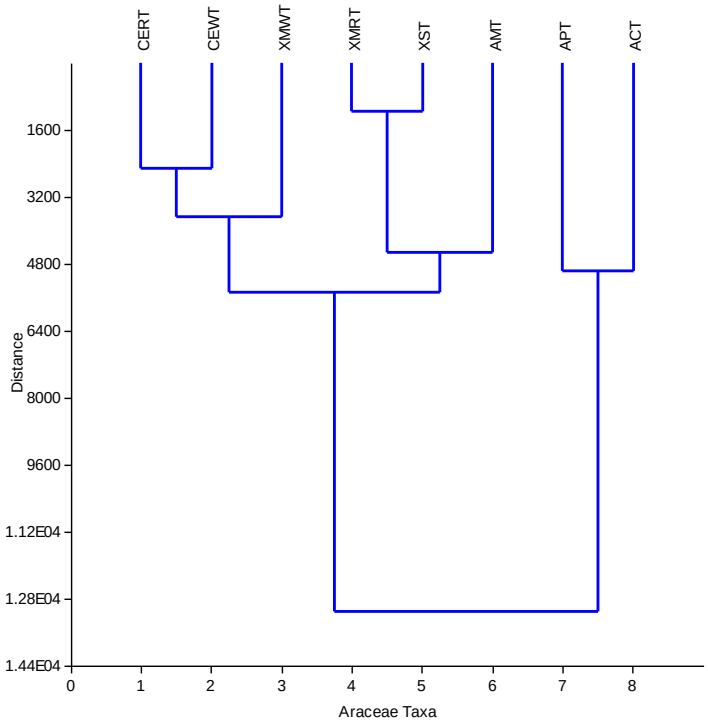

Figure 2. Paired group cluster analysis (PGCA) dendrogram of the studied taxa of Araceae based on their corm nutritive parameters.
Legend: ACT - *Alocasia cucullata*; APT - *Alocasia plumbea*; AMT - *Alocasia macrorrhiza*; CERT - *Colocasia esculentum* var. *antiquorum*; CEWT - *Colocasia esculentum* var. *esculentum*; XMRT - *Xanthosoma mafaffa* (Red); XMWT - *Xanthosoma mafaffa* (White); XST – *Xanthosoma saggitifolium*.

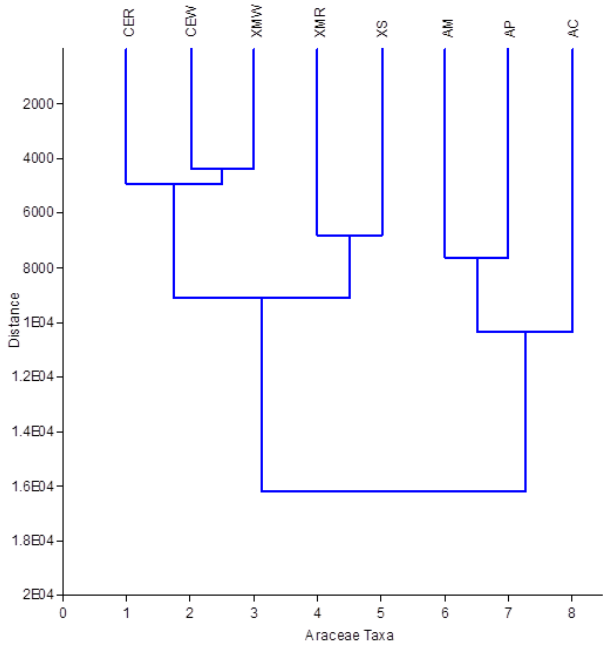

Figure 3. Paired group cluster analysis (PGCA) dendrogram of the studied taxa of Araceae based on their combined leaf and corm nutritive parameters.
Legend: AC - *Alocasia cucullata*; AP - *Alocasia plumbea*; AM - *Alocasia macrorrhiza*;
CER - *Colocasia esculentum* var. *antiquorum*; CEW - *Colocasia esculentum* var. *esculentum*;
XMR - *Xanthosoma mafaffa* (Red); XMW - *Xanthosoma mafaffa* (White); XS – *Xanthosoma saggitifolium*.

Discussion

Primary and secondary metabolites determined in the taxa studied can be employed in delimiting the taxa. Green and Oguzor (2009) also used plant metabolites, especially nutritional parameters, to re-check the taxonomy of four corm-producing members of the family Araceae.

The result of the proximate analysis carried out on the leaves and corms of the Araceae taxa shows that the samples have high carbohydrate content ranging from 68.46% to 79.82% in the leaves and 40.55% to 77.08% in the corms. This is in agreement with the work of Amanze (2009) who reported high carbohydrate content for the tubers of seven varieties of *Colocasia* and *Xanthosoma* in South Eastern Nigeria. The moisture content in the studied taxa which ranges from 10.5% to 18% in the leaves and 16.67% to 52.33% in the corms also agrees with the same author and the work of Igbabul *et al.* (2014). However, the moisture content is higher in the corms than in the leaves. The protein content was generally higher in the leaves than in the corms for all the taxa studied. Worthy of note here is the fact that young tender leaves of each of the taxa was used for this research, which is the part many indigenous people feed on. Although there was no comparison between the protein content of the young and older leaves of the taxa studied, young leaves of different plant species have been ascertained to accumulate more protein content than the older leaves (Popovic *et al.*, 2001; Vicente *et al.*, 2011). The ash, crude fat and fibre contents reveal varying percentages in the leaves and corms of all the taxa studied. Their composition is still within the safe range for consumption.

Saponins are antimicrobial in nature and have also been reported to enhance animal health and production. They are also potential sources of drugs to maintain human health (Ezeabara *et al.*, 2014). Saponins are common in a variety of higher plants and usually found in all the plant parts including seeds (Sparg *et al.*, 2004). They were present in varying degrees in the leaves and corms of all the taxa studied, though relatively higher in the corms. However, the value was highest in the leaf and corm of *Xanthosoma saggitifolium*. High saponin content in plant stimulates antifungal properties in them and makes them safe and healthy for consumption (Papadopoulou *et al.*, 1999).

Aroids are known to produce large amounts of oxalic acid most of which is deposited as crystals of calcium oxalate (Mayo *et al.*, 1997). The percentage oxalate was relatively higher in the corms than in the leaves of the taxa studied. This agrees with the report of Amanze (2009) that species of the genera *Colocasia* and *Xanthosoma* contain "unpleasant amount" of calcium oxalate in their corms and cormels. The highest percentage oxalate was detected in the corms of *Xanthosoma saggitifolium*. According to Duncan *et al.* (2000), the high content of oxalate in some plants deters even herbivores from feeding on such plants. This is particularly true of the Araceae taxa and especially those used for this research. The parts humans feed on are usually subjected to some detoxifying treatments (Johns and Kubo, 1988).

Tannins, which are water soluble polyphenols (phenolic), have been reported to be present in many plants foods (Chung *et al.*, 1998). Tannins are also commonly referred to as Tannic Acid. As an antioxidant, tannins play vital roles in maintaining human health; they also serve as natural defense mechanism against microbial infections in plants (Atanassova and Christova-Bagdassarian, 2009; Daniel, 2009). Tannin is present in varying levels in all the taxa studied and the content is generally higher in the corms than in the leaf samples. The highest value was recorded in the leaf and corm of *Xanthosoma saggitifolium*. It is noteworthy that, *X. saggitifolium* also has the highest saponin content in its leaf and corm and the highest calcium oxalate content in its corms.

Vitamins are known to act as antioxidants (Karakaya and Kavas, 1999; Daniel, 2009). They help the body to absorb calcium and phosphorus needed for bone growth and maintenance. They also block some of the damage caused by free radicals. One of the very important vitamins is vitamin C which is needed for the growth and repair of tissues in all parts of human body. It is a water-soluble vitamin and is also known as ascorbic acid. All the taxa studied have varying contents of vitamin C. In the leaf samples, the highest value of 4.34 mg/100 g was recorded in *Xanthosoma saggitifolium* while the highest value recorded for the corm, 0.96

mg/100 g was found in *Xanthosoma mafaffa* (White). The amount of vitamin C intake needed by humans daily depends on factors such as age and gender. Pregnancy and the state of health can also influence the daily requirement. On the average, daily intake of 80 - 200 mg per day will enhance the functions of the vitamin in the human body (Weber *et al.*, 1996).

The mineral elements detected in the taxa studied can be grouped into three classes according to Nielsen (2003). The bulk elements, which include Potassium (K) and Calcium (Ca); the essential trace elements which include Iron (Fe), Chromium (Cr), Zinc (Zn), Copper (Cu), Cobalt (Co), Manganese (Mn) and Molybdenum (Mo). The third class is the non-essential elements which include Nickel (Ni), Arsenic (As), Bromine (Br), Titanium (Ti) and Rubidium (Rb). This classification is based on their biological effect, diseases that occur due to their deficiency and toxicity due to overdose.

The result of these mineral analysis of the leaves and corms of the taxa of Araceae studied revealed that all the taxa are generally enriched with mineral nutrients especially the bulk elements - potassium (K) and calcium (Ca), though Potassium was not detected in the leaves of *Colocasia esculentum* var. *esculentum*. Bailey (1992) reported that green leaves are generally rich in Potassium. Potassium and Calcium function in the regulation of membrane potentials, electrolyte balance, muscle contraction, building up of bones and teeth in humans and animals (FAO/WHO, 1998)

Trace elements function in close association with enzymes in the body of humans, they bind with, transport and release oxygen in the body. They also play important role in the control of infection and cell immunity. Deficiency of some trace elements like Cobalt, Iodine, Iron and Zinc in human diet is often suspected to be the missing link in some of the unexplained human diseases such as osteoporosis, osteoarthritis, hypertension and some forms of heart disease (Beard, 2001; Nielsen and Hunt, 2014).

Fe, Zn, Cu, Co, Mn and Mo, examples of the essential trace elements, were detected in the leaves and corms of the all the taxa, Cr was also detected in all the taxa studied except in the leaves of *Xanthosoma saggitifolium*. The non-essential element Ni was detected in the leaves and corms of all the taxa; As, Br and Rb were detected in all the corms of the corm-producing taxa but was not detected in the leaves of *Alocasia macrorrhiza*, *Alocasia plumbea, Xanthosoma mafaffa* (red) and *Xanthosoma saggitifolium*. On the other hand, Ti was not detected in the leaves of *Colocasia esculentum* var. *antiquorum*, *Colocasia esculentum* var. *esculentum*, *Xanthosoma mafaffa* (red) and *Xanthosoma mafaffa* (white). It was not also detected in the corms of *Alocasia cucullata*, *Alocasia plumbea*, *Colocasia esculentum* var. *esculentum*, *Xanthosoma mafaffa* (red) and *Xanthosoma saggitifolium*. These can be used in delimiting the taxa of Araceae studied.

The results of the paired group cluster analysis using the leaves alone, the tubers alone and the leaves and tubers combined together reveals consistent clustering of the Araceae taxa. For each of the categories, the taxa were classified into two main clusters. The clustering also supported the generic classification of the three genera used for this work, though there were some overlaps especially with the members of the genera *Xanthosoma* and *Colocasia*. The three species of *Alocasia* were grouped together in each of the three categories with *A. macrorrhiza* and *A. plumbea* being more closely related.

Conclusions

Both the leaves and corms of the Araceae taxa in this study from the genera *Alocasia*, *Colocasia* and *Xanthosoma* are rich sources of essential minerals and vitamins needed for healthy living in humans. Also, the taxa of these genera can be delimited or separated based on their proximate, oxalate, tannin and mineral constituents.

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Conflict of Interests

The authors declare that there are no conflicts of interest related to this article.

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