Original Research Article

A Multivariate Analysis of Taro Accessions for Physicochemical Properties revealed three Distinct Groups.

ABSTRACT

Taro is an important staple meal for rural people in resource-poor nations in sub-Saharan Africa countries. This study looked at the proximate, mineral, and anti-nutrient content of whole taro corm. Understanding the extent and distribution of genetic diversity in taro is critical for creating conservation and enhancement initiatives. The study's purpose was to assess nutritional diversity and construct a taro pre-breeding population for high dry matter and low oxalate levels. 188 taro accessions were procured and planted in alpha lattice design in 2019 at Ebonyi State University's teaching and experimental fields. The corms were picked from each accession, washed, and shipped to Nigeria's National Root Crop Research Institute Biochemistry Laboratory. The corms were freeze-dried, crushed, and analyzed for physiochemical parameters using the standard techniques of analysis provided by the Association of standard Analytical Chemists. Significant differences were observed among the taro populations in dry matter content (22.53%), ash (2.46%), crude lipid (0.60%), fibre (1.74%), crude protein (7.79%), carbs (9.97%), and energy (76.48 Kcal). Potassium content was 638.91 mg/100 g, sodium (28.39 mg/100 g), calcium (35.18 mg/100 g), phosphorus (117.61 mg/100 g), iron (7.78 mg/100 g), zinc (2.84 mg/100 g), and manganese (2.03 mg/100 g). The soluble, insoluble, and total oxalate concentration was 74.18 mg/100 g, 218.76 mg/100 g, and 291.63 mg/100 g, respectively. A hierarchical cluster analysis of taro accessions revealed three distinct groupings, with cluster three distinguished by high dry matter content and an intermediate oxalate level. The findings revealed the existence of a considerable differential in nutritional content among the taro populations analyzed. Taro is divers in its dry matter and anti-nutrient content. Clustering the accessions according to their merit would aid breeders in sorting genotypes for eating quality metrics like high dry matter and low oxalate levels. These results, needs further work for reliability.

Comment [A1]: carbohydrates

Keywords: Proximate, Oxalate, Mineral, Taro, *Colocasia esculenta,* Proximate, *Diversity*,

Comment [A2]: Why Italic?

1. INTRODUCTION

Taro makes a significant contribution to the diets and economy of people in many developing nations. As food all parts of taro plant are edible except for the skin of the taro corm and the true anatomical roots [1]. Primarily, taro is grown for its starchy corm [2] and rarely leaves, petioles and inflorescences are also edible [1]. The corms are rich in carbohydrate while, the leaves are rich in protein [3]. It also possesses appreciable amount of minerals, vitamins and essential amino acids like phenylalanine and leucine. Moreover, taro has small starch grains [4] as compared to other food crops. It can aid diabetic patients,

the aged people and children with allergy and intestinal disorders [5-7]. The leaves are an important part of Pacific Island culture and are more often used for feeding animals in Vietnam [8]. The corm peels are also utilized as feed for ruminants and poultry farm [9].

Taro belongs to the oxalate-rich food group [10]. Oxalate is an organic acid (Oxalic acid) that has a significant impact on eating quality. Oxalic acid is a food toxin with negative effects on human nutrition [11, 12]. If consumed raw, it causes acridity and swelling of the lips, mouth, and throat tissues [11]. Eating oxalate-rich foods also reduces calcium bioavailability and leads to kidney stone formation [12]. Effort has been put forth to identify germplasm, growth conditions and breeding practices that result in food crops with high dry matter and lower oxalate content [13-15] however, there has been no sustained effort to explore their genetic basis [1]. The acceptability of taro is also highly influenced by the anti-nutrient contents [16] that demands screening taro cultivars for corm quality. So far, taro breeding essentially focuses on corm yield and disease resistance. But, less was done for taro eating quality, early maturity, adaptation to specific environments, tolerance to soil salinity, and high planting density [17]. The challenges are many; however, the present studies were focused on exploring diversity among taro accessions and developing pre breeding population for high dry matter content and low oxalate level. The research question was therefore, do taro accessions have enough genetic diversity for high dry matter and low oxalate? Is it possible to create a pre-breeding population to improve taro for the desired traits? The objective of the study is to assess variation among taro accessions for nutritional and anti-nutritional contents. The hypothesis include taro accessions does not vary significantly in dry matter and oxalate content.

Comment [A3]: having

2. MATERIAL AND METHODS

2.1. Treatments

A total of 188 corm samples from Nigerian taro accession populations were used in this study (Table 1). It was profiled at the National Root Crop Research Institute Biochemistry laboratory in Nigeria. The tests were run in duplicate.

2.2. Data collection

Data on proximate, mineral, and oxalate content were collected. For proximate analysis, the values of moisture percentage, ash, crude fiber, crude lipid, crude protein, carbohydrate, energy, and percentage of dry mater were determined using standard procedures. The mineral content of key nutrients like potassium, sodium, calcium, phosphorus, iron, zinc, and manganese was also investigated. The anti-nutrients like oxalate content of taro corms was determined, including soluble and total oxalate, with the difference representing insoluble oxalate content.

2.3. Proximate analysis

2.3.1. Moisture content in percentage

Horwitz's standard methods [18] were used to calculate the moisture percentage. To achieve a consistent weight, stainless steel oven dishes were cleaned and dried for one hour in a 100^{o}C oven. After cooling in

a desiccator, they were weighed. In each dish, two grams of sample were placed and dried in an oven at 100^{o}C until a constant weight was obtained. After cooling in a desiccator, the dishes and samples were weighed. The percentage of moisture content was calculated as

$$\%\ \text{Moisture Content} = \frac{\text{W2} - \text{W3}}{\text{W2} - \text{W1}} * \frac{100}{1}$$

Where: W1 is the dish's weight (g), W2 is the sample's weight before ashing plus the dish's weight (g), and W3 is the sample's weight after ashing plus the dish's weight (g).

Comment [A4]: Two grams sample is very less moisture content determination. At least five grams sample size should be there in oven dry method.

Comment [A5]: Before oven dry

Comment [A6]: After one hour in oven. In oven ashing is not taking place.

Table 1: List of Accessions Used for Biochemical Analysis

NO	ACC	NO	ACC	NO	ACC	NO	ACC	NO	ACC	NO	ACC	NO	ACC
1	EBNFC001	28	EBNFC032	55	EBNFC059	82	EBNFC086	109	NCe005-14	136	NCePink-4	163	NCe011-8
2	EBNFC002	29	EBNFC033	56	EBNFC060	83	EBNFC087	110	NCe005-15	137	NCePink-5	164	NCe011-9
3	EBNFC003	30	EBNFC034	57	EBNFC061	84	EBNFC088	111	NCe005-16	138	NCePink-6	165	NCe011-10
4	EBNFC004	31	EBNFC035	58	EBNFC062	85	EBNFC089	112	NCe005-17	139	NCePink-7	166	NCe011-11
5	EBNFC006	32	EBNFC036	59	EBNFC063	86	EBNFC090	113	NCe005-18	140	NCePink-8	167	NCe011-12
6	EBNFC007	33	EBNFC037	60	EBNFC064	87	EBNFC092	114	NCe005-19	141	NCePink-9	168	NCe011-13
7	EBNFC008	34	EBNFC038	61	EBNFC065	88	EBNFC093	115	NCe002-C	142	NCePink-10	169	NCe003-2
8	EBNFC009	35	EBNFC039	62	EBNFC066	89	EBNFC094	116	NCe002-1	143	NCePink-11	170	NCe003-4
9	EBNFC010	36	EBNFC040	63	EBNFC067	90	EBNFC095	117	NCe002-2	144	NCePink-12	171	NCe003-5
10	EBNFC011	37	EBNFC041	64	EBNFC068	91	EBNFC097	118	NCe002-3	145	NCePink-13	172	NCe003-7
11	EBNFC012	38	EBNFC042	65	EBNFC069	92	EBNFC098	119	NCe002-4	146	NCePink-14	173	NCe003-1
12	EBNFC014	39	EBNFC043	66	EBNFC070	93	EBNFC099	120	NCe002-5	147	NCePink-15	174	NCe003-6
13	EBNFC016	40	EBNFC044	67	EBNFC071	94	EBNFC100	121	NCe002-6	148	NCePink-16	175	NCe012-1
14	EBNFC017	41	EBNFC045	68	EBNFC072	95	NCe005-C	122	NCe010-2	149	NCePink-17	176	NCe012-2
15	EBNFC018	42	EBNFC046	69	EBNFC073	96	NCe005-1	123	NCe010-1	150	NCePink-18	177	NCe012-3
16	EBNFC019	43	EBNFC047	70	EBNFC074	97	NCe005-2	124	NCe010-3	151	NCePink-19	178	NCe012-4
17	EBNFC020	44	EBNFC048	71	EBNFC075	98	NCe005-3	125	NCe010-4	152	NCePink-20	179	NCe012-5
18	EBNFC022	45	EBNFC049	72	EBNFC076	99	NCe005-4	126	NCe010-5	153	NCePink-21	180	NCe012-7
19	EBNFC023	46	EBNFC050	73	EBNFC077	100	NCe005-5	127	NCe010-6	154	NCePink-22	181	NCe012-8
20	EBNFC024	47	EBNFC051	74	EBNFC078	101	NCe005-6	128	NCe010-7	155	NCePink-23	182	NCe012-9
21	EBNFC025	48	EBNFC052	75	EBNFC079	102	NCe005-7	129	NCe010-18	156	NCe011-1	183	NCe001-1
22	EBNFC026	49	EBNFC053	76	EBNFC080	103	NCe005-8	130	NCe010-19	157	NCe011-2	184	NCe001-2
23	EBNFC027	50	EBNFC054	77	EBNFC081	104	NCe005-9	131	NCe010-20	158	NCe011-3	185	NCe001-3
24	EBNFC028	51	EBNFC055	78	EBNFC082	105	NCe005-10	132	NCe010-21	159	NCe011-4	186	NCe001-4
25	EBNFC029	52	EBNFC056	79	EBNFC083	106	NCe005-11	133	NCePink-1	160	NCe011-5	187	NCe001-5
26	EBNFC030	53	EBNFC057	80	EBNFC084	107	NCe005-12	134	NCePink-2	161	NCe011-6	188	NCe001-6
27	EBNFC031	54	EBNFC058	81	EBNFC085	108	NCe005-13	135	NCePink-3	162	NCe011-7		

ACC: Accessions

2.3.2. Ash percentage

The Horwitz [18] procedure was used to determine the percentage of ash. Two grams of each sample were placed in a silica dish that had been ignited, cooled, and weighed. The dish and samples were ignited gently at first, then at 550^{o}C for 3 hours in a muffle furnace, until a white ash was obtained. The dish and contents were weighed after cooling in a desiccator. Finally, the percentage ash was calculated using the equation below.

$$\% \text{ Ash} = \frac{\text{W3} - \text{W1}}{\text{W2} - \text{W1}} * \frac{100}{1}$$

Where: W1 is the weight of the dish (g), W2 is the weight of the sample before ashing plus the weight of the dish (g), and W3 is the weight of the sample after ashing plus the weight of the dish (g)

2.3.3. Crude lipid percentage

The lipid content was determined using the soxhlet extraction method Horwitz [18]. A round bottom flask with a capacity of 500 mL was filled to the soxhlet extractor with 300 mL petroleum ether. Two grams of samples were placed in a labeled thimble. The cotton wool was used to close the extractor thimble. For six hours, the apparatus was heated. The cover was removed and dried in an oven for one hour at 105^{o}C. The flask was cooled in a desiccator and weighed. The crude lipid was then calculated using the following formula.

$$\% \text{ Cruid lipid} = \frac{\text{Weight of lipid}}{\text{Weight of sample}} * \frac{100}{1}$$

2.3.4. Percentage of crude fibre

The method described by Horwitz [18] was used to calculate crude fiber. Three grams of the sample were weighed into a 50 ml beaker, and the fat was extracted with petroleum ether three times by stirring, settling, and decanting. The extracted sample was air dried before being transferred to a 600 ml dried beaker. The beaker was then filled with 200 ml of 1.25% Sulphuric acid (H_2SO_4) and a few drops of antifoaming agent. The beaker was placed on a digestion apparatus with a pre-adjusted hot plate and boiled for 30 minutes, rotating the beaker periodically to prevent solid from adhering to the sides of the beaker. After 30 minutes, the mixture was allowed to stand for one minute before being filtered through a Buchner funnel. The insoluble matter was washed with boiling water without breaking pressure until it was acid-free. A wash bottle containing 200 ml of 1.25% sodium hydroxide (NaOH) solution was used to wash the residue back into the original flask. It was boiled quickly for 30 minutes again, with the same precautions as before. After 30 minutes of boiling, it was allowed to stand for one minute before being filtered immediately under suction. The residue was washed with boiling water, 1% hydrochloric acid (HCl), and boiling water again until it was acid-free. It was washed three times with ether and twice with alcohol. The residue was placed in an ash dish and dried to a constant weight at 100^{o}C. The ash was incinerated (burned) for 30 minutes at 600^{o}C before being cooled in a desiccator and weighed. The fiber

content of the sample was determined by subtracting the oven dry weight from the weight after incineration. This was expressed as a percentage of the original sample weighted for analysis.

$$\% \text{ Crude fiber} = \frac{\text{Oven dry sample} - \text{weight of sample incineration x } 100}{\text{Weight of sample taken}}$$

2.3.5. Percentage of cured protein

The Kjeidahl method was used to determine crude protein. In the Kjeldahl flask, two grams of samples were placed. The flask was filled with anhydrous sodium sulphate (5g of Kjeldahl catalyst). With a few boiling chips, 25 ml of concentrated H_2SO_4 was added. In the fume chamber, the flask was heated until the sample solution became clear. Allowing the sample solution to cool to room temperature, it was transferred to a 250 ml volumetric flask and filled to volume with distilled water. The apparatus was assembled and the distilled unit was cleaned. A distillate collector was filled with 5 ml of 2% boric acid (H_3BO_3) solution and a few drops of methyl red indicator (100 ml conical flask). The conical flask was positioned beneath the condenser. The sample digest was then pipetted into the apparatus and washed down with distilled water for 5 ml. The digest received 5 ml of 60% sodium hydroxide solution (NaOH). The distillate was collected in the receiving flask after the sample was heated to 100 ml. The receiving flask's content was titrated with 0.049 M H_2SO_4 to a pink end point. The same procedure was applied to a blank made of filter paper. The sample's nitrogen content was calculated as follows:

$$\text{Total Nitrogen} = \frac{(\text{Tittre} - \text{Blank}) \text{ x Normality of acid x } N_2}{\text{weight of sample}}$$

The nitrogen factor is equal to 6.25, and the crude protein percentage was calculated using the formula below.

$$\% \text{ Crude protein} = \% \text{ total Nitrogen x factor } (6.25)$$

2.3.6. Determination of carbohydrate and energy

The carbohydrate content and calorific value of the sample were calculated using the formula described in [19] with little modification on carbohydrate.

$$\%\text{CHO} = 100\% - (\% \text{ MC} + \% \text{ CP} + \% \text{ CL} + \% \text{ CF} + \% \text{ Ash})$$
$$\text{Energy (Kcal)} = \{(\% \text{ CHO x } 4) + (\% \text{ Cp x } 4) + (\% \text{ Cl x } 9)\}$$

Where: CHO, MC, CP, CL, and CF are abbreviations for carbohydrate, moisture content, crude protein, crude lipid, and crude fiber, respectively.

2.3.7. Percentage of dry matter

One hundred grams of corms were collected from each accession, their fresh weight was recorded, and they were then cut into small pieces with a stainless steel knife. The cut pieces were dried in a hot air oven by gradually raising the temperature from 65^0C to 85^0C and then maintaining at 85^0C until two consecutive weights were constant, and the percent dry matter was calculated by dividing the dry weight of corms by the fresh weight of corms and then multiplied by 100.

$$\text{Dry matter of corms (\%)} = \frac{\text{Total dry weight of corms(g)}}{\text{Total fresh weight of corms (g)}} * 100$$

2.4. Oxalate determination

The soluble and total oxalate concentrations were determined using the method described by Savage *et al*. [20] with a slight change in sample size. The soluble oxalate concentration was calculated as follows. Two grams of finely ground freeze-dried taro corm were weighed into 250 ml beakers, and 50 ml of distilled water was added. For 15 minutes, the beakers were immersed in an 80°C water bath. Allowing the extract to cool, it was quantitatively transferred to a 100 ml volumetric flask and volume was made up with distilled water. Similarly, two grams of finely ground freeze-dried taro corm were weighed into a 250 ml beaker and 50 ml of 2M HCl was added. For 15 minutes, the beakers were immersed in an 80°C water bath. After allowing the extract to cool, it was quantitatively transferred to a 100 ml volumetric flask and made up to volume with 2M HCl. Each corm sample was subjected to two extractions.

In beakers, 125 ml of filtrate was measured and four drops of methyl red indicator were added. This was followed by the addition of concentrated NH_4OH solution (drop by drop) until the test solution changed colour from salmon pink to faint yellow (pH 4-4.5). Each portion was then heated to 90^oC, cooled, and filtrated to remove the ferrous ion-containing precipitate. The filtrate was heated to 90^oC once more, and 10 ml of 5% $CaCl_2$ solution was added while constantly stirring. After heating, it was centrifuged for 5 minutes at 2500 revolutions per minute (rpm). The precipitate was completely dissolved in 10 ml of 20% H_2SO_4 solution after the supernatant was transferred. At this point, the total filtrate resulting from digestion of 2 g of sample was made up to 300 ml. Aliquots of 125 ml of the filtrate was heated until-boiling and then titrated against 0.05 M standardized $KMnO_4$ solution to a faint point colour which persists for 20 seconds. The oxalate content was calculated using the formula,

$$\text{Oxalate } \left(\frac{\text{gm}}{100\text{ g}}\right) = \frac{\text{T x (Vme)(DF) x } 10^5}{\text{(ME) x Mf}}$$

Where: T = $KMnO_4$ titre (ml) and Vme = the volume mass equivalent (i.e., 1 cm^3 of 0.05 M $KMnO_4$ solution is equivalent to 0.00225 g anhydrous oxalic acid). DF = the dilution of factor VT/A (2.4), where VT = the total volume of titrate (300 ml) and A is the used aliquot (125 ML), ME = the molar equivalent of $KMnO_4$ in oxalate ($KMnO_4$ redox reaction), and Mf = the mass of flour used.

2.5. Mineral analysis

Flame photometry was used to determine potassium and sodium concentrations following procedures outlined by Chen *et al*. [21].

$$\mathrm{K}\left(\frac{\mathrm{mg}}{100\ \mathrm{g}}\right) \text{ or } \mathrm{Na}\ \left(\frac{\mathrm{mg}}{100\ \mathrm{g}}\right) = \frac{100}{\mathrm{W}}\ \mathrm{x}\ \frac{1}{1000}\ \mathrm{x}\ \mathrm{X}\ \mathrm{x}\ \frac{\mathrm{Vf}}{\mathrm{Va}}\ \mathrm{x}\ \mathrm{D}$$

Where: K = potassium, Na = sodium, W = weight of the sample used, X = the concentration (in ppm) from the curve, Vf = the total volume of extract, Va = the volume of the extract flame, and D = the dilution factor.

The phosphorus concentration was determined using the MolybdoVanadate method [22], and the absorbance was measured in a spectrophotometer at a wavelength of 540 nm with the reagent blank set to zero.

$$\mathrm{P}\left(\frac{\mathrm{mg}}{100\ \mathrm{g}}\right) = \frac{100}{\mathrm{W}}\ \mathrm{x}\ \frac{\mathrm{av}}{\mathrm{as}}\ \mathrm{x}\ \mathrm{C}\ \mathrm{x}\ \frac{\mathrm{ve}}{\mathrm{va}}$$

Where: W = the weight of the ashed sample, av = the absorbance of the test sample, as = the absorbance of the standard phosphorus solution, C = the concentration of the standard phosphorus solution, Ve = the total volume of the extract, and va = the volume of the extract analysed

Furthermore, the contents of zinc, iron, and manganese were determined using the automatic absorption spectrophotometer (AAS) method described by Carpenter and Hendricks [23].

2.6. Cluster analysis

Optimum number of clustering is determined by choosing the number of clusters in k-means clustering [24]. Agglomerative hierarchical cluster analysis based on average Silhouette width method [25], the pooled mean of nutritional traits classified 188 taro accessions into three groups (Graph 1). The precision of clustering was checked by using entanglement coefficient (Graph 2). Entanglement coefficient close to unity shows the precision of the clustering.

3. RESULTS

3.1. Proximate content

The analysis of variance revealed a highly significant ($P < 0.01$) difference in proximate, oxalate, and mineral concentrations across taro accessions (Table 2). The average dry matter content was 22.53%, with a range of 13.82% to 29.94% (Figure.1). The proportion of ash content varied significantly, with a mean of 2.46% and a range of 0.10% to 5.50%. In terms of lipid content, the taro population averaged 0.60%, ranging from 0.05% to 0.85%. The percentage of fiber content varied significantly across the taro accessions studied, with a mean performance of 1.74% and a range of 1.40% to 2.18%. In terms of crude protein content, the average performance of taro accessions was 7.79%, ranging from 3.38 to 9.36%.

Carbohydrate content ranged from 1.67 to 17.83%, with a mean performance of 9.97% for taro accessions. The energy content ranged from 44.11 to 113.48 Kcal, with the mean performance of taro accessions being 76.48 Kcal.

Comment [A7]: kcal

Comment [A8]: kcal

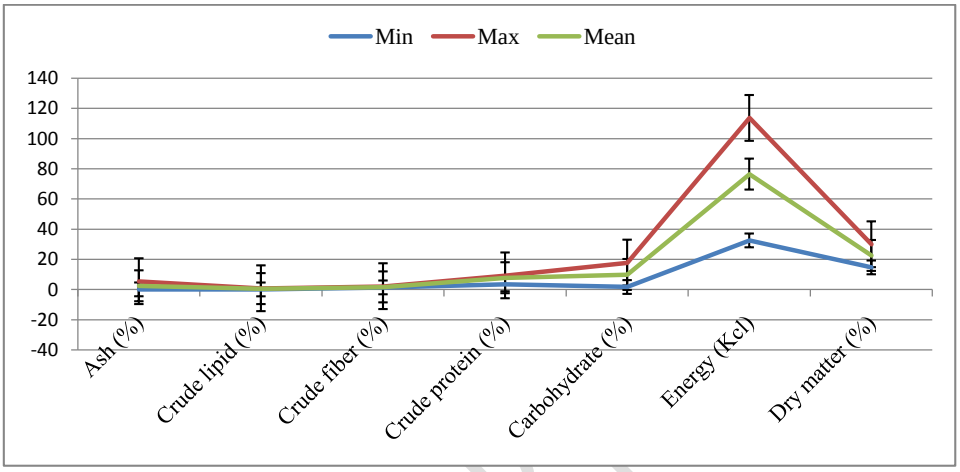

Figure 1: Proximate analysis results for the taro population studied in Nigeria.

3.2. Oxalate content

Oxalate exists as soluble and insoluble form. Insoluble oxalate was calculated as a variance between total oxalate and soluble oxalate. The mean performance of taro population for soluble, insoluble and total oxalate content was 74.18mg/100g, 218.76mg/100g and 291.63mg/100g ranging from 26.94 to 120.61 mg/100g, 75.68 to 341.52 mg/100g and 29.55 to 440.11 mg/100g, respectively (Figure 2).

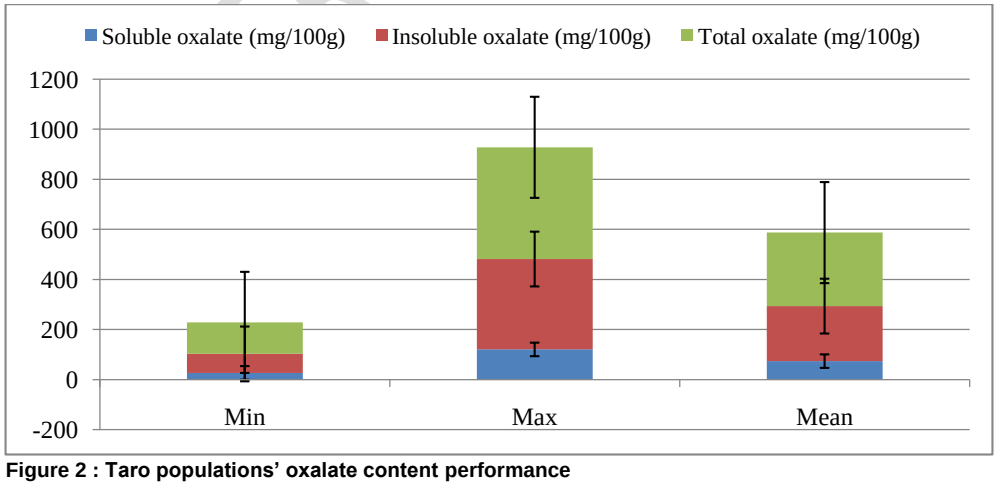

Figure 2 : Taro populations' oxalate content performance

3.3. Mineral Content

The mean performance of taro population in potassium content was high (638.91mg/100g) ranging from 476.17 to 762.83mg/100g (Figure 3). The mean performance of taro population in sodium content was 28.39mg/100gm, ranging from 19.84 to 34.61 mg/100g. The mean performance of taro population in calcium was 35.18mg/100g, ranging from 21.90 to 50.41mg/100g. The mean performance of taro populations in phosphorus content was 117.61mg/100g and ranging from 10.47mg/100g to 196.75 mg/100g. Taro accessions also variable in their iron content with mean performance of 7.78mg/100g, and ranging from 2.19 mg/100g to 9.42 mg/100g. The mean performance of taro population in zinc content was 2.84mg/100g, and ranging from 1.67 mg/100g to 4.98 mg/100g. The mean performance of taro population in manganese content was 2.03mg/100g, ranged from 1.09mg/100g to 2.96mg/100g.

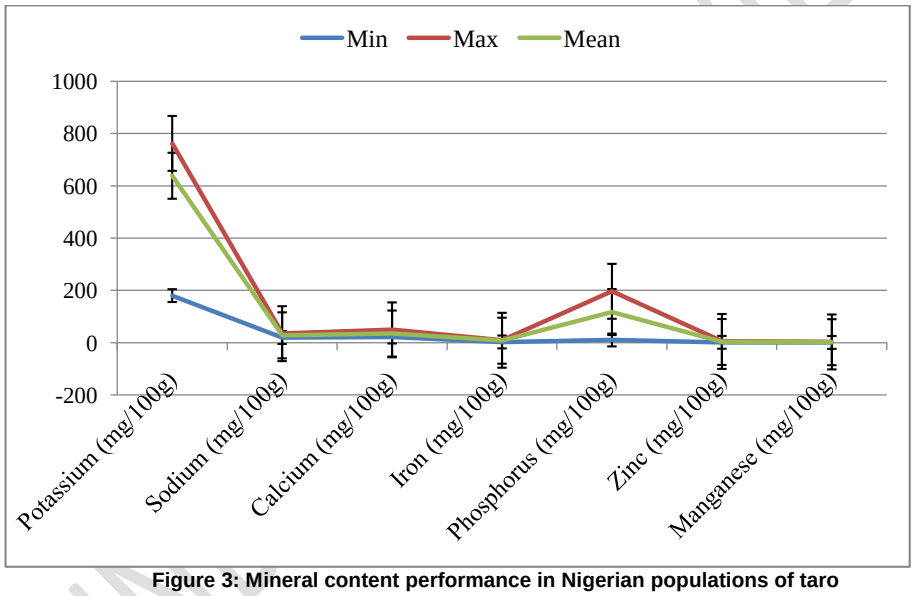

Figure 3: Mineral content performance in Nigerian populations of taro

Table 2: Analysis of Variance (Mean Squares), Minimium , Maximium , Mean and Standerd Devation (Sd) for 18 Nutritional Traits of 188 Taro Accessions Studied In Abakaliki, Nigeria (2019)

Traits	Minimum	Maximum	Mean	Sd	CV (%)	R^2 (%)
Moisture content (%)	70	85	77.45**	3.04	2.07	83
Ash (%)	0.09	5.5	2.46**	0.42	11.01	76
Crude lipid (%)	0.05	0.83	0.6**	0.1	8.13	84
Crude fiber (%)	1.39	2.2	1.73**	0.13	1.45	98
Crude protein (%)	3.38	9.36	7.79**	0.94	4.32	92
Carbohydrate (%)	1.65	17.83	9.96**	2.75	15.77	80
Energy (Kcl)	32.51	113.62	76.42**	12.59	8.63	84
Dry matter (%)	14.64	29.96	22.56**	3.05	7.24	83
Soluble oxalate (mg/100g)	26.94	120.61	73.88**	21.6	12.01	89
Insoluble oxalate (mg/100g)	75.68	361.01	219.71**	41.31	6.93	92
Total oxalate (mg/100g)	126.01	446.23	293.58**	53.63	6.05	93
Potassium (mg/100g)	180.3	762.83	638.94**	78.03	9.09	66
Sodium (mg/100g)	19.82	34.63	28.29**	3.23	7.15	76
Calcium (mg/100g)	21.88	49.23	35.14**	4.95	8.19	79
Iron (mg/100g)	2.91	9.42	7.77**	0.7	5.98	73
Phosphorus (mg/100g)	10.47	196.75	117.32**	10.45	7.12	62
Zinc (mg/100g)	1.65	4.98	2.84**	0.43	10.11	74
Manganese (mg/100g)	1.07	2.97	2.04**	0.34	8.57	84

MSg: mean squares of genotype, MSe: Mean Square of errors, CV: cumulative variance

Comment [A9]: standard

Comment [A10]: kcal

3.4. Cluster Analysis

Optimum number of clustering was determined by choosing the number of clusters in k-means clustering. Agglomerative hierarchical cluster analysis classified 188 taro accessions into three groups (Figure 4). The precision of clustering was checked by using entanglement coefficient (Figure 5). Entanglement coefficient close to unity shows the precision of the clustering. The first, second and third clusters were made up of 32 (17.02%), 65 (34.50%), and 91(48.40%) accessions (Figure 6). Accessions in cluster I were distinguished by high and highly significant (P <0.001) cluster mean values for insoluble oxalate (282.76 mg/100g), total oxalate (366.77 mg/100g), moisture content (79.30%), and soluble oxalate (86.42 mg/100g) (Table 3). The same cluster, however, was distinguished by low dry matter (20.70%), energy (69.03 Kcl), crude fibre (1.62%), crude lipid (0.51%), and crude protein (6.35%) contents. Accessions in cluster I (C-2) were distinguished by having high and highly significant cluster mean values for moisture content (79.76%) and ash (2.54%). The same cluster (C-2), on the other hand, was distinguished by low crude lipid (0.59%), crude fibre (1.71%), dry matter (20.23%), energy (66.88Kcal), and carbohydrate (7.59%) contents. Accessions in cluster III were distinguished by having high and highly significant cluster mean values for energy content (87.62 Kcal), dry matter (25.23%), carbohydrate (12.18%), crude protein (8.27%), crude fibre (1.80%), and crude lipid (0.65%). The same cluster (C-3), however, was distinguished by low total oxalate (271.68%) and moisture content. Accessions in Cluster 3 were explicitly identified as having a high percentage of dry matter and low oxalate content, and these characteristics are an indicator of the true quality parameters of taro improvement.

Comment [A11]: kcal

Comment [A12]: kcal

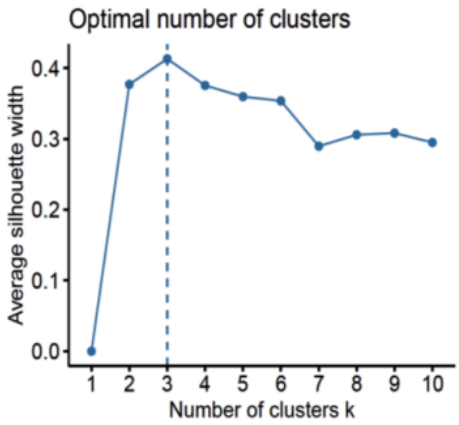

Figure 4: Optimal number of clusters for 188 taro accessions using nutritional variables

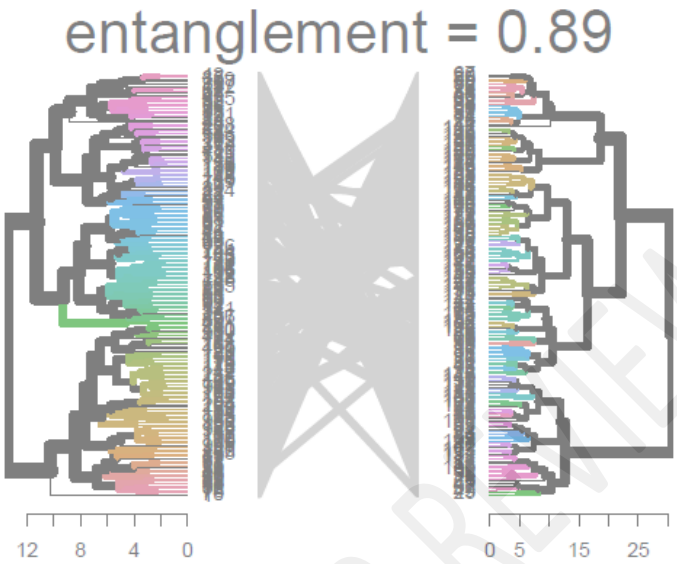

Figure 5: Entanglement coefficient showing the precise clustering of 188 taro accessions in to three cluster groups

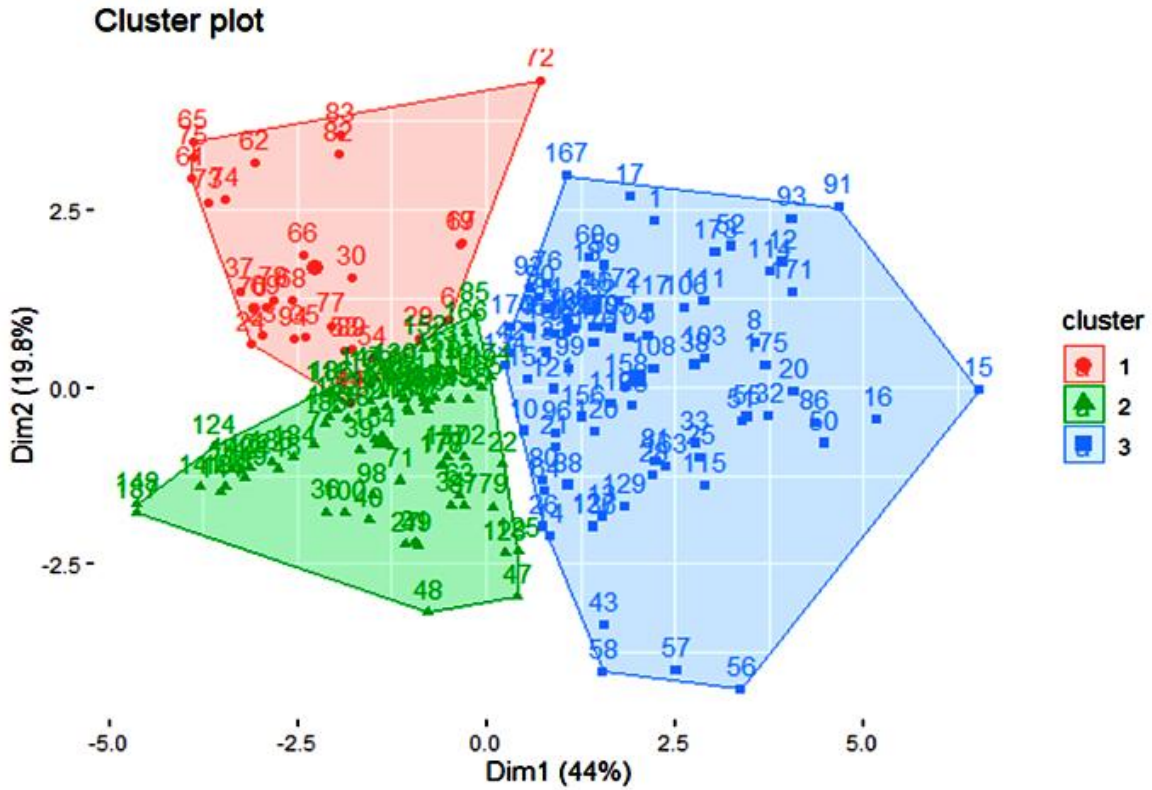

Figure 6: Hierarchical Clustering Analysis Showing Cluster and Individuals within Cluster for 11 Variables of 188 Taro Accessions Studied in Nigeria (2019)

Table 3: Description of phenotypic groups in 188 taro accessions for 11 characters tested in, Nigeria (2019)

Variables	C- 1=32 17.02% Mean ± SD	C- 2=65 34.57% Mean ± SD	C- 3=91 48.40% Mean ± SD	P<0.001
Energy	69.03±6.11	66.88±7.54	87.62±7.68	***
Dry matter	20.70±1.49	20.23±2.06	25.23±1.92	***
Carbohydrate	9.89 ±1.88	7.59±2.09	12.18±1.67	***
Crude protein	6.35±0.84	7.31±0.68	8.27±0.51	***
Crude fibre	1.62±0.13	1.71±0.09	1.80±0.13	***
Crude lipid	0.51±0.07	0.59±0.06	0.65±0.10	***
Ash	2.44±0.41	2.54±0.40	2.34±0.41	***
Soluble oxalate	86.42±20.31	77.57 ±19.83	68.73±19.35	***
Insoluble oxalate	282.76±34.58	209.39±17.67	205.03±39.26	***
Total oxalate	366.77±44.5	319.23 ±50.56	271.68±56.62	***
Moisture content	79.30±1.49	79.76±1.88	74.764±1.88	***

4. DISCUSSION

4.1. Variation in quantitative traits

In our study highly significant variations were observed among taro accessions for proximate, oxalate and mineral contents. These significant differences observed among taro accessions may be due to genotypic differences or environmental factors or other factors [26]. Buragohain *et al*. [27] reported same among taro accessions studied in India. Our finding revealed that moisture content in taro accessions was high (77.76%) as compared to moisture content reported by Khatemenla *et al.* [13] among Indian taro (74.00%) and by Otache *et al.* [28]) among Nigerian cassava (69.00%). Low moisture content in yam indicates high dry matter content, which is an important indicator of good eating and textural quality in root and tuber crops [29]. However, in our study, we found low dry matter (22.56%) compared to the dry matter reported by Khatemenla *et al.* [13] for Indian taro (26%) and Otache *et al*. [28] for Nigerian cassava (31%).

In the current study, there was a low but significant variation in crude protein, crude fiber, and crude lipid among taro accessions. However, Aregheore and Perera [30] found no significant differences in the same traits among nine taro accessions studied in Samoa. The variation in the report could be due to a difference in the number of accessions used. The maximum (9.36%) crude protein record in this study exceeds crude protein values reported for Indian taro (7.18%) [13], Nigerian cocoyam (6.9%) [31], Nigerian yam (8.71%) [32], Nigerian cassava (3.50%) [28], Ugandan sweet potato (7.48%) [33] and very low crude protein (3.6%) reported by Aregheore and Perera (2003) in Samoan taro while, Boampong *et al.* [34] reported very high crude protein (13 to 25%) among 18 taro genotypes tested in Ghana.

In the present study we observed Low but, highly significant variation among taro accession in carbohydrate content varying from 1.67 to 17.67% fresh weight basis. However, very high carbohydrate content (62 to 76% dry weight basis) was reported by [34] among 18 taro accessions tested in Ghana. The variation in carbohydrate content can impact the eating quality (taste), textural quality and preference by consumers [28] and the difference in carbohydrate may be due to the activity of enzymes involved in

carbohydrate synthesis. Corms with high starch content might be dry and firm in texture after cooking and an indicators for good eating quality among Samoans [30].

4.2. Oxalate content

Oxalates are believed to be responsible for acridity which is a much disliked culinary quality of taro. In this study, highly significant differences were observed among taro accessions for oxalate contents ranging from 126.01mg/100gm to 446.23mg/100gm with a mean of 293.58mg/100gm. Gouveia *et al.* [35] reported higher oxalate ranging 224.40 to 528.10 mg/100g with a mean of 328.40 g/100mg among seven taro genotypes quantified for oxalate content under drought conditions. Oxalate may exist as soluble form or insoluble salts chiefly with calcium or combination of both in plants [20]. Discrepancy in oxalate content is consistent and significantly associated with the photosynthetic rate, carbohydrate metabolism and protein synthesis suggesting that these are important traits critical to the understanding of taro oxalate synthesis caused by drought and how they affect corm quality [35]. Similarly, many researchers reported variation in oxalate content of taro plant. For instance, wild taro contain higher oxalate than cultivated taro [27]. African taro cultivars were reported more acrid than the Pacific taro cultivars [36]. Variation in oxalate content has also been reported among corm parts, harvest time, and taro cultivars [37]. Generally, the threat to health posed by oxalates in taro are significantly reduced by the various processing methods used before its consumption [38].

4.3. Mineral composition

In the present study highly significant variations were observed among taro accessions for potassium, sodium, calcium, phosphorus, iron, zinc and manganese. The variation in minerals content may be because of genetic components, environmental effect, cultural practices, chemical composition of the soil, time of harvesting and amount of water available [34, 39]. Variation of mineral composition in different parts of taro corms have also been reported (Mergedus *et al.* [40].

5. CONCLUSION

Finding out the taro's nutritional and anti-nutritional components can help to reveal important details about the crop. According to the study, cultivars differ in their levels of oxalate and dry matter. Accessions with less oxalate content have a lot of dry substance. In taro breeding programmes, these accessions can be utilized to produce taro with high eating qualities. To reduce malnutrition and the prevalence of other diet-related disorders, taro production and consumption should be promoted nationally as a fourth tuber crop to be grown alongside sweet potato, potato, and yam. This will increase the underutilised tuber's alternatives for use after it has been treated.

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