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Nutritional evaluation of leafy vegetables of *Corchorus olitorius* family from Ekiti State, Nigeria

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ABSTRACT

Proximate composition, mineral contents, anti-nutritional factors as well as non-starch polysaccharide components of three varieties of a commonly consumed leafy vegetable: *Corchorus olitorius*; *Sooro var*., *Amugbadu var*. and *Oniyaya var*. were investigated using standard analytical techniques. The levels of fat content were low, ranged at 1.98-2.22g/100g. The results of crude fibre (11.2-12.9g/100g) and crude protein (17.5-29.6g/100g) in this study were higher than the range reported for most Nigerian leafy vegetables. Mineral analysis results showed that the samples were good sources of essential minerals especially potassium and iron while non-nutritive/toxic minerals were contained in trace amounts. The result of both mineral ratios and mineral safety index showed that the *Corchorus olitorius* varieties could not pose any health risk for the consumers. Phytate had the highest concentrations (5.30-6.10mg/100g) representing 43.10-68.2% of the total anti-nutritional factors. However, anti-nutrients levels were generally low in this study. Phy:Zn (0.424) and [CA][Phy]/[Zn] (0.049) molar ratios showed that only *Sooro* would promote Zn bioavailability. Compositions of non-starch polysaccharides were generally low with neutral detergent fibre (NDF) having the highest concentration in each of the samples. Statistical analysis showed that there were no significant differences among the samples in most of the determinations except PEP %, K, Ca, Mg and [phy]:[Zn].

Keywords: Antinutrients, *Corchorus olitorius*, minerals, non-starch polysaccharides, Proximate

INTRODUCTION

Corchorus olitorius (Linn) is among the edible vegetables commonly consumed in most African countries especially in Nigeria. Vegetables are very important as they possess essential food ingredients which can be used to build up our body system. Vegetables are major sources of both macro and micro nutrients in Africa especially in the rural areas of developing countries where starch based food are mainly consumed for survival. *Corchorus olitorius* is a member of the family titiaceae (an angiosperm family). It is commonly called 'Jew mallow', 'bush okro' or 'jute'.It is popularly called *Ewedu* in Yoruba, *Ahihara* in Igbo and *Malafiya* in Hausa lands. *Corchorus olitorius* had been in existence since about 200 years ago mainly cultivated in the tropics. It is a tall vegetable plant, with a height of between 2- 4m, mainly unbranched stem or with few short branches. The leaves are usually distributed in an alternate manner. *Corchorus olitorius* contain small yellow flowers and the fruit has many seeds enclosed in the form of capsule (Loumeren and Alercia, 2016). Literature reports had indicated that different parts of jute have been effectively used in the treatment of cardiac diseases, pains, chronic cystitis, gonorrhea and tumors (Samilova and Lagodich, 1977; Abu-Hadid *et al.*, 1994). *Corchorus olitorius* was also reported to contain series of biological activities such as hypoglycemic, antimicrobial, anti-oxidants and anti-inflammatory (Abo *et al.*, 2008; Semira *et al.*, 2007; Oboh *et al.*, 2009; Nishiumi *et al.*, 2006).Various researches have been conducted on the medicinal and biological values of *Corchorus olitorius*, but little investigations have been carried out on the nutritional and especially the anti-nutritional composition of the vegetable. In this study, three common varieties of *Corchorus olitorius* were analyzed for proximate, mineral compositions, mineral safety index, levels of anti-nutritional factors, mineral bioavailability and non-starch polysaccharides components. The objective is to assess their chemical compositions and elaborate on the nutritional and health implications to the consumers.

MATERIALS AND METHODS

Sample collection and treatment

Three varieties of *Corchorus olitorius* (*Sooro*, *Amugbadu* and *Oniyaya*) were collected from three different farms in Ado-Ekiti (Oke-Osun, Igirigiri and Irasa). Identification was done at the Department of Plant Science and Biotechnology, Ekiti State University, Ado-Ekiti. The leaves were separately rinsed with deionized water and air-dried on a clean cloth for seven days, constantly turned over during drying for effectiveness and prevention of fungal growth. The dried samples were grounded separately into fine powder with mortar and pestle, sieved through 2.0 mm mesh, kept in polythene containers and refrigerated pending further analysis (Fasakin, 2004).

Proximate analysis

Proximate analysis was carried out following the methods of Association of Official Analytical Chemists (AOAC, 2006) while carbohydrate was determined by difference. The calorific value (kJ) was calculated by multiplying the values of crude protein, crude fat and carbohydrate by 17, 37 and 17 respectively (Atwater factors). Proportions of energy contributions due to protein (PEP %), fat (PEF %) and carbohydrate (PEC %) as well as utilizable energy due to protein (UEDP %) were also calculated from the proximate composition.

Mineral elements' determination

The minerals were analyzed from the solution obtained by initially dry ashing the samples at 550^{o}C. Filtered solutions were used to determine Na, K, Ca, Mg, Zn, Fe, Mn, Cu, Pb, Co, Cd, Ni and Se atomic absorption spectrophotometer (Buck Scientific Model- 200A/210, Norwalk, Connecticut 06855). Phosphorus was determined colorimetrically by Spectronic 20 (Gallenkamp, UK) using the phosphovanado molybdate method (AOAC, 2006). All chemicals used were of British Drug House (BDH, London, UK) analytical grade. Earlier, the detection limits for the metals in aqueous solution had been determined using the methods of Varian Techtron (Varian, 1975). The optimal analytical range was 0.1-0.5 absorbance units with coefficients of variation from 0.9% to 2.21%. From the mineral elements determined, further calculations were made.

The following mineral ratios were calculated from the mineral levels: Na/K, Na/Mg, Ca/Mg, Ca/P, K/Na, Zn/Cu, K/Co and [K/(Ca + Mg)] (Watts, 2010).

Mineral Safety Index (MSI)

The mineral safety index (MSI) of elements were calculated using equation 1;

$$\text{Calculated MSI} = \frac{\text{MSI x Research data result}}{\text{RAI}} \qquad (1)$$

(Hatcock, 1985)

Where, MSI = mineral safety index Table (standard), RAI = recommended adult intake

Determination of phytochemicals/antinutritional factors

The phytochemical components of the vegetable samples were analyzed as follow:

Determination of phytic acid and phytin phosphorus

4 g of the sample was soaked in 100 mL 2 % HCl for 3 hours and then filtered. 25 mL of the filtrate was placed in a 100mL conical flask and 5mL of 0.03 % NH_4SCN solution was added as indicator. 50 mL of distilled water was added to give it the proper acidity (pH 4.5). This was titrated with ferric chloride solution which contained 0.005 mg of Fe per mL of $FeCl_3$ used until a brownish yellow colour persisted for 5 min. Phytin phosphorus (Pp) was determined and the phytic acid content was calculated by multiplying the value of Pp by 3.55 (Adeyeye *et al.,* 2017). Each milligram of iron is equivalent to 1.19 mg of Pp.

Determination of tannin

200 mg of the sample was weighed into a 50 mL sample bottle. 10 mL of 70 % aqueous acetone was added and properly covered. The bottles were put in an orbital shaker and shaken for 2 hours at 30^{o}C. Each solution was then centrifuged and the supernatant stored in ice. 0.2 mL of each solution was pipetted into test tubes and 0.8 mL of distilled water was added. Standard tannic acid solutions were prepared from a 0.5 mg/mL stock and the solution made up to 1 mL with distilled water. 0.5mL folin reagent was added to both sample and standard followed by 2.5 mL of 20 % Na_2CO_3. The solutions were then vortexed and allowed to incubate for 40 minutes at room temperature after which absorbance were taken against a reagent blank concentration of the sample from a standard tannic acid curve (Makkar and Goodchild, 1996).

Determination of oxalate

1g of the sample was weighed into 100 mL conical flask. 75mL of 1.5 NH_2SO_4 was added and the solution was carefully stirred intermittently with a magnetic stirrer for about 1 hour and then filtered using Whatman filter paper. 25mL of sample filtrate was titrated hot (80-90^{o}C) against 0.1M $KMnO_4$ solution till faint pink colour appeared that persisted for at least 30 seconds (Day and Underwood, 1986).

Determination of alkaloid

5.0 g of the sample was weighed into a 250 mL beaker and 200 mL of 10 % acetic acid in ethanol was added and covered and allowed to stand for 4 hrs. This was filtered and the extract was concentrated on a water bath to one quarter of the original volume. Concentrated ammonium hydroxide was added drop wise to the extract until the precipitation was complete. The whole solution was allowed to settle and the precipitate was collected and washed with dilute ammonium hydroxide and then filtered. The residue is the alkaloid which was dried and weighed (Harborne, 1973).

Determination of saponin

5.0 g of the sample was put into a conical flask and 100 mL of 20 % aqueous ethanol were added. The sample was heated over a hot water bath for 4h with continuous stirring at about 55°C. The mixture was filtered and the residue re-extracted with another 200 mL 20 % ethanol. The combined extracts were reduced to 40mL over water bath at about 90 ^{o}C. The concentrate was transferred into a 250 mL separating funnel and 20 mL of diethyl ether was added and shaken vigorously. The aqueous layer was recovered while the ether layer was discarded. The purification process was repeated. 60 mL n-butanol was added. The combined n-butanol extracts were washed twice with 10 mL of 5 % aqueous sodium chloride. The remaining solution was heated in a water bath after evaporation; the sample was dried in the oven to a constant weight (Obadoni and Ochuko, 2001). The saponin content was calculated as percentage.

$$\%\ \text{Saponin} = \frac{\text{Final weight of the dried content}}{\text{Weight of the sample}} x100$$

Determination of flavonoid

The method of Boham and Kocipai-Abyazan (1974) was followed in the determination of flavonoid. 5 g of the sample was extracted repeatedly with 100 mL of 80 % aqueous methanol at room temperature. The whole solution was filtered through Whatman filter paper (125 mL). The filtrate was later transferred into a crucible and evaporated into dryness and weighed to a constant weight.

Calculation of the mole ratios

The [phytate]:[Zn], [Ca]:[phytate], [phytate]:[Fe] and [Ca][phytate]:[Zn] mole ratios were calculated as previously described (Wytts and Triana-Tejas, 1994; IZNCG, 2004).

$$[\text{Phytate}]:[\text{Zn}] = \frac{\text{phytate } \left(\frac{mg}{100\,g}\right)/660}{\text{Zinc } (\text{mg}/100)/65.38} \qquad (2)$$

$$[\text{Ca}]:[\text{Phytate}] = \frac{\text{calcium } \left(\frac{mg}{100\,g}\right)/40.08}{\text{phytate } \left(\frac{mg}{100\,g}\right)/660} \qquad (3)$$

$$[\text{Phytate}]:[\text{Fe}] = \frac{\text{phytate } \left(\frac{mg}{100\,g}\right)/660}{\text{Iron } (\text{mg}/100)/55.85} \qquad (4)$$

$$[\text{Ca}][\text{phytate}]:[\text{Zn}] = \frac{(\text{phytate } \left(\frac{mg}{100\,g}\right)/660) \ \ (\text{calcium } \left(\frac{mg}{100\,g}\right)/40.08)}{\text{Zinc } (\text{mg}/100)/65.38} \qquad (5)$$

Non-starch polysaccharide (Fibre fractions) determinations

Acid detergent fibre (ADF), neutral detergent fibre (NDF) and acid detergent lignin (ADL) were determined following the procedure described by Van Soest and Robertson (1980). Both cellulose and hemicellulose composition were determined using the method described by Usoro *et al*. (1982) with little modification.

Statistical Analysis

Mean, standard deviation and coefficient of variation in percent were determined (Oloyo, 2001). The calculated Chi-square (Chase, 1976) was subjected to the Table value for P = 0.05 to see if there is significant difference among the samples in the parameters determined.

RESULTS AND DISCUSSION

The Proximate composition of the three varieties of *Corchorus olitorius*, the proportion of energy contributions(%) due to fat, protein and carbohydrate as well as the total energy (kJ/100g) are given in Table 1. Moisture contents (%) which ranged from 7.44-13.5were lower than 15.58and 23.57 reported for *Amarathus cruentus* and *Celusia argenta* respectively (Chionyedua *et al*., 2009). High moisture content is typical of all vegetables as it affects their keeping quality. High ash content of the samples is an indication that they could be rich in mineral elements. The levels of dietary fibre (11.2-12.9g/100g) in this study were higher than 6.66% reported by Chionyedua *et al*. (2009) for similar sample and 8.61% reported for *Amaranthus hybridus* (Akubugwo *et al*., 2007).Vegetables are generally high in dietary fibre and this quality has greatly assisted the consumers in facilitating faecal elimination, lower the risk of coronary heart diseases, constipation, diabetes and hypertension, and colon cancer (Ishida *et al*., 2000). The crude fat of the samples (1.98-2.22g/100g) was very low. Literature results showed, vegetables are known for their low fat concentration levels: *Amaranthus cruentus* (0.45%); *Celusia argenta* (0.21%) (Akubugwo *et al*., 2007). The low levels of fat in the samples will improve the health of the consumers. The crude protein in the *C. olitorius* samples ranged from 17.5-29.6g/100g with *Oniyayavar* taking the lead in terms of concentration with about 44.6% of total. Protein is very important in food, both nutritionally and as functional ingredients. It plays an important role in determining the texture of a food. Literature reports of protein concentration are as follows (%): *Amaranthus cruentus* (12.66); *Celusia argenta* (9.35) (Akubugwo *et al*., 2007); *Momordica foecide* (4.6) Hassan and Umar, 2016; *Piper guineeses* (29.78) and *Tritium triangulare* (31.0) (Akindahunsi and Salawu, 2005). Pearson (1976) had reported that any plant food that can provide more than 12.0% of its caloric value from protein is considered a good protein source. Two out of the three samples meet this requirement. One of the varieties (*Oniyaya var.*) fell within the recommended 23-56g/100g human daily protein requirement (NRC, 1989); other two varieties: *Sooro* (17.5g/100g) and *Amugbadu* (19.3g/100g) were below the minimum. The concentrations of carbohydrate (31.8-48.5g/100g) were not too high. This could be as a result of relatively high protein levels. The range of percentage contributions to total energy by fat (PEF%), protein (PEP%) and carbohydrate (PEC%) as well as utilizable energy due to protein assuming 60% utilization (UEDP%) were (6.29-7.04), (24.9-44.9), (48.3-68.9) and (14.9-27.) respectively. Percentage energy contributed by carbohydrate (PEC%) had the highest across board. Among the three samples, *Oniyaya var*. had the highest level of PEP% and UEDP%. This was a result of same variety having the highest level of protein among the samples. The energy contributed in kiloJoule (kJ) by protein, fat and carbohydrate respectively in the samples were: 298, 73.3 and 825 (*Sooro var.*); 328, 82.1 and 785 (*Amugbadu var.*) 503, 74.4 and 541 (*Oniyaya var.*).In the same vein, carbohydrate contributed the highest energy among the three samples. Statistical analysis of samples showed that the result were not significantly different at P=0.05 except in PEP% where *Oniyaya var*. differs significantly from others.

Table 1: Proximate composition (%) and percentages of energy contributions from fat, protein and carbohydrate from the three varieties of *Corcorus olitorius* analyzed

Parameters	SP	RD	ST	Mean	SD	CV %	χ^2	Remark
Moisture	7.44	10.1	13.5	10.3	3.04	29.4	1.78	NS
Fat	1.98	2.22	2.01	2.07	0.131	6.32	0.017	NS
Ash	11.3	9.36	11.7	10.8	1.25	11.6	0.290	NS
Fibre	12.9	12.7	11.2	12.3	0.929	7.57	0.141	NS
Protein	17.5	19.3	29.6	22.1	6.53	29.5	3.85	NS
CHO	48.5	46.2	31.8	42.2	9.05	21.5	3.89	NS
PEP%	24.9	27.4	44.9	32.4	10.90	33.6	7.33	S
PEF%	6.29	7.04	6.82	6.7	0.39	5.7	0.04	NS
PEC%	68.9	65.6	48.3	60.9	11.1	18.2	4.02	NS
UEDP%	14.9	16.4	27	19.4	6.60	33.9	4.48	NS
Energy (kJ/100g)	1197	1198	1120	1172	44.7	3.82	3.42	NS

SP = *Soorovar.,* RD=*Amugbadu var.,* ST= *Oniyaya var.,* S= results significantly different at p=0.05, υ= n-1=2, NS = results not significantly different at p=0.05, υ= n-1=2, PEP% = percentage energy due to protein, PEF%= percentage energy due to fat, PEC% = percentage energy due to carbohydrates, UEDP% =utilizable energy due to protein at 60% utilization.

Results of the elemental (mineral) contents of the *C. olitorius* are depicted in Table 2. Among the macro-elements, potassium (K) had the highest concentration in each of the samples mg/kg (% of total): *Sooro*, 424 (61.6%), *Amugbadu* 167 (52.6%) and *Oniyaya* 258 (44.4%). This showed that K took more than forty percent of the total minerals in all the samples. Potassium which is an intracellular cation is usually bound to protein. Both Na and K are essential in maintaining the body pH and control glucose absorption in the body (NRC, 1989). The percentages of calcium (Ca) in the samples are 6.75% (*Sooro*), 5.57% (*Amugbadu*) and 6.14% (*Oniyaya*). Calcium can co-ordinate other inorganic elements in the body especially Na, Mg and K thereby correcting their excess. Also, adequate availability of Ca in the diet can enhance effective utilization of Fe in the body (Fleck, 1976, Adesina *et al.*, 2022). Among the micro-minerals, cobalt and selenium recorded trace amounts. Very low concentrations of Pb in all the samples is a nutritional advantage as Pb is not good for any biochemical function in the body and its presence is an indication of onset of pollution. The levels of cadmium in the samples (0.025-0.030 mg/kg) were also low. Just like Pb, Cd is also not required in the body for biochemical process. The iron (Fe) contents in this study were moderately high (3.31-5.01mg/kg). The requirements of Fe for men, women and children are 12mg, 18mg and 10-15mg respectively (Adesina *et al.*, 2022). Decreased cognitive development and poor learning had been associated with inadequate iron in the diet (FAO, 1997). The levels of Zn (0.398-1.24mg/kg) were below the Zn allowance of 15-20 mg per day (NRC, 1989).Low levels of selenium in *C.olitorius* samples may reduce its functions in the prevention of poisonous effects of heavy metals and cancer (Ahmad et al., 2018). The chi-square results revealed existence of significant difference in three macro-elements namely: K, Ca and Mg; others were not significantly different at P=0.05 and v=n-1=2.

The importance of mineral ratios in nutrition cannot be over emphasized; they are sometimes more important than the levels of minerals themselves (Watts, 2010; Adeyeye *et al.*, 2020). The ratios of interest in this study (Table 3) were Ca/Mg, Ca/P, Na/Mg, K/Na, Zn/Cu, K/Co and K/(Ca+Mg). The ratios emphasize the importance of balance between them as well as the effects of disruption of their relationship. In this report, all the values of Ca/Mg were below the recommended range of 3.0-11.0 with ideal balance of 7.0 (NRC, 1989).

Table 2: Mineral contents (mg/kg) of the three varieties of *Corcorus olitorius* analyzed

Minerals	SP	RD	ST	Mean	SD	CV %	χ^2	Remark
Na	15.4	21.6	28.5	21.8	6.55	30.0	3.93	NS
K	424	167	258	283	130.3	46.0	120	S
Ca	46.5	17.7	35.7	33.3	14.5	43.7	12.7	S
Mg	194	104	252	183	74.6	40.7	60.7	S
Cu	0.030	0.054	0.092	0.059	0.031	53.3	0.033	NS
Cd	0.025	0.030	0.027	0.027	0.00252	9.21	0.0005	NS
Co	0.002	0.00011	0.0003	0.001	0.00104	130	0.0027	NS
Fe	5.01	4.12	3.31	4.147	0.850	20.5	0.349	NS
Mn	0.017	0.023	0.00011	0.013	0.0119	88.8	0.0211	NS
Zn	1.24	0.398	0.466	0.701	0.468	66.7	0.624	NS
Pb	0.0002	0.0004	0.00012	0.00024	0.000144	60.1	0.0002	NS
Se	0.00012	0.0003	0.00015	0.00019	0.000096	50.8	0.0001	NS
P	2.29	2.62	3.10	2.67	0.407	15.3	0.124	NS

SP = *Soorovar.*,RD=*Amugbadu var.*, ST= *Oniyaya var.*, χ^2 = Chi-square, S= results significantly different at $p_{=0.05,}$ $\upsilon_{= n-1=2,}$ NS $_=$ results not significantly different at $p_{=0.05,}$ $\upsilon_{= n-1=2}$

The Ca/P weight ratio in the samples ranged from 6.76-20.3; the recommended range is 2.6- 3.6. Ca/P ratio of less than 0.5 could have some negative effects on Ca absorption in the intestine, absorption of phosphorus and bone formation (NRC, 1989). The maximum limit set for Na/K weight ratio was 0.6. Anything above this value could lead to the risk of developing high blood pressure. It is therefore noteworthy that none of results was up to this critical level. If Na/K ratios are favourable, K/Na weight ratios are also expected to be favourable. The acceptable ideal values for Na/Mg, Zn/Cu and K/Co are 2.0-6.0, 4.0-12.0 and 2000 respectively. The results in this study differ significantly from these values. Most of the results varied significantly among the samples as could be seen in the levels of coefficient of variation in percent (CV %).

Table 3: Computed mineral ratios of the three varieties of *Corcorus olitorius* analyzed

Ratios	SP	RD	ST	Mean	SD	CV %	χ^2	Remark	RBI	AIR
Ca/Mg	0.240	0.170	0.142	0.184	0.050	27.4	0.028	NS	7	3.0-11
Ca/P	20.3	6.76	11.52	12.86	6.874	53.5	7.35	S	2.6	1.5-3.6
Na/K	0.036	0.129	0.110	0.092	0.049	53.4	0.053	NS	2.4	1.4-3.4
Na/Mg	0.079	0.208	0.113	0.133	0.067	49.9	0.066	NS	4	2.0-6.0
K/Na	27.5	7.73	9.05	14.8	11.070	74.9	16.6	S	-	-
Zn/Cu	620	3618	1553	1931	1534	79.5	2439	S	8	4.0-12
K/Co	212000	1518182	860000	863394	653098	75.6	988046	S	2000	-
ME*	3.53	2.74	1.79	2.69	0.868	32.3	0.560	NS	2.2	-

ME*= milliequivalent ratio of [k/(Ca+Mg)], RBI= reference balance ideal, AIR = acceptable ideal range, χ^2 = Chi-square, S= results significantly different at $p_{=0.05,}$ $\upsilon_{= n-1=2,}$ NS $_=$ results not significantly different at $p_{=0.05,}$ $\upsilon_{= n-1=2,}$ SP = *Soorovar.*, RD=*Amugbadu var.*, ST= *Oniyaya var.*

Table 4: Mineral safety index of the three varieties of *Cochorus olitorius* analyzed

Samples	Fe		Na		Ca		P		Zn		Cu		Mg		Se	
	cV	D	cV	D	cV	D	cV	D	cV	D	cV	D	cV	D	cV	D
SP	2.24	4.46	0.148	4.65	0.387	9.61	0.019	9.98	2.73	30.27	0.045	32.96	7.28	7.72	0.024	13.98
RD	1.84	4.86	0.207	4.59	0.147	9.85	0.022	9.98	0.876	32.12	0.081	32.92	3.9	11.1	0.06	13.94
ST	1.48	5.22	0.274	4.53	0.297	9.7	0.026	9.97	1.03	31.97	0.138	32.86	9.45	5.55	0.03	13.97

cV= calculated value, TV= standard table value (Fe = 6.7; Na= 4.8; Ca= 10; P = 10; Zn= 33; Cu =33; Mg =15, Se =14), D =difference (TV-cV),SP = *Soorovar.*, RD=*Amugbadu var.*, ST = *Oniyaya var.*

Table 5: levels (mg/100g) of anti-nutritional factors present in the analyzed varieties of *Corcorus olitorius* analyzed

Antinutrients	SP	RD	ST	Mean	SD	CV %	χ^2	Remark
Tannin	0.240	0.190	0.300	0.243	0.055	22.6	0.025	NS
Phenol	0.150	0.080	0.160	0.130	0.044	33.5	0.029	NS
Alkaloids	0.130	0.070	1.93	0.710	1.06	149	3.15	NS
Saponin	2.00	1.60	3.70	2.43	1.12	45.8	1.02	NS
Flavonoids	0.59	0.62	0.85	0.687	0.142	20.7	0.059	NS
Phytates	5.30	6.10	5.50	5.633	0.416	7.39	0.062	NS
Oxalate	0.250	0.280	0.330	0.287	0.040	14.1	0.011	NS

χ^2 = Chi-square, NS $_=$ results not significantly different at $p_{=0.05}$, $\upsilon_{= n-1=2}$, SP = *Soorovar.*, RD=*Amugbadu var.*, ST= *Oniyaya var.*

The calculated mineral safety index of the *Corchorus olitorius* samples is shown in Table 4. The Table (standard) values obtained from literature for the selected elements are Mg (15.0), Na (4.80), Cu(33.0), Fe(6.70), Zn (33.0) Ca (10.0), P(10.0) and Se (14.0).

The above Table values were obtained from the recommended adult intake (RAI) and minimum toxic dose (MTD) values. For example, the RAI of Mg is 400mg and the MTD is 6000mg or 15times the RAI and therefore, the standard MSI for Mg is 15. This applies to other Table MSI. The difference between the Table MSI and the calculated MSI (TV-cV) were positive for all the selected elements in each of the sample. This implies, none of the mineral elements might be overloading the body (Adeyeye *et al*., 2019; Adeyeye *et al*., 2020). Zn had recorded negative values of TV-cV in most literature studies. High doses of Zn had been reported to interact with other minerals such as Fe and Cu therefore reducing their bioavailability. Also, positive difference reported for Cu in this study indicated that Cu would not impair Zn, Mn and Fe metabolism (Uddin *et al*., 2019).

In the anti-nutritional factors (Table 5), phytate had the highest concentration (mg/100g) in each of the samples; 5.30 (*Sooro*), 6.10 (*Amugbadu*) and 5.50 (*Oniyaya*). The percentages of phytate in the total antinurients are 61.2 (*Sooro*), 68.2 (*Amugbadu*) and 43.1 (*Oniyaya*). The Phy levels in this report were higher than the following literature values (mg/100g): Basil plant leaf (1.30), cocoyam leaf (1.19) and cam wood plant leaf (1.00) (Opega *et al*., 2016). The phytates levels in this study were however lower than 2760reported by Olaleye *et al*. (2019) for *Vernonia amygdalina*. In the same vein, the tannin and total phenol reported for *V. amygdalina* were (mg/100g) 4.80 and 4.65 respectively (Olaleye *et al*., 2019). These values were far above the present results. The oxalate contents in this report (0.25-0.33mg/100g) were lower than 4.08-6.42mg/100g in groundnut seed samples (Adeyeye, 2011) but compared favourably with 0.20 mg/100g reported by Opega *et al*. (2016) for sweet potato leaf. Too much oxalate impact negatively on Ca absorption and utilization (Maqsood *et al*., 2019; Adeyeye *et al*., 2019). The anti-nutritional factors are generally low in this report. The statistical analysis revealed that results were not significantly different among the samples in all the parameters determined.

Table 6 shows the Phy:Fe, Phy:Zn, Ca:Phy and [Ca][Phy]/[Zn] molar ratios of the *C. olitorius* varieties. Foods with Phy:Zn molar ratios below 10.0 were reported to show adequate Zn bioavailability (Igwe *et al*., 2013). Another better indicator of bioavailability of Zn is [Ca][Phy]/[Zn] molar ratio (Davies and Warrington, 1986; Ellis *et al*., 1987). From the literatures, ratios greater than 0.5 would interfere with Zn bioavailability. Looking at the predictors (i.e. Phy:Zn and [Ca][Phy]/[Zn]), only *Sooro* had results lower than the critical values.; others were higher. The Ca:Phy ratios in this report ranged from 4.69-14.2. The levels of Ca:Phy had been linked with Phy precipitation in solution, such that values less than 6.1 would make precipitation of Phy in solution incomplete; the percentage of Phy that remains in solution gets increased with decreasing Ca:Phy ratio (Wise, 1983; IZNCG, 2004). The Chi-Square results revealed that significant difference was only observed in Phy:Zn where *Sooro var* differ significantly from others.

Table 6: Concentrations of phytate, Zn, Ca and calculated [phytate]/[Zn], [Ca]/[phytate] and [Ca][phytate]/[Zn] interrelationship of the vegetables analyzed

Parameters	SP	RD	ST	Mean	SD	CV %	χ^2	Remark
Phytates	5.30	6.10	5.50	5.63	0.416	7.39	0.062	NS
Calcium	4.65	1.77	3.57	3.33	1.45	43.7	1.27	NS
Zinc	1.24	0.0398	0.0466	0.442	0.691	156	2.16	NS
Fe	0.501	0.412	0.331	0.415	0.085	20.5	0.035	NS
[Phy]:[Fe]	0.895	1.25	1.41	1.18	0.262	22.1	0.116	NS
[phy]:[Zn]	0.424	15.2	11.7	9.10	7.72	84.8	13.1	S
[Ca]:[Phytate]	14.2	4.69	10.5	9.80	4.79	48.9	4.68	NS
[Ca] [Phytate]:[Zn]	0.049	0.663	1.03	0.580	0.496	85.4	0.847	NS

χ^2 = Chi-square, S= results significantly different at $p_{=0.05}$, $\upsilon_{=n-1=2}$, NS = results not significantly different at $p_{=0.05}$, $\upsilon_{=n-1=2}$, SP = *Soorovar.*,RD=*Amugbadu var.,* ST= *Oniyaya var.*

Table 7: Non starch polysaccharide (NSP) components of the vegetable samples analyzed (%)

Parameter	SP	RD	ST	Mean	SD	CV %	χ^2	Remark
NDF	15.3	8.51	5.66	9.82	4.95	50.4	4.99	NS
ADF	10.6	6.42	4.11	7.04	3.29	46.7	3.07	NS
ADL	5.41	4.30	2.05	3.92	1.71	43.7	1.50	NS
Cellulose	5.19	2.12	2.06	3.12	1.79	57.3	2.05	NS
HMC	4.72	2.09	1.55	2.79	1.70	60.9	2.06	NS

NSP=non starch polysaccharide, CEL= cellulose, HMC= hemicelluloses, ADF=acid detergent fibre, ADL= acid detergent lignin, NDF=neutral detergent fibre, χ^2 = Chi-square, NS = results not significantly different at p=0.05, υ= n-1=2, SP = *Soorovar.*,RD=*Amugbadu var.*, ST= *Oniyaya var.*

The non-starch polysaccharide (NSP) components of the *C. olitorius* varieties are depicted in Table 7. The following were investigated: neutral detergent fibre (NDF), acid detergent fibre (ADF), acid detergent lignin (ADL), cellulose and hemicelluloses (HMC). The trend of abundance of all these parameters are *Sooro var*>*Amugbadu var* >*Oniyaya var*. Also, in each of the samples, NDF was most concentrated followed by ADF. Tang *et al*. (2010) had reported 55.6-71.7% (NDF) and 31.9-49.6% (ADF) for rice varieties. These values were far higher than the levels obtained in this report. Van Soest and Robertson (1980) had described ADF as a portion of plant fibre, including cellulose and lignin from cell walls, xylans and other components. The levels of ADL, cellulose and HMC reported for *Vigna subterranean* whole seed flower were (%): ADL (7.17), cellulose (2.41) and HMC (0.84). The ADL concentrations in this study (2.05-5.41%) were lower than the literature value; but the present HMC levels (2.09-4.72%) were much higher. ADL has been the most common lignin method in ruminant nutrition, although it underestimates lignin as a result of solubulization of some lignin at the ADF step in the procedure (Ramulu and Udayasekhara, 2004). The statistical analysis (Chi-Square) at P=0.05, v=n-1 = 2 showed no significant differences among the samples in all the parameters determined.

CONCLUSION

This research has shown that the *Corchorus olitorius* varieties investigated contain varied proportions of the parameters determined. The low fat contents in this study would make the vegetables suitable for obese people. The results have also shown that the samples are good sourcesof protein and crude fibre and can therefore reduce the body cholesterol level, also good in nutritive minerals especially K and Fe and contains only very trace amount of toxic mineral elements and moreover, the body will not be overloaded with any of the minerals. The mineral ratios showed that the samples could not pose any health risk to consumers.Although the concentrations were low, the non-starch polysaccharide would play a very good role in digestion and reduction in the incidence of colon cancer, diabetes, obesity and other degenerative diseaseswhen consumed (Marlett *et al*., 2002; Sarker and Rahman, 2017). The statistical analysis results showed that no significant difference existed among the *Corchorus olitorius* samples in most of the parameters determinedexcept PEP %, K, Ca, Mg and [phy]:[Zn].

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