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Evaluation of Selected Heavy Metals and Macronutrients Status of 10 Medicinal Plants from Nigeria

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Abstract: *Ten important herbal plants from the South-west of Nigeria were analyzed for their heavy metal (K, Na, Ca, Mn, Mg, Cu, Fe, Zn, Pb and P) and macro-nutrient status using an atomic absorption spectrophotometer. The most prevalent heavy metals were K (162 – 524 mg/mL) and Ca (102 – 472 mg/mL) followed by Mg (48.10 – 136.00 mg/mL) and Na (3.51 – 10.10 mg/L). The highest level of K (524.00 ± 5.70mg/mL) and Ca (472.00 ± 1.44 mg/mL) were found in Senna alata and Senna podocarpa, respectively. Out of all the plants, Dissotia rotundifolia had the highest concentrations of Mg (136.00 ± 0.28 mg/mL) and Na (10.10 ± 0.03 mg/mL). The results showed that the level of Cu (0.65 – 1.48 mg/mL) and Zn (2.40 – 6.77 mg/mL) found in the herbal plants were much lower than the reported range of the elements in agricultural products.*
Keywords: *medicinal plants, digestion, macronutrient status, agricultural products*

I. Introduction

The role of trace elements in human nutrition and disease cannot be over-emphasized. Even though the mineral elements form a small proportion of total composition of most plant materials and of total body weight and they do not contribute to energy value of food, they are of great physiological importance particularly in the body metabolism (Schwart, 1995). Their importance ranged from role as biological essential components to imbalance created when excess of one interferes with the functions of another. Mineral elements function as mineral electrolyte and ions performing osmotic and regulatory functions in the body fluid dynamics. Various minerals are also co-enzymes in certain biochemical reactions in the body (Mensah *et al.*, 2008). Records from ancient Egypt, Assyria, China and India show that the use of plants for medicinal purposes extends back to earliest recorded history (Trease, 1989). Today, it is recognized that these elements play an important role in nutrition. Their functions are varied and may depend on their chemical forms or their location in the body tissues or blood fluids. Many elements form important part of enzymes to increase the rate of chemical reactions in the cells. These enzymes can be used over and over again because the elements can be effective even when present in only very low concentration in the cells of the body. All plants contain varying amount of mineral element. The extent to which plants take up metals depends on the binding of trace analytes to soil constituents; other sources may include pesticides and fertilizers (Ansari *et al.*, 2009). Majority of the Africans today depend either totally or partially on traditional medicine called ethno medicine for healing. Today in Nigeria, there is an increase in the acceptance and utilization of traditional medicine partly because of scientific support for some of their medicinal uses (Odetola and Akojeun, 2000). Many medicinal plants are cheaper and more accessible to most people in the developing countries than orthodox medicine, and there is lower incidence of adverse effects after use (Sofowora, 1993). Trace minerals have both curative and preventive role in combating diseases but according to Schumacher (1991), they can be dangerous and toxic when in excess. It is therefore important that the levels of some of these mineral elements in herbal plants be established. The need to ensure the quality control of plant products using modern techniques and applying suitable standards have been emphasized by the World Health Organization (1992). This paper reports on the evaluation of mineral element composition of ten selected medicinal plants from Nigeria. Ajasa *et al*. (2004) have reported on the heavy trace metal and macronutrient status of some herbal plants of Nigeria and there are many literature reports on the determination of metal content of herbal, medicinal and aromatic plants from other parts of the world (Majid *et al.* 1995; Vartika *et al*. 2001) but no literature data are available on the mineral element composition of these particular medicinal plants that are evaluated.

II. Materials And Methods

Material

Ten different medicinal plants were used in this work (Table 1): *Sida acuta*, *Mormodica charantia*, *Boerhaavia diffusa*, *Gossypium hirsutum* and *Occimium gratissimum* were collected from the Botanical Garden of the University of Ibadan while *Phyllantus reticulata*, *Paullina pinnata*, *Senna podocarpa*, *Senna alata* and *Dissotis rotundifolia* were collected from the Botany and Microbiology Department also within University of

Ibadan. The plants were identified by the Herbarium Unit of Department of Botany, University of Ibadan, Ibadan. The samples were air dried and then pulverized.

Reagents

Analytical reagent grade concentrated acids (HClO4 and HNO3) were used. Ultra-pure water was used during the course of the experiment. Stock standard solutions containing 1000 ppm Na, K, Mg, Ca, Fe, Pb, Zn, Mn, Cu and P were used. An appropriate dilution of the stock solutions gave the calibrations standards of each element. All chemicals were purchased from Merck Chemicals, Nottingham, UK.

Atomic absorption spectrophotometer

An atomic absorption spectrophotometer (AAS; Analysengerate GmbH model 200A; Buck Scientific, Germany) was used for metal determination with Cathodeon (England) hollow cathode lamps for K, Mg, Ca, Zn and Mn, Buck Scientific hollow cathode lamps for Cu, Na and Pb, and Fischer Scientific hollow cathode lamps for Fe, used as radiation sources. The elements were measured under the optimum operating conditions with an air-acetylene flame. Phosphorus levels of the plants samples were determined by a colorimeter (Technicon AAII Autoanalyzer) at 630 nm. An ultra-pure water filter (Elgastat UHQ machine, Veolia, UK) was used to generate the ultra-pure water for dilution. Distilled water was used to generate ultra pure water.

Sample treatment

Samples were digested by the wet ashing method using concentrated nitric and perchloric acids (1: 1, v/v) following the methods of Ajayi *et al.* (2004) and Akwaowo *et al.* (2000). The digests were filtered into a 100-ml standard flask and made up with ultrapure water. Mg, Ca, Fe, Pb, Zn, Mn and Cu were determined by absorption and Na and K by emission using a Buck Scientific model 200A AAS.

Statistical analysis

The samples (0.50 g) were separately digested and subjected to analysis as described above. The analysis was carried out in triplicate per sample. The results obtained were statistically analyzed by one way analysis of variance (ANOVA). Means were compared by the Duncan's multiple range test (Duncan 1955); significant differences between any two means were determined at the 5% level.

III. Results And Discussion

The mineral concentrations of the medicinal plants tested are shown in Table 2. The mineral elements which were determined by AAS numbered 10: Na, K, Ca, Mg, Zn, Cu, Fe, Pb, P and Mn. There are many factors which can influence the concentration of various elements in plants. These include the nature of the element, its content and form in the soil, soil type and pH, the crop variety, proximity to external sources of pollution and many other factors (Femenia *et al.*, 1995; Adeleke and Abiodun, 2010). All the plants appeared to be an important source of minerals as the result from the study showed that the metals were accumulated to some extent by the medicinal plants. Elemental studies of the plants showed that they contained a large amount of nutrients and were rich in K, Ca and Mg. The presence of important mineral elements inside these plants shows that they could be nutritious plants (Jonathan *et al.,* 2011). Significant variations occurred in the mineral concentration among the samples analyzed.

The Na concentration levels ranged from 3.51 ± 0.03 mg/L to 10.14 ± 0.03 mg/L; *S. acuta* had the lowest while *D. rotundifolia* had the highest; most samples had a Na concentration between 4.64 ± 0.06 and 6.89 ± 0.03 mg/L. The Na concentration in *S. alata*, *O. gratissimum* and *B. diffusa* were comparable. The values for *M. charantia*, *P. pinnata* and *G. hirsutum* were also comparable and similarly those for *S. podocarpa* and *P. reticulate*. The Na contents in these medicinal plants were higher than those reported in the literature by Onyeike and Acheru (2002) for castor, coconut, dikanut, groundnut, melon, oil bean and palm kernel seeds (Table 3) used in the preparation of Nigerian diets. Sodium is known to play a crucial role in conduction of nerve impulse (Oderinde *et al.*, 2008). The medicinal plants had a K concentration in the range of 162.00 ± 2.82 to 524.00 ± 5.70 mg/L. The K concentration was comparable in *P. pinnata*, *P. reticulata* and *S. podocarpa*. *S. alata* had the highest while *S. acuta* had the lowest values. Potassium concentration of the plants is higher than those reported for fresh fish (*Oreochromis niloticus*, *Clarias lazera* and *Mormyrus rume*) samples (Otitologbon *et al.*, 1997). K is the most mportant intracellular element that is required for various physiological functions (Olaniyi *et al.*, 1993). Potassium is also good for nerves and muscle functions (Komolafe *et al*., 2006). Mg concentration was highest in *D. rotundifolia* and lowest in *P. pinnata*; the concentration ranged from 47.30 ± 0.28 to 136.14 ± 0.28 mg/L. The concentration was comparable for *P. reticulata*, *O. gratissimum*, *G. hirsutum*, *S. podocarpa* and *S. alata*.

The result of the elemental study of the medicinal plants showed that the Ca concentration ranged from 102.00 ± 0.00 to 472.00 ± 1.44 mg/L, most samples being in the range of 203.85 ± 2.81 to 278.54 ± 1.41 mg/L.

G. hirsutum had the highest Ca concentration while *S. acuta* had the lowest. The Ca content of these plants was higher than those obtained for watermelon (*Citrullus vulgaris*) and pumpkin (*Cucurbita pepo*) seed kernel and paprika (*Capsicum annuum*) seed flour (El-Adawy and Taha, 2001) (Table 3). The Pb concentration levels ranged from 0.03 ± 0.00 to 0.13 ± 0.01 mg/L; a large number of the plant samples that were studied in the present work had values between 0.03 ± 0.00 and 0.06 ± 0.00 mg/L. *S. acuta* had the highest while *P. reticulata* and *M. charantia* had the lowest. The concentration of Pb was also the same for *D. rotundifolia*, *G. hirsutum*, *S. podocarpa* and *O. gratissimum*. This is comparable to the result reported by Ajasa *et al.* (2004) in which the concentration of Pb was comparable in *Anacardium occidentalis* and *Azadirachta indica*, *Butyrospermum paradoxum*, *Mangifera indica*, *Zingiber officinales* and *Hyptis suaveolens* and similarly between *Ocimum canum*, *Morinda lucida*, *Solanum erianthum* and *Solanum torvum* in a range of 0.31-0.35 mg/L. The level of Pb accumulation in the plant samples is well below 10 mg/mL, which is the permissible limit for medicinal plants (Aliyu *et al.*, 2008). The Zn concentration varied from 2.40 ± 0.11 to 6.77 ± 0.08 mg/L; four of the samples had < 3.00 mg/L. *S. alata* had the lowest Zn concentration and *B. diffusa* the highest. Zn is required to prevent growth and mental retardation in humans (Fagbemi, 2007). The concentration of Zn was comparable in *S. alata*, *S. podocarpa*, *P. pinnata* and *O. gratissimum* with a range of 2.40 ± 0.08 to 2.87 ± 0.11 mg/L while *P. pinnata* and *O. gratissimum* had the same value, 2.80 ± 0.08 mg/L.

Cu is involved in many physiological and biochemical reactions in humans. It is ubiquitous and is an essential trace element for animals and plants (Donde and Virkar 1996). Its concentration in the medicinal plants studied ranged from 0.65 ± 0.01 to 1.48 ± 0.01 mg/L. Cu and Zn are usually considered as micronutrients. According to Allaway (1968) and Ajasa *et al.* (2004) the range of elements in agricultural products should be between 4-15 mg/L for Cu and 15-20 mg/L for Zn. The results obtained from the herbal plants studied, when compared with these values, showed that the plants accumulate these metals in ranges that fall within limits proposed by these authors. The P concentration in the medicinal plants analyzed varied from 26.80 ± 0.42 to 59.90 ± 2.74 mg/L; *S. acuta* had the lowest while *P. reticulata* had the highest values. Phosphorus is needed for bone growth, kidney function and cell growth; it also plays a role in maintaining the body's acid-alkaline balance (Nzikou *et al.*, 2006). The level of P concentration was comparable in four of the samples: *M. charanta*, *S. podocarpa*, *G. hirsutum* and *O. gratissimum* in a range of 31.40 ± 3.13 to 36.00 ± 0.00 mg/L. The Fe concentration ranged from 3.96 ± 0.01 to 20.20 ± 0.14 mg/L, with most of the values lying between 4.33 ± 0.03 to 7.65 ± 0.01 mg/L. *P. reticulata* had the lowest Fe concentration while *D. rotundifolia* had the highest. The Fe content 6.98 ± 0.01 mg/mL of *S. acuta* is the same as 6.98 ± 0.43 mg/100 g that was obtained for soybean products (Garcia *et al.*, 1998). The relatively high concentration of Fe in the medicinal plants (3.96 ± 0.01 for *P. reticulate* to 20.20 ± 0.14 mg/mL for *D. rotundifolia*) is quite encouraging because of its requirements for blood formation (Oladele and Aina, 2007); it may perhaps provide the opportunity of using these plants as a food tonic for convalescing patient. Mn concentration ranged from 0.27 ± 0.00 to 2.10 ± 0.00 mg/L; most samples had contents from 0.32 ± 0.00 to 0.71 ± 0.00 mg/L. *S. podocarpa* had the lowest Mn concentration while *D. rotundifolia* had the highest. Vegetables are known to supply the needed vitamins and also Fe, Ca, Mg, Zn and other minerals which are important for human health and they are the most affordable source of minerals and vitamins for African families (Schutlink *et al.*, 1987; Rossel, 1991; Ajayi and Aghanu, 2011). Though much is known about the functional role of a number of elements, the best foreseeable benefit for human health, by mineral nutrition, is in obtaining the correct amount of supplementation in the right form at the right time. The contents found for the mineral elements studied may suggest that their use in moderate quantities would provide the range of amounts of Cu, Fe and Zn necessary for a healthy diet. P and Zn play crucial roles in actively metabolizing cells, particularly in relation to energy metabolism and photo-synthesizing of leaves; they also play key roles in energy cycle. Mg and Fe are components of chlorophyll.

Ca is an indispensable component of the structure of the body. The bones and teeth owe their hardness and strength to the presence of these minerals (Uddoh, 1998). Ca is aided in its structural role by its interactions with P and Mg. It forms about 2% of the body although there are individual variations. The adult body contains an average of 1200 g, over 90% of which is present in the bones and teeth. The remaining Ca is present in all tissue cells and extra cellular fluids or in the blood plasma in a state of constant exchange with the skeletal Ca. Mg works with Ca to maintain healthy bones (Ajayi *et al*., 2007). Calcium, potassium and magnesium are required for repair of worn out cells, strong bones and teeth in humans, building of red blood cells and for body mechanisms (Aliyu *et al.*, 2008). The concentrations of K, Mg and Ca in the medicinal plants make them sources of these mineral elements and, if included in a diet, can supply the body with them.

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Table 1 Scientific, local and family name and medicinal properties of leaves of herbal plants investigated.

Scientific name	Local name	Family name	Medicinal properties	
Boerhnaria diffusa	*Etipase eranla*	Nytaginacae	Mild laxative, vermifuge, miscarriage	Oliver-Bever (1986)
Dissoltis rotundifolia	*Apo iba*	Malastomaceae	Cough, asthma, pneumonia	Dalziel (1937)
Gossypium hirsutum	*Eponkon*	Malvaceae	Analgesic, antipyretic, tuberculosis	Dalziel (1937)
Mormodica charantia	*Ejinrin*	Curcubitaceae	Diarrhea, dysentery,	Oliver-Bever (1986)
Occimium gratissimum	*Efirin*	Labiatae	Antimicrobial, mosquito repellant	Oliver-Bever (1986)
Paullina pinnata	*Kakesenla*	Sapindaceae	Jaundice, yellow fever, miscarriage	Oliver-Bever (1986)
Phyllantus reticulata	*Iranje*	Euphorbiaceae	Malaria, bleeding	Dalziel (1937)
Sida acuta	*Agidimagbayin*	Malvaceae	Catarrh, dysentery, nephritis	Dalziel (1937)
Senna alata	*Asunrun*	Caesalpiniaceae	Chronic gonorrhea antifungal ringworm	Owoyale et al., (2005)
Senna podocarpa	*Ajanrere*	Caesalpiniaceae	Dysentery	Oliver-Bever (1986)

Table 2 Mineral element composition* of the leaves of herbal plants (mg/mL).

	Macronutrients							Micronutrients		
Plant species	Na	K	Mg	Ca	Fe	P	Mn	Cu	Zn	Pb
Boerhnaria diffusa	4.74 ± 0.03^{f}	410.00±2.84^{c}	129.00±0.28^{b}	203.00±2.81^{cd}	5.86±0.01^{f}	58.40±0.24^{a}	1.01±0.00^{b}	1.34±0.02^{abc}	6.77±0.08^{a}	0.08±0.01^{b}
Dissoltis rotundifolia	10.10±0.03^{a}	385.00±2.84^{d}	136.00±0.28^{a}	278.00±1.41^{bcd}	20.20±0.14^{a}	48.30±1.41^{b}	2.10±0.00^{a}	1.11±0.04^{d}	6.55±0.00^{b}	0.05±0.00^{cd}
Gossypium hirsutum	5.83±0.06^{c}	339.00±5.66^{e}	64.80±0.28^{f}	472.00±1.44^{ab}	7.65±0.01^{b}	34.10±0.28^{d}	0.63±0.00^{d}	1.45±0.02^{ab}	4.28±0.11^{c}	0.05±0.01^{de}
Mormodica charantia	5.06±0.03^{e}	436.00±5.69^{b}	93.30±0.28^{c}	238.00±1.41^{cd}	7.61±0.01^{b}	31.40±3.13^{d}	0.61±0.00^{e}	1.48±0.01^{a}	4.36±0.00^{c}	0.03±0.00^{f}
Occimium gratissimum	4.66±0.03^{g}	305.00±2.84^{f}	62.80±0.28^{g}	321.00±1.41^{bc}	4.33±0.03^{a}	36.00±0.00^{d}	0.32±0.00^{i}	0.65±0.01^{e}	2.87±0.11^{f}	0.04±0.01^{de}
Paullina pinnata	5.42±0.03^{d}	225.00±2.83^{h}	47.30±0.28^{i}	225.00±2.82^{cd}	6.04±0.01^{e}	40.60±0.44^{c}	0.50±0.00^{f}	1.26±0.01^{c}	2.87±0.11^{f}	0.04±0.01^{ef}
Phyllantus reticulate	6.89±0.03^{b}	273.00±2.84^{g}	62.40±0.28^{g}	316.40±2.82^{bc}	3.96±0.01^{h}	59.90±2.74^{a}	0.37±0.00^{h}	1.28±0.21^{bc}	3.10±0.00e	0.03±0.00f
Sida acuta	3.51±0.03^{h}	162.00±2.82i	48.10±0.28^{h}	102.00±0.00^{e}	6.98±0.01^{c}	26.80±0.42^{e}	0.71±0.00^{c}	1.37±0.01^{abc}	3.81±0.11^{d}	0.13±0.01^{a}
Senna alata	4.64±0.06^{g}	524.00±5.70^{a}	68.00±0.28^{d}	253.00±2.81^{cd}	6.86±0.01^{d}	42.50±0.00^{e}	0.44±0.00^{g}	1.00±0.01^{d}	2.40±0.11^{g}	0.06±0.01^{c}
Senna podocarpa	6.85±0.03^{b}	279.00±0.00^{g}	66.20±0.57^{e}	435.00±1.41^{a}	4.42±0.01^{g}	31.70±4.48^{d}	0.27±0.00^{j}	1.01±0.01^{d}	2.56±0.11^{g}	0.05±0.01^{de}

*Values are means±standard deviations of triplicate determinations. Means in the same row with the same letters are not significantly different (P≤ 0.05).

Table 3 Mineral element composition (mg/100g) of some plant species by some authors

Plant Species	Na	K	Mg	Ca	Fe	P	Mn	Cu	Zn	Pb
AD[a]	136.900	32.000	145.070	120.600	0.527	NA	NA	0.000	0.014	0.002
AM[a]	12.600	100.700	96.000	21.500	11.3000	NA	NA	0.167	1.555	0.002
PC[a]	101.800	151.700	406.000	32.300	6.800	NA	NA	0.006	2.637	0.008
SA[a]	375.000	132.500	47.500	5.100	2.730	NA	NA	2.740	1.530	0.175
VB[a]	70.000	230.000	65.000	315.2	0.760	NA	NA	6.475	0.620	0.071
WMSF[b]	33	150	542	150	12.1	127	9.9	2.1	10.6	NA
PSKF[b]	38	1176	483	130	10.9	1090	8.9	1.7	8.2	NA
PSF[b]	37	1279	396	163	14.6	989	7.2	3.72	6.7	NA
CAS[c]	2.30±0.066	15.5±0.066	NA	NA	0.293±0.001	NA	NA	0.151±0.001	NA	0.004±0.01
COS[c]	2.53±0.001	15.4±0.001	NA	NA	0.489±0.001	NA	NA	0.200±0.001	NA	0.002±0.01
DS[c]	2.02±0.066	15.6±0.011	NA	NA	0.315± 0.00	NA	NA	0.139± 0.00	NA	0.054±0.001
GS[c]	1.90±0.066	16.2± 0.01	NA	NA	0.130±0.001	NA	NA	0.126±0.001	NA	0.066± 0.001
MS[c]	1.2 ±0.02	16.5± 0.00	NA	NA	0.352±0.001	NA	NA	0.158±0.001	NA	0.076± 0.00
OBS[c]	2.65±0.001	16.8± 0.00	NA	NA	0.328±0.001	NA	NA	0.233± 0.00	NA	0.055± 0.001
PKS[c]	1.47±0.001	13.4±0.001	NA	NA	0.132± 0.00	NA	NA	0.162±0.001	NA	0.044± 0.001
AO[de]	613± 0.60	6380± 25	1540± 26	6103 ±15	35.6± 0.02	100± 2	89.9± 0.03	2.96± 0.01	3.31± 0.02	0.44± 0.02
AI[de]	138± 0.60	19220± 55	5630± 12	3543± 15	188± 0.10	900± 10	46.5± 0.04	1.12± 0.01	15.7± 0.01	0.49± 0.03
BP[de]	544± 0.03	8170± 16	5380± 10	21850± 40	96.1± 0.05	300± 15	31.7± 0.06	10.3± 0.01	8.87± 0.01	0.21± 0.02
MI[de]	43.6± 0.03	7470± 15	1372± 9	18810± 11	46.6± 0.01	100± 4	133± 0.06	3.07± 0.01	3.24± 0.01	0.29± 0.03
ML[de]	176± 0.97	13100±101	5470± 59	51340± 21	122± 0.02	598± 8	685± 0.02	16.5± 0.01	33.6± 0.01	0.35± 0.01
OC[de]	111± 1.18	36600±350	3230± 14	32420± 52	241± 0.05	3700±35	51.3± 0.04	15.1± 0.01	30.8± 0.01	0.33± 0.02
SE[de]	79.6± 0.31	28750± 51	3160± 9	7280± 30	178± 0.05	3400±15	34.1± 0.02	21.7± 0.01	24.2± 0.01	0.31± 0.02
ST[de]	78.7± 0.49	31550± 02	2460± 70	11390± 20	208± 0.03	3101± 5	48.7± 0.06	13.9± 0.02	23.4± 0.01	0.34± 0.02
ZO[de]	322± 2.00	25280±113	4210± 10	2610± 10	144± 0.05	1803±15	413± 0.70	14.4± 0.01	33.3± 0.01	0.26± 0.04
HS[de]	72.5± 0.05	18260±233	4780±10	19780± 8	142± 0.10	1200±27	39.4± 0.30	24.4± 0.01	35.1± 0.01	0.28± 0.02