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Der Pharma Chemica, 2012, 4(5):1962-1968
(http://derpharmachemica.com/archive.html)

ISSN 0975-413X
CODEN (USA): PCHHAX

Compositional Elemental Assessment of Some Core Herbal Plants used in Northern Ghana by Instrumental Neutron Activation Analysis.

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ABSTRACT

Six herbal samples commonly used as medicine in the Ghanaian traditional health care system for the treatment of various ailments were analysed for 15 elements (As, Ca, Cl, Cr, Cu, Fe, K, Mg, Mn, Na, P, Sb, Se, V and Zn) using the highly accurate and sensitive INAA.. The medicinal or pharmacological roles of most of these elements were discussed. Generally, Ca, Cl, Mg, P, and K were found in high concentrations while Na, Fe, Mn, Cu, Cr and Zn were found in appreciable concentrations with As, Se, Sb and V measured in traces. These base line data provide justification for the medicinal usage of these herbs in the treatment of different diseases. The results therefore, showed that these herbs are enriched with mineral elements that could enhance the curative process of ill health. Toxicologically, As and Sb were found within safe limits.

Keywords: Northern Ghana, Herbal plants, Traditional Medicine, INAA

INTRODUCTION

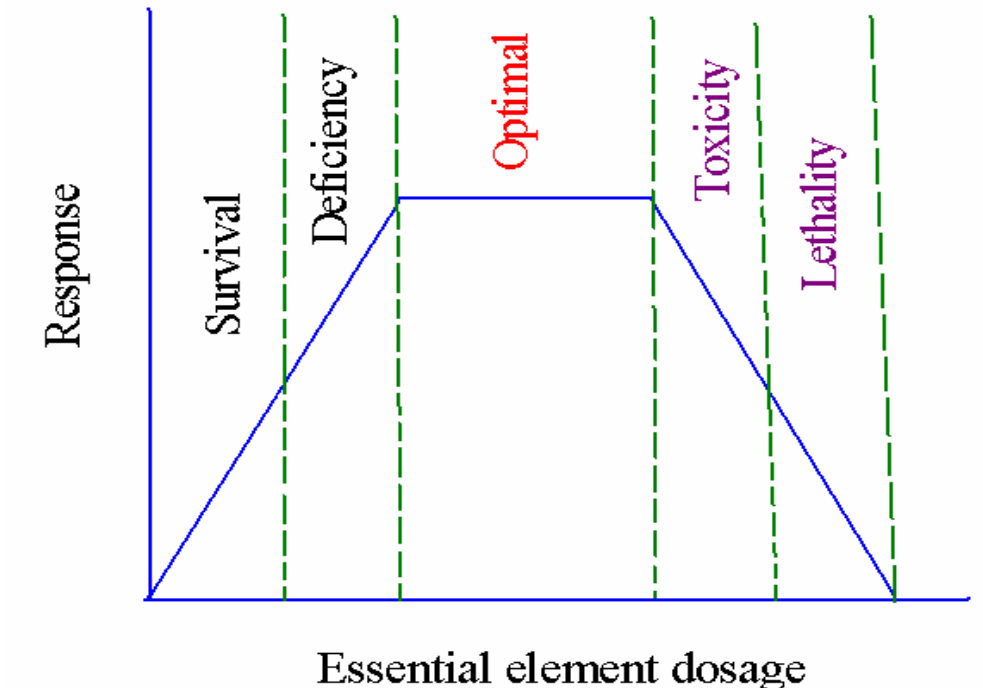
Africa has arguably one of the richest biodiversity and perhaps the rich complement of phytochemicals and secondary metabolites of plants in the world. Arising from these phytodiversities, plants have from antiquity been used as sources of medicament against various ailments [1]. Nevertheless, in Northern Ghana as in most part of Africa, traditional medicine is still perceived to be "Voodoo" and "Primitive" due to inadequate documentation on the herbs used for this practice [2]. Decoctions or concoctions and at times plasters of various parts of indigenous medicinal plants are used in the treatment of various diseases such as typhoid fever, malaria, headaches, piles, sore throat, scurvy, catarrh, diabetes, burns, rheumatism etc.

In rural areas where access to modern health facilities is limited by the level of development, plants/herbs remain the mainstay of the health care system [3]. In Northern Ghana (mostly populated by rural dwellers), indigenous herbal plants remain the fundamental form of medicine for health care delivery largely due to the ultra poor status of the populace. Ironically, it is a taboo in some tribes to attend the inadequate number of already ill – equipped and distant modern healthcare facilities available. The Ghanaian government realising that these areas are being bestowed with ample wealth of plant resources therefore, encourages the use of indigenous forms of medicine rather than expensive imported pharmaceutical drugs [4, 5].

Due to the potential impact on human health, the pharmacological properties which are mainly attributed to the active phytochemical contents of these medicines must be scientifically investigated in order to lend credence to their efficacy and potency [6]. Again, it is well established that essential trace elements play a very important role in the formation of active chemical constituents present in medicinal plants and are, in part, responsible for their

medicinal properties [7]. However, adequate quantitative and qualitative knowledge of essential element content in these medicinal plants which follow a dose – response curve as shown in figure 1 is generally lacking.

Figure 1.0: Dose – response curve of every essential element.



Source: [8].

Moreover, recent development of the scavenge for precious minerals (usually gold) through illegal and indiscriminate surface mining popularly termed as "galamsy" which uses toxic chemicals for extraction by the populace within Northern Ghana, leaves much to be desired in the environment. Besides, due to the ever – increasing environmental pollution and industrialization, the World Health Organization (WHO) in a number of resolutions emphasized the need to ensure the quality control of plant products by using modern techniques and applying suitable standards [9]. Also, there is a resurgence of interest in herbal medicine for the treatment of various ailments, predominantly because aside the prohibitive cost of allopathic drugs, their unavailability in remote areas, but the popular belief that, naturally occurring products are without any adverse side-effects [10].

With this background, the present study was undertaken to examine the elemental composition of frequently used (core) medicinal plants for the treatment of various illnesses in Northern Ghana. It is hoped that this study will provide baseline data that will help define the dose rates of these medicinal plants for their safe use. Also, elemental characterization of these medicinal plants will serve as quality assurance for traditional health care. In this regard, various techniques such as Atomic Absorption Spectrometry (AAS), Inductively Coupled Plasma connected to Atomic Emission Spectrometry (ICP – AES) and Mass Spectroscopy (ICP – MS), X – Ray Florescence spectroscopy (XRF) and Instrumental Neutron Activation Analysis (INAA) have been used for the analysis of elements in biological systems. Apart from the high degree of specificity, accuracy and reliability with improved sensitivity of INAA, it has add advantages of been free from reagent blanks corrections, rare interferences, seldom matrix and offers easy sample preparation [11]. Hence, compositional elemental assessment of some core herbal plants used in Northern Ghana by INAA is justified.

MATERIALS AND METHODS

Sampling

The medicinal uses and scientific names of the herbs studied, which were obtained in large municipal market shops of Northern Ghana (Tamale, Bawku and Bolgatanga), are presented in Table 1. About 2 kilograms of each herb were packed into clean polyethylene bags and transported to the Neutron Activation Analysis Centre of the National Nuclear Research Institute (NNRI), at the Ghana Atomic Energy Commission, Accra, Ghana.

Samples and Standard Preparation

At the NNRI, all the samples were milled into fine power using a vibratory dics mill (Retsch RS 100) and then homogenized with a high-speed home- styled blender with stainless steel blades. About five replicates (in the range of 200 -250 mg) of each homogenized sample were accurately weighed onto pre – cleaned polyethylene films wrapped and heat sealed. Standard reference material Peach leave (NIST, 1547) was similarly prepared. All samples and standards were then located in 7 ml polyethylene vials, stack with cotton and heat sealed for irradiation.

Table 1. Classification of herbal plants and their medicinal uses in Northern Ghana

Common name	Scientific name	Parts used	Medicinal uses
Bitter leaf tree	*Vernonia amygdalina*	roots	Stomach, gastrointestinal problems, anti-helminth, anti-malarial, laxative,
Neem	*Azadirachta indica*	bark	tiredness, cough, fever, appetite, worm infestation, wounds, vitiated conditions of kapha, vomiting, skin diseases, excessive thirst, and diabetes
Linn	*Jatropha curcas*	seeds	crawcraw, diuretic, mange, purgative / laxative, rheumatism, ringworm and other skin diseases, vesicant (to raise blisters).
Ginger	Zingiber officinale	rhizome	Analgesic, Blood purifier, Appetizer, Digestive, Stimulant, Sciatica, Asthma, Cough, Rheumatism, Muscular trouble, Chronic bronchitis.
Moringa	*Moringa oleifera*	leaves	Purgative, poultice to sores, headaches, piles, fevers, sore throat, bronchitis, eye and ear infections, scurvy, catarrh, control glucose levels and reduce glandular swelling
Aloe vera	*Aloe barbadensis Miller*	leaves	burns, abrasions, anti-inflammatory agents, peptic ulcer, analgesic, antiviral, anti-bacterial and antifungal

Irradiation and Counting

Irradiation of samples and standard were accomplished via the Pneumatic Rabbit System, operating at a pressure of 0.6 MPa within the inner (No. 2) irradiation channel of Ghana's research reactor, operating at half power. Short, medium and long irradiations schemes were performed in other to determine the varying half – lives of radionuclides present. Decay and counting times were varied depending on their half lives. The radionuclides were assayed for their activities using a computer – based gamma – ray spectroscopy system.

Table 1 Classification of radionuclides based on irradiation time (t_i), half – live ($T_{1/2}$), cooling time (t_d) and counting time (t_c).

Radionuclide	t_i	$T_{1/2}$	t_d	t_c
^{28}Al, ^{52}V ^{27}Mg, ^{49}Ca, ^{37}Cl	30 s – 2 min	2 – 10 min	1 – 5 min	300 s
^{56}Mn, ^{24}Na, ^{42}K, ^{64}Cu, ^{87}Sr,	10 min	min - hours	10 min–1 hr	600 s
^{76}As, ^{122}Sb,	1 hr	hours – days	1 – 2 days	1 hr
^{51}Cr, ^{59}Fe, ^{65}Zn, ^{75}Se	6 hr	days – years	3 days – 1 month	12 hr – 24 hr

RESULTS AND DISCUSSION

The accuracy and reproducibility of the analytical method for this facility has previously been reported by various authors using different analytical standards [5, 6, 13, 14]. It was generally established that the measured elements are mostly within 10% of their certified values indicating a good agreement between these measured values and the reported values from the issuing agencies for these standards. Elemental concentrations in the various herbs studied were calculated using the relative method of standardization in INAA with NIST, 1547 Peach leave as an appropriate multielemental comparator standard. The data from these calculations were statistically evaluated using statistical packages (SPSS version 16 and Microsoft excel 2010) from which graphs were drawn for easy comparison. The results of elemental concentration levels of these herbs are presented in Table 3 as mean values with their associated uncertainties in the measurements expressed as the absolute standard deviation based on five replicates.

Table 3 shows that the core herbal plants general are a good source of most mineral (essential and trace) elements which can be transferred to humans through the food chain on consumption of these plants or their decoctions. Some of these elements from a medical point of view are important constituents of a wide variety of complex pharmacologically active phytochemicals (i.e. lycopense, glulation, aphrodisiac, vitamins, alkaloids, lactones, flavonoids etc.) that could protect the human body from various diseases and help develop defence mechanisms for combating various ailments by boosting the immune system. However no single herb is enriched with all the essential elements. This assessment to a large extend explains, the synergical use of these herbs by traditional medicine practitioners in Northern Ghana for the treatment of various ailments. It therefore shows that a combination of these herbs (plants) hold tremendous promise in providing the variable secondary metabolites and mineral supply that could enhance the curative process of ill health [15].

Table 3: Concentration levels of elements in six different herbal samples analysed by INAA

Elements	*Vernonia amygdalina*	*Azadirachta indica*	*Jatropha curcas*	Zingiber officinale	*Moringa oleifera*	*Aloe barbadensis Miller*
µg/100g						
As	ND	ND	13.76±0.02	5.13±0.01	ND	15.42±0.06
Sb	71.4±5.3	ND	10.8±1.9	23.9±3.5	41.9±7.1	62.0±8.6
Se	25.31±2.01	19.51±1.98	ND	11.39±0.84	21.38±0.72	14.69±0.47
V	53.17±1.41	ND	75.28±3.01	107.36±5.11	36.2±1.24	ND
mg/kg						
Cu	8.75±0.09	12.13±0.36	18.50±1.41	10.03±0.11	16.67±1.04	21.05±1.81
Fe	511.87±7.28	78.59±2.53	53.07±0.97	462.73±6.15	346.31±3.01	173.29±2.04
Mn	129.19±7.11	153.1±.6.0	183.90±7.21	117.66±4.96	97.04±2.52	81.74±1.81
Na	714.4±15.1	571.18±14.32	648.8±14.88	139.8±7.1	658.5±39.8	419.4±12.06
Cr	64.07±2.91	1.09±0.01	ND	ND	13.74±0.63	ND
Zn	61.02±4.12	41.95±2.96	17.98±1.83	35.46±2.01	67.70±3.74	24.63±1.99
mg/g						
K	7.19±0.05	10.52±0.81	1.941±0.011	5.31±0.05	8.41±0.10	3.682±0.026
Mg	1.671±0.013	5.409±0.068	0.827±0.010	2.06±0.04	8.97±0.36	3.13±0.01
P	0.813±0.031	3.94±0.04	3.28±0.03	1.75±0.01	2.49±0.03	0.097±0.003
Ca	2.17±0.03	18.97±0.42	7.521±0.064	14.13±0.36	17.03±0.22	2.69±0.01
Cl	1.11±0.01	0.417±0.007	0.084±0.001	1.041±0.004	0.970±0.003	0.841±0.002

All the herbal samples showed high concentrations of Ca, C1, K, Mg and P with concentrations ranging from Cl (0.084±0.001) mg/g in *Jatropha curcas* (*J. curcas*) to Ca (18.97±0.42) mg/g in *Azadirachta indica* (*A. indica*). Hence, they are the most abundant (major or macro) elements in the leaves, barks, seeds and stem in the herbs. These elemental concentrations are well within range of other medicinal plants reported by other authors [16, 17]. Histographic comparisons of means of these macroelements present in all the herbal samples are shown in figure 2. Figure 2 shows that, out of six samples studied, the mean concentration of Ca, which were of the order of *A. indica*,> *Moringa oleifera* (*M. oleifera*) > *Zingiber officinale* (*Z. officinale*), particularly recorded the highest out of the five macroelements identified.

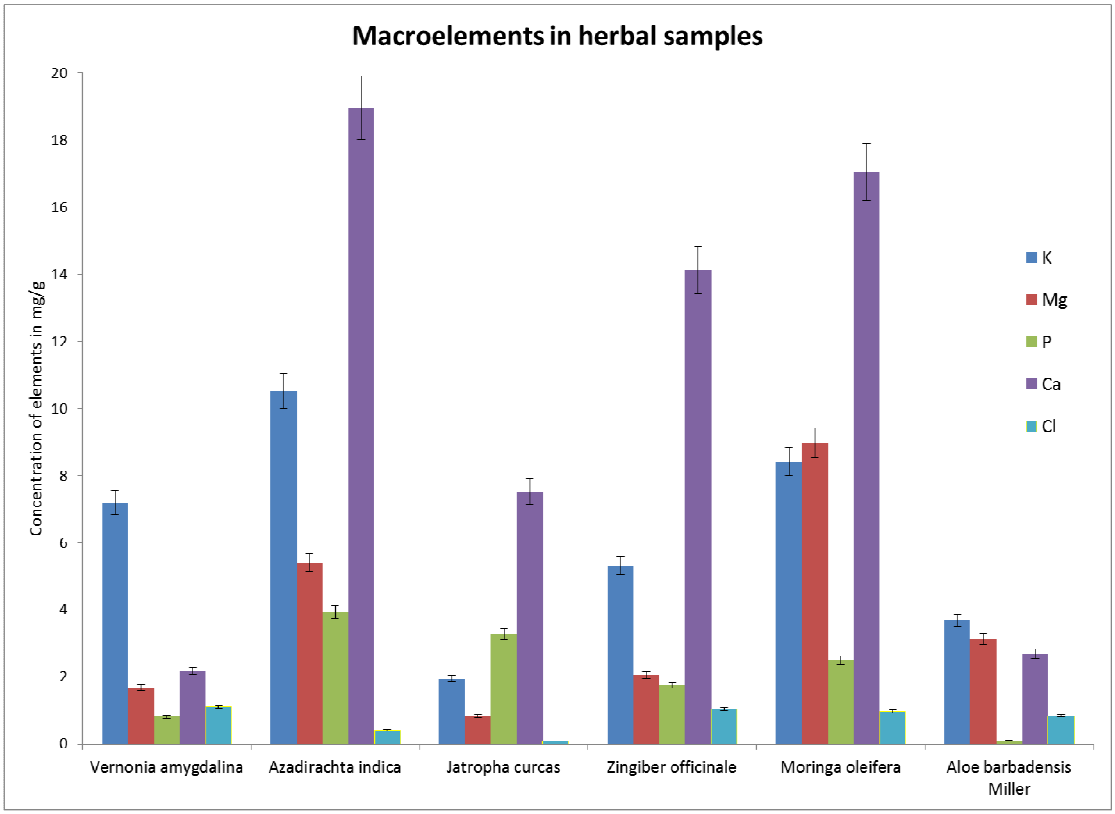


Figure 2. Figure 2 shows varying Macroelemental concentration levels in herbal samples

Ca is required for the absorption of dietary vitamin B, for the synthesis of the neurotransmitter acetylcholine, for the activation of enzymes such as the pancreatic lypase. The recommended daily allowance of Ca for children is between 500 and 1000 mg and for adults 800 mg [18, 19]. It is also the main constituent of the skeleton and also

very important in regulating many vital cellular activities such as nerve and muscle function, hormonal actions, blood clotting and cellular mortality [20]. The decreasing order of the observed K in the herbal samples was *A. indica* > *M. oleifera* > *V. amygdalina* > *Z. officinale* > *Aloe barbadensis Miller* (*A. barbadensis*) > *J. curcas*. K (10.52±0.81) recorded the second highest concentration. It is accumulated within human cells by the action of the Na, K- ATPase (sodium pump) and it is an activator of some enzymes; in particular co-enzyme for normal growth and muscle function [21]. The biological roles for K and Ca are essential for disease prevention and control and may, therefore, contribute to some of the traditional medicinal influences of the plants [15].

The concentration of Mg ranged from 0.827 to 8.97 mg/g while that of P was from 0.097 to 3.94 mg/g. Mg is considered the most important mineral for stress relief. Its chief function in the body includes bone mineralization, building of proteins, and transmission of nerve impulse and maintenance of teeth. Magnesium deficiency results in renal failure, acute diarrhoea and protein–caloric malnutrition [14]. P is primarily an intercellular electrolytic (cation) element that is responsible for maintaining balance in extra-cellular fluid of the human body. Medicinally, P is a source of strength, vitality and it helps in the maintenance of cardiac rhythm. Cl (0.084 – 1.11) mg/g in combination with Na and K are important elements for the maintenance of acid–base equilibrium and of osmotic pressure of body fluids [21].

Again, it can be seen in Table 3 that, concentrations for minor (micro) elements such as Cu, Fe, Mn, Na, Cr, and Zn were found in the medium range of Cr (1.09±0.01) mg/kg in *A. indica* to Na (714.4±15.1) mg/kg in *V. amygdalina*. Similar orders of magnitude of some of elements in other plants were reported by Choudhury et al., [18] and Debrah et al., [6]. Pictorial representations of the means of these microelements are shown in figure 3.

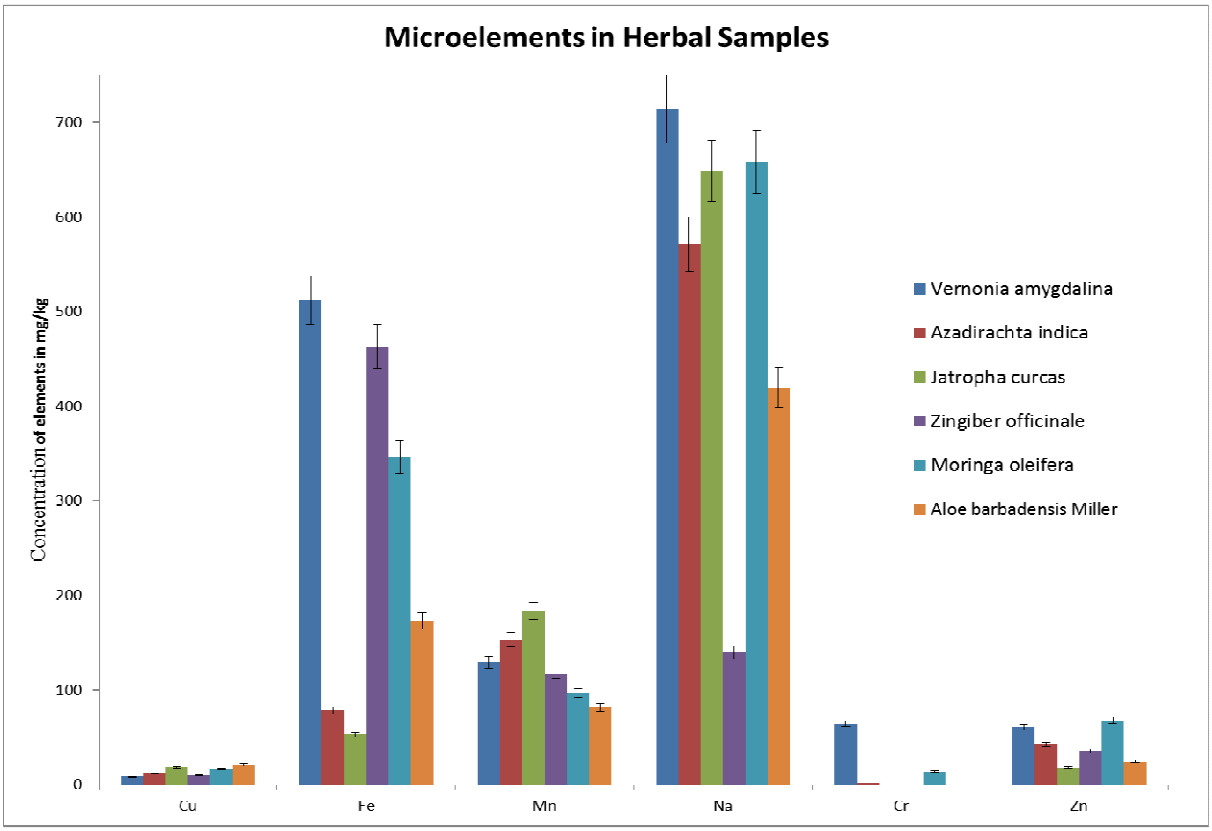


Figure 3: Concentration of Microelements in herbal samples.

Figure 3 portrays that, Na is the predominant element in most of the herbal samples analysed whereas the converse is true for Cu (8.75 – 21.05) mg/kg, Zn (17.98 – 67.70) mg/kg and Cr (1.09 – 64.07) mg/kg which was not detected in *A. barbadensis*, *Z. officinale* and *J. curcas* samples. Zn is involved in the working of genetic materials, proteins, sperm production and development of foetus and pharmacologically responsible for healing of wounds, exhibiting antioxidant properties and immune reactions [22]. Mn (81.74 – 183.90) mg/kg, which was present in appreciable concentrations in most of the samples, is thought to work synergistically with Zn for several important enzymatic processes. These are responsible for reducing nervous irritability and eliminating fatigue [23, 24]. Cu is essential to the human body because it forms an essential component of many enzymatic systems, such as cytochrome oxidase, lysyl oxidase and ceruloplasmin, an iron-oxidizing enzyme in blood.

Cu, V, Fe, Mn and other trace elements may be responsible for the effective treatment of cold, cough, nervine tonic and also enhance body resistance to many diseases [25]. High Fe (511.87±7.28) mg/kg content particularly in *V. amydgalina* could explain the use of this herb in treating stomach and gastrointestinal digestive problems. It is a constituent of haemoglobin, myoglobin and a number of enzymes. However excess intake can lead to Fe toxicity. Cr is asscociated with the maintenance of blood sugar, prevention of arteriosclerosis and control of cholesterol levels. It is also suggested that Cr has a potential beneficial antioxidant effect in patients with type 2 diabetes when combined with Zn and Cu supplements [26].

Arsenic (As) which was not detected in three of the samples (*V. amygdalina*, *A. indica* and *M. oleifera*) was found in traces. From the toxicological point of view, the concentration of Arsenic in the detected herbal samples is below the daily intake tolerance level of 2 µg/day/kg body weight set by the World Health Organization; hence it cannot cause any undesirable effect. Comparatively Sb and Se, which could not be determined in *A. indica* and *J. curcas* samples respectively, were also measured in traces for the other samples. Se (25.31 – 11.39) µg/100g, functions as an antioxidant, quenching of radicals and is important in the formation of glutathione peroxidase. A careful scrutiny of Table 3 shows that these potential toxic elements were also measured in traces. There is however, the need for further research into quantifying other toxic or potentially toxic elements such as Hg, Cd, Ni and Pd in other to establish the safe use of these herbs.

Even though, these elements have been categorized into major, micro and trace elements, all the herbal samples have varying degree of concentrations of the same elements in any category. This variation in elemental concentration can be directly linked to the differences in the mineral composition of the soil in which the plants are grown. Other contributory factors for these variations in the elemental concentrations are attributed to the determining role played by the environmental conditions (type of soil, pollution, industrial region, use of pesticides or fertilizers), climatological conditions and the differential elemental uptake by the respective plants from the soil [18, 27, 28].

CONCLUSION

The essential elements in six herbal samples that are commonly used in Northern Ghana for the treatment of various ailments has been detected and quantified by INAA. Generally, the results showed that, Ca, Cl, P, Mg and K were present in high concentrations in all the herbal samples. Cu, Fe, Mn, Na, Cr and Zn were found in appreciable concentrations while As, Sb, Se and V were present in traces. These elements play very important role in the formation of active chemical constituents present in the herbs samples and are, in part, responsible for their medicinal properties. The results therefore, show that the studied herbal samples are well enriched in various degrees with essential elements for human use. The data obtained in present study which serve as a snapshot of the general practice of traditional medicine within Northern Ghana will be useful in understanding the pharmacological action of medicinal plants, also these data will help in defining the dose rates as well as in the synthesis of modern drugs.

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