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Assessment of Metals Linked to Diabetes in Some Medicinal Plant Seeds from Nigeria with Antihyperglycemic Activity

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ABSTRACT

Mineral and heavy elements are parts of food component that cannot be synthesized within the human body, but are essential for optimal body health condition. The imbalance of essential elements and accumulation of heavy metals in diabetic patients have been linked to pathogenesis of diabetes with adverse numerous effects. Thus, the determination of mineral and heavy metals composition and concentration of plant seeds with anti-hyperglycaemic activity.

This study was designed to determine the levels of both mineral and heavy metals in the 10 medicinal plant seeds. Mineral elements; Na, Mg, K, Ca, Mg, Fe and heavy metals; Ni, Pb, Cd, Cr, Co, Mo, Al and Hg levels were determined in both the seed powders and methanol extractsof Picralima nitida, Croton penduliflorous, Monodora myristica, Cyperus esculentus, Parkia biglobosa, Erythrococca anomala, Butyrospermum paradoxum, Momrodica charantia, and Monodora tenuifolia using Atomic Absorption Spectroscopy (AAS) technique. The analysis revealed varied concentration of the mineral and heavy elements contents in the seed powders and extracts. The order of mineral elements concentration were; K>Ca>Fe>Mg>Na>Zn. Heavy metals levels in the seed powders was in the range of 16.09 ± 0.27 ppm – 4.94 ± 1.17 ppm for Al, the most abundant in the seed powders while Pb (0.41 ± 0.24 ppm – 0.15 ± 0.01 ppm) as the least abundant in the seed powders. Amount of the heavy elements in the seed extracts were found to be below the recommended tolerable weekly intake; Cr (492.8 ppm), Pb (291.2 ppm) and Cd (19.0 ppm). The heavy metals mean concentrations in the seed powders and their extracts were found to be within the permissible levels recommend by WHO. The continuous use of these plant seeds as therapeutic agent or food products may not pose any adverse health risk with daily recommended doses compliance

INTRODUCTION

Metals are inorganic elements that occur naturally and available in very small quantity in the living tissues but are eminent for the essential life process [1]. Some of these metals are required in high quantity in the tissues of the body, thus called macro elements [2] and are needed in daily feed intake with the minimum of 100 mg per each macro elements (magnesium, sodium and potassium) [3]. On the contrary to the macro elements, the daily requirement in the body system is lower than 100 ppm, and therefore called micro-elements [4]. Metals are required for various physiological functions like balancing of water, enzymes cofactors, for muscle contraction and relaxation, pulse transmission through the norms. The normal metabolic functioning of micro elements strictly depends on their normal level within the body tissues [5]. Many studies have reported that imbalance of trace elements can adversely affects islet of pancreas and lead to development of diabetes [6] and generation of reactive oxygen species. The resulting oxidative stress could reduce the gene promoter activityof insulin and MRNA expression in islet cells of pancreas by hyperglycemic condition [7-9].

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In contrast to essential elements, some heavy metals/toxic accumulations have been linked to type 2 diabetes. Industrialization and pollution are potential source of toxic metals to human and to the environment. Toxic metals like lead, nickel, cadmium and arsenic have been implicated in glucose uptake disruption and in alternation of related molecular mechanism in regulation of glucose [10]. Recently, the use of plants and plants parts in medicine have been an upsurge of interested despite the medical and pharmaceutical development. The word's population up till 70-80% still relies on non-conventional medications, mostly chemical substances derived from plant or plant parts [11].

The use of medicinal plants is common in developing countries for primary health care system where synthetic drugs are unaffordable, more so, the availability of traditional medicinal plants is culturally acceptable [12]. In addition, the therapeutic application of medicinal plants always depends on the chemical constituents that often accounted for their effectiveness [13]. However, accumulation of toxic metals in plants is a serious environmental concerns not because of toxic nature of some metals to the plants, but because of rate of heavy metals transfer from the soil into the food chain, and the adverse effects it might cause in human [14]. The quality control of medicinal plants used as food, functional food, nutritional or dietary supplements is very important, not only for herbal medicine safety but for food safety.

Thus, the investigation of both nutritional and toxic metals in plants seeds is required to establish the scientific evidence catering for the herbal medicines. The plant seeds on which this study was conducted on are important medicinal seeds in Nigeria for the treatment of diabetes and other ailment. The level of nutritional and heavy metals in these plants seeds have not be documented scientifically.

MATERIALS AND METHODS

Chemicals

The chemicals and reagents used for this work were of analytical grade, purchased from Sigma Aldrich (USA). Concentrated HCl, concentrated HNO_3, distilled water, deionised water, Con. H_2SO_4, stock solutions of mineral and heavy metals, were employed during the course of the study. The glassware and plastic used were rinsed in diluted HNO_3 and further rinsed with deionised water.

Sample collection and preparation

Seeds of *E. anomala*, *P. nitida*, *M. myristica*, *M. chrantia* and *C. penduliflorous* were bought in the month of July, 2013 from a local market (Bode) in Ibadan, Oyo state. *B. Sapida, B. paradox*, *P. biglobosa* and *C. esculentus* were brought from Saki West LGA of Oyo State in the month of January, 2014 while *M. tenuifolia* seeds were collected from the botanical garden, University of Ibadan, Oyo state. All the seeds were identified at the Herbarium unit of Department of Botany, University of Ibadan, Ibadan. The seeds were cleaned and dried at room temperature, weighed and then grounded to coarse powder using a commercial grinder. The pulverized seeds were weighed and then stored at room temperature (20-25°C) until required for further analysis.

Seed extract preparation

The pulverised seeds of each plant were used for the extraction. This was carried out by weighing 500 g ground plant materials into an aspirator bottles and were soaked with 2.0 L methanol for a week with stirring intermittently on the 7th day, the mixture was filtered under reduced pressure using Buchner funnel connected to the vacuum pump. The filtrates were concentrated using rotary evaporator at a temperature of 40°C and pressure of 626 mmHg, yields were determined and stored in the refrigerator at -4°C until further uses.

Digestion of the Seed Powders and Extracts

The seed powders and seed extracts were digested in 100.0 mL digestion bottles using Khemnani et al. [15] method. 10.0 mL conc. HNO_3 was added into the digestion tubes containing 1.0 g of the samples kept for 24 hrs and then heated at 50°C for additional 4 hrs. The solutions were finally boiled with the mixture of concentrated acids; HCl and HNO_3 in a ratio of 1:5 for additional 4 hrs for the total digestion of all the organic matters and then filtered into 25.0 mL standard flask after cooling. The final volumes of the samples were made up to the mark by the addition of deionized water. An Analyst 700 Atomic Absorption Spectrophotometer, Perkin Elmer (USA) coupled with a computer system installed with WINLAB 32 software was used for both calibration curve preparation and the readings of the absorbance. Different concentrations of the tested metals were prepared from the stock solutions for the preparation of the calibration curves; nitrous gas flame was used for determination of aluminum and molybdenum while acetylene flame was used for others. The working standard solutions of all the metals to be determined were made by diluting the stock solution containing 1000 ppm of each metal.

RESULTS AND DISCUSSION

Mineral Element Composition of the Seed Powders

Mineral elements form a small portion of most plant materials total composition and of total body weight; they of great physiological important in the body metabolism. Many play a vital role in general well-being and the cure of disease. The composition of the element in the seed powders showed that *P. nitida* seed powder contains 98.98 ± 0.05 ppm of potassium as the most abundant followed by calcium (55.89 ± 2.21 ppm), iron (53.62 ± 4.64 ppm), magnesium (19.23 ± 1.53 ppm), zinc (5.92 ppm) and manganese (0.45 ± 0.06 ppm) as the least abundant element **(Table 1)**. Like the seeds of *P. nitida*, potassium was also the most predominant element in the seed powders of *B. paradoxum* and *B. sapida* with the concentrations of 83.99 ± 0.06 ppm and 87.95 ± 1.40 ppm respectively. The seed powder of *B. sapida* have iron (71.12 ± 3.96 ppm) as the next most abundant element followed by calcium (63.88 ± 0.61 ppm) and magnesium (63.88 ± 5.76 ppm) and lastly manganese (2.43 ± 0.03 ppm) while the second most predominant mineral elements in *B. sapida* seed powder was iron (73.15 ± 7.22 ppm) followed by calcium (63.82 ± 0.61 ppm). Concentration of 0.38 ± 0.01 ppm was obtained for manganese as the least abundant mineral elements in *B. sapida* seed powder.

Table 1. Mineral element composition of the seed powders (ppm).

	Seed powders									
Parameters	**PN**	**CP**	**MM**	**CE**	**PB**	**BS**	**EA**	**BP**	**MC**	**MT**
Calcium	55.89 ± 2.21^{cd}	92.76 ± 4.14^{b}	45.96 ± 6.17^{d}	60.37 ± 2.94^{c}	63.88 ± 5.76^{c}	63.82 ± 0.61^{c}	86.38 ± 10.72^{b}	108.35 ± 9.27^{a}	67.20 ± 4.11^{c}	86.79 ± 1.97^{b}
Magnesium	19.23 ± 1.53^{e}	28.64 ± 0.48^{d}	29.23 ± 0.08^{d}	5.54 ± 0.53^{f}	39.58 ± 1.39^{b}	35.29 ± 0.17^{c}	99.13 ± 0.17^{a}	21.88 ± 3.03^{e}	5.164 ± 0.72^{fg}	2.71 ± 0.07^{g}
Potassium	98.98 ± 0.05^{a}	99.180 ± 0.00^{a}	52.94 ± 0.047^{c}	5.06 ± 0.77^{e}	83.99 ± 0.06^{b}	87.95 ± 1.40^{b}	88.17 ± 2.43^{b}	99.07 ± 0.06^{a}	27.78 ± 0.48^{d}	33.19 ± 0.25^{d}
Copper	1.35 ± 0.28^{a}	0.62 ± 0.37^{d}	0.79 ± 0.08^{b}	0.58 ± 0.00^{d}	0.30 ± 0.07^{e}	0.78 ± 0.08^{ed}	0.73 ± 0.04^{cde}	0.21 ± 0.01^{e}	0.57 ± 0.09^{d}	0.63 ± 0.11^{cd}
Sodium	5.00 ± 1.2^{ab}	3.352 ± 0.32^{cde}	4.04 ± 0.26^{bc}	3.74 ± 0.12^{cd}	2.38 ± 0.25^{e}	2.74 ± 0.11^{de}	3.95 ± 0.93^{bc}	2.61 ± 0.62^{de}	5.45 ± 0.51^{a}	3.209 ± 0.47^{cde}
Zinc	5.72 ± 0.18^{b}	7.57 ± 0.36^{a}	2.29 ± 0.37^{d}	1.61 ± 0.06^{e}	2.50 ± 0.06^{d}	3.07 ± 0.19^{c}	1.66 ± 0.15^{e}	2.42 ± 0.13^{d}	2.66 ± 0.30^{cd}	1.80 ± 0.11^{e}
Manganese	0.45 ± 0.06^{a}	0.3 ± 0.02^{cd}	0.22 ± 0.04^{fg}	0.27 ± 0.01^{ef}	0.43 ± 0.03^{ab}	0.38 ± 0.01^{bc}	0.30 ± 0.01^{de}	0.20 ± 0.01^{gh}	0.15 ± 0.01^{h}	0.22 ± 0.01^{fg}
Iron	53.62 ± 4.64^{c}	27.14 ± 3.31^{d}	42.41 ± 4.33^{c}	83.47 ± 6.80^{a}	71.12 ± 3.96^{b}	73.15 ± 7.22^{ab}	49.69 ± 5.18^{c}	29.34 ± 3.04^{d}	48.35 ± 5.44^{c}	26.45 ± 1.77^{d}

Values were expressed as mean ± SD; Values sharing a common superscript in the same column are not significant different at $p<0.05$

Mineral elements concentration in plants could be affected by various factors which include pH, proximity to the external sources of pollution, the soil type and the element nature. The highest calcium concentration was found in *P. biglobosa* (108.35 ± 9.27 ppm). Potassium was the next most abundant in *P. biglobosa* with the valueof 99.07 ± 0.06 ppm followed by iron (29.34 ± 3.04 ppm) and magnesium (21.88 ± 3.03 ppm). The lowest concentrations of manganese (0.21 ± 0.01 ppm) and copper (0.20 ± 0.01 ppm) were recorded for *P. biglobosa* seed powder.

From the **Table 1**, it can be seen that *E. anomala* seed powder has highest concentration of magnesium (99.13 ± 0.17 ppm), follow by potassium (88.17 ± 2.4 ppm), calcium (86.38 ± 10.72 ppm) followed by iron (49.69 ± 5.18 ppm). Manganese was the least abundant element in the seeds of *E. anomala* with the concentration of 0.30 ± 0.01 ppm. In the same way like *P. nitida* and *P. biglobosa* seed powders, the most abundant element in *C. penduliflorous* seed powder was potassium (99.18 ± 0.00 ppm) followed by calcium (92.76 ± 4.4 ppm), Magnesium (28.64 ± 0.84 ppm) and lastly iron (27.14 ± 3.31 ppm). Manganese was the least abundant element in the seed powder of *C. penduliflorous* with concentration of 0.3 ± 0.02 ppm.

The seed powders of *M. chrantia* and *M. tenuifolia* have calcium (67.20 ± 4.11 ppm and 86.79 ± 1.97 ppm) as the most abundant element. Unlike other seeds, iron was the second most abundant element in the seed powder of *M. chrantia* with concentration of 48.35 ± 5.44 ppm while potassium (33.19 ± 0.25 ppm) was the next most abundant in *M. tenuifolia* seed powder after iron. The lowest manganese concentrations were found in *M. chrantia* (0.15 ± 0.01 ppm) and *M. tenuifolia* (0.22 ± 0.01 ppm) respectively. The highest iron concentration was found in *C. esculentus* (83.47 ± 6.08 ppm) followed by calcium (60.37 ± 2.94 ppm) magnesium (5.54 ± 0.53 ppm) and lastly potassium (5.06 ± 0.77 ppm). Manganese (0.27 ± 0.04 ppm) was the least abundant element in *C. esculentus*. The seed powder of *M. myristica* were rich in calcium (45.96 ± 6.17 ppm), potassium (52.94 ± 0.04 ppm) and iron (42.41 ± 4.33 ppm). *M. myristica* was low in copper (0.79 ± 0.08 ppm) and Manganese (0.22 ± 0.04 PPM) respectively. The comparisonof the seeds mineral elements composition revealed that *P. nitida, C. penduliflorous, M. myristica, P. biglobosa, B. sapida* and *E. anomala* seed powders have potassium as the most as the most abundant element. The seed powders also showed high concentrations of calcium, magnesium, iron and sodium.

Mineral Element Composition of the Seed Extracts

Table 2 showed the mineral elements composition of the seed extracts. It was observed that the most predominant elements in all the seed extracts were potassium, calcium and sodium. The values obtained for potassium, calcium and sodium were in the range of (10.01 ± 0.0.48-0.200 ± 0.05 ppm) (4.12 ± 0.00-36.79 ppm) and 1.06 ± 0.07 – 6.15 ± 1.16 ppm respectively.

The highest concentration of iron was found in *P. nitida* seed extracts (3.47 ± 0.00 ppm) followed by *M. chrantia* (0.48 ± 0.10 ppm), *M. tenuifolia* (0.27 ± 0.02 ppm) and lastly *B. sapida* (0.22 ± 0.13 ppm). The seed extract with least abundant of iron was *C. penduliflorous* with the value of 0.03 ± 0.00 ppm. *P. nitida* extract has the highest concentration of copper (1.64 ± 0.24 ppm) followed by *B. sapida* (0.31 ± 0.19 ppm). *M. myristica* and *M. tenuifolia* extracts have the same copper concentration of 0.26 ± 0.01 ppm. *M. charantia* was found to have the least concentration of copper (0.13 ± 0.02 ppm) **(Table 2)**. The concentrations of manganese and zinc in *M. charantia* seed extracts were in the range of (0.54 ± 0.06-0.10 ± 0.02 ppm) and 0.08 ± 0.00-0.93 ± 0.09 ppm) respectively. Poor glycaemia control in diabetes, alters the level some of the essential micro elements like Zn, Mg, Mn, Cr and Fe by increasing the urinary excretion and their concomitant decrease in the blood. Metallic contents regulation in the body is a pre-requisite for their normal [5].

Table 2. Mineral element composition of the seed extracts (ppm).

	Seed extracts									
Parameter	**PN**	**CP**	**MM**	**CE**	**PB**	**BS**	**EA**	**BP**	**MC**	**MT**
Calcium	17.13 ± 0.47^{bc}	4.120 ± 0.00^{d}	17.700 ± 0.18^{ab}	16.90 ± 0.15^{bc}	9.04 ± 0.52^{cd}	14.66 ± 0.55^{bc}	24.30 ± 0.76^{b}	14.66 ± 0.55^{bc}	12.195 ± 0.96^{cd}	36.79 ± 1.97^{a}
Magnesium	4.64 ± 0.57^{b}	0.69 ± 0.04^{e}	3.29 ± 0.19^{c}	2.11 ± 0.83^{d}	6.20 ± 0.45^{a}	3.08 ± 0.50^{c}	0.94 ± 0.10^{e}	1.07 ± 0.13^{e}	0.66 ± 0.01^{e}	0.71 ± 0.71^{e}
Potassium	9.97 ± 0.05^{a}	0.92 ± 0.0.38^{e}	0.37 ± 0.10^{g}	0.20 ± 0.05^{h}	0.57 ± 0.0.10^{f}	9.01 ± 0.68^{b}	10.01 ± 0.48^{a}	8.97 ± 0.01^{b}	7.98 ± 0.04^{c}	5.98 ± 0.10^{d}
Copper	1.640 ± 0.24^{a}	0.18 ± 0.02^{a}	0.26 ± 0.04^{a}	0.20 ± 0.02^{a}	0.21 ± 0.02^{a}	0.314 ± 0.19^{a}	0.41 ± 0.05^{a}	0.22 ± 0.00^{a}	0.13 ± 0.02^{a}	0.26 ± 0.01^{a}
Sodium	1.06 ± 0.07^{c}	1.199 ± 0.26^{c}	1.34 ± 0.26^{c}	2.15 ± 0.27^{b}	1.66 ± 0.04^{c}	1.61 ± 0.11^{c}	6.15 ± 1.16^{a}	1.10 ± 0.00^{c}	3.45 ± 0.51^{b}	1.71 ± 0.24^{c}
Zinc	0.93 ± 0.09^{a}	0.08 ± 0.00^{e}	0.15 ± 0.03^{de}	0.24 ± 0.06^{cde}	0.24 ± 0.05^{cde}	0.30 ± 0.02^{b}	0.24 ± 0.00^{cde}	0.19 ± 0.01^{cd}	0.26 ± 0.10^{bc}	0.18 ± 0.01^{cde}
Manganese	0.12 ± 0.00^{a}	0.10 ± 0.02^{a}	0.10 ± 0.04^{a}	0.54 ± 0.06^{a}	0.17 ± 0.01^{a}	0.15 ± 0.07^{a}	0.11 ± 0.20^{a}	0.53 ± 0.06^{a}	0.07 ± 0.01^{a}	0.12 ± 0.01^{a}
Iron	3.47 ± 0.00^{a}	0.03 ± 0.03^{f}	0.15 ± 0.02^{c}	0.17 ± 0.03^{e}	0.170 ± 0.05^{e}	0.22 ± 0.13^{d}	0.15 ± 0.01^{e}	0.15 ± 0.01^{d}	0.48 ± 0.10^{b}	0.27 ± 0.02^{cd}

Values were expressed as mean ± SD; Values sharing a common superscript in the same column are not significant different at *p<0.05*

Heavy Element Composition of the Seed Powders

On the contrary to the nutritional elements composition of the seed powder, analysis of the toxic elements in the seed powders showed that metals concentration were not above the normal range for the standardization and safety of medicinal plants. In all the plant seeds, aluminum, molybdenum, and chromium were found to be the most abundant with concentrations range of (11.12 ± 0.24-4.94 ± 1.17 ppm), (4.29 ± 0.01-1.26 ± 0.25 ppm) and (14.01 ± 6.00-2.03 ± 0.01 ppm) respectively **(Table 3)**. The values obtained for lead, cobalt and silver in this study for all the seed samples were low and in the range of (0.41 ± 0.24-0.15 ± 0.01 ppm) for lead, (0.80 ± 0.00-0.6 ± 0.01 ppm) for cobalt and (0.22 ± 0.25-0.02 ± 0.00 ppm) for silver.

Table 3. Heavy element composition of the seed powders (ppm).

	Seed powders									
Parameters	**PN**	**CP**	**MM**	**CE**	**PB**	**BS**	**EA**	**BP**	**MC**	**MT**
Lead	0.25 ± 11^{bc}	0.21 ± 0.04^{b}	0.20 ± 0.00^{bcd}	0.25 ± 0.02^{bc}	0.27 ± 0.01^{b}	0.18 ± 0.01^{cd}	0.41 ± 0.24^{a}	0.38 ± 0.01^{a}	0.39 ± 0.03^{a}	0.15 ± 0.01^{d}
Cobalt	0.21 ± 0.00^{a}	0.80 ± 0.00^{a}	0.12 ± 0.01^{ef}	0.07 ± 0.00^{fg}	0.60 ± 0.01^{g}	0.14 ± 0.02^{de}	0.64 ± 0.02^{b}	0.06 ± 0.01^{g}	0.15 ± 0.05^{de}	0.18 ± 0.01^{bc}
Chromium	2.51 ± 1.39^{ef}	14.07 ± 0.00^{b}	8.91 ± 1.09^{c}	7.42 ± 0.31^{d}	3.08 ± 0.11^{e}	25.97 ± 0.66^{a}	3.01 ± 0.26^{ef}	3.40 ± 0.14^{e}	2.03 ± 0.01^{f}	3.04 ± 0.01^{ef}
Cadmium	3.29 ± 0.02^{a}	0.92 ± 0.01^{b}	0.08 ± 0.01^{d}	0.17 ± 0.01^{bc}	0.17 ± 0.02^{bc}	0.16 ± 0.00^{bc}	0.56 ± 0.05^{bb}	0.17 ± 0.01^{bc}	0.14 ± 0.01^{bc}	0.50 ± 0.13b^{cd}
Silver	0.14 ± 0.01^{c}	0.37 ± 0.00^{ab}	0.06 ± 0.01^{abc}	0.11 ± 0.00^{c}	0.02 ± 0.00^{b}	0.05 ± 0.01^{c}	0.50 ± 0.01^{a}	0.02 ± 0.02^{c}	0.01 ± 0.00^{c}	0.22 ± 0.25^{bc}
Nickel	4.70 ± 0.21^{a}	1.85 ± 0.04^{d}	2.33 ± 0.04^{c}	2.07 ± 0.09^{cd}	0.51 ± 0.08^{f}	3.17 ± 0.27^{b}	0.04 ± 0.00^{fg}	0.17 ± 0.01^{g}	1.42 ± 0.04^{e}	2.00 ± 0.01^{d}
Aluminum	4.94 ± 1.17^{d}	16.06 ± 0.27^{a}	7.45 ± 0.60^{cd}	10.14 ± 0.24^{bcd}	13.99 ± 1.27^{ab}	8.38 ± 1.22^{bcd}	16.35 ± 0.30^{a}	11.12 ± 0.24^{abc}	9.14 ± 0.55^{bcd}	5.16 ± 0.47^{cd}
Molybdenum	2.72 ± 0.10^{cd}	2.99 ± 0.14^{d}	2.55 ± 0.01^{de}	4.29 ± 0.01^{a}	3.72 ± 0.07^{b}	3.47 ± 0.18^{b}	3.04 ± 0.17^{d}	4.40 ± 0.13^{a}	2.37 ± 0.04^{e}	1.26 ± 0.25^{f}

Values were expressed as mean ± SD; Values sharing a common superscript in the same column are not significant different at *p<0.05*

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Heavy Element Composition of the Seed Extracts

Table 4 showed the results of heavy elements contents of the seed extracts. The present study showed that concentration of lead was prominent in *B. sapida* (0.18 ± 0.02 ppm) and found in minimum concentration in *M. tenuifolia* (0.05 ± 0.00 ppm). Lead was not detectable in *P. nitida*, *C. penduliflorous*, *M. myristica*, *P. biglobosa* and *E. Anomala*. Cadmium concentration was only detectable in *P. biglobosa* (0.18 ± 0.19 ppm) in trace amount. Silver was not detectable in all the seed extracts. The average concentration of molybdenum was 0.40 ± 0.3 ppm in *M. myristica* and 0.420 ± 0.35 ppm in *C. esculentus*. Molybdenum was not detectable in the rest of the seed extracts.

Table 4. Heavy element composition of seed extracts (ppm).

	Heavy metals concentration in seed extracts									
Metals	**PN**	**CP**	**MM**	**CE**	**PB**	**BS**	**EA**	**BP**	**MC**	**MT**
Lead	ND	ND	ND	0.15 ± 0.00^{a}	ND	0.18 ± 0.02^{a}	ND	0.15 ± 0.01^{a}	0.16 ± 0.06^{a}	0.05 ± 0.00^{b}
Cobalt	0.07 ± 0.05^{a}	0.05 ± 0.00^{ab}	0.07 ± 0.04^{a}	0.05 ± 0.00^{ab}	0.08 ± 0.00^{a}	0.07 ± 0.02^{a}	0.08 ± 0.03^{a}	0.07 ± 0.02^{a}	0.02 ± 0.02^{a}	0.08 ± 0.16^{a}
Chromium	0.06 ± 0.05^{a}	0.02 ± 0.01^{b}	0.03 ± 0.02^{ab}	0.03 ± 0.00^{ab}	0.04 ± 0.00^{ab}	0.04 ± 0.10^{ab}	0.03 ± 0.01^{ab}	0.04 ± 0.01^{ab}	0.03 ± 0.08^{ab}	0.04 ± 0.10^{ab}
Cadmium	ND	ND	ND	ND	0.18 ± 0.19	ND	ND	ND	ND	ND
Silver	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Nickel	1.51 ± 0.06^{a}	0.93 ± 0.10^{d}	1.36 ± 0.14^{b}	1.07 ± 0.12^{c}	0.22 ± 0.02^{f}	1.16 ± 0.13^{c}	0.02 ± 0.01^{g}	0.06 ± 0.00^{g}	0.72 ± 0.02^{e}	0.82 ± 0.04^{de}
Aluminum	0.82 ± 0.06^{bcd}	0.52 ± 0.01^{e}	0.64 ± 0.01^{cde}	0.73 ± 0.54^{bcde}	0.57 ± 0.00^{de}	0.88 ± 0.31^{bc}	0.68 ± 0.03^{cde}	0.75 ± 0.09b^{cde}	1.01 ± 0.20^{b}	1.37 ± 0.26^{a}
Molybdenum	ND	ND	0.400 ± 0.37^{a}	0.420 ± 0.35^{a}	ND	ND	ND^{b}	ND	ND	ND

Values were expressed as mean ± SD of triplicate experiments; Values sharing a common superscript in the same column are not significantly different at *p<0.05*

The cobalt and chromium concentrations in the seed extracts were in trace amount. The obtained value for cobalt was in the range of 0.02 ± 0.02-0.08 ± 0.02 ppm while chromium was in the range of 0.02 ± 0.01-0.06 ± 0.05 ppm. Nickel was found to be abundant in *P. nitida* (1.51 ± 0.06 ppm) followed by *M. myristica* (1.36 ± 0.14 ppm), *B. sapida* (1.16 ± 0.13 ppm) and *C. esculentus* (1.07 ± 0.12 ppm). *E. anomala* was found to be having the least value of nicked (0.02 ± 0.01 ppm) while aluminum concentration was found to be in the range of (0.57 ± 0.00-1.37 ± 0.26 ppm). Environmental factors which include season of sample collection, the plant age, atmosphere and pollution and condition of soils in which the plant grows have great effects on the concentration of elements which varies from plant to plant region to region. Extraction process also determines the amount of these metals contents in the extracts.

DISCUSSION

Mineral elements determination in plants is very essential since the quality of numerous foods and medicines depends on the type and content of the mineral and heavy elements. The therapeutic role of metals in human health has started gaining the attention of scientists and nutritionist [6]. Thus, necessitating absolute estimation of these mineral and heavy elements in the seeds and the seed extracts. Many studies have reported some essential metals imbalance adverse effect on pancreatic islet and development diabetes [6]. The imbalance of the essential metals also manifested production of reactive oxygen species (ROS) during diabetes [6]. Magnesium is the most abundant macro elements which is required for the activity of more than 300 enzymes for their important physiological functions in the human body [16]. Glucose homeostasis, nerve transition, DNA and RNA productions are involved by enzymes containing Mg [16], thus deficiency of magnesium might lead to a decrease in insulin mediated glucose uptake [17]. However, supplementation of Mg prevents insulin resistance and also reduces the risk of diabetes development [18]. Mn function in several enzymes as a cofactor with those involved in production of bone marrow, and carbohydrates protein and fats metabolism [19]. Mn also serves as pyruvate carboxylase cofactor that plays a role in different types of in the conversion of non-carbohydrate compounds into glucose through gluconeogenesis for their next use. Mn is required for normal synthesis of insulin, secretion and its metabolism alteration which has been implicated in diabetes development. Cu is also an essential mineral, which is required for various biological functions. It involves in catalytic activity of superoxide dismutase (SOD) that part takes in the cells protection from superoxide radicals [20]. The imbalance of Cu is implicated in cholesterol elevation by the disruption of normal high density lipoproteins (HDL) and low density lipoproteins (LDL) balance. Deficiency in Cu has also been reported as the cause for the development of cardiovascular diseases [21]. Zn is a trace element that is essential for normal cell processing for examples, cell division and apoptosis Zn also involves in many biochemical pathways like transcription, translation and cell divisions [22]. Zn also plays a role in insulin secretion and storage which increases the glucose uptake [23].

Cr biological activity depends on its valence state and the type of valences it forms [24,25]. Cr in trivalent form has high biological activity necessary for glucose optimal uptake by cell. Cr also regulates blood glucose and insulin levels through stimulation of insulin signal pathway and metabolism by up-regulating glucose transporter (GLUT4) translocation in muscle cells [26]. Deficiency of Cr results in the blood glucose levels elevation and Cr persisted for long period, may result into diabetes development [27].

Accumulation of some toxic metals; Pb, Nickel, Cd and As have also been identified in diabetes patients to cause disruption of the glucose up take and alteration of related molecular mechanism in glucose regulation. Toxic metals deposition in the tissues are non-degradable, therefore, if metals remain for a long period in the tissues; its elimination often difficult. Tissues have certain levels of metals tolerance, and beyond the threshold limits tissues get destroyed as a result of the metal toxicity [28].

CONCLUSION

In this study conducted on the assessments of nutritional and heavy elements composition of some plant seeds with antidiabetic activity showed that, the amount of the nutritional elements in the seed powders and extracts found not to be above WHO limit and thus, could serve supplements for their deficiency in the body. Heavy metals determined in the plants seeds were cadmium, aluminum, lead, chromium, silver, nickel, mercury and molybdenum; their concentrations were found to be below the tolerance level recommend by the WHO. This study provides scientific evidence of the safety of these medicinal plant seeds grown in different parts of Nigeria and further strengthens the use of the medicinal plant seeds for food or herbal products preparation for the control of diabetes and its pathogenesis complications.

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CONFLICTS OF INTEREST

There was no conflict of interest between all the authors regarding the publication of this article.

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