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Comparative Phytochemical, Antinutrient and Trace Metal Composition of the Leaf, Flower and Seed of *Moringa oleifera* L. Grown in Southern Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Author KR designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors ED and UU managed the analyses of the study. Author UU managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Secondary metabolites, proximate, anti-nutrients, mineral and trace metals distribution in three parts (leaf, flower and seed) of *Moringa oleifera* L. grown locally in Akwa Ibom State, Southern Nigeria were investigated and compared using standard analytical procedures. The three plant parts indicated the presence of different secondary metabolites. Saponins, terpenoids, alkaloids and glycoside were common to the three plant parts at varying levels of abundance. Proximate results (% dry weight) of the plant parts indicated the following ranges: moisture (13.65 ± 0.54 – 35.23 ± 0.05); ash (3.13 ± 0.30 – 6.54 ± 0.01); crude fibre (8.59 ± 0.02 – 14.12 ± 0.01); crude lipids (3.10 ± 0.00 – 6.18 ± 0.02) and crude protein (5.15 ± 0.01 – 10.25 ± 0.03). Anti-nutrient profile (mg/100g DW) of the three plant parts recorded the following ranges: phytate (5.30 ± 0.03 – 9.60 ± 0.70); HCN (0.04 ± 0.00 – 1.01 ± 0.00) and oxalate (0.40 ± 0.01 – 0.82 ± 0.02). The mineral

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composition showed that among the mineral elements investigated, *Moringa oleifera* leaf was the richest in iron, zinc and sodium than the flower and seed, the flower was the richest in magnesium, while the seed was found to be the richest in calcium and potassium. The trace metal composition indicated mean ranges (mg/100 g DW) as follows: (0.005 – 0.008) Cd, (0.012 – 0.003) Pb, (1.210 – 2.202) Ni, (0.180 – 0.256) Cu, (1.401 – 1.684) Cr, and Mn (0.977 – 1.105). The results of the trace elements obtained were within acceptable limit stipulated by the World Health Organization for plants. Antinutrient analysis of the extracts indicated low levels of phytic acid, oxalates, and hydrocyanides below the lethal doses. These results, therefore, validate the various ethnomedicinal uses of the leaf, flower and seed of *Moringa oleifera* in the treatment of many diseases.

Keywords: Antinutrient; phytochemistry; trace metal; composition; Moringa oleifera.

1. INTRODUCTION

The use of plants or plant-derived substances in the area of traditional and modern medicines as well as a food supplement has long been established. Medicinal plants are now becoming very interesting owing to their versatile competency and the fact that they contain some natural products which produce definite physiological action on the human body. These compounds (bioactive substances) include tannins, alkaloids, carbohydrate, terpenoids, steroids and flavonoids and are said to be non-essential to the plant producing them in most cases [1]. It has been reported that many of these secondary metabolites found in plants have vital roles as a mediator of ecological interaction, that is, they function in ensuring a continued survival of a particular organism in certain hostile environments where there is competition with other organisms [2].

The plant *Moringa oleifera* is a small graceful, deciduous tree with sparse foliage, often resembling a leguminous specie at a distance, especially when in flower, but immediately recognized with fruit. The leaf is usually 90 cm long with opposite pinnae, spaced about 5 cm apart and the flower is usually produced throughout the year in regions with more constant seasonal temperatures and with constant rainfall. It can grow well in the humid tropics or hot dry lands and can survive destitute soils. The plant provides a rich and rare combination of zeatin, quercetine, β-sitosterol, caffeoyquinic acid and kaempferol [3-4]. The flower contains nine amino acids, sucrose, D-glucose, traces of alkaloids and other secondary metabolites [5].

Various parts of this plant like leaf, root, seed, flower and immature pods have been reported for their various medicinal benefits. These range from anti-inflammatory [6-7], anti-asthmatic [8], analgesic [9-10], antipyretic [11], antihypertensive, diuretic and cholesterol lowering [12-14], antioxidant [15-17,5], antitumor activity [18], antispasmodic and antiulcer activities [19-20] and as cardiac and circulatory stimulants [21-22], among others.

It has been established that the quantitative and qualitative phytochemistry of plants from the same family is usually different [23]. The chemical composition of plants usually varies with season, geographical region, nutrient-content of soil where they are planted, environment, growing conditions and plant physiology. In Nigeria, *Moringa oleifera* plant has a wide acceptance and has been used for several purposes.

Although several reports exist on the phytochemistry of this plant, sourced from Nigeria and elsewhere but no attempt has been made at a comparative assessment of phytochemicals present in the leaves, flowers and seeds of *Moringa oleifera*. Therefore, the present study presents an evaluation of the variations in qualitative, quantitative phytochemistry and trace metal composition of the leaves, flowers and seeds of *Moringa oleifera* locally grown in Idu village, Uruan Local Government Area in Akwa Ibom State, Southern Nigeria.

2. MATERIALS AND METHODS

2.1 Plant Material

The fresh leaves, flowers and seeds of *Moringa oleifera* used in this study were harvested from *Moringa* plant locally planted in Idu village, Uruan Local Government Area, Akwa Ibom State, Southern Nigeria, in September 2017. Plant parts were identified and authenticated by a taxonomist in the Department of Botany and Ecological Studies, University of Uyo, Nigeria.

The Voucher Specimen (No. 223902) have been deposited at the Herbarium of the Department of Botany and Ecological Studies, University of Uyo, Uyo, Nigeria.

2.2 Sample Preparation and Extraction

The leaf, flower and seed were separated, washed, shade-dried and reduced to powder using an electrical grinder (Binatone BLG-402, China) to increase the surface area of the sample during extraction. The pulverized sample materials (2 kg each) were exhaustively macerated with 10L of 75% (v/v) ethanol for 72 h at room temperature. The liquid mixtures obtained were filtered, and the filtrate concentrated under reduced pressure in a rotary evaporator (WG-EV311-V, Wilmad-LabGlass, USA) at 40°C until they became completely dry. The extracts were stored in a sealed container and kept in a refrigerator at 4°C until analysis.

Samples for trace elements determination were dried in an oven at a temperature of 105°C for 6 hours to eliminate water and other liquids. The samples were then desegregated to fine sizes using an electrical grinder (Binatone BLG-402, China) and the resulting powdered samples were sieved mechanically to obtain fractions that are approximately 60 µm. They were then stored in a polyethene bag and put in an airtight container for digestion and atomization. All reagents and chemicals used in this study were of analytical grade (AnalaR) and were sourced from Sigma-Aldrich Chemical Company, United Kingdom.

2.3 Proximate Analyses

These analyses were undertaken to determine the moisture, ash, crude fibre, fat and crude protein content in the leaves, flowers and seeds of *Moringa oleifera* The moisture content of *M. oleifera* leaves was determined by drying the leaves in an oven (Gallenkamp OV-330, UK) at 105 °C until a constant weight was obtained [24] (method 14:004). The percentage moisture content was derived from the equation:

$$Moisture\ (\%) = \frac{W_2 - W_3}{W_2 - W_1} \times 100$$

Where,

W_1 = Initial weight of empty crucible,
W_2 = Weight of crucible + sample before drying,
W_3 =Final weight of crucible + sample after drying

Total ash was determined by Furnace incineration described by [24] (method 14:006) using about 1.0 g of oven-dried sample. This analytical method is based on the vaporization of water and volatiles by burning organic substances in the presence of oxygen in the air to CO_2 at a temperature of 550°C for 5 hours. The % ash content was calculated as:

$$Ash\ (\%) = \frac{Weight\ of\ Ash}{Weight\ of\ Original\ Sample} \times 100$$

Crude fibre was determined using the method of [24] (method14:020). The percentage of crude fiber was determined as per the formula:

$$Crude\ fibre\ (\%) = \frac{Weight\ after\ drying}{Weight\ of\ Sample} \times 100$$

Crude protein content was evaluated by converting the nitrogen content determined by Kjeldahl's method (6.2 N). Fat was determined by the method described elsewhere [24] using the Soxhlet system. The carbohydrate content was estimated as the difference obtained after subtracting the values of the organic protein, fat, ash and fiber from the total dry matter. The calorific value of the sample was obtained by multiplying the values of the crude protein, lipid and carbohydrate by 4, 9 and 4 respectively and taking the sum of the products.

2.4 Mineral Analysis

Mineral digestion was done following the method earlier reported [25]. The concentrations of calcium, magnesium, iron and zinc were determined using an atomic absorption spectrophotometer (AAS Unicam 919) in conjunction with reference mineral standards from Unicam Limited, United Kingdom. The flame photometer (PFP7/C, Jenway Limited, UK) was used for determination of potassium concentration in the extract.

2.5 Phytochemical Analysis

Phytochemical tests to identify the constituents of the extract were performed using standard procedures outlined by previous co-workers [26-27]. Precisely, screening of alkaloids was carried Dragendroff's and Mayer's reagents, saponins by Frothing and Fehling's tests. Liebermann's and Keller-Killiani's tests detected cardiac glycosides, tannins by the Ferric chloride test and phlobatannins by hydrochloric acid test. Flavonoids were detected by the magnesium

metal/hydrochloric acid test, triterpenes by the chloroform/acetic anhydride/sulfuric acid test and anthraquinones by the benzene/ammonia solution test.

Quantitative determination of alkaloids was by the method of Harborne [26], saponin by the method used by Obadoni and Ochuko [28] and cardiac glycosides was performed using the Buljet's reagent as described by El-Olemy and co-workers [29]. Briefly, for alkaloids, 5 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 h. This was filtered and the extract was concentrated on a water bath to one-quarter of the original volume. Concentrated ammonium hydroxide was added dropwise to the extract until the precipitation was complete. The whole solution was allowed to settle and the precipitated was collected and washed with dilute ammonium hydroxide and then filtered. The residue is the alkaloid, which was dried and weighed.

For saponins, exactly 100 cm^3 of 20% aqueous ethanol was added to 5 grams of the plant sample in a 250 cm^3 conical flask. The mixture was heated over a hot water bath for 4 hours with continuous stirring at a temperature of 55 ^{0}C. The residue of the mixture was re-extracted with another 100 cm^3 of 20% aqueous ethanol after filtration and heated for 4 hours at a constant temperature of 55°C with constant stirring. The combined extract was evaporated to 40 cm^3 over a water bath at 90°C. 20 cm^3 of diethyl ether was added to the concentrate in a 250 cm^3 separator funnel and vigorously agitated from which the aqueous layer was recovered while the ether layer was discarded. This purification process was repeated twice. 60 cm^3 of n-butanol was added and extracted twice with 10 cm^3 of 5% sodium chloride. After discarding the sodium chloride layer the remaining solution was heated in a water bath for 30 minutes, after which the solution was transferred into a crucible and was dried in an oven to a constant weight. The saponin content was calculated as a percentage of the weight of the plant sample.

In the case of cardiac glycosides, 1 g of the powdered sample was soaked in 100 ml of 70% alcohol for 2 hrs before filtration. Using lead acetate and Na_2HPO_4 solution, the obtained extracts were purified before the addition of freshly prepared Buljet's reagent. The difference between the intensity of colors of the experimental and blank samples (distilled water and Buljet's reagent) gave the absorbance, which is proportional to the concentration of glycosides.

2.6 Antinutrient Analysis

The composition of oxalate was determined using the method outlined by Sanchez-Alonso and Lachica, [30] and hydrocyanic acid by that of AOAC [24]. Phytic acid was determined by a method put forward by McCance and Widdowson [31].

2.7 Data Handling

All analyses were done in triplicate and values obtained were expressed as the mean ± standard error of the mean (Mean ± SEM).

3. RESULTS AND DISCUSSION

3.1 Results

The results of the qualitative and quantitative phytochemical analyses of leaves, flowers and seeds of *Moringa oleifera* are shown in Tables 1 and 2, while those of the proximate composition and mineral element composition are shown in Tables 3 and 4. Also, results of the levels of anti-nutrients, as well as trace metals in the leaves, flowers and seeds of *M. oleifera*, are shown in Tables 5 and 6 respectively.

3.2 Discussion

3.2.1 Phytochemical analysis

The result of phytochemical analysis of leaves, flowers and seeds of *Moringa oleifera* (Table 1) indicates the presence of medicinally active constituents in all the plant parts studied. Anthraquinones, phlobatannins and tannins are absent in the leaves, flowers and seeds of *M. oleifera.* This is in contrast to previous findings from *Moringa oleifera* leaves from Malaysia which was found to contain tannins and phlobatannins [32] Alkaloids, cardiac glycosides and terpenes/steroids are present in all the three plant parts being investigated. While flavonoid is present in the flowers and seeds of *M. oleifera* only, deoxy sugar and carbohydrate are found only in the leaves and seeds of the plant and not in the flowers. The medicinal properties of these bioactive compounds are quite numerous and have been well documented [33-37].

Table 1. Contents of phytochemicals in the leaf, flower and seed extract of *Moringa oleifera*

Phytochemical	Tests/reagents	Detection		
		Leaf	Flower	Seed
Alkaloids	Dragendroff's	+	+	+
	Mayer's	+	+	+
Anthraquinones	Benzene/ammonia solution	-	-	-
Flavonoids	Magnesium metal, HCl	-	+	+
Cardiac glycoside	Liebermann's	+	+	+
	Keller-Killiani's			
Terpenes/steroids	Chloroform, H_2SO_4 acid	+	+	+
Phlobatannins	HCl acid solution	-	-	-
Saponins	Frothing	+	+	+
	Fehling's tests	+	+	+
Tannins	Ferric chloride solution	-	-	-
Deoxy sugar	Glacial acetic acid	+	-	+
Carbohydrate	Molish	+	-	+

Table 2. Quantitative determination of some bioactive compounds in the leaf, flower and seed extract of *Moringa oleifera*

Phytoconstituents	Concentration (mg/100 g)		
	Leaf	Flower	Seed
Alkaloids	0.09 ± 0.00	0.25 ± 0.00	0.19 ± 0.00
Cardiac glycosides	0.12 ± 0.00	0.22 ± 0.00	0.21 ± 0.00
Saponins	0.35 ± 0.01	0.72 ± 0.00	0.46 ± 0.01
Terpenoids	1.68 ± 0.03	2.32 ± 0.04	1.91± 0.05

Each value represents mean ± SEM of three determinations analyzed individually in triplicate

Table 3. Proximate composition of leaf, flower and seed of *Moringa oleifera*

Parameters (%)	Leaf	Flower	Seed
Moisture	35.23 ± 0.05	21.82 ± 1.02	13.62 ± 0.54
Ash	6.54 ± 0.01	3.13 ± 0.30	4.04 ± 0.04
Crude fibre	11.21 ± 0.02	14.12 ± 0.01	8.59 ± 0.11
Crude lipids	5.23 ± 0.02	3.10 ± 0.00	6.18 ± 0.02
Crude protein	9.63 ± 0.01	5.15 ± 0.01	10.25 ± 0.03
Carbohydrate	32.16 ± 0.03	52.68 ± 0.05	57.32 ± 0.06
Calorific value (Kcal/KJ)	214.23/896.34	259.22/1084.58	325.90/1363.57

Each value represents mean ± SEM of three determinations analyzed individually in triplicate on dry weight (DW) basis

Table 4. Levels of anti-nutrients in leaf, flower and seed extract of *Moringa oleifera*

Antinutrients (mg/100 g DW)	Leaf	Flower	Seed
Phytate	5.30 ± 0.03	7.32 ± 0.03	9.60 ± 0.70
HCN	0.04 ± 0.00	0.09 ± 0.00	1.01 ± 0.00
Oxalate	0.40 ± 0.01	0.61 ± 0.01	0.82 ± 0.02

Values are mean ± SEM calculated as mg/100 g dry weight analyzed individually in triplicate

The result of the quantitative phytochemical determination shows that the flowers of *M. oleifera* are the richest in alkaloids (0.25 mg/100g), cardiac glycosides (0.22 mg/100g), saponins (0.72 mg/100g) and terpenoids (2.32 mg/100g) compared to the other two plant parts (flower and seed) studied. The amount of alkaloids present in the leaf (0.09 mg/100g) was lower than 0.36 mg/100g obtained in a similar determination from *M. oleifera* leaves from Malaysia [32].

Table 5. Levels of mineral elements in leaf, flower and seed extract of *Moringa oleifera*

Mineral (mg/100 g DW)	Leaf	Flower	Seed
Calcium	184.98 ± 1.87	136.34 ± 0.01	216.62 ± 1.23
Iron	254.45 ± 2.00	98.11 ± 0.02	132.34 ± 0.55
Magnesium	143.32 ± 1.04	154.32 ± 0.40	104.56 ± 1.10
Potassium	43.64 ± 0.63	38.21 ± 0.13	47.12 ± 0.05
Zinc	37.32 ± 0.20	14.19 ± 0.01	28.03 ± 0.10
Sodium	21.02 ± 0.32	8.05 ± 0.04	15.90 ± 0.03

Values are mean ± SEM calculated as mg/100 g dry weight analyzed individually in triplicate

Table 6. Levels of trace elements in leaf, flower and seed extract of *Moringa oleifera*

Trace elements (mg/100 g DW)	Leaf	Flower	Seed
Cadmium	0.008 ± 0.001	0.006 ± 0.002	0.005 ± 0.001
Lead	0.003 ± 0.000	0.024 ± 0.001	0.012 ± 0.000
Nickel	2.202 ± 0.010	1.392 ± 0.040	1.210 ± 0.010
Copper	0.256 ± 0.003	0.182 ± 0.013	0.180 ± 0.000
Chromium	1.504 ± 0.020	1.684 ± 0.001	1.401 ± 0.100
Manganese	1.105 ± 0.001	1.128 ± 0.020	0.977 ± 0.012

Values are mean ± SEM calculated as mg/100 g dry weight analyzed individually in triplicate

Generally, these findings indicate that more phytochemical constituents are in abundance in the flower and closely followed by the seed. This may be attributed to the fact that the flower and the seed of *M. oleifera* are good storage organs of these mentioned bioactive compounds and that in most cases, maximum accumulation of chemical constituents occurs at the time of flowering and subsequent seed formation than during leaf formation. The presence of these bioactive compounds in the leaves, flowers and seeds strongly corroborates the various pharmacological activities of this plant and supports its widespread use in traditional medicine.

3.2.2 Proximate composition

The proximate composition of the leaf, flower and seed of *M. oleifera* is given in Table 3. The result indicates mean (% dry weight) ranges of (13.62 – 35.23); (3.13 – 6.54); (8.59 – 14.12); (3.10 – 6.18) and (5.15 – 10.25) for moisture content, ash, crude fibre, crude lipids, and crude protein respectively, while the result for calorific value (Kcal/KJ) records a range of 43.31 - 98.45. These ranges are quite different from the values (% dry weight) of 8.52, 7.99, 2.10, 22.44 and 17.99 obtained for moisture, ash, crude fat, crude protein and crude fiber content found in the leaves of *M. oleifera* from Bangkok, Thailand [38]. The result indicates that *M. oleifera* leaf has the highest value (35.23%) for moisture content while the least value for moisture content (13.62%) is obtained for the seed. This result is far higher than 7.5% obtained for leaf and 4.0% for the seed of *M. oleifera* sourced from Gong Badak area Terrengganu, Malaysia [39]. High moisture content recorded by the leaf when compared to other parts of the plant indicates that the leaf is more prone to deterioration than other parts (seed and flower) since food with high moisture contents is prone to perishability [40].

The ash result indicated that the leaf recorded the highest (6.54%), while the flower recorded the lowest (3.13%). The high ash content seen in the leaf showed a reflection of the mineral content preserved in the leaf. Crude fibre content which is the insoluble residue of an acid hydrolysis followed by an alkaline one reveals that *M. oleifera* flower had the highest (14.12%), while the seed part recorded the least value (8.59%).

The results for crude lipids are generally low with the seed having the highest value of 6.18% while the least value of 3.10% is found for the flower. Lipids provide very good sources of energy and aids in the transport of fat soluble vitamin, insulates and protects internal tissue and contribute to important cell processes [41]. The highest protein content of 10.25% is found for *M. oleifera* seed which is closely followed by the leaf (9.63%) and finally the flower with 5.51%. The level of carbohydrate was highest in the seed (57.32%) while the least value (32.16%) was found in the leaf of the plant. The calorie value (kcal) has been found to be in the order: leaf

(214.23) < flower (259.22) < seed (325.90). The variation in the proximate compositions of different parts (leaf, flower and seed) of *M. oleifera* can be explained in terms of disparities in food and water translocation rates, stage of development and maturity of the plant parts among others.

3.2.3 Anti-nutrient composition

Levels of hydrogen cyanide, oxalate, and phytic acid in the leaf, flower and seed extract of *Moringa oleifera* were generally low and are given in Table 4.

The content of hydrogen cyanide (mg/100g) was in the order: seed (1.01) > flower (0.09) > leaf (0.04). Interestingly, these values are well below the lethal dose of 35 mg/100 g [42]. Also, the quantity of total oxalate in the extract follows a similar trend in abundance with *M. oleifera* seed having the highest amount (0.82 mg/100 g). These values are below the toxic level of 2-5 g/100 g [43]. Oxalates are known to complex with calcium to form calcium crystals which get deposited as stones and are associated with blockage of renal tubules [36].

The level of phytic acid follows the trend of abundance observed for hydrogen cyanide and oxalate. The highest amount (9.60 mg/100 g) was found in the seed while the least amount (5.30 mg/100 g) was observed in the leaf. Phytic acid is the major phosphorus storage compound in African leafy vegetables [44]. Although phytic acid is an antioxidant, it has been shown to inhibit absorption of minerals. Phytic acid chelates multivalent metal ions such as zinc, calcium and iron, thus it is a strong inhibitor of iron-mediated free radical generation [45]. The disadvantage of this is that a diet high in phytate content reduces the bioavailability of zinc, iron and calcium and has adverse effects on the digestion of proteins and starches [46]. It is an established fact that most of these toxicants are eliminated during processing and cooking [47].

3.2.4 Mineral element and trace metal composition

The Mineral element composition of leaf, flower and seed of *Moringa oleifera* is given in Table 5. This result indicates that the leaf, flower and seed to be a cheap source of sodium, calcium, magnesium, potassium, iron and zinc. It also shows that *Moringa oleifera* seed records the highest calcium content (216.62 mg/100 g), the leaf gives the highest iron content (254.45 mg/100 g) and the flower gives the richest magnesium content (154.32 mg/100 g). Other mineral elements studied also show variations in their amounts. This shows that mineral uptake (mineral transportation) which involves active transport of ions within plant parts are different and are said to be influenced by environmental factors such as aeration and temperature. There has been no established fact about which part of a plant accumulates more minerals as it is a function of several factors including the physiology of the plant. Earlier findings have implicated mineral elements in many significant health-promoting functions within the human body [48-49] and thus, consumption of *M. oleifera* might play useful roles in optimizing their availability and utilization.

The results for the concentration of trace metals (cadmium, lead, nickel, copper, chromium and manganese) in *M. oleifera* leaf, flower and seed are presented in Table 6. The results indicate mean ranges (mg/100 g DW) as follows: 0.005 – 0.008) Cd, (0.012 – 0.003) Pb, (1.210 – 2.202) Ni, (0.180 – 0.256) Cu, (1.401 – 1.684) Cr, and (0.977 – 1.105) Mn. From the results, *M. oleifera* leaf recorded highest concentration of cadmium, lead, nickel and cobalt followed by the flower and then the seed. In terms of copper and manganese content, the flower of *M. oleifera* recorded the highest concentration followed by the leaf and then the seed. The leaf records the highest concentration of trace elements followed by flower and then seed which can be explained by the fact that absorption of nutrients (including trace elements) and photosynthesis activities usually occur in the leaves. The results of trace elements obtained in this study are within the acceptable limit for Cu (3 – 15 mg/kg); Pb (1 – 5 mg/kg), Mn (1 – 50 mg/kg); Cd (1 – 5 mg/kg); Cr (1 – 10 mg/kg) stipulated by the World Health Organization (WHO) for plants. The results for Pb (0.003), Cu (0.256), Cr (1.504) and Mn (1.105) for leaf and seed [Pb (0.012), Cu (0.180), Cr (1.401) and Mn (0.977)] obtained in this study agree, though they differ slightly with Pb (0.065), Cu (0.070), Cr (0.054) for leaf and Mn (0.065), Pb (0.027), Cu (0.233), Cr (0.018) and Mn (0.016) for seed earlier reported [50] for *M. oleifera* grown around a mechanic workshop in Ibadan, Western Nigeria. The slight variation in the concentration of the trace metal is a function of the physical and chemical nature of soil where the plant was planted and can be altered by innumerable environmental and human factors.

4. CONCLUSION

The results of this study have shown variations in the phytochemical, proximate, antinutrient, mineral and trace element composition of the leaf, flower and seed of *Moringa oleifera*. These results clearly showed that the leaf, flower and seed contain an appreciable amount of carbohydrate, protein, fibre and lipid in addition to some mineral elements. The results of the trace elements obtained in this study are quite low and within the acceptable limit. The low levels of antinutrients– phytic acid, oxalates and hydrocynides suggest that the consumption of leaf, flowers and seeds of *M. oleifera* is not harmful and therefore not expected to produce any adverse health effects. The presence of some phytochemicals which have great pharmacological significance supports the ethnomedicinal use of this plant in the treatment of diseases. This study, therefore, concludes that *Moringa oleifera* leaf, flowers and seed can contribute significantly to the human nutritional requirements, while also offering adequate protection against some diseases.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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