Comparison of metal content in seeds of *Moringa ovalifolia* and *Moringa oleifera*

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The study aimed at determining the minor and major elements present in seeds of *Moringa ovalifolia* and *Moringa oleifera*. The seeds were air-dried after collection, then ground to a fine powder and digested with acids in a microwave system prior to analysis by inductively coupled plasma optical emission spectroscopy (ICP-OES). The concentration of different elements in *M. ovalifolia* seeds such as Ca, K, Fe, Ni, Cu, Mn, Co and Cd varied (P<0.05) amongst the 3 sites were sampled. However, no significant difference (P>0.05) in the concentrations of elements such Mg, Li, Ba, Si, Al, Na and Zn was observed between sites. Potassium (K) was found to be present in highest amounts at all sites with average concentration of 7938 mg/kg while Li (10.78 mg/kg) had the lowest concentration. This study showed that the content of some metals in *M. ovalifolia* seeds varied depending on geographical sites. Both *M. ovalifolia* and *M. oleifera* seeds are a good source of important minerals and need to be explored further for use as supplements and ready source of dietary minerals in animal and human food.

Key words: Elemental analysis, Inductively Coupled Plasma Optical Emission Spectroscopy, macronutrients,

INTRODUCTION

In many developing countries, the supply of minerals is inadequate to meet the mineral requirements of farm animals and rapidly growing population (Anjorin et al., 2010). Minerals are essential in animal feed and human nutrition. Minerals cannot be synthesized by animals and humans but are provided from plants or mineral-rich
There are 13 known species in the Moringaceae family and *M. oleifera* is the most widely studied and cultivated as a multi-purpose tree (Ramachandran et al., 1980). The only endemic southern Africa Moringa species is *Moringa ovalifolia* which is distributed from central-southern Namibia to south-western Angola (Dyer, 1975). Moringa seeds have a number of benefits. For instance, they contain iron and amino acids in addition to anti-inflammatory and antiseptic properties (Padayachee and Bijnath, 2012).

Determination of minerals and trace elements is important in enhancing production efficiency in plants and foods (Rodriguez et al., 2011). Some of the trace elements, which include iron, manganese, zinc and copper, are essential micronutrients with a variety of biochemical functions in all living organisms (Hicsonmez et al., 2012). Different elements have many functions in plant growth and development. Metal ions, including iron, zinc and copper, are required for catalytic and structural properties of many proteins and are therefore essential for growth and development of all organisms. Essential elements also play a major role in nerve transmission, blood circulation, cellular integrity, energy production and muscle contraction (Belay and Kiros, 2014). However, excessive amounts of these metals, or of non-essential metals such as cadmium (Cd) and lead, are toxic and inhibit plant growth (Guo et al., 2008).

The macronutrients are distinguished between two sub groups, major ones and secondary ones. The nutrients like nitrogen (N), phosphorus (P) and potassium (K) are referred to as the major macro-elements, and calcium (Ca), magnesium (Mg), and sulfur (S) are the secondary ones. The micronutrients, which are needed only in trace amounts, are iron (Fe), manganese (Mn), boron (B), zinc (Zn), copper (Cu), molybdenum (Mo), chloride (Cl), sodium (Na), nickel (Ni), silicon (Si), cobalt (Co) and selenium (Se) (Ronen, 2007; Pakade et al., 2013). Micronutrients are important just like macro-elements. Plant performance is crucially dependent on adequate supply of all elements including those that are demanded in relatively small quantities (Ronen, 2007).

The aim of the study was to compare the mineral content present in *M. ovalifolia* and *M. oleifera* seeds. Elements found in the seeds were divided in two categories, namely major (Ca, K, Mg and Na) and minor (Ba, Cd, Co, Li, Mn, Si, Al, Zn, Cu, Ni and Fe) elements. To the best of the authors’ knowledge, no such comparative study of the two species has been done before and the elemental composition of *M. ovalifolia* seeds is yet to be reported.

**MATERIALS AND METHODS**

**Chemicals and reagents**

Nitric acid (HNO₃) and hydrogen peroxide (H₂O₂) were purchased from Sigma Aldrich (Johannesburg, South Africa). Ultra-pure water from a Milli-Q Millipore purification system (MA, USA) was used in the experiment.

**Instruments**

Metal content were analyzed using inductively coupled plasma optical emission spectroscopy (ICP-OES) (Spectro Genesis, Spectro, Germany). Before metal analysis, samples were digested using the microwave instrument (Anton Par, Switzerland).

**Sample collection**

*M. oleifera* seeds were collected from one of the biggest and oldest Moringa farms in Limpopo Province, South Africa. *M. ovalifolia* seeds were collected in Namibia from the following areas: Moringa Farm (designated as area A, which is 40 km west of Okahandja, Okjozondjupa region), Halali (designated as area B, situated in Etosha National Park, Kunene region), and in Tsumeb (designated as area C, Oshikoto region). A map of Namibia showing the collection areas is provided in Figure 1. Samples were collected in paper bags.

**Preparation of samples**

Dry seeds were deshelled and the resulting kernels were ground into fine powder using a pestle and mortar. Samples were kept in a cool dry place until use.

**Microwave digestion of seeds for metal analysis**

The method by Pakade et al. (2013) was used. A mass of 0.1 g ground seed powder was placed in a microwave digestion vessel and concentrated nitric acid (8 mL) and hydrogen peroxide (2 mL) were added. Digestion was carried out for about 30 min in the microwave. After digestion, the samples were transferred to a 25 mL volumetric flask and made up to volume with deionised water. The solutions were directly analysed for metal content using ICP-OES and results were expressed as mg/kg of dry weight.

**Data analysis**

The experiments were carried out in triplicates and results presented as mean ± standard deviation (SD). Normality of the data was tested using Kolomongorov-Smirnov test and the normally distributed data was analyzed by ANOVA and means were compared with a post-hoc Scheffe multiple comparison test, using SPSS™ for windows® version 18. All analyses were done at confidence interval (CI) = 95%, α = 0.05.

**RESULTS AND DISCUSSION**

**Comparison of metal content in *M. ovalifolia* and *M. oleifera* seeds from different sites**

Both minor elements: (Ba, Cd, Co, Li, Mn, Si, Al, Zn, Cu, Ni, Fe) and major elements (Ca, K, Mg and Na) were present in seeds of *M. ovalifolia*. The concentrations of...
minor elements in the two Moringa species are shown in Table 1, while that of major elements are shown in Figure 1. Similar types of elements were detected in *M. oleifera*. Among the micro nutrients, barium (Ba) had the lowest concentration (1.5-2.1 mg/kg) at all three sites of *M. ovalifolia*. This was followed by Co and Cd. Fe had the highest concentration among the micronutrients (62.7-84.7 mg/kg) and this is followed by the Zn (59.1-63.9 mg/kg) and Al (23.2-28.4 mg/kg). There was no significant difference (P>0.05) in site concentrations of Ba, Li, Si, Al, and Zn, whereas there was a significant difference (P<0.05) in Fe, Ni, Cd, Mn, Co and Cu concentrations at different sites. Cd concentration at site A (6.2 mg/kg) was significantly higher (P<0.05) to sites B (3.9 mg/kg) and C (3.9 mg/kg). There was a lower concentration of Co from site C (1.92 mg/kg) compared to sites A (3.4 mg/kg) and B (3.8 mg/kg). Site C had a higher concentration of Mn (26.5 mg/kg) compared to site A (17.7 mg/kg) and B (18.8 mg/kg). This illustrates that the concentration of some of these individual micro nutrients varied according to the site.

The concentration of K was highest in all sites compared to other elements (average of 6399.9 mg/kg) among the macro nutrients (Figure 2). This might be because potassium is generally found in the highest concentration in plants and is the third most abundant mineral in the human body. Except for N, the plants require more potassium than any other nutrient. Thus, its mobility in the plant allows it to influence almost all aspects of plant growth. Potassium increases crop yield and improves quality, it increases root growth and improves drought resistance (Armstrong et al., 1998). Ajayi (2008) reported that seeds were good sources of mineral elements. The study by Ajayi (2008) revealed that potassium as the most prevalent mineral element with concentration of 2470 and 1680 ppm in *Artocarpus heterophyllus* and *Treculia africana*, respectively. Mg is the second highest macronutrient in the seeds followed by Ca and Na.

The variation observed in some metal concentration of *M. ovalifolia* seeds may have been due to either different genetic makeup of the plants or more probably due to
Table 1. Concentration (mg/kg; dry weight) of minor elements in *M. ovalifolia* and *M. oleifera* seeds from different sites (Mean ± SD of 3 replicates are presented).

<table>
<thead>
<tr>
<th>Elements</th>
<th><em>M. ovalifolia</em> Site A (Moringa Farm)</th>
<th><em>M. ovalifolia</em> Site B (Halali)</th>
<th><em>M. ovalifolia</em> Site C (Tsumeb)</th>
<th><em>M. oleifera</em> Limpopo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ba</td>
<td>2.1±0.1</td>
<td>1.5±0.1</td>
<td>1.5±0.1</td>
<td>1.9±0.4</td>
</tr>
<tr>
<td>Cd</td>
<td>6.2±0.3</td>
<td>4.0±0.9</td>
<td>4.0±0.1</td>
<td>3.7±0.1</td>
</tr>
<tr>
<td>Co</td>
<td>3.4±0.2</td>
<td>3.8±0.1</td>
<td>1.9±0.4</td>
<td>2.8±0.3</td>
</tr>
<tr>
<td>Li</td>
<td>10.9±0.1</td>
<td>10.8±0.1</td>
<td>10.8±0.1</td>
<td>10.8±0.1</td>
</tr>
<tr>
<td>Mn</td>
<td>17.7±0.2</td>
<td>18.8±0.1</td>
<td>26.5±1.0</td>
<td>21.2±0.2</td>
</tr>
<tr>
<td>Si</td>
<td>12.6±0.1</td>
<td>13.9±0.4</td>
<td>13.3±0.6</td>
<td>16.6±0.7</td>
</tr>
<tr>
<td>Al</td>
<td>28.4±2.6</td>
<td>25.8±1.5</td>
<td>23.2±0.8</td>
<td>16.0±0.9</td>
</tr>
<tr>
<td>Zn</td>
<td>59.1±0.9</td>
<td>63.9±0.4</td>
<td>65.5±0.3</td>
<td>64.0±1.2</td>
</tr>
<tr>
<td>Cu</td>
<td>29.8±0.4</td>
<td>29.0±0.2</td>
<td>12.5±0.3</td>
<td>7.5±0.4</td>
</tr>
<tr>
<td>Ni</td>
<td>27.4±1.0</td>
<td>11.1±1.4</td>
<td>19.2±1.2</td>
<td>38.8±6.4</td>
</tr>
<tr>
<td>Fe</td>
<td>84.7±2.2</td>
<td>79.1±0.2</td>
<td>62.7±0.7</td>
<td>93.9±5.1</td>
</tr>
</tbody>
</table>

Figure 2. Comparison of concentration of major elements in seeds of *M. ovalifolia* from different sites in Namibia (Site A, B and C) and *M. oleifera* (from Limpopo, South Africa). Means (±SE) of three replicates are presented. Mean with the same letters were not significantly different from each other (p<0.05).

Among the micronutrients, there were no significant differences in the concentrations of Ba, Li, Zn, Si and Co in the seeds of the two species (Table 1). There were significant differences in the concentrations of Cd, Mn, Cu,
Among the macronutrients, there was no significant difference in the concentration of K of the two species (Figure 3) but there were significant differences in the concentration of Ca, Mg and Na. However, the general trends of the micro- and macro-nutrients elements in the seeds of the two Moringa species were the same. Elements that are highest in M. 

ovalifolia were also highest in M. oleifera and vice versa. M. ovalifolia seeds had higher concentrations of the following elements: Ca (2428 mg/kg), K (6400 mg/kg), Mg (3975 mg/kg), Cu (29.8 mg/kg) and Al (28.4 mg/kg) than that of M. oleifera. M. oleifera seeds have higher concentrations of Si (16.5 mg/kg), Fe (93.9 mg/kg), Na (545.2 mg/kg) and Ni (38.8 mg/kg) compared to M. ovalifolia. A study by Anjorin et al. (2010) reported that Ca and Mg were relatively higher in M. oleifera leaves and seeds from Nigeria. However, this study also showed high content of Ca and Mg in M. oleifera (South Africa) and M. ovalifolia (Namibia) seeds. This indicates that Moringa seeds are good source of Ca and Mg, and hence they can be used in farm animals or humans as food. Some people cook and eat flesh Moringa pods, especially M. oleifera, that contain seeds as a source of food. This practice should thus be encouraged as these may prove to be a good source of much needed micro- and macro- nutrients.

Comparison of metal content with normal levels

The Cd, Cu, and Zn concentrations in the seeds were compared to the deficient, normal and phytotoxic levels (Table 2). The concentrations of these metals in M. ovalifolia and M. oleifera seeds is within the normal levels. Therefore, according to this analysis, the Moringa seeds in this study are fit for human consumption. Although levels of trace elements in the soil are much higher (Pakade et al., 2013), there is little accumulation in the biomass to reach phytotoxic levels. This is important for human consumption of Moringa seeds as food.

Conclusion

This study showed that some metal content of M.
ovalifolia seeds varies depending on geographical location (sites). Both M. ovalifolia and M. oleifera seeds are a good source of important minerals and needs to be explored further for use as a supplement and ready source of dietary minerals in animal and human food. There was a significant variation in micronutrients and macroelements in M. oleifera and M. ovalifolia seeds for some elements but also some did not show significant differences. This might be attributed to the variable uptake of minerals by the plants and variable agro-ecologies of the different regions. M. oleifera is the most well-known of the genus and its given recognition as a multipurpose tree. However, more studies needs to be done on M. ovalifolia for its potential as food and medicinal plant.

Conflict of Interests

The authors have not declared any conflict of interests.

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