Comparison of Eleven Heavy Metals in *Moringa Oleifera* Lam. Products

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Eleven heavy metals in various products of *Moringa oleifera* were analyzed to determine eleven heavy metals (Al, As, Cd, Cr, Cu, Fe, Pb, Mn, Hg, Ni, and Zn) using Inductively Coupled Plasma-Mass Spectrometry. The products of *M. oleifera* were purchased in Nakhon Pathom, Thailand. All products were digested with nitric acid solution before determining the concentrations of heavy metals. The recoveries of all heavy metals were found to be in the range of 99.89-103.05%. Several criteria such as linearity, limits of detection, limits of quantification, specificity, precision under repeatability conditions and intermediate precision reproducibility were evaluated. Results indicate that this method could be used in the laboratory for determination of eleven heavy metals in *M. oleifera* products with acceptable analytical performance. The results of analysis showed that the highest concentrations of As, Cr, Hg, and Mn were found in tea leaves while the highest concentrations of Al, Cd, Cu, Fe, Ni, Pb, and Zn were found in leaf capsules. Continuous monitoring of heavy metals in *M. oleifera* products is crucial for consumer health.

Key words: *Moringa oleifera*, Heavy Metals, Products, Leaves, ICP-MS

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*Moringa oleifera* Lam. (family, *Moringaceae* and genus, *Moringa*) is a useful Thai plant. The leaf extracts have hypocholesterolemic[1] and hypolipidemic effects[2]. Additionally, the leaves have been reported to have antioxidant[3], hypoglycemic[4], and antiatherosclerotic activities[5]. The seed extracts showed antispasmodic, antiinflammatory and diuretic activities[6,7]. Furthermore, the seed extract has been shown to have ameliorative effect on liver fibrosis in rats[8]. A recent study of the nutritional value of *M. oleifera* leaves found that the dried leaves are composed of amino acids such as alanine, threonine, tyrosine, methionine, valine, phenylalanine, isoleucine, leucine, histadine, lysine, tryptophan, and cystine, fatty acids such as α-linolenic acid, heneicosanoic acid, γ-linolenic acid, palmitic acid, and capric acid, and several minerals such as calcium, phoshorus, magnesium, potassium, sodium, sulphur, zinc, copper, manganese, iron and selenium. Moreover, the leaves also reported to consist, vitamin A, vitamin E, β-carotene, fiber, condensed tannins, and polyphenols[9]. The phytochemical investigation for bioactive compounds of *M. oleifera* seeds showed the presence of glycosides such as 4-alpha-L-rhamnosylxy-benzylglucosinolate, niazimicin and niazirin, beta-sitosterol and moringa oil[8]. In summary, the nutritional characterization of leaves and seeds from *M. oleifera* indicated that they are rich in nutrients and possess some medicinal properties. Therefore, leaves and seeds of *M. oleifera* were prepared for herbal medicines, dietary supplements, and functional drinks.

The popular uses of leaves and seeds from *M. oleifera* raise the question about safety and health of their products, especially due to the heavy metal concentrations. Daily exposure to heavy metals above the permissible limits has been associated with mental retardation, cancer, neuropathy, hepatic dysfunction and renal failure[10]. Our previous studies concerning the simultaneous analysis of heavy metals have

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**Short Communications**

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The popular uses of leaves and seeds from *M. oleifera* raise the question about safety and health of their products, especially due to the heavy metal concentrations. Daily exposure to heavy metals above the permissible limits has been associated with mental retardation, cancer, neuropathy, hepatic dysfunction and renal failure[10]. Our previous studies concerning the simultaneous analysis of heavy metals have

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determined the concentrations of eleven heavy metals including aluminum (Al), arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), lead (Pb), manganese (Mn), mercury (Hg), nickel (Ni), and zinc (Zn) in raw leaves and leaf capsules of *Moringa oleifera* Lam. by using Inductively Coupled Plasma-Mass Spectrometry (ICP-MS)\(^{[11,12]}\). The results indicate that the concentrations of Al, As, Cd, Cr, Hg, Mn, Ni, and Pb in all samples of raw leaves as well as those of Al, As, Cr, and Hg in all samples of leaf capsules were within permissible limits and normal ranges. In contrast, the concentrations of Fe in all samples of raw leaves as well as those of Cu, Fe, and Zn in all samples of leaf capsules were higher than permissible limits. Furthermore, the concentrations of Cu and Zn in some samples of raw leaves as well as those of Cd, Mn, Ni, and Pb in some samples of leaf capsules were also higher than permissible limits and normal ranges. The overall conclusion is that samples of leaf capsules showed higher concentrations of Cd, Cu, Fe, Mn, Ni, Pb, and Zn compared to those in samples of raw leaves. Therefore, the present study was aimed at investigating the concentrations of those heavy metals in several commercial products made from leaves and seeds of *M. oleifera*. Finally, the results are compared with our previous reports.

The ultrapure water ASTM type I, 18.3 MΩ·cm resistivity, obtained by purifying distilled water with the TKA GenPure UltraPure Water Machine (TKA Wasseraufbereitungssysteme GmbH, Germany) was used for preparing all solutions. Nitric acid, an analytical reagent grade (lot K40352656 935), used for digestion was purchased from Merck, Darmstadt, Germany. An ICP multi-element standard solution XIII (Lot HC813513, Agilent, USA) was diluted with 5% v/v nitric acid solution. Working standard solutions of heavy metals were freshly prepared. All glassware and plastic bottles were cleaned by soaking with 20% v/v nitric acid solution for at least 24 h and rinsed several times with 5% v/v nitric acid solution to eliminate surface contamination.

Samples of *M. oleifera* products (n=35), tea leaves, dried seeds, leaf capsules, leaf powders, and functional drinks were purchased from several selected occasional markets and grocery stores in Amphoe Mueang, Nakhon Pathom province, Thailand, during the period Sep 2011 to Mar 2012. All samples were kept in the Department of Pharmaceutical Chemistry, Faculty of Pharmacy, Silpakorn University, Nakhon Pathom, Thailand. The dried samples were stored in a desiccator while the samples of functional drinks were stored in dry condition at room temperature in well-closed containers.

The samples of tea leaves and dried seeds were grounded separately with an IKA MF-10 Microfine Grinding Mill (Werke GmbH and Co. KG, Germany), equipped with a 0.5 mm pore size sieve and high-grade stainless steel grinders. All powder samples were stored in a desiccator to protect them from moisture before digestion. The sample digestion procedure was performed according to previous reports\(^{[11,12]}\). Approximately 1 g of each sample was digested by adding 10.0 ml of 60% v/v nitric acid solution in a 100 ml Pyrex beaker covered with watch glass on a hot plate at 120-130°C. This mixture was heated until the solution was fully digested and clear. The clear digested solution was allowed to cool and then filtered. The digested filtrate was diluted to appropriate concentration with ultrapure water. The resulting digestate was analyzed using ICP-MS. All samples were digested in triplicate. The resulting concentrations for all samples were calculated by determining the average of the triplicate measurements.

The concentrations of eleven heavy metals including Al, As, Cd, Cr, Cu, Fe, Hg, Mn, Ni, Pb, and Zn in resulting digestates were analyzed by an ICP-MS spectrometer (Model 7500 ce, Agilent). The operating conditions and acquisition parameters are given in Table 1. Prior to analysis, instrument optimization was performed using standard solutions. The calibration curves were prepared from an ICP multi-element standard solution XIII by diluting with 5% v/v nitric acid solution and storing as stock solutions. Working standard solutions were prepared daily in 5% v/v nitric acid solution.

| TABLE 1: ICP-MS OPERATING CONDITIONS AND ACQUISITION PARAMETERS |
|-------------------------------------------------------------|
| Parameter                  | Value              |
| Auxiliary gas flow        | 0.89 L/min         |
| Plasma gas flow           | 15 L/min           |
| RF power                  | 1500 W             |
| Mass range                | 7-208 amu          |
| Total acquisition time    | 260 s              |
| MS analytical settings    | 20 sweeps/reading  |
|                          | 1 reading/3 replicate |
|                          | 3 replicates       |

ICP-MS: Inductively coupled plasma-mass spectrometry, RF: radio frequency
Heavy metal results from the ICP-MS were quantified against standard curves generated from one blank (0 µg/l) and six different concentrations of standard reference solutions run separately. Quality control was assessed by running a laboratory reagent blank once after every five samples. The concentrations of eleven heavy metals were expressed in mg/kg of samples. The validation parameters such as linearity, limits of detection (LODs), limits of quantification (LOQs), specificity, precision under repeatability conditions and within-laboratory reproducibility were examined. The procedures were performed under the European Standard for the analyses of heavy metals[13,14]. The validation of an analytical method was carried out to ensure reliability of the results. The results of regression analysis on calibration curves are presented in Table 2. Linearity was determined from the regression plots by the least squares method. The correlation coefficients ($r^2$) of all calibration curves were between 0.9990 and 0.9998, showing good linear relationships over the ranges of heavy metal concentrations. Reagent blank determinations were used to correct the instrument readings.

As shown in Table 3, the precision was expressed by the relative standard deviations (RSD) for $n=10$. The intraday repeatability (RSD, 0.126 to 0.843%) and interday reproducibility (RSD, 0.351 to 1.204%) exhibited the good precision. The LODs, LOQs, and recoveries of all heavy metals are shown in Table 4. The recovery and reproducibility of the method was estimated by spiking several already analyzed samples with varied concentrations of standard solutions of heavy metals and processed as previously described. The recoveries of all heavy metals were between 99.89 and 103.05%. The recoveries and RSDs listed were acceptable. This method is a useful tool for rapid determination of eleven heavy metals in M. oleifera products.

The concentrations of eleven heavy metals (Al, As, Cd, Cr, Cu, Fe, Hg, Mn, Ni, Pb, and Zn) in M. oleifera products from this study are shown in Tables 5 and 6. The concentrations of As, Cd, Hg, Pb, Cu, Fe, and Zn in M. oleifera products are shown in Table 5. The ranking of toxic heavy metal concentrations in M. oleifera products was Pb>As>Cd>Hg while that of essential element concentrations was Fe>Zn>Cu. As shown in Table 6, the concentrations of Al (53.833-564.168 mg/kg) and Cr (0.093-2.631 mg/kg) from all analyzed samples were within the normal ranges (Al 1,000 and Cr 0.03-14 mg/kg) prescribed by the previous reports[15,16], except for those of Ni (11.360-115.417 mg/kg) from most of analyzed samples that showed the concentrations more than two times higher than the maximum level (5 mg/kg)[15,16]. Furthermore, the

### TABLE 2: RESULTS OF REGRESSION ANALYSIS ON CALIBRATION CURVES

| Heavy metals | Regression equations | Correlation coefficients ($r^2$) |
|--------------|----------------------|---------------------------------|
| As           | $y=0.2947x+0.9358$    | 0.9997                          |
| Cd           | $y=0.3568x+0.1588$    | 0.9995                          |
| Hg           | $y=0.2547x+0.9581$    | 0.9998                          |
| Pb           | $y=0.3414x+0.8756$    | 0.9998                          |
| Cu           | $y=0.0987x+0.0016$    | 0.9990                          |
| Fe           | $y=0.0983x+0.0123$    | 0.9992                          |
| Zn           | $y=0.9578x+0.0369$    | 0.9997                          |
| Al           | $y=0.2458x+0.5692$    | 0.9996                          |
| Cr           | $y=0.3458x+0.0456$    | 0.9996                          |
| Mn           | $y=0.4597x+0.0165$    | 0.9998                          |
| Ni           | $y=0.6215x+0.3264$    | 0.9996                          |

### TABLE 3: RSD OF THE MEASUREMENTS

| Heavy metals | RSD, % | Intraday precision | Interday precision |
|--------------|--------|--------------------|--------------------|
| As           | 0.79   | 0.83               | 1.12               |
| Cd           | 0.83   | 0.84               | 1.20               |
| Hg           | 0.75   | 0.84               | 1.07               |
| Pb           | 0.84   | 0.83               | 1.17               |
| Cu           | 0.83   | 0.83               | 1.19               |
| Fe           | 0.50   | 0.83               | 1.16               |
| Zn           | 0.83   | 0.83               | 1.20               |
| Al           | 0.13   | 0.83               | 0.35               |
| Cr           | 0.57   | 0.83               | 0.78               |
| Mn           | 0.45   | 0.57               | 0.56               |

RSD: Relative standard deviations and $n=10$

### TABLE 4: LOD, LIMITS OF QUANTIFICATION AND RECOVERIES OF ALL HEAVY METALS

| Heavy metals | LOD (µg/l) | LOQ (µg/l) | Recovery (%) |
|--------------|-----------|------------|--------------|
| As           | 3.36      | 9.93       | 101.56       |
| Cd           | 1.22      | 3.56       | 103.05       |
| Hg           | 3.39      | 10.06      | 102.69       |
| Pb           | 4.45      | 13.13      | 101.05       |
| Cu           | 1.56      | 4.57       | 99.89        |
| Fe           | 3.55      | 9.96       | 100.06       |
| Zn           | 2.08      | 6.12       | 100.23       |
| Al           | 2.47      | 7.18       | 101.69       |
| Cr           | 0.87      | 2.24       | 102.41       |
| Mn           | 1.05      | 3.05       | 103.01       |
| Ni           | 1.70      | 4.95       | 102.35       |

LOD: Limit of detection, LOQ is limit of quantification and $n=10$
concentrations of Mn (92.301-216.675 mg/kg) from some of analyzed samples (Table 6) were higher than the maximum level (90 mg/kg)\textsuperscript{[15,16]}.

Overview of Tables 5 and 6, the concentrations of As (<1.574 mg/kg), Cd (<0.182 mg/kg), Hg (0.010-0.366 mg/kg), Pb (0.001-3.285 mg/kg), Al (53.833-439.106 mg/kg), and Cr (0.093-2.631 mg/kg) from all analyzed samples of tea leaves, dried seeds, leaf powders, and functional drinks were fairly low and comparable to previous records\textsuperscript{[15,16]}. Whereas the concentrations of Cu (6.452-28.294 mg/kg), Fe (154.236-922.311 mg/kg), and Zn (55.639-156.518 mg/kg) from all analyzed samples of leaf capsules were higher than those found previously in 2010\textsuperscript{[15,16]}. The concentrations of Fe (37.831-469.085 mg/kg), Zn (33.361-139.679 mg/kg), and Ni (8.361-91.391 mg/kg) from all analyzed samples of tea leaves, leaf powders, and functional drinks were also higher than those of 2010’s data\textsuperscript{[15,16]}. Moreover, the concentrations of Fe (86.753-223.130 mg/kg) and Zn

\begin{table}[h]
\centering
\caption{CONCENTRATIONS OF As, Cd, Hg, Pb, Cu, Fe, AND Zn IN MORINGA OLEIFERA PRODUCTS}
\begin{tabular}{|l|c|c|c|c|c|c|}
\hline
\textbf{Products} & \textbf{As} & \textbf{Cd} & \textbf{Hg} & \textbf{Pb} & \textbf{Cu} & \textbf{Fe} & \textbf{Zn} \\
\hline
\textbf{Tea leaves} & & & & & & & \\
Sample number 1 & 0.386 & 0.115 & 0.128 & 2.175 & 21.365 & 250.067 & 139.679 \\
Sample number 2 & 0.186 & 0.075 & 0.057 & 2.156 & 7.442 & 201.823 & 81.866 \\
Sample number 3 & 0.735 & 0.155 & 0.087 & 3.155 & 7.798 & 201.587 & 105.574 \\
Sample number 4 & 1.574 & 0.182 & 0.054 & 3.285 & 6.915 & 324.286 & 113.406 \\
Sample number 5 & 0.130 & 0.160 & 0.052 & 1.214 & 5.879 & 174.723 & 49.287 \\
Sample number 6 & 0.333 & 0.080 & 0.366 & 2.328 & 10.680 & 372.398 & 59.093 \\
Sample number 7 & 0.568 & 0.100 & 0.091 & 2.227 & 11.245 & 469.085 & 86.784 \\
Sample number 8 & 0.123 & 0.068 & 0.050 & 1.175 & 3.015 & 115.352 & 41.326 \\
Sample number 9 & 0.456 & 0.120 & 0.236 & 2.567 & 12.402 & 388.025 & 59.332 \\
Sample number 10 & 0.598 & 0.135 & 0.298 & 2.893 & 12.691 & 396.230 & 61.028 \\
\hline
\textbf{Dried seeds} & & & & & & & \\
Sample number 11 & 0.225 & 0.075 & 0.055 & 1.705 & 7.542 & 92.655 & 114.879 \\
Sample number 12 & 0.380 & 0.141 & 0.065 & 1.235 & 4.234 & 223.130 & 55.831 \\
Sample number 13 & 0.761 & 0.078 & 0.084 & 1.121 & 6.478 & 86.753 & 82.016 \\
Sample number 14 & 0.402 & 0.152 & 0.068 & 1.212 & 4.325 & 220.120 & 56.320 \\
Sample number 15 & 0.653 & 0.069 & 0.082 & 0.012 & 6.120 & 85.326 & 81.306 \\
\hline
\textbf{Leaf capsules} & & & & & & & \\
Sample number 16 & 0.459 & 0.087 & 0.088 & 2.344 & 13.714 & 197.927 & 103.604 \\
Sample number 17 & 0.180 & 0.102 & 0.171 & 1.548 & 28.294 & 168.549 & 87.442 \\
Sample number 18 & 0.030 & 0.355 & 0.055 & 24.032 & 16.165 & 922.311 & 156.518 \\
Sample number 19 & 0.028 & 0.277 & 0.056 & 8.860 & 13.747 & 569.412 & 133.592 \\
Sample number 20 & 0.541 & 0.069 & 0.072 & 1.650 & 11.569 & 256.217 & 72.714 \\
Sample number 21 & 0.646 & 0.126 & 0.060 & 1.902 & 6.529 & 317.988 & 74.354 \\
Sample number 22 & 0.445 & 0.074 & 0.070 & 1.522 & 7.277 & 652.592 & 59.852 \\
Sample number 23 & 0.523 & 0.068 & 0.069 & 1.563 & 10.986 & 154.236 & 71.265 \\
Sample number 24 & 0.631 & 0.123 & 0.063 & 1.963 & 6.452 & 312.580 & 75.230 \\
Sample number 25 & 0.493 & 0.598 & 0.068 & 1.426 & 7.023 & 593.951 & 55.639 \\
\hline
\textbf{Leaf powders} & & & & & & & \\
Sample number 26 & 0.025 & 0.072 & 0.038 & 2.751 & 2.692 & 87.876 & 107.929 \\
Sample number 27 & 0.189 & 0.069 & 0.051 & 1.591 & 3.126 & 37.831 & 57.010 \\
Sample number 28 & 0.135 & 0.089 & 0.065 & 1.689 & 10.235 & 98.769 & 105.369 \\
Sample number 29 & 0.129 & 0.102 & 0.087 & 1.987 & 12.369 & 102.360 & 104.256 \\
Sample number 30 & 0.235 & 0.112 & 0.097 & 1.872 & 11.362 & 84.239 & 89.325 \\
\hline
\textbf{Functional drinks} & & & & & & & \\
Sample number 31 & 0.012 & 0.056 & 0.023 & 0.501 & 3.201 & 102.359 & 42.356 \\
Sample number 32 & 0.032 & 0.012 & 0.010 & 0.043 & 1.235 & 112.365 & 39.254 \\
Sample number 33 & n.d. & n.d. & n.d. & 0.001 & 0.892 & 89.235 & 33.361 \\
Sample number 34 & 0.056 & 0.023 & 0.018 & 0.005 & 2.012 & 98.236 & 47.012 \\
Sample number 35 & 0.021 & 0.015 & 0.011 & 0.013 & 1.892 & 105.692 & 39.235 \\
\hline
\end{tabular}
\end{table}
TABLE 6: THE CONCENTRATIONS OF Al, Cr, Mn, AND Ni IN MORINGA OLEIFERA PRODUCTS

| Products                | The concentrations (mg/kg) of heavy metals |
|-------------------------|-------------------------------------------|
|                         | Al  | Cr  | Mn  | Ni    |
| Tea leaves              |     |     |     |       |
| Sample number 1         | 256.221 | 1.604 | 62.086 | 42.833 |
| Sample number 2         | 206.662 | 1.347 | 216.675 | 31.616 |
| Sample number 3         | 182.419 | 0.893 | 77.047 | 13.992 |
| Sample number 4         | 266.378 | 1.911 | 55.624 | 22.339 |
| Sample number 5         | 248.715 | 0.505 | 63.803 | 12.612 |
| Sample number 6         | 404.342 | 2.417 | 78.929 | 91.391 |
| Sample number 7         | 409.831 | 1.429 | 104.526 | 32.427 |
| Sample number 8         | 131.653 | 0.732 | 29.567 | 15.766 |
| Sample number 9         | 425.362 | 2.498 | 89.362 | 86.325 |
| Sample number 10        | 439.106 | 2.631 | 92.301 | 87.012 |
| Dried seeds            |     |     |     |       |
| Sample number 11        | 53.833 | 0.566 | 19.854 | 9.631 |
| Sample number 12        | 195.869 | 0.736 | 17.075 | 2.310 |
| Sample number 13        | 61.424 | 0.282 | 11.970 | 5.968 |
| Sample number 14        | 187.926 | 0.802 | 16.985 | 2.430 |
| Sample number 15        | 60.897 | 0.236 | 10.981 | 5.813 |
| Leaf capsules           |     |     |     |       |
| Sample number 16        | 246.548 | 1.043 | 45.613 | 2.973 |
| Sample number 17        | 209.902 | 1.128 | 57.180 | 9.229 |
| Sample number 18        | 290.017 | 1.291 | 143.133 | 56.829 |
| Sample number 19        | 512.629 | 1.199 | 207.015 | 115.417 |
| Sample number 20        | 263.584 | 1.204 | 124.272 | 12.175 |
| Sample number 21        | 336.070 | 1.582 | 55.405 | 4.915 |
| Sample number 22        | 564.168 | 1.766 | 148.692 | 3.937 |
| Sample number 23        | 259.987 | 1.123 | 120.398 | 12.036 |
| Sample number 24        | 326.281 | 1.495 | 54.398 | 4.890 |
| Sample number 25        | 534.321 | 1.689 | 139.254 | 3.601 |
| Leaf powders            |     |     |     |       |
| Sample number 26        | 286.208 | 2.425 | 53.332 | 8.361 |
| Sample number 27        | 242.933 | 1.665 | 64.338 | 16.068 |
| Sample number 28        | 277.365 | 0.754 | 78.356 | 33.564 |
| Sample number 29        | 298.361 | 0.897 | 96.326 | 41.230 |
| Sample number 30        | 302.560 | 1.235 | 79.235 | 56.234 |
| Functional drinks       |     |     |     |       |
| Sample number 31        | 102.356 | 0.561 | 35.693 | 12.036 |
| Sample number 32        | 99.325 | 0.689 | 29.365 | 14.910 |
| Sample number 33        | 79.210 | 0.093 | 19.354 | 11.360 |
| Sample number 34        | 89.356 | 0.108 | 30.290 | 23.026 |
| Sample number 35        | 98.320 | 0.198 | 31.291 | 19.031 |
| Normal ranges*          | 1000 | 0.03-14 | 50.90 | 0.02-5 |

*Normal ranges prescribed by the previous reports. %SD: 0.001-0.956, SD: Standard deviation

(55.831-114.879 mg/kg) from all analyzed samples of dried seeds were higher than those of 2010’s data[15,16].

To achieve the aim of this study, the method was developed for rapid determination of eleven heavy metals in M. oleifera products. For various products from M. oleifera the average concentrations of heavy metals decrease in the order: Al (255.718 mg/kg)>Fe (247.608 mg/kg)>Zn (78.373 mg/kg)>Mn (73.135 mg/kg)>Ni (26.408 mg/kg)>Cu (8.54 mg/kg)>Pb (2.449 mg/kg)>Cr (1.164 mg/kg)>As (0.362 mg/kg)>Cd (0.122 mg/kg)>Hg (0.087 mg/kg).

Among M. oleifera products, tea leaves had the highest average concentrations of As (0.509 mg/kg), Hg (0.142 mg/kg), Cr (1.597 mg/kg), and Ni (43.6313 mg/kg) while leaf capsules had the highest average concentrations of Cd (0.188 mg/kg), Pb (4.681 mg/kg), Cu (12.176 mg/kg), Fe (414.576 mg/kg), Al (354.351 mg/kg), and Mn (109.536 mg/kg). Moreover, leaf powders had the highest average concentration of Zn (92.778 mg/kg). However, the concentrations of As (<1.574 mg/kg), Hg (<0.366 mg/kg), Al (53.833-564.168 mg/kg), and Cr (0.093-2.631 mg/kg) in all M. oleifera products were lower than those found previously in 2010[15,16].

In addition, Tables 5 and 6 showed that the concentrations of heavy metals in M. oleifera products were higher than those in raw leaves when compared to our previous study[11]. The concentrations of heavy metals in leaf capsules as shown in Tables 5 and 6 were similar to those found in our previous report[12]. Prevalence of heavy metals in M. oleifera products especially elevated levels of As, Cd, Hg, and Pb, pose severe health risks to the consumers. Continuous monitoring of heavy metals in M. oleifera products is important for quality control of M. oleifera products.

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