Ornamental Date Palm and Sidr Trees: Fruit Elements Composition and Concerns Regarding Consumption

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ABSTRACT
Ornamental date palm and sidr trees growing near or within urban areas are exposed to heavy metals (HMs) contamination. This study aimed to determine the elemental composition and HMs concentrations of fruits from ornamental date palm and sidr trees to evaluate their relative safety for human/animal consumption. The results showed that while these fruits contain varying quantities of essential nutrients (macro and trace elements), the concentrations of macro elements and trace elements in the fruits varied significantly depending on location. The concentrations levels were within the acceptable limits and thus safe. Heavy metals were also present in the fruits at different locations. The concentrations of the HMs were within the permissible limits in the majority of the locations, with the exception of some samples collected from sites with increased traffic density; which had lead (Pb), chromium (Cr), and cadmium (Cd), concentrations above the permissible limits. Washing the fruits reduced the load of HMs contamination in most of the samples; however, the concentrations were still above the maximum allowable limits (MAL) in highly contaminated samples. Accordingly, fruits produced by ornamental date palm and sidr trees may pose some risk for human and animal consumption depending on the location and contamination level of specific HMs.

Introduction
Date palm (Phoenix dactylifera L.) and sidr (Ziziphus spina-christi L.) trees are valued trees and play a significant role in the economy and history of Middle Eastern countries (Osman and Ahmed, 2009, El Hadrami and Al-Khayri, 2012). Besides their economic value, these trees are commonly used as ornamental trees due to their tolerance to both salinity and drought (Mattar et al., 2021; Osman and Ahmed, 2009). Also, date palm and sidr trees produce delicious and nutritious fruits that can be of benefit for human/animal consumption (El Hadrami and Al-Khayri, 2012, Ahmed et al., 2021a; Alhakmani et al., 2014).

The date palm is a member of the Phoenix genus, which contains 14 species of palms (Salomón-Torres et al., 2021). Date fruit is rich in nutrients, proteins, dietary fibers, minerals, and vitamins (Rambabu et al., 2020), and contains significant amounts of phytosterols, polyphenols, and carotenoids that possess antioxidant properties (Ahmed et al., 2021b; Mia et al., 2020; Yasin et al., 2015). These fruits contain ample quantities of both macro and micronutrients which are essential for the proper functioning of the human body (Al-Shahib and Marshall, 2003; Rambabu et al., 2020).

Sidr is a tree species that belongs to the Ziziphus genus (Osman and Ahmed, 2009). It is one of the few native tree species in the Arab region. The fruit contains sugars and minerals, and is rich in vitamin C, beta-carotene, and proteins (Amoo and Atasie, 2012). Dates and sidr fruits are highly valued in the UAE. However, growing them in and near urban areas, especially along city roads, exposes their fruits to air pollutants and heavy metals (HMs) from automotive exhaust.

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Heavy metals term refers to a group of metals and metalloids that have an atomic density greater than 4 g cm$^{-3}$ (Hawkes, 1997). Beyond a specific concentration, most HMs are toxic. Lead (Pb), cadmium (Cd), chromium (Cr), mercury (Hg), nickel (Ni), strontium (Sr), copper (Cu), and zinc (Zn) are toxic to humans even at very low concentrations (Mahurpawar, 2015; Sall et al., 2020). Although HMs such as manganese (Mn), Cu, Zn, Ni, and iron (Fe) are vital for normal physiological functions in humans, animals, and plants, exceeding the permissible intake limits can lead to toxicity (Alhusban et al., 2019; Korfali et al., 2013; Mahurpawar, 2015; Nagajyoti et al., 2010).

Plants primarily absorb HMs via roots, but HMs uptake via leaves can occur to a lesser extent (Nagajyoti et al., 2010). Heavy metals can accumulate in vegetative tissues and fruits, which is a major path for human exposure (Dghaim et al., 2015; Nagajyoti et al., 2010). Additionally, plants growing along roadways, near urban and industrial areas are sometimes irrigated by treated water (recycled water), which could result in further HMs accumulation in the soil and lead to toxic concentrations in trees (Abdulaal et al., 2017; Aldjain et al., 2011; Dghaim et al., 2015; Salama et al., 2019). It has been recommended that date fruits from ornamental date palms be washed to minimize HM contamination and render them safe for human consumption (Aldjain et al., 2011).

Date and sidr trees are grown in many different areas of cities in the United Arab Emirates (UAE); almost in every garden, square and avenue. However, no studies are available regarding the element composition and HMs concentrations of the fruits. Therefore, the objectives of this study were: to determine the element composition and the HMs concentrations of fruits from ornamental date palm and sidr trees in different regions in Al Ain city, to investigate the effectiveness of a washing treatment on HMs concentrations of the fruits, and to evaluate the public health risks of consuming contaminated fruits based on the standard limits set by Food and Agriculture Organization (WHO/FAO).

**Materials and Methods**

**Sample Collection**

Date fruit (*Phoenix dactylifera* L.) (45 samples representing 15 locations), and sidr fruit (*Zizyphus spinosa-christi* L.) (15 samples representing 5 locations) at ripe stage were collected from the Al Ain city area. Sampling locations were selected to represent different types and levels of anthropogenic activities (Table 1 and Figure 1). Control date and sidr samples were collected from a location 25 km from Al Ain city and any source of pollution. Sidr fruit samples were collected in late April and early May 2020, and date samples were collected in late August and early September 2020. Three trees from each site were randomly selected 15 Kg of date and 3 Kg of sidr fruit were transported to the lab for analysis. Samples were prepared for analysis immediately after collection.

**Preparation and Analysis of Fruit Samples**

Fruits of each collected sample were divided into two groups, washed and unwashed. For preparing the washed group, 500 g of fruit was washed three times with 500 mL of deionized distilled water as described by Aldjain et al. (2011). In each group, fruits were cut to separate the pulp from the seeds. For sidr, the pulp tissue was dried in an air oven at 50°C for 3 days, and then 3 replicates of the ground dried tissue were used. For date, the pulp tissue was mashed using mortar and pestle and 3 homogenous samples of fresh flesh were used for analysis. Samples were then digested using a microwave-assisted process. Macro-elements (K, P, Ca, Mg, S, Na) Microelements (Fe, Mn, Cu, Ni, Zn) and HMs (Al, Sr, Cd, Cr, Pb, As) were analyzed in the digested samples using inductively coupled plasma-optical emission spectrometry (ICP-OES) according to a method described by Jin et al. (2002) and Hseu (2004) modified by Ahmed et al. (2021c). The results were expressed as the mean in mg/kg fresh weight for date and dry weight for sidr.

To insure the accuracy and reliability of the analysis results, strict quality control/ quality assurance measures were implemented.
Table 1. Collection locations of date and sidr samples with their respective type and level of anthropogenic activity.

| Location | Anthropogenic activity | Activity type | Activity level |
|----------|------------------------|---------------|----------------|
| 1        | Traffic                | low           |                |
| 2        | Traffic                | high          |                |
| 3        | Industrial activities | high          |                |
| 4        | Traffic                | high          |                |
| 5        | Traffic                | low           |                |
| 6        | Traffic                | low           |                |
| 7        | Traffic                | low           |                |
| 8        | Traffic                | low           |                |
| 9        | Traffic                | high          |                |
| 10       | Traffic                | low           |                |
| 11       | Traffic                | low           |                |
| 12       | Traffic                | low           |                |
| 13       | Traffic                | low           |                |
| 14       | Traffic                | low           |                |
| 15       | Traffic                | high          |                |
|          | Sidr samples           |               |                |
| 1        | Traffic                | high          |                |
| 2        | Traffic                | low           |                |
| 3        | Traffic                | high          |                |
| 4        | Industrial activities | high          |                |
| 5        | Traffic                | high          |                |

Figure 1. Locations of collected date and sidr samples in Al Ain city, UAE, 15 locations for date (D), and 5 locations for sidr (S), plus the control location. The gray squares represent the sites with HMs contaminated fruits. [https://www.worldmap1.com/map/united-arab-emirates/al-ain-map.asp](https://www.worldmap1.com/map/united-arab-emirates/al-ain-map.asp).
Quality Assurance

Precautions and controls: The chemicals and reagents used in this analysis were of high purity. Before usage, glassware was thoroughly cleaned with detergent and rinsed with deionized water, 1% nitric acid (HNO3) and deionized water several times. Proper care was taken during sample and standards preparation and storage. Samples were diluted when needed.

Quality Control

Calibration standards were prepared from stock 1000 μg/ml standard solution (Merck Brand), 1000 mg/l standard element for each metal (Sigma-Aldrich, St. Louis, MO, USA), as (0.1, 1.0, 10, 50 μg/ml) from each standard was mixed with 1% HNO3 to create the calibration curves. Calibration standards were checked for linearity, using 100 μg/ml mixed standard solution. The reagent blank (same volumes of all reagents used in the processing of the samples) was checked, and the calibration blank (1 ml of concentrated HNO3 in 100 ml deionized water) was checked.

The samples were prepared accurately by weighing 0.10 to 0.20 g of sample into the microwave digestion vessels followed by adding 10 ml of concentrated HNO3 (63.01%) and 2 ml hydrochloric acid (36.46%). The vessels were capped and place in the microwave digestion system. The CEM Mars 5 microwave digestion system was used to extract the elements from the samples. The digestion procedure is based upon the recommendation in USEPA method 3015A guidelines United States environmental Protection Agency (USEPA) 3015A, (1998). The metal concentrations of the aspirate prepared sample solutions were determined from the calibration curve. The ICP-OES detection limit of Cd was < 0.001 mg/kg, Cr was < 0.005, Pb was < 0.011, As was < 0.009, Ni was < 0.003 mg/kg.

Statistical Analysis

The data were analyzed by analysis of variance using SAS (SAS Institute Inc., 2000, Cary, NC, USA) (SAS 2009). Comparisons between locations were conducted using least significant differences test (LSD). Comparisons of washed and unwashed samples within a location were conducted using the t-test; P ≤ 0.05.

Results and Discussion

There are no established limits by WHO/FAO for toxic metals in date and sidr fruits. This study used the general recommended MALs set by FAO/WHO for food stuffs and plants such as fruits and vegetables as a reference for comparison and safety evaluation for date and sidr fruits. The HMs are a natural part of soil and their concentrations in soil can increase with increased anthropogenic activities. However, the present study did not carry out soil HMs profiling, and no investigations were found in the literature regarding HMs contamination in Al Ain city.

Date Fruit

Heavy Metals

Table 1 presents the mean Pb concentrations in unwashed and washed date samples collected at 15 locations around Al Ain city. Significant variations (P < .05) with regard to Pb concentration among date samples from different locations were noted. Lead concentrations in the unwashed date samples ranged from <0.011 to 1.92 mg/kg. Date samples from locations 2, 3, 4, and 9 had higher Pb concentrations compared to the other sites with 1.9, 1.4, 1.4, and 1.2 mg/kg, respectively (Tables 1, 2, and Figure 1). The elevated concentration of Pb in date samples collected from these sites could be attributed to high traffic density near locations 2, 3, and 9 and industrial activities near location 4 (Table 1 and Figure 1). These values are well above the MAL established by WHO/FAO (0.1 mg/kg)
(Table 2). Similarly, Pb concentrations exceeding the MAL in dates have been described in other Middle Eastern countries. For instance, significant levels of Pb contamination were noted in date samples collected from high traffic density urban locations in Riyadh, Saudi Arabia, although the values were within the MALs established by WHO/FAO (Aldjain et al., 2011). Additionally, Pb concentrations in date cultivars were found to be above the MAL at many urban locations in Saudi Arabia (Salama et al., 2019). In Egypt, an investigation of HMs in fruits and vegetables revealed that dates had a Pb concentration of 0.22 mg/kg, which was high (Radwan and Salama, 2006).

While washing the date fruits slightly reduced the Pb load, there was no statistical difference between washed and unwashed fruits; and the values were still above the MAL in the highly contaminated samples (Table 2). Generally, the accumulation of Pb in the environment occurs through aerial deposition on plant and soil surfaces (Aldjain et al., 2011). This might explain the reduction in Pb concentrations noted in the washed samples from the same locations (Table 2). Lead is recognized as an extremely toxic environmental contaminant and can lead to severe illnesses (Mahurpawar, 2015; Sall et al., 2020). Based on the above results, date fruits from ornamental date palm trees may have Pb contamination depending on the location and thus, may possess risk for human and animal consumption.

Arsenic, chromium, and cadmium were present at concentrations below the detection limit of ICP-OES. The As, Cr, and Cd concentrations were <0.009, <0.005, and <0.001 mg/kg, respectively, at all locations including control and washed fruits (Table 2). These values were far below MALs set by WHO/FAO (Table 2). In contrast, in Saudi Arabia, high concentrations of As, Cr, and Cd (0.171, 0.122, and 0.090 mg/kg, respectively) were found in date fruits collected from different urban areas (Salama et al., 2019). Also, significant levels of Cd contamination were found in dates collected from several urban locations in Riyadh, Saudi Arabia; however, the concentrations were within the MALs (Aldjain et al., 2011).Arsenic, chromium, and cadmium are considered extremely toxic environmental contaminants (Mahurpawar, 2015; Sall et al., 2020), and can accumulate in edible tissues via uptake from phosphate fertilizers, polluted sewage water, soil, and environmental pollutants (Nagajyoti et al., 2010; Salama et al., 2019). For instance, Cd can cause kidney, lung, and skeletal diseases and also increases the risk for cancer (Mahurpawar, 2015). Chromium amounts exceeding the MAL can result in some conditions, including lung cancer (Mahurpawar, 2015; Pillay et al., 2003). The above results show that the concentrations of As, Cr, and Cd in date fruits examined from 15 locations in Al Ain were within the safe limits for human and animal consumption.

Aluminum concentrations in the unwashed date samples ranged from 1.3 to 13.3 mg/kg. Significant differences (P < .05) in Al concentrations between different locations were noted (Table 2). The lowest Al concentration was detected in the control sample (1.3 mg/kg), whereas the highest concentration (13.3 mg/kg) was noted in date sample from location 15. Among all sites, date samples collected from locations 1, 13, and 15 had the highest Al concentrations, i.e., 11.14, 11.27, and 13.34 mg/kg, respectively (Table 2). In some date fruits, washing significantly reduced (P < .05) the Al load. This indicates the deposition of air dust and pollutants on plant surfaces causing fruit contamination. Aluminum concentrations detected in this study are comparable with those reported in date samples collected from various urban areas in Saudi Arabia with a range of 0.9–15.2 mg/kg (Salama et al., 2019). However, the Al concentration in date fruits was 23–41 mg/kg in a study by Kuras et al. (Kuras et al., 2020). In the present study, the variations in Al concentrations noted among date samples collected from different locations could be attributable to the difference in Al concentration in soil and fertilizer, or plant variety. Also, this could explain the only slight reduction in the Al concentration in some washed date fruits compared with the unwashed fruits (Table 2). The Al concentrations observed in this study were lower than the range normally found in date fruit. Therefore, it is unlikely that the Al concentrations in dates, even in areas with high anthropogenic activities, represent a significant health risk.

Strontium concentrations in the unwashed date samples ranged from 1.2 to 23.2 mg/kg. Significant differences (P < .05) in Sr concentrations were noted among different locations (Table 2). Date samples collected from location 4 had the highest Sr concentration (23.2 mg/kg), whereas control sample had
Table 2. Concentrations of heavy metals (mg/kg) in unwashed and washed fruits collected from date palm trees grown as ornamental landscape plants in different locations in Al Ain city.

| Location | Pb     | As     | Cr | Cd | Al | Pb     | As     | Cr | Cd | Al |
|----------|--------|--------|----|----|----|--------|--------|----|----|----|
| Control  | <0.011 c | <0.009 a | <0.005 a | <0.001 a | 13.1 ± 0.0 e | 12.2 ± 0.0 g | <0.011 c | <0.009 a | <0.005 a | <0.001 a | 1.9 ± 0.0 d | 1.9 ± 0.0 e | 1.9 ± 0.0 e | 1.9 ± 0.0 e |
| 1        | <0.011 c | <0.009 a | <0.005 a | <0.001 a | 11.1 ± 0.9 b* | 7.9 ± 0.1 e | <0.011 c | <0.009 a | <0.005 a | <0.001 a | 7.7 ± 0.3 b | 6.2 ± 0.1 d | 6.2 ± 0.1 d | 6.2 ± 0.1 d |
| 2        | 1.92 ± 0.25 a | <0.009 a | <0.005 a | <0.001 a | 4.8 ± 0.0 d* | 7.6 ± 0.2 e | 1.75 ± 0.05 a | <0.009 a | <0.005 a | <0.001 a | 3.1 ± 0.1 c | 6.2 ± 0.7 d | 6.2 ± 0.7 d | 6.2 ± 0.7 d |
| 3        | 1.46 ± 0.072 a | <0.009 a | <0.005 a | <0.001 a | 6.4 ± 0.6 c* | 12.5 ± 0.4 d* | 1.25 ± 0.01 ab | <0.009 a | <0.005 a | <0.001 a | 2.2 ± 0.2 d | 9.8 ± 0.2 c | 9.8 ± 0.2 c | 9.8 ± 0.2 c |
| 4        | 1.47 ± 0.001 a | <0.009 a | <0.005 a | <0.001 a | 4.8 ± 0.3 d* | 23.1 ± 0.0 a* | 1.11 ± 0.21 ab | <0.009 a | <0.005 a | <0.001 a | 2.0 ± 0.0 d | 20.9 ± 0.3 a | 20.9 ± 0.3 a | 20.9 ± 0.3 a |
| 5        | 0.11 ± 0.01 b | <0.009 a | <0.005 a | <0.001 a | 10.1 ± 0.3 b* | 17.3 ± 0.8 c* | 0.08 ± 0.03 b | <0.009 a | <0.005 a | <0.001 a | 3.0 ± 0.0 cd | 14.5 ± 0.2 bc | 14.5 ± 0.2 bc | 14.5 ± 0.2 bc |
| 6        | <0.011 c | <0.009 a | <0.005 a | <0.001 a | 6.3 ± 0.0 c | 3.8 ± 0.1 f | <0.011 c | <0.009 a | <0.005 a | <0.001 a | 5.8 ± 0.1 b | 3.6 ± 0.1 e | 3.6 ± 0.1 e | 3.6 ± 0.1 e |
| 7        | <0.011 c | <0.009 a | <0.005 a | <0.001 a | 6.0 ± 0.1 c* | 3.2 ± 0.1 f | <0.011 c | <0.009 a | <0.005 a | <0.001 a | 2.9 ± 0.1 c | 3.6 ± 0.1 e | 3.6 ± 0.1 e | 3.6 ± 0.1 e |
| 8        | <0.011 c | <0.009 a | <0.005 a | <0.001 a | 5.3 ± 0.1 c* | 15.1 ± 0.2 c | <0.011 c | <0.009 a | <0.005 a | <0.001 a | 3.3 ± 0.1 c | 14.6 ± 1.5 bc | 14.6 ± 1.5 bc | 14.6 ± 1.5 bc |
| 9        | 1.23 ± 0.01 a | <0.009 a | <0.005 a | <0.001 a | 4.2 ± 0.2 d | 15.8 ± 0.2 c | 1.03 ± 0.01 ab | <0.009 a | <0.005 a | <0.001 a | 3.2 ± 0.1 c | 15.8 ± 0.2 b | 15.8 ± 0.2 b | 15.8 ± 0.2 b |
| 10       | <0.011 c | <0.009 a | <0.005 a | <0.001 a | 8.7 ± 0.1 c | 6.3 ± 0.1 e | <0.011 c | <0.009 a | <0.005 a | <0.001 a | 8.2 ± 0.7 b | 6.1 ± 0.0 d | 6.1 ± 0.0 d | 6.1 ± 0.0 d |
| 11       | <0.011 c | <0.009 a | <0.005 a | <0.001 a | 9.9 ± 0.9 b | 16.0 ± 0.2 c | <0.011 c | <0.009 a | <0.005 a | <0.001 a | 9.8 ± 0.2 a | 15.3 ± 0.4 b | 15.3 ± 0.4 b | 15.3 ± 0.4 b |
| 12       | <0.011 c | <0.009 a | <0.005 a | <0.001 a | 10.3 ± 0.8 b* | 12.0 ± 0.6 d | <0.011 c | <0.009 a | <0.005 a | <0.001 a | 3.7 ± 0.1 c | 11.1 ± 0.8 c | 11.1 ± 0.8 c | 11.1 ± 0.8 c |
| 13       | <0.011 c | <0.009 a | <0.005 a | <0.001 a | 11.2 ± 0.9 b | 8.6 ± 0.7 e | <0.011 c | <0.009 a | <0.005 a | <0.001 a | 10.9 ± 0.6 a | 8.2 ± 0.2 c | 8.2 ± 0.2 c | 8.2 ± 0.2 c |
| 14       | <0.011 c | <0.009 a | <0.005 a | <0.001 a | 6.6 ± 0.3 c | 19.4 ± 0.9 b* | <0.011 c | <0.009 a | <0.005 a | <0.001 a | 6.3 ± 0.5 b | 15.2 ± 0.5 b | 15.2 ± 0.5 b | 15.2 ± 0.5 b |
| 15       | <0.011 c | <0.009 a | <0.005 a | <0.001 a | 13.3 ± 0.7 a* | 15.3 ± 1.1 c | <0.011 c | <0.009 a | <0.005 a | <0.001 a | 9.1 ± 0.9 a | 13.9 ± 0.4 bc | 13.9 ± 0.4 bc | 13.9 ± 0.4 bc |

WHO/FAOy MALsz = no established MAL

*Data represent mean ± SE (n = 3). Means with different letter(s) in the same row are significantly different at P ≤ 0.05 using LSD test, and means with "" of unwashed is significant compared to washed using t test.

WHO/FAO = World Health Organization

MALs = maximum allowable limits (mg/kg) set by WHO/FAO 2007 and 2011. ‘-’ = no established MAL
lowest Sr concentration. High Sr concentrations were noted in date samples collected from locations 5 and 14, with 17.3 and 19.4 mg/kg, respectively. An analyses of date fruits from Middle Eastern countries revealed that the Sr concentration ranged from 3.3 to 12 mg/kg (Kuras et al., 2020). Soils are known to contain an average of ~240 mg/kg Sr (ATSDR. (Agency for Toxic Substances and Diseases Registry), 2005). Additionally, some soil amendment samples were found to contain high Sr concentrations, for instance publicly owned treatment works (POTW) sewage sludges, phosphate fertilizers, limestone, and manure, had approximately 250, 610, 610, 80 mg/kg dry weight, respectively (ATSDR. (Agency for Toxic Substances and Diseases Registry), 2005). Thus, the differences in Sr concentrations noted in this study between samples collected from different locations might be attributed to Sr concentrations in the soil, fertilizers, and the plant uptake capacity. Stable Sr has no harmful effects in humans at the levels normally present in the environment (ATSDR. (Agency for Toxic Substances and Diseases Registry), 2005). However, it is difficult to evaluate the health risks associated with Sr for consumers as there is no standard maximum limit for Sr set by international organizations or documented data for consumption rates of dates by consumers in the UAE.

**Macro Elements**

Table 3 presents the mean concentrations of macro elements in unwashed and washed date fruit samples collected from 15 different locations. The macro element concentrations in date fruit samples showed significant variation ($P < .05$) between different locations of collection. The concentration of K was the highest at all locations, whereas that of other macro elements showed variable patterns. Additionally, some fruit samples showed significant changes in the mineral content after the washing treatment (Table 3). Variation among samples from different locations could be attributed to soil, irrigation, fertilizer, and/or plant cultivar differences (Kuras et al., 2020; Perveen and Bokahri, 2020).

Significant differences ($P < .05$) in K concentrations were noted among date samples collected from different locations (Table 3). The concentrations of K in the unwashed date samples ranged from 1658.1 to 5731.5 mg/kg. The K content was the highest at location 6 and lowest at location 4. Additionally, the washing treatment significantly ($P < .05$) reduced the amount of K in fruits at most locations. Dates are considered an exceptional source of K (Kuras et al., 2020). The range of K content in date fruit reported in this study was considerably lower than those reported by Perveen and Bokahri (2020) and Kuras et al. (2020), with 6789.11–8171.24 and 7276–9303 mg/kg, respectively.

Phosphorus content was in the range 226.4–798.5 mg/kg in unwashed samples. Significant differences ($P < .05$) in P content were found among date samples collected from different locations. The P content of fruits was the highest at location 13, and lowest at locations 4 and 10, respectively (Table 3). Most of the locations showed significantly ($P < .05$) lower P contents after the washing treatment. These concentrations are comparable to those reported in Iranian varieties (431–795 mg/kg) and Saudi Arabian varieties (468–1041 mg/kg) (Kuras et al., 2020).

Magnesium concentrations exhibited significant variation ($P < .05$) among date samples from different locations. Magnesium concentration was in the range of 236.2–677.0 mg/kg in the unwashed samples (Table 3). The control sample showed the lowest Mg concentration, whereas sample collected from location 13 had the highest Mg concentrations. The Mg concentrations reported in this study are lower than those reported in different date varieties from Saudi Arabia (502–801 mg/kg) (Kuras et al., 2020), but higher than those found in Omani date varieties (616.8–761.8 mg/kg) (Siddiqi et al., 2020). The washing treatment significantly ($P < .05$) reduced Mg concentration date fruits, depending on the location (Table 3).

The Ca content ranged from 289.6 to 849.6 mg/kg in the unwashed date fruits (Table 3), with the highest value at location 11 and the lowest values at control location. The washing treatment significantly ($P < .05$) decreased the Ca content of dates at most locations, based on the location. The Ca concentrations reported in the current study are similar to those reported by Siddiqi et al. (2020) in different date varieties (490.7–595.8 mg/kg) and higher than those reported by Kuras et al. (2020) (118–529 mg/kg).
| Location | K     | P     | Mg    | Ca    | Na    | S     |
|----------|-------|-------|-------|-------|-------|-------|
|          |       |       |       |       |       |       |
| Control  | 2774.6 ± 12.56 | 434.4 ± 6.80 | 236.2 ± 4.30 | 289.6 ± 4.00 | 27.6 ± 1.00 | 37.8 ± 1.00 |
| 1        | 4576.9 ± 37.68 | 679.5 ± 5.28 | 478.0 ± 5.20 | 337.6 ± 9.50 | 51.6 ± 1.40 | 445.1 ± 1.40 |
| 2        | 42680.0 ± 68.10* | 632.0 ± 2.80* | 515.9 ± 5.30* | 466.5 ± 14.10 | 45.9 ± 1.40* | 513.0 ± 2.30* |
| 3        | 42947.0 ± 58.00* | 698.6 ± 4.10* | 585.7 ± 7.10* | 399.5 ± 2.40* | 51.7 ± 2.00 | 517.9 ± 1.30* |
| 4        | 16581.0 ± 13.80 | 226.4 ± 3.50 | 244.5 ± 4.00 | 477.6 ± 3.00 | 17.5 ± 1.30 | 140.3 ± 2.50* |
| 5        | 50193.0 ± 30.30* | 705.9 ± 1.10* | 644.3 ± 1.80* | 710.6 ± 39.50* | 30.3 ± 0.60* | 488.5 ± 5.00c* |
| 6        | 57315.0 ± 13.90 | 487.5 ± 5.80 | 551.4 ± 2.90 | 339.8 ± 4.10 | 31.0 ± 0.30 | 679.5 ± 2.90 |
| 7        | 39139.0 ± 136.00 | 628.3 ± 3.10 | 370.7 ± 1.80 | 298.6 ± 6.60f | 74.2 ± 0.60b | 487.5 ± 3.00c |
| 8        | 31428.0 ± 26.10 | 589.8 ± 6.60 | 579.9 ± 6.90 | 638.3 ± 5.10c | 60.2 ± 1.10c | 420.2 ± 6.80 |
| 9        | 42577.0 ± 35.80 | 508.0 ± 5.30 | 555.4 ± 3.50ab | 728.6 ± 6.30 | 82.4 ± 2.00 | 536.8 ± 1.60 |
| 10       | 22647.0 ± 57.10 | 342.5 ± 2.70de | 284.2 ± 2.20 | 490.5 ± 5.10d | 57.6 ± 1.40c | 226.1 ± 2.00 |
| 11       | 48385.0 ± 12.20 | 696.3 ± 4.80 | 630.6 ± 6.40 | 849.6 ± 22.20 | 57.4 ± 1.20 | 639.4 ± 8.10 |
| 12       | 52663.0 ± 32.10 | 671.0 ± 1.30b | 568.0 ± 8.00ab | 805.8 ± 16.50 | 28.4 ± 0.00d | 653.3 ± 9.60a |
| 13       | 55747.0 ± 22.00a | 798.5 ± 5.80 | 677.0 ± 7.40 | 630.6 ± 15.10 | 89.7 ± 1.60a | 667.0 ± 9.20a |
| 14       | 43284.0 ± 63.80 | 688.8 ± 2.90 | 558.0 ± 3.30 | 466.0 ± 2.20 | 15.5 ± 0.00 | 569.8 ± 6.40b |
| 15       | 46973.0 ± 58.20 | 653.3 ± 1.30 | 606.7 ± 4.40ab | 678.0 ± 2.80c | 20.8 ± 0.00 | 469.9 ± 5.20 |

| Location | K     | P     | Mg    | Ca    | Na    | S     |
|----------|-------|-------|-------|-------|-------|-------|
|          |       |       |       |       |       |       |
| Control  | 27535.0 ± 32.60 | 413.3 ± 2.10 | 223.0 ± 2.60 | 283.6 ± 2.20 | 46.2 ± 0.50 | 330.0 ± 2.20 |
| 1        | 45321.0 ± 47.20 | 603.7 ± 7.00 | 469.5 ± 3.90 | 308.2 ± 2.8ef | 49.2 ± 1.40 | 339.1 ± 1.40 |
| 2        | 38499.0 ± 52.10 | 577.5 ± 3.60 | 489.6 ± 4.70 | 372.9 ± 4.70 | 35.0 ± 1.30 | 426.3 ± 2.20 |
| 3        | 38597.0 ± 68.30 | 595.6 ± 7.50 | 496.5 ± 1.40 | 299.3 ± 4.7f | 39.5 ± 1.20 | 470.7 ± 2.1b |
| 4        | 16465.0 ± 17.00 | 218.8 ± 10.00 | 236.8 ± 0.8d | 405.4 ± 12.1d | 17.3 ± 1.0e | 126.4 ± 1.5e |
| 5        | 44628.0 ± 17.80 | 612.2 ± 4.10 | 557.7 ± 3.8ab | 604.1 ± 7.1b | 26.2 ± 0.9d | 442.7 ± 5.1bc |
| 6        | 57184.0 ± 89.30 | 485.1 ± 4.60 | 544.7 ± 1.6ab | 336.0 ± 1.2e | 31.0 ± 0.1de | 677.8 ± 2.6a |
| 7        | 39139.0 ± 60.30 | 591.6 ± 2.10 | 337.3 ± 4.3c | 271.8 ± 4.8f | 71.2 ± 1.3ab | 386.1 ± 5.7bc |
| 8        | 28622.0 ± 44.90 | 524.0 ± 8.00 | 541.9 ± 2.5ab | 600.6 ± 6.8b | 57.1 ± 2.8b | 400.3 ± 1.2c |
| 9        | 35667.0 ± 69.40 | 447.4 ± 2.5c | 469.8 ± 3.8bc | 674.1 ± 3.8bc | 79.1 ± 0.2a | 481.0 ± 1.2b |
| 10       | 22332.0 ± 61.40 | 368.0 ± 2.0d | 274.3 ± 8.1d | 428.1 ± 1.4d | 62.4 ± 0.9b | 252.2 ± 10.6d |
| 11       | 48122.0 ± 74.60 | 624.3 ± 1.4b | 622.6 ± 4.6a | 809.3 ± 2.0a | 57.0 ± 3.8b | 693.1 ± 3.9a |
| 12       | 50966.0 ± 38.50 | 614.3 ± 3.5b | 502.5 ± 3.2b | 699.4 ± 2.2b | 24.3 ± 1.1de | 559.4 ± 5.1ab |
| 13       | 54299.0 ± 62.00 | 797.8 ± 7.2a | 629.0 ± 4.4a | 621.3 ± 6.2b | 82.8 ± 1.8a | 606.7 ± 3.3a |
| 14       | 37735.0 ± 46.50 | 622.7 ± 7.5b | 526.1 ± 2.9ab | 426.1 ± 3.3d | 21.0 ± 2.1d | 481.2 ± 3.1b |
| 15       | 40393.0 ± 23.90 | 623.8 ± 5.6b | 598.5 ± 5.2a | 604.9 ± 3.4b | 23.6 ± 0.6d | 466.4 ± 5.0bc |

*Data represent mean ± SE (n = 3). Means with different letter(s) in the same column are significantly different at P ≤ 0.05 using LSD test, and means with ** of unwashed is significant compared to washed using t test.
The concentration of Na in date fruits ranged from 15.5 to 89.7 mg/kg the unwashed fruits (Table 3); varying significantly \((P < .05)\) between locations. The highest concentrations were detected at locations 9 and 13. Almost half of the locations showed a significant effect of washing treatment on Na content (Table 3). Compared with the results of this study, Siddiqi et al. (2020) reported lower Na content in dry date samples (47.5 mg/kg), whereas Habib and Ibrahim (2011) reported higher Na concentrations in 18 date varieties (88.1–168.3 mg/kg). These differences could be due to soil, irrigation, fertilizer, and plant cultivar variations (Kuras et al., 2020; Perver and Bokahri, 2020).

Sulfur concentrations ranged from 378.7 to 679.54 mg/kg in the unwashed date samples. Sulfur concentrations in date samples varied significantly \((P < .05)\) among different locations, with the highest value at location 6 and the lowest value at location 4. Depending on the location, washing treatment significantly \((P < .05)\) affected the S content of fruits, (Table 3).

Based on the results obtained in this study, fruits harvested from ornamental date palm trees contain high amounts of macro elements, making them a good source of essential nutrients. Washing treatment significantly \((P < .05)\) reduced macro elements load in fruits depending on locations.

**Trace Elements**

In the present study, significant differences \((P < .05)\) in Ni concentrations were noted among different locations (Table 4). The Ni concentrations in the unwashed date samples ranged from \(< 0.1\) to 0.7 mg/kg. The highest Ni concentration was observed in date samples collected from locations 3 and 5, whereas the lowest concentrations were noted in date samples from locations 1, 4, 7, and 13. Control samples contained higher Ni concentration than samples collected from locations 1, 4, 6, 7, 13, 14, and 15. Several studies have investigated Ni contamination in dates. For instance, similar finding was noted in Omani date fruits and leaflets with less than 4 mg/kg Ni, which was considered safe (Williams and Pillay, 2009). However, in Jordan, higher Ni concentrations were found in date palm leaflets collected from urban, suburban, and industrial areas and highways (26.07, 18.0, 35.0, and 40.0 mg/kg, respectively) than in rural and control areas (14.0 and 5.0 mg/kg, respectively) (Al-Khaifat and Al-Khashman, 2007). Additionally, an investigation of Ni concentrations in Omani date palms grown in soils containing high Ni concentrations revealed that Ni did not accumulate in leaflets and fruits despite the relatively high Ni concentration in the soil (34–153 mg/kg). This may explain the reduced Ni concentrations noted in the present study in washed fruits compared with unwashed ones that could have air dust and pollutants on the surface. Nickel concentrations higher than 100 mg/kg in soil and 10 mg/kg in plant tissues are toxic to plants (Davison et al., 2007). Among HMs, the presence of Ni in foods is of particular concern because of its high toxicity and carcinogenicity (Davison et al., 2007). In plant tissues, elevated Ni concentrations impair the nutrient balance and negatively impact cell membrane functions (Nagajyoti et al., 2010). There is no established MAL for Ni in date fruit, but in the literature, a Ni concentration of \(< 1\) mg/kg is recommended (Jones, 1998). In the present study, the Ni concentrations in date fruits were far below the recommended level. Thus, it is unlikely that Ni at such concentrations represents a health risk.

The Cu concentrations in the unwashed date samples ranged from 0.8 to 3.2 mg/kg. Significant differences in Cu concentrations among different locations were noted (Table 4). The lowest concentration was noted in the control sample, whereas the highest Cu concentration was noted in a sample collected from location 15. Similarly, date samples from various Middle Eastern countries have been showed to contain Cu concentrations of 1.6–7.0 mg/kg (Kuras et al., 2020). The use of micronutrient fertilizers may increase the Cu concentration to alarming levels and may need to be monitored (Radwan and Salama, 2006). There is no established regulatory limit for Cu in date fruits. However, it is unlikely that the Cu concentrations detected in dates in the present study would present any significant health risk because the amounts are within the range normally present in plants (Nagajyoti et al., 2010).

The Zn concentrations in the unwashed dates varied significantly \((P < .05)\) among different locations, ranging from 0.9 to 5.4 mg/kg (Table 4). The highest Zn concentration was noted in a sample collected from location 11, whereas the lowest concentration was noted in the control
### Table 4. Concentrations of trace elements (mg/kg) in unwashed and washed fruits collected from date palm trees grown as ornamentals at different locations in Al Ain city.

| Location | Ni   | Cu   | Zn   | Fe   | Mn   | Ni   | Cu   | Zn   | Fe  | Mn  |
|----------|------|------|------|------|------|------|------|------|-----|-----|-----|
| Control  | 0.5 ± 0.0 c | 0.8 ± 0.0 c | 0.9 ± 0.8 e | 2.8 ± 0.2 e* | 0.7 ± 0.0 e | 0.4 ± 0.0 a | 0.8 ± 0.0 d | 0.5 ± 0.5 d | 2.4 ± 0.0 e | 0.7 ± 0.0 d |
| 1        | <0.0 c | 0.9 ± 0.0 c | 2.5 ± 0.3 c | 13.1 ± 0.0 c* | 2.8 ± 0.1 c | <0.0 c | 0.9 ± 0.0 c | 2.2 ± 0.2 c | 12.8 ± 0.5 c | 2.8 ± 0.4 b |
| 2        | 0.5 ± 0.2 c | 1.2 ± 0.0 b | 3.5 ± 0.2 bc | 12.1 ± 0.3 c* | 3.1 ± 0.2 b | 0.5 ± 0.0 a | 1.0 ± 0.0 d | 2.6 ± 0.2 c | 6.6 ± 0.2 e | 2.2 ± 0.0 b |
| 3        | 0.7 ± 0.0 a* | 3.1 ± 0.1 a | 4.2 ± 0.3 b | 15.9 ± 0.4 bc* | 4.2 ± 0.0 ab | 0.2 ± 0.0 b | 3.0 ± 0.1 b | 4.1 ± 0.1 b | 8.9 ± 0.3 d | 3.5 ± 0.1 ab |
| 4        | 0.0 ± 0 e | 1.6 ± 0.0 b | 2.2 ± 0.3 c | 8.7 ± 0.1 d* | 1.4 ± 0.0 d | <0.0 c | 1.6 ± 0.1 d | 2.1 ± 0.5 c | 3.8 ± 0.0 e | 1.3 ± 0.0 c |
| 5        | 0.7 ± 0.0 a* | 1.5 ± 0.0 b | 2.6 ± 0.0 c | 18.6 ± 0.3 b* | 3.5 ± 0.2 b | 0.4 ± 0.1 a | 1.2 ± 0.0 d | 2.7 ± 0.0 c | 16.0 ± 0.1 b | 3.1 ± 0.1 b |
| 6        | 0.2 ± 0.1 d | 2.0 ± 0.0 bc | 3.5 ± 0.0 bc | 15.7 ± 0.3 bc | 2.4 ± 0.0 c | 0.2 ± 0.1 b | 2.0 ± 0.1 cd | 3.4 ± 0.1 bc | 12.6 ± 0.6 c | 2.4 ± 0.2 b |
| 7        | <0.0 e | 1.3 ± 0.0 b | 2.8 ± 0.0 c | 12.0 ± 0.3 c | 1.4 ± 0.0 d | <0.0 e | 1.2 ± 0.2 d | 2.4 ± 0.0 c | 7.6 ± 1.2 de | 1.2 ± 0.1 c |
| 8        | 0.5 ± 0.2 c | 1.2 ± 0.0 b | 2.3 ± 0.0 c | 12.6 ± 0.1 c* | 5.0 ± 0.1 a | 0.5 ± 0.0 a | 1.1 ± 0.0 d | 2.2 ± 0.2 c | 8.9 ± 0.7 d | 4.6 ± 0.2 a |
| 9        | 0.6 ± 0.0 ab* | 1.5 ± 0.2 b | 2.7 ± 0.5 c | 17.7 ± 0.9 b | 1.9 ± 0.0 cd | 0.4 ± 0.1 a | 0.9 ± 0.0 d | 2.3 ± 0.2 c | 9.0 ± 0.2 d | 1.6 ± 0.0 cd |
| 10       | 0.4 ± 0.0 c* | 1.0 ± 0.0 c | 2.9 ± 0.1 c | 14.7 ± 0.4 bc* | 1.5 ± 0.0 d | 0.2 ± 0.1 b | 1.0 ± 0.0 c | 2.6 ± 0.9 c | 13.8 ± 0.3 c | 1.4 ± 0.0 c |
| 11       | 0.6 ± 0.3 ab* | 2.2 ± 0.1 ab | 5.4 ± 0.4 a | 17.2 ± 0.9 b | 4.3 ± 0.0 ab | 0.3 ± 0.0 ab | 2.1 ± 0.0 c | 5.3 ± 0.5 a | 16.6 ± 0.3 b | 3.8 ± 0.0 ab |
| 12       | 0.4 ± 0.0 c | 2.9 ± 0.1 a | 4.7 ± 0.2 b | 18.4 ± 0.9 b* | 2.1 ± 0.0 c | 0.4 ± 0.0 a | 2.4 ± 0.0 c | 4.2 ± 0.2 b | 9.6 ± 0.7 d | 1.6 ± 0.0 c |
| 13       | <0.0 e | 1.6 ± 0.0 b | 4.6 ± 0.9 b | 25.4 ± 0.8 a* | 3.4 ± 0.3 b | <0.0 c | 1.3 ± 0.0 d | 4.3 ± 0.0 b | 24.3 ± 1.8 a | 3.3 ± 0.0 b |
| 14       | 0.3 ± 0.0 d* | 2.4 ± 0.1 ab | 2.7 ± 0.1 c | 11.8 ± 0.5 c | 2.9 ± 0.0 b | 0.2 ± 0.0 b | 2.0 ± 0.0 c | 2.6 ± 0.4 c | 7.7 ± 0.6 de | 2.7 ± 0.1 b |
| 15       | 0.3 ± 0.0 d* | 3.2 ± 0.0 a | 2.8 ± 0.3 c | 16.4 ± 0.4 bc | 3.3 ± 0.2 b | 0.2 ± 0.0 b | 4.2 ± 0.1 a | 3.0 ± 0.5 c | 12.5 ± 0.5 c | 3.2 ± 0.1 b |

*Data represent mean ± SE (n = 3). Means with different letter(s) in the same column are significantly different at P ≤ 0.05 using LSD test, and means with * of unwashed is significant compared to washed using t test.
sample. An investigation of HMs in fruits and vegetables revealed that dates had Zn concentrations of 3.3–4.42 mg/kg (Radwan and Salama, 2006). Zinc concentrations in the present study were within the range normally found in date fruits, i.e., 0.6–11 mg/kg (Kuras et al., 2020). Zinc toxicity is limited relative to other HMs, only exposure to high concentrations (oral LD so of 3 g/kg) has toxic effects (Plum et al., 2010). Thus, the Zn concentrations determined in the present study do not present any significant toxicity risk. Date fruits could be a good source of Zn for humans and animals.

Wide variation in Fe concentration was detected among date samples from different locations. The Fe concentration of the unwashed date samples ranged from 2.8 to 25.4 mg/kg (Table 4). The highest Fe concentration was found from location 13, and the lowest concentration was observed with the control sample. Washing treatment significantly reduced the Fe concentration of the date fruits depending on locations. The range of Fe concentration found in this study is wider than that reported by Kuras et al. (2020) who reported Fe concentrations ranging from below detection limits to 8.7 mg/kg. This wide range could be due to irrigation, fertilizer, soil, and plant cultivar differences (Kuras et al., 2020; Perveen and Bokahri, 2020). Our results suggest that fruits collected from ornamental date palm trees can be a source of Fe for humans and animals.

Manganese concentrations in the unwashed date samples ranged from 0.7 to 5.0 mg/kg. Significant differences (P < .05) in Mn concentrations were recorded among date samples collected from different locations (Table 4). The highest and lowest amounts of Mn were detected in sample 8 and the control, respectively (Table 4). Comparable Mn concentrations have been reported by Habib and Ibrahim (2011) and El Brima (2019), with a range of 1.1 and 3.5 mg/kg and an average of 2.9 mg/kg respectively, whereas Kuras et al. (2020) reported a broad range of Mn content (3.7–12 mg/kg). Our results suggest that dates harvested from ornamental date palm are a good source of Mn for human and animal health.

The variability in trace element concentrations between samples from different locations could be due to differences in soil, irrigation water, date variety, fertilizers, and plant varieties (Al Juhiami et al., 2020; Kuras et al., 2020; Perveen and Bokahri, 2020). The findings of this study show that date fruits from ornamental date palms contain concentrations of trace elements that would be nutritious for humans and animals. Washing treatment significantly reduced trace elements load in fruits depending on locations. Additionally, it is unlikely that the trace elements concentrations detected in dates in the present study would present any significant health risk because the amounts are within the range normally present in plants.

**Sidr Fruit**

**Macro and Micronutrients**

Concentrations of macro and micronutrients in unwashed and washed fruits collected from ornamental sidr trees are presented in Table 5. Among all macro elements and across all locations, K showed the highest concentrations in the unwashed samples (9869.5–18927.2 mg/kg); with the highest in the control sample. The K concentrations found in sidr fruits in this study are considerably higher than those reported by Osman and Ahmed (2009) as 8670.5 mg/kg, and by Amoo and Atasie (2012) as 679.8 mg/kg. Our results reinforce the importance of sidr fruit as a good source of K, which plays a vital role in regulating blood pressure and heart health (Weaver, 2013). Washing treatments had no significant effect on K concentration in the fruit (Table 5).

The second most abundant element in the unwashed sidr fruits was Ca (1343.8–2866.2 mg/kg), with the highest concentration found in samples from location 3 (Table 5). Washed fruits showed significantly (P < .05) lower levels of Ca than unwashed fruits from all locations. While this Ca content was substantially lower than that reported by Osman and Ahmed (2009) (3395 mg/kg); sidr fruit can be an important source of Ca for humans and animals.

Phosphorus concentrations ranged from 1210.8 to 1369.1 mg/kg in the unwashed fruits, with the highest P concentration in fruits from location 1 (Table 5). Washed fruits showed significantly (P < .05) lower levels of P than unwashed fruits from all locations. The range of P content
Table 5. Concentrations of macro elements and trace elements (mg/kg) in unwashed and washed fruits collected from sidr trees grown as ornamental landscape plants at different locations in Al Ain city.

| Location | Control | Washed | Washed | Washed | Washed |
|----------|---------|--------|--------|--------|--------|
|          |         |        |        |        |        |
| K        | 18927.2 ± 87.1 a | 12725.9 ± 31.5 b | 18514.4 ± 99.4 a | 9869.5 ± 39.6 c | 12638.4 ± 89.3 b |
| Ca       | 19591 ± 33.1 d | 1343.8 ± 21.3 e | 2305.7 ± 75.5 c | 2866.2 ± 36.4 a | 2322.7 ± 65.3 c |
| P        | 1332.2 ± 12.5 a | 1369.1 ± 45.4 a | 1210.8 ± 41.6 b | 1243.7 ± 76.7 b | 1244.8 ± 34.5 b |
| Mg       | 722.6 ± 52.6 a | 554.7 ± 7.3 b | 789.1 ± 23.1 a | 721.3 ± 16.7 a | 731.1 ± 28.3 a |
| S        | 677.4 ± 33.6 a | 411.4 ± 9.5 b | 694.0 ± 39.9 a | 248.9 ± 1.5 d | 341.2 ± 42.8 c |
| Na       | 96.2 ± 2.9 b | 120.6 ± 3.56 a | 85.0 ± 2.6 c | 85.8 ± 0.0 c | 93.2 ± 3.1 c |
| Ni       | 3.6 ± 0.0 d | 9.8 ± 0.6 a | 3.5 ± 0.0 d | 6.0 ± 0.5 b | 4.5 ± 0.1 c |
| Cu       | 3.4 ± 0.02 a | 3.9 ± 0.03 a | 3.4 ± 0.0 a | 2.3 ± 0.0 b | 2.9 ± 0.1 b |
| Fe       | 26.9 ± 4.2 b | 89.8 ± 9.6 a | 29.6 ± 2.9 b | 32.7 ± 4.4 b | 33.5 ± 2.9 b |
| Zn       | 10.1 ± 0.5 a | 7.7 ± 2.7 c | 11.3 ± 0.5 a | 8.9 ± 1.6 b | 9.3 ± 0.4 ab |
| Mn       | 3.7 ± 0.0 ab | 4.1 ± 0.6 a | 3.3 ± 0.1 b | 2.9 ± 0.4 b | 3.3 ± 0.1 b |

*Data represent mean ± SE (n = 3). Means with different letter(s) in the same row are significantly different at P ≤ 0.05 using LSD test, and means with ‘*’ of unwashed is significant compared to washed using t test.
reported in this study was noticeably higher than that reported by Amoo and Atasie (2012) as 347.5 mg/kg. According to the results of the study, sidr fruit from ornamental sidr trees are obviously a good source of P for animal and human. Based on the findings of this study, fruits harvested from ornamental sidr trees contain high amounts of macro elements, making them a good source of essential nutrients. Additionally, washing treatment significantly ($P < .05$) reduced P concentrations load in sidr fruits depending on locations.

The concentration of Mg ranged from 554.7 to 789.1 mg/kg in the unwashed fruits, with the highest amount in sidr fruit samples from location 2. Washed fruits had significantly ($P < .05$) lower Mg concentrations than unwashed fruits at all locations, except at location 3 (Table 5). The concentrations of Mg in this study are comparable with those reported by Osman and Ahmed (2009) as 763 mg/kg but higher than those reported by Amoo and Atasie (2012) as 357 mg/kg. These results indicate that the fruits harvested from the ornamental sidr trees have a considerable amount of Mg, making it a good source of this essential element.

Sulfur concentrations in the unwashed sidr samples varied significantly ($P < .05$) between different locations, with a range of 248.9 to 694.0 mg/kg. The greatest value was found at location 2 in and the lowest value was noticed at location 3. These variations among different samples are mainly caused by differences in environmental factors. Washing treatment significantly ($P < .05$) reduced the S content of sidr fruits at all locations, except at location 3 (Table 5). Overall, these findings suggest that sidr fruits contain a significant quantity of S and could be a good source for it.

Sodium concentrations ranged from 85.0 to 120.6 mg/kg in the unwashed fruits. The Na concentrations reported in this study are lower than that reported by Amoo and Atasie (2012) as 550.1 mg/kg. The variations in macro element concentrations between different locations could be caused by differences in soil, irrigation water, fertilizer, plant uptake ability and/or plant cultivar. The results of this study indicate that fruits of ornamental sidr tree can be a good source of macro elements for human and animal consumption. Washing treatment significantly ($P < .05$) reduced macro elements concentrations load in sidr fruits depending on locations.

The Ni concentrations in the unwashed sidr samples ranged from 3.5 to 9.8 mg/kg. The highest Ni concentration was observed in sidr samples collected from location 1, and the lowest concentration was noted in samples collected from locations 2 and 5. The Ni concentration significantly ($P < .05$) varied between sidr samples from different locations (Table 5). Differences in Ni concentrations could be attributed to the differences in Ni concentrations in soil. High Ni concentrations in soil (>100 mg/kg) and in plant tissues (10 mg/kg) are toxic to plants (Davison et al., 2007). There is no established MAL for Ni in sidr fruit, but in the literature, a Ni concentration of <1 mg/kg is recommended (Jones, 1998). The Ni concentrations in the present study did not exceed the recommended concentration level found in plants. Thus, it is unlikely that Ni at such concentrations represents a health risk.

Copper concentrations differed significantly ($P < .05$) between different locations (Table 5), with a range of 2.3 to 3.9 mg/kg in the unwashed samples. These concentrations are higher than those reported by Nyanga et al. (2013) (0.7–1.6 mg/kg) in sidr fruit. There is no established regulatory limit for Cu in sidr fruit. However, it is unlikely that the Cu concentrations detected in sidr in the present study would present any significant health risk for human or animal because the amounts are within the acceptable range present in plant (Nagajyoti et al., 2010).

Among trace elements, the concentration ranges of Fe, Zn, and Mn were 26.9–89.8, 7.7–11.3, and 2.9–4.1 mg/kg in the unwashed fruits, respectively (Table 5). In the study conducted by Osman and Ahmed (2009), Fe concentration of sidr fruit pulp was 71.99 mg/kg, whereas Zn concentration (65.23 mg/kg) was higher than that determined in the present study. By contrast, Amoo and Atasie (2012) reported higher Fe and Zn concentrations in sidr fruits (399.6 and 569.3 mg/kg, respectively). Manganese concentrations found in this study were comparable with that reported by Amoo and Atasie (2012). Significant differences ($P < .05$) in trace element concentrations were found between washed and unwashed samples at most locations (Table 6). The results of this study indicate that sidr fruit contains high concentrations of trace elements within acceptable ranges and could therefore be
a highly nutritious food source for human and animal consumption. Moreover, washing treatment significantly \((P < .05)\) reduced macro elements concentrations load in sidr fruits depending on locations.

**Heavy Metals**

The mean Pb concentrations in unwashed and washed sidr fruit samples collected from five locations in Al Ain city is presented in Table 6. The Pb and As concentrations in sidr fruit samples were below the detection limits of ICP-OES and thus below the MALs set by WHO/FAO (Table 6). The Cd concentrations in the unwashed sidr samples ranged from \(<0.001\) to \(2.30\ \text{mg/kg}\), and varied significantly \((P < .05)\) among different locations. Samples collected from locations 1 and 3 had the highest Cd concentrations, 0.94 and \(2.30\ \text{mg/kg}\), respectively. Control and samples from locations 2, 4, and 5, had Cd concentration below the detection limit \((<0.001\ \text{mg/kg})\). The Cd concentration of sidr fruit samples collected from location 3 was above the MAL set by WHO/FAO (Table 6). Sample 1 and 3 were collected from high density traffic areas (city center) (Table 1 and Figure 1). The low concentration of Pb relative to Cd could be attributed to plant uptake capacity and ability to accumulate HMs (Aldjain et al., 2011). Cadmium can contaminate edible plant tissues via several sources; contaminated soil, phosphate fertilizers, and polluted sewage water (Salama et al., 2019).

The Cr concentration in the unwashed sidr fruits ranged from 1.6 to \(2.7\ \text{mg/kg}\). Samples collected from locations 1 and 3 showed the highest Cr concentrations of 2.5 and \(2.7\ \text{mg/kg}\), respectively (Table 6), while the lowest Cr concentration was in the control and sample from location 4. Increased anthropogenic activities could increase HMs concentrations in soil and in air (Salama et al., 2019); which may explain the high levels of Cr in sidr samples collected from urban areas (sites 1 and 3) (Table 1 and Figure 1). The Cr concentrations of sidr fruit samples collected from locations 1 and 3 were above the MAL recommended by WHO/FAO (Table 6). Based on location, the washing step reduced the Cd and Cr concentrations on the fruits; for instance, in the sample collected from location 3, the concentrations were still above the MAL (Table 6).

Different plants can absorb HMs and accumulate them in their tissues through primarily root and leaf uptake (Antionius and Kochhar, 2009; Nagajyoti et al., 2010). Depending on the plant species, plants can uptake toxic contaminants such as Pb, As, Cr, and Cd and incorporate them in the food chain, leading to health risks (Mahupawar, 2015; Sall et al., 2020). Based on the above results, sidr fruits from ornamental sidr trees grown in urban areas may have Cd and/or Cr contamination above acceptable limits depending on the location and thus, are a risk for human and animal consumption.

Aluminum concentrations in the unwashed sidr fruits significantly differed among samples collected from different locations \((P < .05)\) in a range from 9.1 to \(10.7\ \text{mg/kg}\), with location 1 showing the highest Al concentration, \(10.7\ \text{mg/kg}\) (Table 6). This concentration is within the range noted for dates in the present study (Al 1.33 to 13.34 mg/kg). Date fruits generally have Al concentrations of 23–41 mg/kg (Kuras et al., 2020), and vegetables have been reported to have significantly higher concentrations of Al than dates (Njenga et al., 2007). Accordingly, it is unlikely that the Al concentrations detected in sidr fruits in the present study would present a significant health risk as these concentrations are within the acceptable ranges in other edible plants.

**Conclusions**

Apart from their utilization as ornamentals, date palm and sidr trees produce delicious and nutritious fruits. Our results showed that these fruits contain varying quantities macro and trace elements. The concentrations of macro elements and trace elements in dates and sidr fruits harvested from ornamental trees varied significantly depending on location. Washing treatment significantly reduced macro and trace elements load in fruits depending on locations. Heavy metals were present in date and sidr fruits from all locations, with large variations in their concentrations between different locations. The concentrations of highly toxic HMs in dates and sidr fruits were within the permissible limits, except in some samples collected from sites with increased anthropogenic sources which had
Table 6. Concentration of micronutrient and heavy metals (mg/kg) in unwashed and washed fruits collected from sidr trees grown as ornamental landscape trees in different regions in Al Ain city areas.

|       | Unwashed           | Washed            | WHO/FAOy MALsz |
|-------|--------------------|-------------------|----------------|
|       | Control 1 2 3 4 5  | Control 1 2 3 4 5 |                |
| Pb    | <0.011ax <0.011a  | <0.011a <0.011a   | <0.011a <0.011a|
| As    | <0.009a <0.009a   | <0.009a <0.009a   | <0.009a <0.009a|
| Cd    | <0.001 c 0.94 ± 0.001b | <0.001c 2.30 ± 0.02a* | <0.001c 0.86 ± 0.05b|
| Cr    | 1.6 ± 0.0 c 2.5 ± 0.0a  | 1.7 ± 0.0b 2.7 ± 0.0a | 1.6 ± 0.0b 1.9 ± 0.0b|
| Al    | 9.9 ± 0.6b* 10.7 ± 0.2a | 9.1 ± 0.2b* 9.4 ± 0.2b* | 5.3 ± 0.4c 9.7 ± 0.3a |

Values are the mean (n = 3) ± SE. Means with different letter(s) in the same row are significantly different at P ≤ 0.05 using LSD test, and means with ‘*’ of unwashed is significant compared to washed using t test.

WHO/FAO = Food and Agriculture Organization

MALs means maximum allowable limit (mg/kg) set by (WHO/FAO 2007 and 2011). ‘–’ means no established MAL.
Pb, Cr, and Cd concentrations above the permissible limits. Washing the fruits reduced the HMs load in the fruits; however, the values were still above the permissible limits in the highly contaminated samples. The results of this study suggest that in most locations, fruits produced by ornamental date palm and sidr trees are safe for human and animal consumption. Fruits from trees in located areas with high vehicular traffic, industrial activities and other anthropogenic activities are likely not safe for consumption, even when washed, due to toxic levels of HMs. Finally, more investigations are needed on conditions at different locations and how those influence the concentrations of HMs and elements that could be toxic and thus impact consumption recommendations and/or use of the fruits for other purposes. Also, further research is necessary for establishing acceptable levels specifically for date and sidr instead of using levels for other fruits.

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Disclosure statement

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