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Mineral Ion Content of the Seeds of Six Cultivars of Bahraini Date Palm (*Phoenix dactylifera*)

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The mineral ion composition of six different cultivars of Bahraini dates palm (*Phoenix dactylifera*) seeds (Khálas, Murzban, Khunaizi, Khawajah, Khasaib Asfor, and Khaseeb) were analyzed using flame atomic absorption spectroscopy (AA and ICPS). Murzban was found to contain the higher mineral ion content. The essential bulk metal ions in the six cultivars were found to be dominant, where $[K^+]$ was the highest and $[Ca^{2+}]$ was the lowest. The decreasing order of essential trace metal ion concentrations is $Fe^{2+} > Mn^{2+} > Zn^{2+}$. Lead ion content was found to be higher than cadmium ion as metal ion pollutant. Mineral ion contents of Bahraini date palm seeds and those of imported coffee grain and barley were studied, because date palm seeds, coffee grain, and barley are used for coffee drinks.

KEYWORDS: Date palm seeds; mineral ions; Bahrain; *Phoenix dactylifera*

INTRODUCTION

For centuries the date palm (*Phoenix dactylifera*) has been an important crop in desert regions of Middle Eastern countries, forming the basis of survival for many nomads. At present 2000 or more different cultivars of date palm exist worldwide (*1*). Most date palms in Bahrain are cultivated in gardens or plantations, as they have been for thousands of years, for their nutritious fruit and many other uses, but there are a number of date palms growing freely in small stands where the water table is high or close to irrigated land, chiefly in the northern part of the Bahrain isle. Scattered individual trees appear in all parts of the desert, particularly in sandy wadis or hollows (*2*).

During 2000−2002, 5 482 824 metric tons of dates were produced by Arabian Gulf countries, of which Bahrain produced 49 524 metric tons (*3*). The chemical composition and nutritive value of date fruit have been extensively reported in the literature. However, information on the chemical composition and nutritional quality of date seeds is limited. The presence of appreciable quantities of proteins, minerals ions, and especially fats makes date seeds valuable as raw material for the production of animal feed. Date palm seeds contain 9.0% fat of which 56.1% is oleic acid, 11.6% linoeic acid, 8.3% lauric acid, 6.0% myristic, and 2.6% stearic acid (*4*). Phytochemical and chromatographic screening showed other organic compounds, such as proteins, alkaloids, steroids, vitamins, phenols, triterpenes, and other classes of compounds, to be present (*5*). Estrone is present in date palm seeds (*6*) and is found in Egyptian date palm (*7*).

In the Arabian Peninsula, date palm seeds are used not only as a staple food but also to make coffee. The aim of this work is to determine the mineral ion content of seeds of six different cultivars of date palm grown in Bahrain: Khálas, Murzban, Khunaizi, Khawajah, Khasaib Asfor, and Khaseeb. The essential mineral ions Na^+, K^+, Mg^{2+}, and Ca^{2+}, the essential trace metal ions Fe^{2+}, Cu^{2+}, Mn^{2+}, Co^{2+}, and Ni^{2+}, as well as Cr^{3+}, and the pollutant metal ions Cd^{2+} and Pb^{2+} were determined to compare the mineral ion composition of the different cultivars and to compare these with coffee grains and barley, which are also used for "coffee" drinks in the Gulf region. In addition to the cultivars of Bahrain, comparison was made with those cultivars grown in Saudi Arabia and United Arab Emirates.

MATERIALS AND METHODS

The seeds of six cultivars under investigation were collected randomly during the period from June to September 2002 from mature fruits. The seeds were washed thoroughly with tap water and then with deionized water and finally dried in the oven at 38 °C. Six milliliters of 65% nitric acid (puriss, Fluka Chemika) was added to one seed of each sample and wet digested in a Milestone ETHOS 900 Microwave Lab-Station. The digested solution was filtered on a vacuum line using a Büchner funnel to determine the weight of the residue (**Table 1**). The filtrate was transferred to a 100 mL volumetric flask and diluted to the mark with deionized water [the high-purity water was obtained by deionizing double-distilled water on a Barnstead Easy pure RF compact ultrapure water system, maximum electrical conductivity test (0.1 μS cm^{-1} at 25 °C)]. The same procedures were used for the preparation of coffee, barley (0.500 g of powdered dry grains), and the blanks. The concentrations of Na^+, K^+, Mg^{2+}, Co^{2+}, Cu^{2+}, Fe^{2+}, Mn^{2+}, Ni^{2+}, Zn^{2+}, Cd^{2+}, and Pb^{2+} were measured using a Shimadzu AA-9800 atomic absorption spectrophotometer except for Cr^{3+}, which was measured by means of an ICPS-5000 Shimadzu sequential plasma spectrophotometer. All analyses were conducted in duplicate.

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Table 1. Weight of Date Palm Seeds Used in Acid Digestions and the Remaining Residues

	Khálas		Murzban		Khunaizi		Khawajah		Khasaib Asfor		Khaseeb		barley grains		coffee grain	
	wt of each seed (g)	residue (g)	wt of each seed (g)	residue (g)	wt of each seed (g)	residue (g)	wt of each seed (g)	residue (g)	wt of each seed (g)	residue (g)	wt of each seed (g)	residue (g)	wt of grains (g)	residue (g)	wt of grains (g)	residue (g)
1	0.639	0.004	0.669	0.002	0.570	0.004	0.477	0.002	0.611	0.004	0.627	0.003	0.501	0.004	0.514	0.000
2	0.669	0.000	0.558	0.007	0.598	0.005	0.533	0.002	0.632	0.005	0.629	0.004	0.521	0.004	0.517	0.000
3	0.717	0.005	0.713	0.005	0.594	0.003	0.501	0.002	0.779	0.004	0.673	0.005	0.502	0.003	0.519	0.000
4	0.608	0.002	0.523	0.006	0.627	0.005	0.418	0.000	0.687	0.004	0.662	0.002	0.514	0.003	0.518	0.000
5	0.639	0.002	0.733	0.005	0.499	0.004	0.507	0.001	0.710	0.005	0.599	0.001	0.498	0.003	0.516	0.000
6	0.614	0.004	0.548	0.005	0.619	0.003	0.476	0.002	0.809	0.002	0.498	0.001	0.506	0.003	0.531	0.000
7	0.617	0.000	0.497	0.005	0.718	0.001	0.499	0.002	0.529	0.000	0.454	0.000				
8	0.611	0.002	0.505	0.002	0.639	0.000	0.481	0.002	0.566	0.000	0.501	0.002				
9	0.734	0.001	0.503	0.003	0.631	0.003	0.424	0.001	0.502	0.000	0.427	0.001				
10	0.490	0.001	0.499	0.002	0.651	0.000	0.511	0.003	0.532	0.001						
11	0.565	0.000	0.503	0.005	0.628	0.000	0.534	0.005	0.593	0.000						
12	0.622	0.003	0.500	0.005	0.654	0.001	0.487	0.002	0.608	0.000						

Table 2. Mineral Content (Micrograms per Gram) of Seeds under Investigation

	residue[a]			K^+			Na^+			Ca^+			Mg^{2+}		
	X^b	S^b	μ95%[b]	X	S	μ95%	X	S	μ95%	X	S	μ95%	X	S	μ95%
Khalás	3123.10	2552.61	46.20	4620.77	676.37	12.78	229.58	57.93	1.04	113.36	17.82	0.33	695.52	38.91	0.73
Murzban	7755.16	3107.46	56.25	5422.47	1586.23	28.71	261.44	79.80	1.44	108.26	33.32	0.60	631.32	39.83	0.72
Khunaizi	4051.82	3320.86	60.11	4887.87	676.47	12.24	245.08	105.63	1.91	86.88	21.35	0.38	678.45	32.17	0.85
Khwajah	3977.59	2219.93	40.18	4598.56	1452.69	26.29	239.97	56.66	1.02	108.31	23.95	0.43	649.81	51.95	0.94
Khasaib Asfor	3048.82	3169.17	57.36	4709.53	731.65	13.24	217.33	52.60	0.95	89.42	25.53	0.46	613.11	59.68	1.08
Khaseeb	3494.55	2351.06	49.14	4906.25	527.14	11.01	232.36	73.08	1.52	64.51	27.53	0.57	664.98	93.20	1.94
barley	6527.51	969.01	24.80	5091.24	451.49	11.55	291.78	167.92	4.29	223.27	14.47	0.37	1067.77	55.71	1.42
coffee				19607.30	582.45	14.91	48.55	17.61	0.451	566.66	27.730	0.71	1759.03	166.41	4.26

	Fe^{2+}			Mn^{2+}			Zn^{2+}			Cu^{2+}			Ni^{2+}		
	X	S	μ95%	X	S	μ95%	X	S	μ95%	X	S	μ95%	X	S	μ95%
Khalás	52.43	41.84	0.75	13.26	4.69	0.08	11.56	1.08	0.02	6.31	3.17	0.05	1.76	2.24	0.04
Murzban	37.80	21.41	0.38	16.26	2.21	0.04	10.74	3.26	0.05	3.76	0.77	0.01	2.12	2.23	0.04
Khunaizi	48.71	35.35	0.64	12.66	1.92	0.03	14.07	5.81	0.10	4.83	1.82	0.03	2.03	1.75	0.03
Khwajah	60.35	40.64	0.73	14.14	2.07	0.03	12.56	3.41	0.06	5.70	2.04	0.03	0.24	0.57	0.01
Khasaib Asfor	38.60	29.25	0.53	15.62	2.67	0.04	14.51	10.48	0.19	4.51	1.96	0.03	0.25	0.54	0.01
Khaseeb	28.92	6.52	0.13	16.96	2.12	0.04	9.99	0.85	0.01	6.30	2.84	0.05	0.34	0.71	0.01
barley	25.27	4.55	0.11	13.18	3.71	0.09	26.41	19.98	0.51	2.71	0.76	0.02	4.25	2.51	0.06
coffee	26.32	2.91	0.07	32.04	1.49	0.03	6.33	1.18	0.03	13.42	0.39	0.01	8.28	1.35	0.03

	Co^{2+}			Cr^{3+}			Pb^{2+}			Cd^{2+}			total mineral content	
	X	S	μ95%	X	S	μ95%	Z	S	μ95%	X	S	μ95%	total bulk metal	total mineral
Khalfis	1.26	2.50	0.04	*c*	*c*	*c*	2.66	4.47	0.08	*d*	*d*	*d*	5659.24	8871.62
Murzban	0.71	1.32	0.02	*c*	*c*	*c*	2.53	3.73	0.07	0.05	0.07	0.00	6423.51	14252.69
Khunaizi	0.03	0.10	0.00	0.05	0.17	3×10^{-1}	0.93	1.92	0.03	0.09	0.12	0.00	5898.29	10033.56
Khwajah	0.82	1.00	0.01	*c*	*c*	*c*	0.37	0.65	0.01	0.04	0.07	0.00	5596.66	9668.52
Khasaib Asfor	0.10	0.20	0.00	*c*	*c*	*c*	0.16	0.56	0.01	0.01	0.03	0.00	5629.40	8752.02
Khaseeb	0.05	0.16	0.00	0.06	0.20	4×10^{-3}	0.00	0.00	0.00	0.02	0.5	0.00	5868.12	9425.35
barley	4.92	3.71	0.09	*c*	*c*	*c*	6.27	3.72	0.09	0.18	0.16	0.00	6674.07	13284.83
coffee	0.60	0.86	0.02	*c*	*c*	*c*	6.92	3.78	0.09	0.46	0.43	0.01	21981.56	22075.95

[a] Residue: what is left of date palm seed after acid digestion. [b] X = measured mean; S = measured deviation; μ95% = confidence intervals ($\mu = \bar{x} \pm (ts/\sqrt{n})$; n = 12 for Khalas to Khasaib Asfor, $n = 9$ for Khaseeb, and $n = 6$ for barley and coffee. [c] Below the detection limit of the ICPS-5000 Shimadzu sequential plasma spectrometer. [d] Below the detection limit of the AA-6800 Shimadzu atomic absorption spectrometer.

RESULTS AND DISCUSSION

The mineral content of six different date palm seeds was analyzed according to a flame atomic absorption technique, and the results are listed in **Table 2**. The higher mineral ion content was found in Murzban, 14252.6 μg/g, whereas Khasaib Asfor had the lowest content, 8752.0 μg/g. The total mineral ion content was in the sequence Murzban > Khunaizi > Khawajah > Khaseeb > Khálas >Khasaib Asfor. The sequence of mineral ion content in all cultivars was $K^+ > Mg^{2+} > Na^+ > Ca^{2+} > Fe^{2+} > Mn^{2+} > Zn^{2+} > Cu^{2+} > Ni^{2+} > Co^{2+} > Cr^{3+}$ with the exception of Khawajah, where $Co^{2+} > Ni^{2+}$. The essential mineral ion content in the six cultivars was found in the order Murzban > Khunaizi > Khaseeb > Khálas > Khasaib Asfor > Khawajah. Potassium was the highest, ranging from 5422.4 to 4598.5 μg/g, and calcium, the lowest, ranging from 113.3 to 64.5 μg/g. Murzban had the highest contents of Na^+ and K^+, 261.4 and 5422.4 μg/g, respectively. Khálas had the highest contents of Ca^{2+} and Mg^{2+}, 113.3 and 695.5 μg/g, respectively. On the other hand, Khasaib Asfor had the lowest content of Mg^{2+} and Na^+, 613.1 and 217.3 μg/g, respectively, Khawajah had the lowest content of K^+ (4598.5 μg/g) and Khaseeb the lowest content of Ca^{2+} (64.5 μg/g). Iron, an essential trace metal for all living organisms, was found to be the highest of the essential trace metal ions, but its concentration varied from one

Table 3. Average of All Cultivar Mineral Contents (Micrograms per Gram) of the Seeds of Bahrain, Saudi Arabia, and UAE

	Bahrain	UAE[a]	Saudi Arabia[b]
Na^+	237.63	57.6	25.84
K^+	4857.58	42174	80.54
Mg^{2+}	655.53	1134.6	65.96
Ca^{2+}	95.12	1030.8	401.15
Cu^{2+}	5.24	9.0	1.55
Zn^{2+}	12.24	27.8	9.44
Mn^{2+}	14.82	22.6	
Cd^{2+}	0.038		2.12

[a] Cultivars from Al-Ain, United Arab Emirates (*4*). [b] Cultivars from Al-Qaseem (central region of Saudi Arabia) and Hail province (northern region of Saudi Arabia) (*5*).

cultivars to another, in the range from 60.3 to 28.9 pg/g; the highest concentration was found in Khawajah and the lowest in Khaseeb. Mn^{2+} content was found ranging from 16.9 to 12.6 μg/g. Unlike Fe^{2+}, there was no wide variation in its content for the different cultivars. Zn^{2+} contents of all cultivars were similar, but Khasaib Asfor had the highest content, 14.5 μg/g, and Khaseeb the lowest, 9.9 μg/g. Cu^{2+} ranged from 6.3 to 3.7 μg/g, Khálas and Khaseeb having the highest and Murzban the lowest. Co^{2+} concentration ranged from 1.2 to 0.03 μg/g, Khálas, Khawajah, and Murzban containing 1.2, 0.82, and 0.7 μg/g, respectively, and Khunaizi having lowest value.

The Ni^{2+} ion is considered to be very toxic to most plants and moderately so to animals (*8*). Murzban, Khunaizi, and Khálas have the highest contents of Ni^{2+} at 2.1, 2.04, and 1.76 μg/g, respectively; the other three cultivars were found to have the lowest levels, ranging from 0.34 to 0.24 μg/g. The Cr^{3+} ion, essential for glucose metabolism, was found to be below the detection limit of ICPS.

Pb^{2+} is found in higher contents in Khálas and Murzban at 2.6 and 2.5 μg/g, respectively, whereas Khaseeb had Pb^{2+} below the detection limit. The content of cadmium was 0.09 μg/g in Khunaizi and below the detection limit in Khálas.

A comparison of the mineral compositions of date palm seeds of cultivars from Bahrain, Saudi Arabia (*5*), and United Arab Emirates (UAE) (*4*) is shown in **Table 3**. Bahraini cultivars were found to have higher concentrations of K^+ and Na^+, whereas UAE cultivars have high concentrations of Mg^{2+}, Ca^{2+}, Zn^{2+}, and Cu^{2+}; Saudi cultivars were found to contain more Cd^{2+} than cultivars of Bahrain, whereas the Mn^{2+} content of UAE cultivars was found to be higher than that of Bahraini cultivars. Cultivars of UAE were found to have a higher content of essential ions, whereas Bahraini cultivars had higher contents than Saudi cultivars: 6440.4, 5845.8, and 573.4 μg/g, respectively. UAE cultivars' content of bulk metal ions was in the order $K^+ > Mg^{2+} > Ca^{2+} > Na^+$, whereas the order for Saudi cultivars was $Ca^{2+} > K^+ > Mg^{2+} > Na^+$ and that for Bahraini cultivars $K^+ > Mg^{2+} > Na^+ > Ca^{2+}$. Bahraini cultivars were found to contain higher Na^+ and K^+ ion concentrations of 237.6 and 4857.5 μg/g, respectively, whereas UAE cultivars had Na^+ and K^+ concentrations at 57.6 and 217.4 μg/g, respectively; Saudi cultivars had 25.8 and 80.5 μg/g, respectively. UAE cultivars were found to contain higher Ca^{2+} and Mg^{2+} concentrations of 1030.8 and 1134.6 μg/g, respectively. The Ca^{2+} content of Saudi cultivars was higher than that of Bahraini cultivars, at 401.1 and 95.1 μg/g, respectively. The differences in the case of trace metal ions were not so high compared to those of the essential metal ions. UAE cultivars were found to contain higher concentrations of Zn^{2+} and Cu^{2+} than Bahraini and Saudi cultivars. Concentrations of Zn^{2+} and Cu^{2+} in UAE cultivars were found to be 22.6 and 27.8 μg/g, respectively, whereas the Zn^{2+} ion content of Saudi cultivars was similar to that of the Bahraini cultivars at 9.4 and 12.2 μg/g, respectively.

However, there is more deviation in the case of Cu^{2+}; its concentration varies from 5.2 μg/g in Bahraini cultivars to 1.5 μg/g in the Saudi cultivars. The Mn^{2+} ion content of UAE cultivars was found at 22.6 μg/g, more than that in Bahraini cultivars, 14.8 μg/g. The Cd^{2+} content was higher in Saudi cultivars compared to concentrations in Bahraini cultivars at 2.1 and 0.03 μg/g, respectively.

Coffee, barley, and date palm seeds are also used as "coffee" drinks in the Arabian Peninsula; **Table 4** compares their mineral ion concentrations. The total mineral ion content of coffee was found to be highest, followed by barley and then date palm seeds, with 22075.9, 12384.8, and 10167.2 μg/g, respectively.

The coffee content of the essential minerals was the highest at 21981.5 μg/g, whereas those for barley and date seeds were 6674.0 and 5845.8 μg/g, respectively. Barley and date seeds possess the same sequence of bulk minerals, in the order $K^+ > Mg^{2+} > Na^+ > Ca^{2+}$, whereas the sequence for coffee is $K^+ > Mg^{2+} > Ca^{2+} > Na^+$. Coffee has higher contents of K^+, Mg^{2+}, and Ca^{2+} than barley and date seeds, whereas barley had the highest Na^+ content, close to that of date seeds, and coffee the lowest. The content of trace minerals was found to be diverse, the coffee sequence being $Mn^{2+} > Fe^{2+} > Cu^{2+} > Ni^{2+} > Zn^{2+} > Co^{2+}$ and the barley sequence, $Zn^{2+} > Fe^{2+} > Mn^{2+} > Co^{2+} > Ni^{2+} > Cu^{2+}$. Coffee had the highest contents of Mn^{2+}, Cu^{2+}, and Ni^{2+} at 32.04, 13.42, and 8.28 μg/g, respectively, whereas barley and date seeds had similar concentrations of 13.18 and 14.82 μg/g, respectively. Barley had more Ni^{2+} than date seeds at 4.29 and 1.13, respectively, whereas date seeds contained more Cu^{2+} (5.24 μg/g) than barley (2.72 μg/g).

Barley had the highest content of Zn^{2+} at 26.42 μg/g, date seeds, 12.24 μg/g, and coffee, 6.33 μg/g. Barley had a higher Co^{2+} concentration at 4.92 μg/g, whereas in coffee and date seeds it is 0.60 and 0.49 μg/g, respectively.

Date seeds were found to contain 44.47 μg/g Fe^{2+}, whereas in coffee and barley Fe^{2+} concentrations were 26.32 and 25.28 μg/g, respectively.

Date seeds had the lowest concentrations of Pb^{2+} and Cd^{2+}, 1.11 and 0.038 μg/g, respectively, compared to coffee and barley at 6.92 and 6.27 μg/g Pb^{2+} and 0.46 and 0.180 μg/g Cd^{2+}, respectively. The level of an element in a human depends on many factors, and generally a range of values is quoted for a particular organ (*9*−*11*). The daily dietary intakes for the minerals under investigation in date palm seeds show that the mineral ion concentrations are within the dietary intake level

Table 4. Mineral Contents (Micrograms per Gram) of Bahraini Date Seeds, Barley, and Coffee

	Na^+	K^+	Mg^{2+}	Ca^+	Fe^{2+}	Mn^{2+}	Zn^{2+}	Cu^{2+}	Ni^{2+}	Co^{2+}	Pb^{2+}	Cd^{2+}	TEBMI[a]	TMI[a]
date seeds	237.63	4857.58	655.53	95.12	44.47	14.82	12.24	5.24	1.12	0.79	1.11	0.03	5845.87	10167.29
barley	291.78	5091.24	1067.77	223.27	25.27	13.18	26.41	2.71	4.25	4.92	6.27	0.18	6674.07	13284.83
coffee	48.55	19607.30	1759.03	566.66	26.32	32.04	6.33	13.42	8.28	0.60	6.92	0.46	21981.56	22075.95

[a] TEBMI, total essential bulk metal ions; TMS, total metal ions.

in humans: Na^+ (2−15 g), K^+ (1400−7400 mg), Mg^{2+} (250−380 mg), Ca^{2+} (600−1400 mg), Fe^{2+} (6−40 mg), Mn^{2+} (0.4−10 mg), Zn^{2+} (5−40 mg), Cu^{2+} (0.5−6 mg), Ni^{2+} (0.3−0.5 mg), Co^{2+} (0.005−1.8 mg). and Cr^{3+} (0.01−1.2 mg) (*9*−*11*).

In conclusion, the mineral contents of date palm seeds of Bahraini cultivars have shown to a certain extent similar sequences of mineral ion concentrations in the order $K^+ > Mg^{2+} > Na^+ > Ca^{2+} > Fe^{2+} > Mn^{2+} > Zn^{2+} > Cu^{2+} > Ni^{2+} > Co^{2+} > Cr^{3+}$; the only exception to this sequence was found in the Khawajah cultivar, which showed $Ni^{2+} > Co^{2+}$. Among the date palm seeds, Murzban was found to contain the maximum total mineral ion concentration of 14252.6 μg/g. The essential metal ions were found in the order $K^+ > Mg^{2+} > Na^+ > Ca^{2+}$; for trace elements the sequence was $Fe^{2+} > Mn^{2+} > Zn^{2+} > Cu^{2+} > Ni^{2+} > Co^{2+} > Cr^{3+}$.

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