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Macronutrients and toxic minerals availability in some Sudanese foods

Rayan Hassan M Hassan[1*], Omer Adam Gibla[2], Esraa Omer Adam[3]
[1-3] Department of Chemistry, College of science, University of Science and Technology, Sudan

Abstract
This study was conducted to measure the availability of the macronutrients (Na, K, Mg, Ca, and p) in addition to thet oxicminerals (Be, Ba, Cd, Cr, Al, Pb, As, Sb, Sn, and Sr) in some traditional Sudanese foods. Fifteen different Samples of food species were collected from the local marketsat Khartoum State.The samples included, Roselle, Tamarindous, Baobab, Doum, Grewia tenax, Chick peas, Lupine, Cajanuscajan, Cowpeas, Gondaila dates, Millet, Wheat and three different types of Sorghum (fetarita, abahmed and tabat).Inductively coupled plasma spectroscopy (ICP) was used for measuring the minerals concentrations. The concentrations were found to be different inthe analyzed species, ranging from very low to significantly high. Sodium was ranged from (<0.1441 ppm) in Gondaila date to (220 ppm) in Roselle. Potassium range was (4,295 ppm) in Sorghum (fetarita) and (27,648ppm) in Doum. Magnesium ranged from(13.51ppm) in Cowpeas to (3,245ppm) in Roselle. Calcium range was (0.1999ppm) in Sorghum (Abahmed) to (1,966.24ppm) in lupines.The lowest phosphorus content was in Baobab (638.5ppm) and the highest in Cajanusc ajan (3,639ppm).The minerals (Be, Cd, Cr, As, Pb, Sr and Sn) showed trace level concentrations in all the analyzed samples. Barium (Ba) and Strontium (Sr) contents were relatively highin Rossele (30.34 and 74.35ppm respectively).

Keywords: cereal grains, macronutrients, ICP, baobab, grewiatenax, undesired minerals

1. Introduction
Sudanese consume a wide range of plant origin food materials, including cereal grains, vegetables and fruits. For their daily meals, the majority of Sudanese depend onwheat, milletand different types of sorghum. Children and adultsfrequently consume some popular food materials, such as dates, cowpeas, chick peas, lupines, baobab fruit pulp, tamarindous pulp, doum pulp, grewia tenax and Roselle. Some of these fruitsare used for juice preparation or as a tea. The species under study can be categorized into three groups depending on the way of consumption.

- **Cereal grains**

Cereal grains consumption in Sudan is dominated by sorghum, wheat and millet. Sorghum was described to be rich in minerals, varying, from (1%) of ironin some forms to higher concentrations of sodium and potassium. Noha A. Mohammed *et al*; (2011) [14] reported that, Sorghum contains Mg (75.02mg/100g), Ca (3.75mg/100g), Fe (2.24mg/100g) and P (100.6mg/100g). Amir *et al*; (2015) [3] analyzed two Sudan esesorghum cultivars (namely fetarita and dabar), where Fetarita cultivar showed Na content as (5.98mg/100g), K (247.23mg/100g), Ca (2.73mg/100g) and Fe(14.54mg/100g). The othercultivar (dabar) showed Na content as (4.83mg/100g), K (307.51mg/100g), Ca (3.33mg/100g) and Fe (11.32mg/100g). A. Mubark Ebrahim *et al*; (2014) [5] reported minerals content of sorghum as Ca(168 mg/kg), K(3,330 mg/kg), Zn(30 mg/kg), Mn(16 mg/kg), Fe(45 mg/kg), Sr(1.2mg/kg), Ni(0.90 mg/kg) and Cu(4.0 mg/kg). Shimelis A. *et al*; (2009) [22] reported minerals content rangesin millet samples, as Ca (50.66 to 319 mg/100g), Mg (78.0 to 201mg/100g), Fe (4.59 to 53.39mg/100g), P (3.46 to 147mg/100g) and Mn(17.61 to 48.43mg/100g). A. Mubark E. *et al*; (2014) determined minerals content of Millet as Ca(219 mg/kg), K(4,995 mg/kg), Zn (34 mg/kg), Mn (13 mg/kg), Fe(138 mg/kg), Sr(1.8 mg/kg), Ni (1.2 mg/kg) and Cu (6.4 mg/kg). Minerals contents of wheat in A. Mubark *et al*; study(2014), wereCa(561 mg/kg), K(5895 mg/kg), Zn(31 mg/kg), Mn(20 mg/kg), Fe(77 mg/kg), Cu(3 mg/kg) and Sr (3.4 mg/kg). Abdelmoneim A. Mohamed (2001) [2] reported significantly high concentrations of iron, magnesium, zinc and copper in sorghum, millet and wheat grains, that, grown in Jebel Marra area.

- **Roselle and forest fruits(baobab, tamarindus, doum, grewatenax)**

Except Roselle these fruits are wild in Sudan.Roselle is highly consumedin Sudanese homes as juiceorhot tea. Baobab, tamarindus, Grewiatenax and Doum areused for juice preparation or directly eaten by children and adults. According to Rahma Ismael *et al* (2016) [16], Roselle was found to be very rich in K (24,138ppm), Mg (3,790ppm), Ca (1,311ppm), P (1,238ppm), and Na (93.92 ppm). Rahma study also, showed relatively high concentrations of some toxic minerals, in roselle, such as Ba (63.53ppm), Al (369ppm) and Sr (99.82ppm). Sanossi *et al* (2013) [20] described considerable availability of Fe (197 to 1,580µg/g), Mn(11 to 924 µg/g), Cu(49 to 73 µg/g) and Zn(37 to 43 µg/g)in three ecotypes of Roselle from Niger. Baobab fruit pulp wasreported to be very rich in K (17,406ppm), Ca (2,282ppm), Mg (1,707ppm), P (537.3ppm) and Fe (939.5ppm), (Esra Ezeldeen M.O., 2018). According to Muthai K.U *et al* (2017) Baobab fruit pulp can be considered as a naturally dry organic food which, is rich in dietary sources including, fibers, potassium, calcium, magnesium, iron and zinc. In a study carried by Osman M.A. (2004) [4], baobab fruit pulp showed high concentrations of K (1240mg/100g), Ca (295mg/100g), Mg (90mg/100g), Na (27.9mg/100g)and Fe (9.3mg/100g).

Rahma Ismaeil *et al* (2016) [16] reported Minerals content of tamarindous fruit pulp as K(9,512ppm), Ca(1,956ppm), Mg(965.8ppm), P(913.2ppm), and Na (52.95ppm), as well asrelatively high concentrations of the undesired minerals Al(566.8ppm), and Ba (16.14ppm). Safia Atuhami *et al* (2016), described tamarindous fruit pulp as a good source of K, Na, Ca, P and Fe. Gali Adamu *et al*; (2016) [8], reported minerals contents of tamarindo usindicapulp extract, asK (187.73mg/100g), Na (112.76mg/100g), Ca (21.57mg/100g), Mg (10.54mg/100g), Fe (1.05mg/100g) and Mn (0.13mg/100g). A. Mubark *et al*; (2014), reported tamarindous pulp minerals contentas K (12,000 mg/kg), Ca (1,310mg/kg), Zn(9.0 mg/kg), Mn (8.0 mg/kg), Fe (96 mg/kg), Cu (7.0 mg/kg), Sr (13.7 mg/kg), Ni (1.3 mg/kg), Co (0.5mg/kg) and Cr(0.5mg/kg). Doum palm (Hyphaenethebaica) is one of the wide spread and famous trees in Sudan where, it's fruit pulpfind high consumption by children as a popular type of food. Waleed Abushora (2004) considered Doum fruit as a good source of the essential minerals, K (2,947.6mg/100g), Ca (284mg/100g), Na (364.7mg/100g), Mg (185.62mg/100g), P (154.6mg/100g) and Fe (12.18mg/100g). Sara O. Mamoon (2017) analyzeddoum fruit pulp powder using (XRF), reported significantly high concentrations ofK (26,600ppm), Ca (3,730ppm), Fe (59.6ppm), Cu (11.63ppm) and Zn (5.49ppm). Sara study also indicated a presence of Sr (16.3ppm) and Pb (1.27ppm) as undesired constituents in food materials. Marafi Abdallateef (2018) [11] reported relatively high concentrations of Ti (22.91ppm) and Si (62.37ppm) in Doum fruit pulp. FAO's Animal Feed Resource Information System (1991-2002) and Bo Gohl's Tropical Feeds (1976-1982) reports, showed minerals content of doum fruit pulp as, K(6.5g/kg), Ca(0.7g/kg), Na(0.1g/kg), Mg(1.0g/kg) and P(1.7g/kg) on dry matter bases. G.O. Mohamed Elhassan and S.M. Yagi (2010) [9] described Grewiatenax as a rich source ofK(817mg/100g), Ca (790mg/100g), Cu (1.5mg/100g), and Zn(1.9mg/100g). Elmuez Alsir (2014), reported Grewia Tenax minerals content as, K(856.25mg/100g), Mg (135.525mg/100g), Na (22.135mg/100g), Fe (8.222mg/100g) and Zn (2.107mg/100g). A. Mubark *et al*; (2014), reported Grewiatenax minerals content as K (9,425 mg/kg), Ca (6,710 mg/kg), Zn (7.0 mg/kg), Mn (7.0 mg/kg), Fe (19.0 mg/kg), Sr (29.3 mg/kg), Ni (0.3 mg/kg) and Cu (4.0mg/kg).

- **Garden crops (Gondaila date, Chick peas, lupines, Cajanuscajan and Cowpeas)**

In Sudan these are economic crops. Gondaila date is a tree fruit whereas the other four crops are legumes. Abdelmoneim E. Suliman *et al*; (2012) [2] studied five date cultivars, including gondaila. The gondaila cultivar, showed minerals content levels as,Ca (59.09ppm), P (16.201ppm), Zn (0.46ppm), and Mn (0.36ppm). Sultana P. *et al*; (2015) [18] reported minerals concentration ranges in three different date fruits as, K (460 to 680mg%), Ca (51 to 60mg%), P (52 to 60mg%), Mg (48 to 53mg%), Fe(0.79 to 0.9mg%), Mn(0.85 to1.1mg%), Zn (0.69 to 0.72mg%), Cu (0.32 to 36mg%), Cr (0.36 to 42mg %) and Se (0.22 to 0.31mg %).

Chick peas were ported to berich with potassium, sodium, magnesium, calcium, phosphorus, iron, manganese, copper, zinc and selenium, (Taylor C. Wallace *et al* 2016) [24]. Abdel moneim A. Mohamed (2001) reported some minerals content of lupines as, Fe (160ppm), Mn (143.18ppm), Zn (9.39ppm), Cu (3.38ppm), Cr(0.18ppm) and Co (0.52ppm). Tizazu H.I. and S. A. Emire (2010) [25] showed chemical composition of lupinesin Ethiopia as P (248.9mg/100g), Fe (12.5mg/100g), Zn (4.68mg/100g),

Ca(82.56mg/100g), Protein (40.22 g/100g), crude fat(8.92 g/100g), total carbohydrates(47.73 g/100g), crude fiber (10.08 g/100g), and crude ash (3.15 g/100g). A. Mubark Ebrahim *et al*; (2014) [5] reported minerals content of Lupinustermis L. as K (6,370mg/kg), Ca (1,660mg/kg), Zn (47mg/kg), Mn (23mg/kg), Fe(28mg/kg), Sr (5.8mg/kg), Ni (6.0mg/kg)and Cu (9.0mg/kg). Cajanuscajan minerals content in the same study was reported to beK (14,900mg/kg), Ca (640mg/kg) Zn (33mg/kg), Fe (35mg/kg), Mn (14mg/kg), Cu (12mg/kg) and Ni (2.8mg/kg). Cowpea is an essential tropical legume crop of African origin and has become an integral part of the traditional cropping system in the semi-arid West African savannah (Steele1972). Cowpea was reported to be a good alternative of meat and fish protein (M. Harmankaya *et al*; 2016) [12]. Sert and Ceyhan (2012) described cowpeas as a good source of K, P, Ca, S, Mg, Fe and Zn. In Sudan, cowpeas are consumed as green leaves, fresh pods, fresh seeds and dry grains. I.K. Asante *et al*;(2007) [10] reported highest mineral concentrations means for 30 cowpea cultivars as K(19,050μg/g), Ca (2,096μg/g), Mg(5,170μg/g), Na (192μg/g) and Cu (12.3μg/g). M. Harmankaya *et al*; (2016) [12] determined chemical composition of three cowpea genotypes, reporting protein range as (27.6 to 30.1%), carbohydrates range as (56.3 to 60%), Fat content as(2.0 to 2.3%) ash content (3.8 to 4.2%), moisture content as (5.9 to 7.2%), and minerals content mean values as K (114.6 mg/100g) Ca (95mg/100g), Mg (209.3mg/100g) P (556.7mg/100g), Fe (5.8mg/100g), Zn (4.4mg/100g) Mn (1.8mg/100g), Cu(1.2mg/100g) andS(148.2mg/100g).

2. Methodology

Fifteen different Sudanese food samples were randomly collected from Khartoum State markets (Sudan).The samples in cluded Roselle, Tamarindous, Baobab, Doum, Grewia tenax, Chick peas, Lupine, Cajanuscajan, Cowpeas, Gondaila dates, Millet, Wheat and three different Sorghum cultivars (Feterita, Abahmed and Tabat). Inductively coupled plasma mass spectroscopy (ICP-MS – PQ9000) was used for measuring the minerals content of the food samples understudy. All the chemicals used were of analytical grade.

3. Results and discussion

Table 1: Macronutrients content of cereal grainssamples (ppm)

Mineral	Cereal grain				
	Fetarita	Abahmed	Tabat	Millet	Wheat
Na	0.4991	11.67	24.86	53.76	58.49
K	4,295	4,563	4,375	5,882	4,587
Mg	1,595	1,244	1,217	1,508	1,300
Ca	34.44	0.01999	11.70	235.8	462.2
P	3,164	2,574	2,260	3,571	2,667

Macronutrients content of cereal grains were found to be relatively high (table1). Sodium and calcium showed clearly different concentrations in the three Sorghum samples. The lowest sodium content was in Fetarita (0.4991ppm) compared with Abahmed (11.67ppm) and Tabat (24.86ppm). Low sodium may be a good property in food, because high sodium is one of the factors that, may increase blood pressure. Millet and Wheat showed almost similar sodium content (53.76 and 58.49ppm respectively). The five cereal grains samples were significantly rich with, K, P and Mg. The lowest calcium contentwas shown by sorghum cultivars (34.44, 0.01999 and 11.70 ppm). In Millet and Wheat Calcium concentrations were relatively high. The Macronutrients concentrations in this study agree with those obtained by Shimelis Admassu, *et al*; (2009) [22] and Noha A. Mohammed, *et al*; (2011) [14]. A. Mubark Ebrahim *et al* (2014) [5] reported potassium as (3,330mg/kg) in sorghum, (4,595mg/kg) in millet and (5,895mg/kg) in wheat. Calcium concentrations according to A. Mubark *et al*; study were (168mg/kg) in sorghum, (219mg/kg) in millet and (561mg/kg) in wheat.

Table 2: Thetoxic minerals content ofcereal grains (ppm)

Mineral	cereal grain				
	Fetarita	**Abahmed**	**Tabat**	**Millet**	**Wheat**
Be	0.0100	0.0100	0.0100	0.0100	0.0100
Sr	1.208	1.419	1.369	1.380	5.601
Ba	0.3793	0.1999	0.1899	0.320	2.845
Cr	0.0599	0.1099	0.0900	0.930	0.190
Cd	$<198\times10^{-7}$	$<198\times10^{-7}$	$<198\times10^{-7}$	$<198\times10^{-7}$	$<2547\times10^{7}$
Al	1.817	5.007	6.098	35.72	23.53
Sn	0.7187	0.6896	0.5998	0.350	0.6190
Pb	$<4727\times10^{7}$	$<4727\times10^{7}$	$<4727\times10^{7}$	$<4727\times10^{-7}$	$<4727\times10^{-7}$
As	$<2547\times10^{7}$	$<2547\times10^{7}$	$<2547\times10^{7}$	0.020	$<2547\times10^{-7}$
Sb	$<6078\times10^{7}$	$<6078\times10^{7}$	$<6078\times10^{7}$	$<6078\times10^{-7}$	$<6078\times10^{-7}$

The toxic minerals concentrations in cereal grains samples were generally low (table 2). Beryllium concentrations were similar in all samples, showing almost negligible values. Barium, strontium, chromium and tin concentrations may be considered at the safe levels. Aluminum showed low concentrations in the three sorghum samples (1.817,5.007 and 6.098ppm) compared with relatively high values in millet (35.72ppm) and wheat (23.53ppm).The five cereal samples may be regarded as free of cadmium, lead, arsenic and antimony.

Table 3: Macronutrients content in gardencrops (ppm)

Mineral	Crop type					
	Roselle	**Cajanuscajan**	**Lupines**	**Gondila Date**	**Cowpeas**	**Chick peas**
Na	220.9	35.9228	28.19	<0.01421	22.23	108.0
K	22,112	17,414	6,931	9,628	12,343	10,275
Mg	3,245	1,302	1,370	728.7	1,351	1,437
Ca	16,436	1,004	1966.241	1,041	689.14	1,152
P	1,606	3,639	2,909	777.6	2,864	2,466

These crops are frequently used by Sudanese people.The analyzed samples showed high concentrations of K, Ca, Mg and P (table3).These crops may be described as very good sources of K, Ca, Mg, and P. Rahma I. A. *et al*; (2016) [16] reported similar concentrations for Roselle. A. Mubark Ebrahim (2014) [5] reported high potassium and calcium concentrations in Cajanuscajan and lupines. Sodium concentrations were relatively low in all samples, ranging from (<0.01421ppm) in Gondaila date to (220.9ppm) in Roselle. Low sodium concentrations in crops may be expected, because sodium ions are very soluble in water, so it may be difficult for plants to absorb higher sodium ions from soils.

Table 4: Toxic minerals content of garden crops (ppm)

Mineral	Crop type					
	Roselle	**Cajanuscajan**	**Lupines**	**Gondaila Date**	**Cowpeas**	**Chickpeas**
Be	0.0200	$<3\times10^{-5}$	0.0100	$<3\times10^{-5}$	0.0100	0.0100
Sr	74.35	7.169	7.851	2.537	7.111	11.98
Ba	30.34	0.7499	7.131	0.3895	0.9688	1.270
Cr	2.067	0.0100	3.416	0.320	$<583\times10^{-4}$	0.0300
Cd	0.0499	198×10^{-7}	198×10^{-7}	198×10^{-7}	198×10^{-7}	198×10^{-7}
Al	223.7	$<333\times10^{-7}$	26.34	11.32	<0.002547	$<333\times10^{-7}$
Sn	0.2796	0.9498	2.497	0.6193	1.019	0.9098
Pb	$<4727\times10^{-7}$	$<4727\times10^{-7}$	0.3296	0.0400	$<4727\times10^{-7}$	$<4727\times10^{-7}$
As	$<2547\times10^{-7}$	$<2547\times10^{-7}$	$<2547\times10^{-7}$	$<2547\times10^{-7}$	$<2547\times10^{-7}$	$<2547\times10^{-7}$
Sb	<0.006078	0.1000	0.0899	0.0899	0.1298	0.0500

The mineralsthat, normally classified ashighly toxic or carcinogenic (Be, Cr, Pb, As, Sn, Sb and Cd), showed significantly low availabilityin the five cropssamples (table4). Aluminum content of Cajanuscajan, cowpea and chick peas was appeared to be very low. Strontium showed different concentrations in the five crops. Roselleshow relatively high availability of Sr (74.35ppm), Al (223.7ppm) and Ba (30.34ppm).

Table 5: Macronutrients content of forest fruits (ppm)

Mineral	Fruit			
	Baobab	**Tamarindous**	**Grewiatenax**	**Doum**
Na	122.3	76.33	69.59	151.3
K	16,081	11,434	9,410	27,648
Mg	1,370	1,208	1,225	1,260
Ca	2,629	1,767	5,412	851.4
P	638.5	902.3	1,103	1,111

Baobab, Tamarindous, Grewiatenax and Doum,were found to be extreme lyrich with Na, K, Ca, Mg and P (Table5). Thefour fruits therefore, may be described as good sources of macronutrients. Potassium concentration was significantly high in the four fruits. When compared with cereal grains and garden crops (tables 1 and 3) the wild fruits samples showed high sodium concentrations. Magnesium showed almost similar availability in the four fruits.

Table 6: The toxic minerals in the forest fruits (ppm)

Mineral	Fruit			
	Baobab	**Tamarindous**	**Grewiatenax**	**Doum**
Be	0.0500	0.0100	0.0100	0.0299
Sr	53.17	24.44	20.47	12.09
Ba	15.16	26.25	13.39	1.937
Cr	0.6993	0.2097	0.2999	0.5290
Cd	<0.000198	<0.000198	0.0100	<0.000198
Al	781.6	55.95	36.93	423.1
Sn	0.4496	0.3296	0.2100	0.6089
Pb	0.2298	<0.004727	<0.004727	<0.004727
As	0.1199	<0.002547	<0.002547	0.0998
Sb	<0.006078	0.000	<0.006078	0.898

The toxic minerals (Be, Cr, Cd, Sn, Pb, As and Sb) showed low concentrations in the four wild fruits (Table 6).All the analyzed samples showed relatively high Aluminum content. Strontium and barium availability may be at risky levels, since the two cations (Sr^{2+} and Ba^{2+}) are classified to be of high toxicity.

4. Conclusion

- All the analyzed food types, were found to be rich sources of the essential macronutrients, Na, k, Mg, Ca and P. Sudanese who consume these food materials, may not need any minerals supplementation additives to their diet.
- The undesired minerals (harmful, toxic or carcinogenic), showed very low concentrations in general. Depending on that, the studied food types may be described, as safe and almost free from any undesirable inorganic contaminants.

5. Recommendations

- Further studies may be needed, to widen the survey in this field or to analyze more other types of foods which are not included in this study such as vegetables and domestic fruits.
- Samples from other Sudan States and areas may need to be studied.

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