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Study of Elemental Concentrations of Some Sudanese Food by Instrumental Neutron Activation Analysis (INAA)

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ABSTRACT

The aim of this study to determine the trace elements and heavy metals in some Sudanese food samples. Food samples have been collected from local markets in different States in Sudan. The average elemental concentrations for Na, Mg, Al, Cl. K, Ca, Mn, Cu, Fe, Zn, Cr and Cd have been determined using Instrumental Neutron Activation Analysis (INAA). Quality control of data analysis was assessed using SRM 1547 (peach leaves). Good agreement was found between certified and determined values. The elemental concentrations showed little difference amongst the different food samples and the values obtained indicate that these items can contribute to the Recommended Dietary Allowance (RDA) for these elements. Correlations between different elements were performed. Hierarchical cluster analysis was done for the data. The obtained average elemental concentrations were compared with data from literature.
KEYWORDS: Elemental concentrations, Food, Instrumental neutron activation analysis (INAA).

INTRODUCTION

Trace elements are essential and play an important roles in biological systems in human body. Some of them form an integral part of several enzymes. Although they are essential, they can be toxic when taken in excess; both toxicity and necessity vary from element to element and from species to species. But also have harmful effects when their intakes exceed the recommended quantities significantly [(1)]. Since food is the primary source of essential elements for humans and it is an important source of exposure to toxic elements either, the levels of trace elements in consumed food products must be determined [(2)].

Soil, air, water are traditionally using as sites for disposal of industrial waste, agricultural chemicals and transportation waste, and thus they have got polluted by heavy metals. Polluted environment supplies heavy metal into food chain. Plants as essential components of natural ecosystems and agro systems represent the first compartment of the terrestrial food chain. Due to their capacity to accumulate toxic elements, they grow and survive on contaminated soil [(3)].

The intake of heavy metals through food chain is important in assessing risk to human health. Increasing environmental pollution has given rise to concern on the intake of heavy metals in humans. These metals enter the human body mainly by two routes namely: inhalation and ingestion. The intake of heavy metals through ingestion depends on the food habit. Many analytical methods have been used in food analysis. Neutron Activation Analysis, NAA, has been successfully used on a regularly basis in several areas of nutrition and foodstuffs. NAA has become an important and useful research tool due to the methodology's advantages [(4)]. The objective of this study is to determine the levels of Na, Mg, Al, Cl. K, Ca, Mn, Cu, Fe, Zn, Cr and Cd in some Sudanese food and assess nutritional adequacy against Recommended Dietary Allowance (RDA).

MATERIALS AND METHODS

Food items; which is more consuming; collected according to the statistical analysis of questioner. Food samples were collected from local markets in different States in Sudan. Food sampling include different categories such as cereals and cereals products, vegetables, fruits and legumes. Table 1 shows Samples codes, common names, scientific names, family, locations and used parts. Dried and homogenized food samples, ranging between 1.0-0.2 g were individually packed in polyethylene irradiation vials for INAA measurement.

INAA measurement:

Samples and standards were irradiated at the Morocco research reactor type Triga Mark II with1 z maximum thermal flux of (1.944x10 n.cm s). The packed samples were individually irradiated for 25 s at a thermal flux of-2-11 -26x10lzncm"z s' 1 in order to facilitate detection of short lived radionuclides. Samples were counted immediately

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for 20 min. Other batch of weighted samples was irradiated for 4 hours to detect long lived radionuclides. After one month cooling interval, the gamma spectrometry system equipped with a high purity germanium detector (HPGe) was used for sample activity measurement. The measured activity of each sample was corrected for decay and counted for one hour. The data acquisition and identification of γ-rays of product radionuclide are identified by their γ-ray energies via Ginie2000 software. Calculations were performed using ko-IAEA program. Table 2 presents the nuclear data and irradiation scheme used for the elemental determination in this work [5]. The accuracy of the analytical procedure used is confirmed by the analysis of SRM 1547 (peach leaves). Table 3 shows the INAA results were stated for quality control material of SRM 1547 (peach leaves).

Table 1 Samples codes, common names, scientific names, family, locations and used parts:

Codes	Common name	Scientific name	Family	Location	Used parts
FS1	Wheat	Triticum aestivum	Poaceae	Barbar	Seeds
FS2	Sorghum	Sorghum bicolor	Poaceae	Barbar	Seeds
FS3	Sorghum	Sorghum bicolor	Poaceae	Kegi	Seeds
FS4	Bread			Barbar	
FS5	Potato	Solanum tuberosum	Solanaceae	Abu Hamed	tuber (stems)
FS6	Corchorus	Corchorus olitorius	Malvaceae	Shandi	Leaves
FS7	Eggplant	Solanum melongena	Solanaceae	Al-gareif	Fruits
FS8	Purslane	Portulaca oleracea	Portulacaceae	Kegi	leaves +stems
FS9	Onion	Allium cepa	Alliaceae	Barbar	Leaves
FS10	Tomato	Solanum lycopersicum	Solanaceae	Atabra	Fruits
FS11	Okra	Abelmoschus esculentus	Malvaceae	Abu Hamad	Fruits
FS12	Potato	Solanum tuberosum	Solanaceae	Al-kamleen	tuber (stems)
FS13	Mango	Mangifera indica	Anacardiaceae	Shandi	Fruits
FS14	Banana	Musa acuminate	Musaceae	Shandi	Fruits
FS15	Mango	Mangifera indica	Anacardiaceae	Shambat	Fruits
FS16	Orange	Citrus sinensis	Rutaceae	Shambat	Fruits
FS17	String beans	Phaseolus vulgaris	Fabaceae	Atbara	Seeds
FS18	Broad Bean	Vicia faba	Fabaceae	Abu Hamed	Seeds
FS19	String beans	Phaseolus vulgaris	Fabaceae	Shandi	Seeds
FS20	Broad Bean	Vicia faba	Fabaceae	Barbar	Seeds

Table 2 Nuclear data used for the elemental analysis:

Target isotope	Target (Reaction) radionuclide	Gamma Energy (keV)	Half Life
Na	23Na (n, γ)24Na	1368.6 / 2754.1	15h
Mg	26Mg (n, γ)27Mg	1014.4	9.46m
Al	27Al(n, γ)28Al	1778.9	2.4m
Cl	37Cl (n, γ)38Cl	1642	37.2m
K	41K (n, γ)42K	1524.58	12h
Ca	48Ca (n, γ)49Ca	3084.4	8.72m
Mn	55Mn (n, γ)56Mn	1810.7	2.58h
Cu	65Cu (n, γ)66Cu	1039.4	5.1m
Fe	58Fe (n, γ)59Fe	1099.2,	44.5d
Zn	64Zn (n, γ)65Zn	1115	344d
Cd	114Cd (n, γ)115Cd	336	53.5h
As	75As (n, γ)76As	559.1	26.3h

Table 3 INAA results were stated for quality control material of SRM 1547 (peach leaves)

Elements	This work	Certificate value	Relative error %
Na	22.70±1.8	24±2	5.38
Mg	4056.62±0.009	4300±0.01	5.66
Al	228.95±7.35	249±8	8.05
Cl	344.8±18.19	360±19	4.22
K	23153.04±0.02	24300±0.03	4.72
Ca (%)	1.44±0.01	1.56±0.02	7.06
Mn	86.48±2.64	98±3	11.75
Cu	3.37±0.36	3.70±0.40	8.8
Fe	196.81±12.63	218±14	9.72
Cr	0.92±0.19	1.0±0.21	7.46
Zn	15.85±0.35	17.9±0.40	11.41

RESULTS AND DISCUSSION

Elemental concentrations for food samples by INAA:

Food samples have been analyzed by INAA and the elemental concentrations of food samples are listed in Table (4) and graphically displayed in Figure (1). In cereals and cereals products samples, the concentration of sodium was found to vary from 26.64 to 151.6 ppm with a mean of 86.36 ppm. Magnesium concentration ranges from 449.5 to 2248 ppm with an average value of 1397.2 ppm. Aluminum, concentration was found to vary from 92.56 to 136.6 ppm with a mean value of 112.22 ppm. The concentration of chlorine ranges from 584.3 to 1294 ppm with an average value of 815.32 ppm. Potassium concentration was found to vary from 2404 to 5224 ppm with a mean value of 3613.25 ppm. The calcium concentration ranges from 277 to 683.8 ppm with an average 450.1 ppm. The concentration of Mn was found to vary from 11.05 to 51.89 ppm with a mean value of 27.14 ppm. Cu concentration was found to be less than detection limits. Iron concentration ranges from 82.2 to 319.4 ppm with an average value of 155.95 ppm. Cr concentration was found to vary from 4.25 to 10.94 ppm with a mean value of 6.93 ppm. Zinc concentration was found to vary from 12.4 to 61.56 ppm with a mean value of 23.24 ppm. In vegetables samples, the concentration of sodium was found to vary from 235.5 ppm to 2501 ppm with a mean value of 1122.37 ppm. Magnesium concentration ranges from 1352 ppm to 3327 ppm with an average value of 2038.8 ppm. Aluminum, concentration was found to vary from 138.1 ppm to 735.4 ppm with a mean value of 411.28 ppm. The concentration of chlorine ranges from 195 ppm to 1264 ppm with an average value of 907.56 ppm. Potassium concentration was found to vary from 1273 ppm to 16160 ppm with a mean value of 6072.3 ppm. The calcium concentration ranges from 626 ppm to 1856 ppm with an average 1068.8 ppm. The concentration of Mn was found to vary from 17.4 ppm to 55.48 ppm with a mean value of 32.32 ppm. Cu concentration ranges from 5.7 ppm to 5.98 ppm with an average value of 5.84 ppm. Iron concentration was found to vary from 106 ppm to 1700 ppm with a mean value of 772.31 ppm. Cr concentration ranges 3.62 ppm to 20.81 ppm with an average value of 11.12 ppm. Zinc concentration was found to vary from 23.3 ppm to 70.91 ppm with a mean value of 42.15 ppm. In fruits samples, the concentration of sodium was found to vary from 847 ppm to 956 ppm with a mean value of 890.43 ppm. Magnesium concentration ranges from 2680 ppm to 4464 ppm with an average value of 3314 ppm. Aluminum, concentration was found to vary from 3514 ppm to 5863 ppm with a mean value of 4503 ppm. The concentration of chlorine ranges from 312 ppm to 943 ppm with an average value of 674 ppm. Potassium concentration was found to vary from 1455 ppm to 1920 ppm with a mean value of 1614 ppm. The calcium concentration ranges from 2283 ppm to 4300 ppm with an average 3533 ppm. The concentration of Mn was found to vary from 64 ppm to 86.2 ppm with a mean value of 74.21 ppm. Cu concentration was found to be less than detection limits. Iron concentration ranges from 3392 ppm to 5181 ppm with an average value of 3960 ppm. The concentration of Cr was found to vary from 6.34 ppm to 54.4 ppm with a mean value of 26.79 ppm. Zinc concentration ranges from 22 ppm to 30 ppm with an average value of 20.9 ppm. In legumes samples, the obtained concentration of sodium was found to vary from 50.33 ppm to 112.3 ppm with a mean value of 83.9 ppm. Magnesium concentration ranges from 1242 ppm to 1750 ppm with an average value of 1590 ppm. Aluminum, concentration was found to vary from 62 ppm to 476 ppm with a mean value of 228 ppm. The concentration of chlorine ranges from 213 ppm to 731ppm with an average value of 448 ppm. Potassium concentration was found to vary from 1230 ppm to 12880 ppm with a mean value of 6367 ppm. The calcium concentration ranges from 438 ppm to 974 ppm with an average 698 ppm. The concentration of Mn was found to vary from 11.3 ppm to 20.47 ppm with a mean value of 15.5 ppm. Cu concentration ranges from 14.5 ppm to 14.95 ppm with an average value of 14.7 ppm. Iron concentration was found to vary from 118.2 ppm to 412.9 ppm with an average value of 277 ppm. Cr concentration ranges from 3.78 to 45.2 ppm with an average value of 33.8 ppm. Zinc concentration was found to vary from 29.3 ppm to 41.37 ppm with an average value of 33.82 ppm.

The comparison of mean elemental concentrations obtained in different food categories showed that the mean elemental concentrations of Na, Al, Ca and Fe were slightly very high in vegetables and fruits, while their concentrations were very low in cereals and cereals products and legumes. On the other hand, the mean concentration of Mg, Cl and Zn was found almost the same value in different food categories. The mean elemental concentration of Mn was found higher in fruits than obtained values in cereals and cereals products, vegetables and legumes. Potassium mean concentration was found slightly high in vegetables and legumes, while concentration was low in cereals and cereals products and fruits. The mean elemental concentration of Cr was found slightly high in fruits and legumes, while concentration found low in cereals and cereals products and vegetables. Elemental concentration vary in different categories due to differences in botanical structure, soil which plants are cultivated and other factors like use of fertilizers, irrigation water and climatological conditions.

Correlation
Correlations between concentrations certain elements can be used as indicators of specific sources [6]. Pair wise correlation was performed. Table 5 show the correlation between the elemental concentrations data for food samples collected from different locations. The correlation data (bold correlation are significant at p <0.05) results showed that are highly correlated with each other, suggesting clearly originating from similar sources.

Cluster analysis
The results of cluster analysis of elements in food samples were obtained as dendograms displaying two main clusters. In the dendogram the first group containing the Na, Zn, Al, Fe, Mg, Ca and Cl were generally as elements in plant. The second group containing only K represents the element which highly enriched from the soil by plant.

Recommended Dietary Allowance (RDA)
By definition, every essential trace elements must have average of intake safe from toxicity but adequate enough to meet nutrition requirements. Essential elements generally are smaller than 100 mg/day. Although the RDA has not been established for some, several have been studied and the U.S Food and Nutrition Board of the National Academy of Sciences has been able to identify how much we should consume. Many foods that would normally be expected to supply the trace minerals unfortunately do not. Many soils are geographically deficient in certain minerals and therefore foods grown are in lack of those nutrients. A similar problem can be caused by over farming or poor soil management [7]. The comparison of recommended dietary allowance and safe daily dietary intake of trace elements with our analyzed values of trace elements are given in Table 6.
Comparison of mean elemental concentration of different food categories with pervious data from literature were listed in Table 7. Generally, the mean concentration of Mg in cereals and cereals products from this study were in the same range of earlier study from Latvia. On the other hand, the mean concentration of Na were lower in study from Latvia and Croatia compared to this study. K concentration in cereals and cereals products in our study and study from Ethiopia were less than the values recorded in study from Latvia. The mean concentration of Ca in cereals and cereals products in study from Latvia and this study were higher compared to values from study from Ethiopia. Mn concentration in cereals and cereals products in study from Latvia, Ethiopia and this study were less than the values recorded in study from Croatia. The mean concentration of Fe in cereals and cereals products in this study were higher compared to values from previous studies from Ethiopia, Latvia and Croatia. On the other hand, the mean concentration of Zn were lower in study from Latvia and Ethiopia compared to this Study and study from Croatia. The mean concentration of Al and Cr in cereals and cereals products were higher in this study compared to values from pervious study from Latvia. In vegetables the mean concentration of Na from this study were higher compared to values reported in study from Ghana. On the other hand, the mean concentration of Mg were lower in study from USA compared to previous study from Ghana and this Study. K concentration in vegetables in study from Ghana were less than the values recorded in earlier study from Sudan and our study. The mean concentration of Ca in vegetables in earlier study from Sudan were higher compared to values from study from Ghana, USA and this study. Mn concentration in vegetables in the previous study from Sudan and this study were less than the values recorded in study from Ghana. The mean concentration of Fe in vegetables in earlier study from Sudan and this study were higher compared to values from study from USA. On the other hand, the mean concentration of Zn were lower in previous study from Sudan and USA compared to this Study.
Results obtained for fruits samples showed that the mean concentration of Na, Mg and Al this study were higher than the values recorded in earlier study from KSA. On the other hand, the mean concentration of K were lower in study from KSA and this study compared to previous study from Bangladesh. Ca concentration in fruits in study from KSA were less than the values recorded in earlier study from Bangladesh and this study. The mean concentration of Mn in fruits in this study were higher compared to values from study from Kenya. Fe concentration in fruits in previous study from Bangladesh and Kenya were less than the values recorded in study from KSA and this study. The mean concentration of Zn in fruits study from Bangladesh and this study were higher compared to values from previous study from KSA and Kenya. On the other hand, the mean concentration of Cr were lower in study from Kenya compared to this Study. In legumes the mean concentration of Na and Zn were higher in earlier study from Turkey and this study than the values recorded in previous study from Jamaica and Lithuania. On the other hand, the mean concentration of Mg. Ca and Mn in study from Turkey, Jamaica and our study were less than values recorded in study from Lithuania. The mean concentration of K in legumes in previous study from Lithuania and Turkey were higher compared to values from study from Jamaica and this study. Cu concentration in legumes in earlier study from Lithuania and Turkey were less than the values recorded in this study. On the other hand, the mean concentration of Fe were lower in previous study from Turkey and Jamaica compared to earlier study from Lithuania and this Study.

Table 4 Elemental concentrations (ppm±SD) of different food categories by INNA:

Elements	Cereals and cereals products	Vegetables	Fruits	Legumes
Na	86.3±68.7	1122±903	890.43±58.11	83.9±30.6
Mg	1397±936	2038±687	3314.25±790.09	1590±235
Al	112.72±22.25	411.28±260.61	4503±986.44	228±219
Cl	815±327	907.56±427.95	674.73±326.01	449±249
K	3613±1294	6072±5786	1631.7±265.35	6367±5823
Ca	450.1±178.5	1068.79±520.12	3533.5±891.1	698±233
Mn	27.14±18.32	32.32±18.1	74.21±11.18	15.5±3.8
Cu	ND	ND	ND	14.71±0.33
Fe	155.95 ±110.24	722.31±468.98	3960.5±823.73	277±149
Cr	6.93±2.83	11.12±7.73	26.79±23.92	24.5±29.3
Zn	32.24±20.8	41.15±19.25	20.90±1.01	33.8±5.33

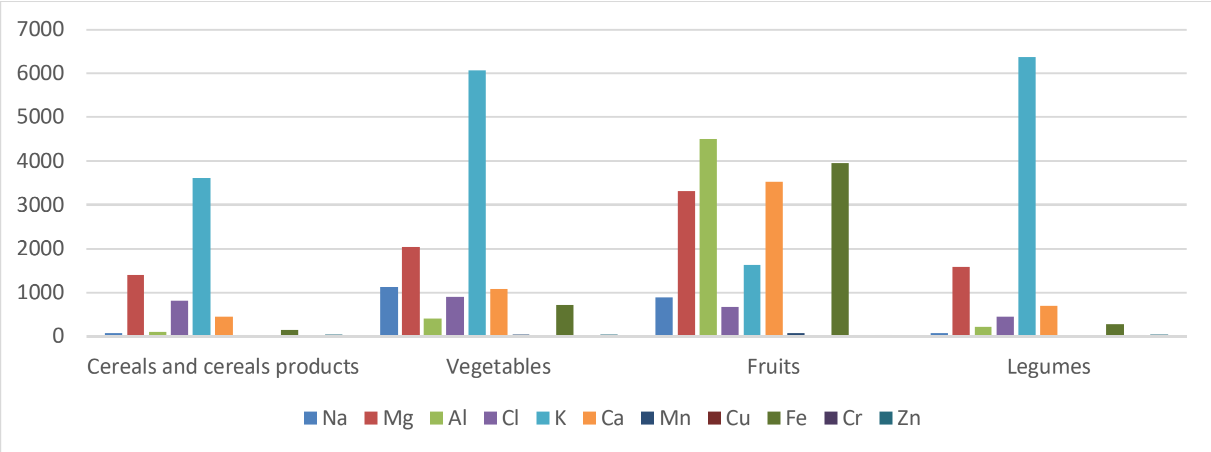

Fig 1 Mean elemental concentrations of different food categories analyzed by INAA

Table 5 shows the correlation between elements:

	Na	Mg	Al	Cl	K	Ca	Mn	Cu	Fe	Zn
Na	1	**0.980** **0.000**	0.932 0.000	**0.999** **0.000**	0.833 0.005	**0.998** **0.000**	**0.991** **0.000**	0.972 0.000	**0.983** **0.000**	0.915 0.001
Mg		1	0.863 0.003	**0.984** **0.000**	0.791 0.011	0.950 0.000	0.962 0.000	0.948 0.000	0.960 0.000	0.890 0.001
Al			1	0.922 0.000	0.719 0.029	0.938 0.001	0.913 0.001	0.868 0.002	0.891 0.001	0.793 0.011
Cl				1	0.832 0.005	**0.980** **0.000**	**0.990** **0.000**	0.966 0.000	0.978 0.000	0.914 0.001
K					1	0.825 0.012	0.878 0.002	0.863 0.001	0.851 0.002	0.957 0.000
Ca						1	**0.990** **0.000**	**0.986** **0.000**	**0.993** **0.000**	0.916 0.001
Mn							1	**0.988** **0.000**	**0.993** **0.000**	0.947 0.000
Cu								1	**0.998** **0.000**	0.947 0.000
Fe									1	0.936 0.000
Zn										1

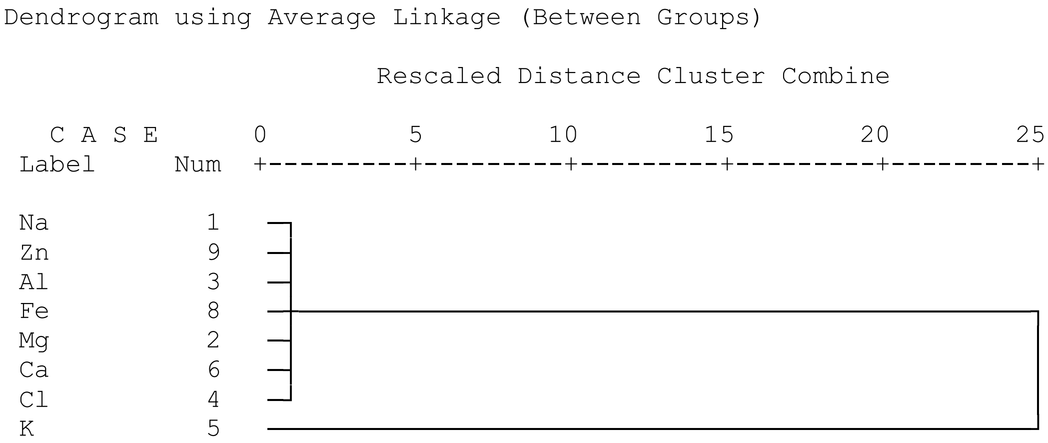

Fig 2 Hierarchical Cluster analysis of food samples

Table 6 Recommended dietary allowance and estimated safe daily intake of trace elements for human beings:

Trace elements analyzed	Maximum concentration of trace elements observed in the food samples (µg/g)				Recommended dietary allowance (RDA)	
	Cereals	Vegetables	Fruits	Legumes	Male	Female
Na	165.3	3682	956.4	112.3	3300mg	2500mg
Mg	3261	5448	4464	1750	400mg	
K	7546	26160	1920	17880	4700mg	
Ca	724.3	4852	4300	1074	1000mg	
Mn	32.55	232.9	115.7	20.47	5mg	
Fe	123	5636	5181	412.9	10-12mg	15mg
Zn	40.3	66.86	20.72	41.37	12-15 mg	15mg

Table 7 Comparison of average of elemental concentration of food samples with data from literature

Food	**Country**	**Elemental concentration (ppm)**											
		Na	Mg%	Al	Cl	K%	Ca%	Mn	Cu	Fe%	Zn	Cr	Cd
Cereals	This work	86.3	0.139	112	815	0.36	0.045	27.14	nd	0.015	32.24	6.93	-
	Latvia [8]	17.4	0.13	1.44		0.47	0.046	28	3.95	0.003	22	0.177	0.013
	Croatia [9]	36.7		-	-	-		53	3.62	0.003	41.5	-	0.037
	Ethiopia [10]			-		0.14	0.15	12.5	5.1	0.005	26.22		1.72
Vegetables	This work	1122	0.20	411.2	907.5	0.607	0.106	32.32	-	0.072	41.12	11.12	-
	Sudan [11]	-	-	-	-	-	0.41	32	13	0.026	26	-	-
	Ghana [12]	250	0.30	-	-	0.29	0.029	49.5	-	-	-	-	-
	USA [13]	-	0.019	-	-	-	0.149	-	6.8	30	25	<0.1	<0.1
Fruits	This work	890	0.33	4503	674	0.16	0.35	74	-	0.39	20.9	26.9	
	KSA[14]	2.35	0.001	0.868	-	0.013	0.002	<lod	0.17	0.112	2.57	<lod	0.033
	Bang [15]	-	-	-	ND	2.16	0.99	<lod	ND	0.036	50.33	-	-
	Kenya [16]							17.29	3.38	0.006	5.77	1.6	
Legumes	This work	83.93	0.159	288	449	0.636	0.069	15.5	14.17	0.027	33.8	24.5	-
	Lithuania [17]	0.04	0.30	-	-	1.47	1.65	43.3	6.29	0.014	20.64	-	-
	Turkey [18]	80	0.15	-	-	1.02	0.095	20.4	7.15	0.004	32.95	-	-
	Jamaica [19]	4.16	0.08	-	-	0.67	0.05	10.6		0.003	16.3	-	-

CONCLUSION AND RECOMMENDATIONS

In this study, it is aimed to determine the trace elements and heavy metals in different food which more consumed in Sudan. Determination of the chemical composition was used successfully to obtain information about the relationship among different food categories: which rich in elemental contents, which can supply a dietary intake of essential nutrients. INAA results showed high levels of Mg, Cl, K and Ca in cereals and cereals products and legumes, while lower levels for Na, Al, Fe, Mn, Cr and Zn in these categories. The data showed high levels of Na, Mg, Al, Cl, K, Ca and Fe in vegetables and fruits, while lower levels for Cr and Zn. Cu and Cd were not detected in food samples except

Cu was detected in legumes only. Chemical composition in food vary depending on many factors such as genetic of the species and environmental factors like the use of fertilizer or post-harvest process. The results of the assessment of deficiency or excess of trace elements can be avoiding the environmentally health-related problem. Ingesting specific food rich with element of interest can supply the dietary of that element. Further research is needed to expand samples numbers which may include new areas.

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