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The Relationship between Kidney Stones and Dietary Habits Using XRF Technique

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ABSTRACT

Kidney stones are considered a severe disease that causes considerable pain and can lead to kidney failure. Dietary habits may be the reason behind the development of stones in the kidneys. Twelve kidney stone samples were collected and analyzed using an X-ray fluorescent technique along with commonly consumed foodstuffs in the Koya region of northern Iraq. It was observed that all of the stones were based on calcium elements. The findings reveal that Ca, Zr, S, and Cl can be the core elements of forming kidney stones in such an area. The core elements were found to include many dietary foods commonly consumed by many in the Koya region. More studies are required, however, to see whether dietary intake may be the main cause of kidney stone formation.

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1. Introduction

Kidney stones disease is a widespread disease that affects a broad number of populations and has been identified as one of the diseases that can cause a great deal of pain to humans, one of the main causes of chronic kidney disease and chronic renal failure[1]. In Asian nations, 1%-5% of societies, 5%-10% in Europe, and 13% of North American societies suffer from the stone disease[2]. These disparities are linked to the socio-economic conditions of these countries, their age, sex, education, social status, environment, dietary habits, and other geographical factors[3, 4]. In general, up to 10–12 percent of men and 5–6 percent of women suffer from kidney stones[5]. A kidney stone is an aggregation of crystals formed by supersaturation of the urine with salts in the kidney. The formation of different types of kidney stones depends on the urinary pH and the type of salt constituents involved in such cases. The formation of stone primarily depends on major constituents. However, knowledge of minor and trace elements is also important for the treatment and development of medicines for kidney stones[6-8]. Kidney stones normally come out of the body in the urine stream, and several stones may create and remove without causing any symptoms[9].

The specific kidney stones are mainly depending upon their composition. There are four main types of stones in the renal. Stones of calcium, struvite, uric acid, and cysteine[10]. Calcium was the most popular stone combined with oxalate, phosphate, or carbonate to form stones. Uric acid and struvite stones are much less common while cystine is a rare stone[11]. 70–80 percent of the stones consist of calcium oxalate (CaOx). In addition, men are more likely to have calcium oxalate or uric acid stones while women have hydroxyapatite or struvite stones[12]. Kidney stones come in various sizes, shapes, and colors. They can be as small as a grain of sand or as large as a golf ball. While many resemble smooth, spherical pebbles, others have rough edges, often created by tiny spokes or even bigger jagged structures called staghorn. Each stone's color depends on its chemical composition. Most are yellow or brown but they can also be tan, gold, or black [13-15]. Furthermore, analysis of the chemical composition of renal stones is important to understand their etiology.

The elemental and chemical study of urinary and kidney stone samples can be carried out using many different analytical methods, such as laser-induced breakdown spectroscopy (LIBS), X-ray diffraction (XRD), X-ray fluorescence (XRF), Fourier transforms infrared (FTIR), X-ray energy dispersive spectrometry (EDS), Proton-induced X-ray emission (PIXE), Scanning electron microscopy (SEM) and so on[16-18].

This research was conducted in the city of Koya-Northern Iraq, where the exact causes and the number of cases of kidney stone disease are not clear due to the absence of daily national registry data. The purpose of this article is to investigate the core elements of kidney stones and investigate their association with local dietary habits using X-ray fluorescence (XRF) to investigate the reasons for the development of such a disease.

2. Materials and Methods

In this research, twelve kidney stones were collected and analyzed from the Koya city hospital as shown in Figure 1. The dimensions of the stones are in the range of a few millimeters.

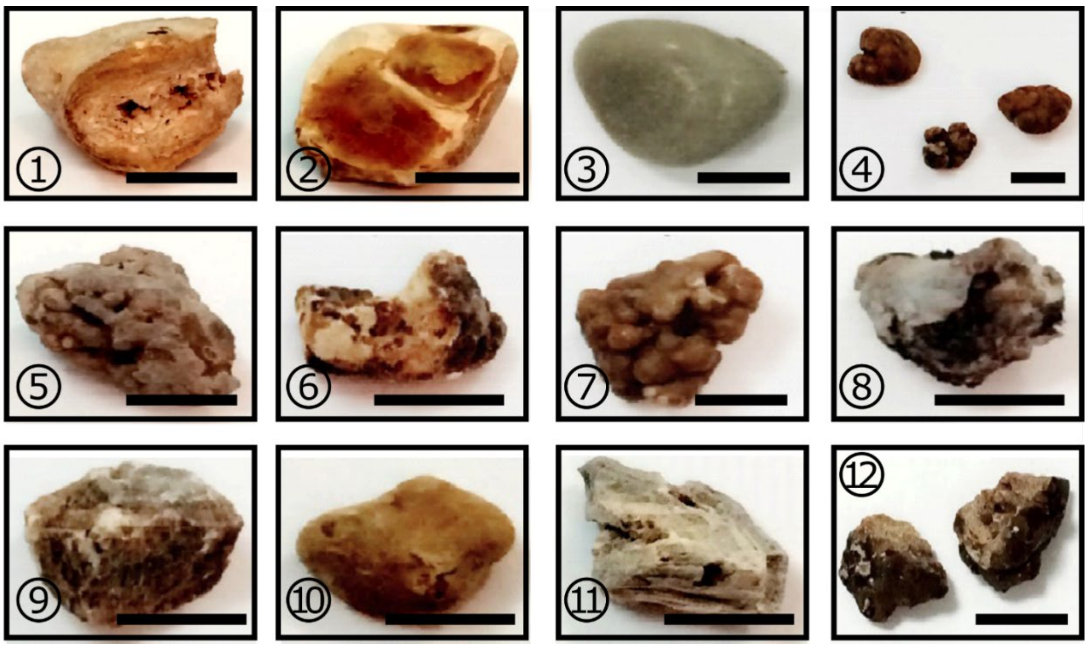

Figure 1. Optical images of the twelve collected kidney stone samples. The scale bar is 1 mm.

In kidney stone procedures, the stones were crushed to a very fine powder and compressed as pellets using a manual pressing machine (TP HERZOG) with a maximum load of 200 KN (Figures 2a and 2b). The percentage of relative mass concentration of elements in local dietary foods in Koya town has been determined by sample analysis including vegetables, coffee, tea, meat, egg, nuts, and seeds. The food samples had been dried first, then crushed to a very fine powder and compressed as pellets in the same way as the stones collected (Figure 2c). KERN ABT (120-4 M) analytical balance was used to find the mass of the powder samples before compression. The pellets were then dried at a temperature of about 45 ° C by Lab Tech Universal Drying Oven LDO-060E at a constant weight to ensure free water was removed. All samples were analyzed using the Energy Dispersive X-Ray Florescence Rigaku NEX CG machine that is available at Koya University, department of physics. The statistical parameters minimum, maximum, mean, SD, and percentage coefficient of variation (%CV) were calculated.

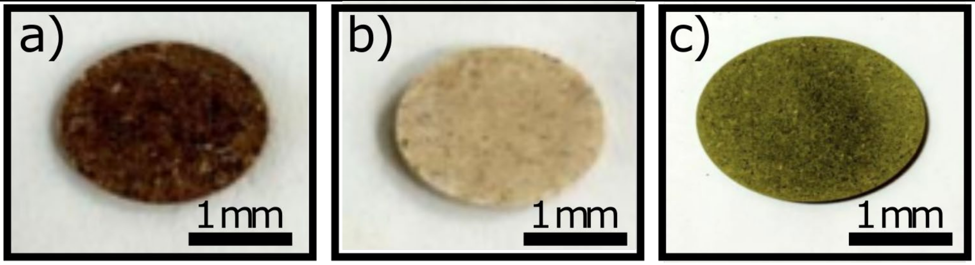

Figure 2. **a)** and **b)** Optical images of the kidney stones in pellet shapes. **c)** Optical image of the diet sample in a pellet shape.

3. Results and Discussion

The relative mass concentration percentage (%) of elements is detected using the X-ray fluorescence (XRF) technique. In addition, the statistical parameters, mean, and standard deviation (SD) were calculated for such elements. If the element occurs only in one sample, the statistical parameters should be classified as N/A (Not Applicable); at least more than two values should exist. A high variable distribution around the mean is expressed by the CV% value greater than 100%, that is, SD exceeds the mean.

3.1 Kidney Stones

Figure 3 shows the results of the XRF analysis of twelve kidney stones. The mass percentage and statistical parameters of stone elements are presented in Table 1s and Table 2s in the supplementary section. According to it, elements such as calcium, sulfur, aluminum, chlorine, zirconium, and phosphorus are present in stones. It can be observed that calcium has the maximum peak values in all stone samples.

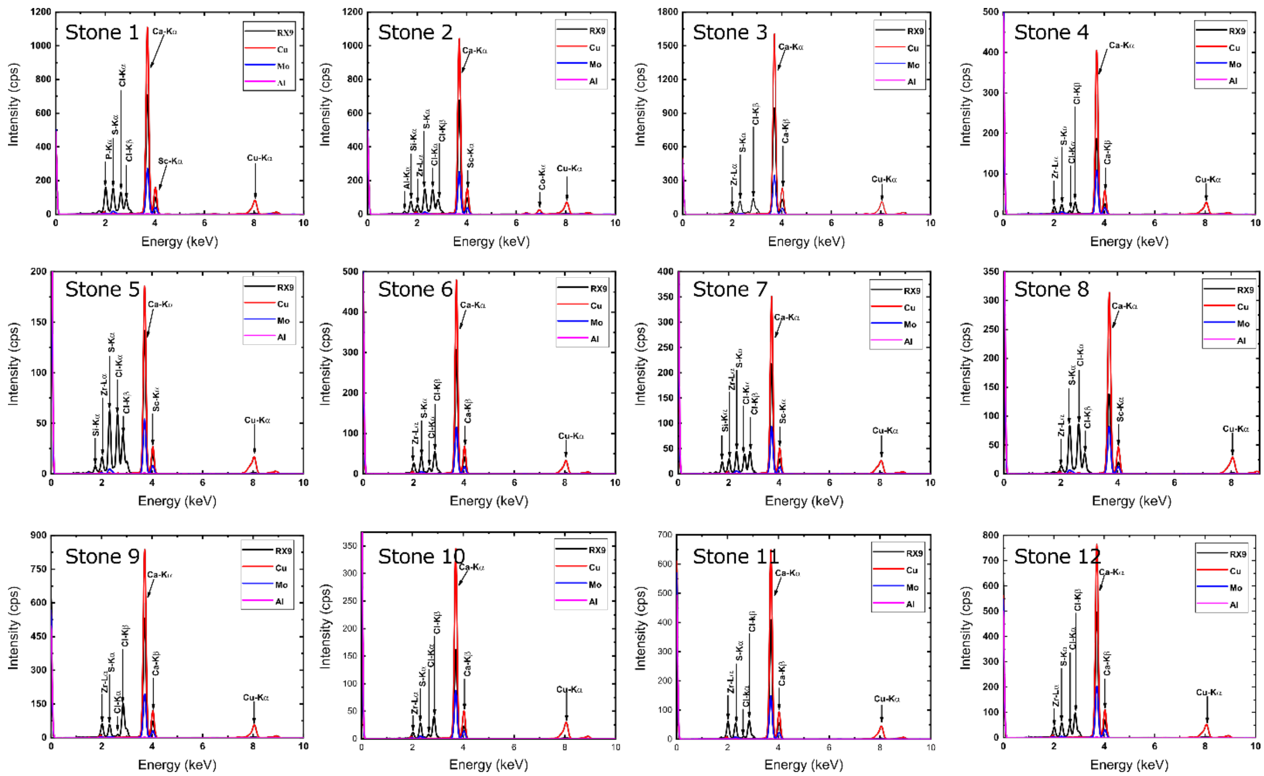

Figure 3. XRF analysis of the collected kidney stones.

Based on the obtained results, Ca is the major component in all analyzed stones which ranges from 52.3% to 99.3% with a mean ± SD of 91.033±14.041%, and CV% value equals 15%. Accordingly, stones samples containing calcium are essential types of kidney stones. Figure 4 shows the mass percentage concentration of major elements in the kidney stone samples. As can be seen from Figure 4a, the Ca element shows the highest mass percentage compared with the other elements in all stone samples.

Moreover, Zr contained in all samples, varied from 0.268% to 0.729%, with a mean±SD of 0.498±0.134% and a percent coefficient of variation of 27% (Figure 4b). S is another element that is detected in all stone samples, which tends to range between 0.037% and 0.377%. The mean value and CV% are around 0.173±0.105% and 61%, respectively (Figure 4c). Additionally, the Cl element appears to range from 0.001% to 0.156% in all concentration samples, with a mean of 0.048±0.044% and CV% equal 91% (Figure 4d). Phosphorous (P) is also detected in three concentration samples between 0.110% and 0.857% (Figure 4e). Aluminum (Al) was found in all samples with a concentration ranging from 0.0121% to 0.548% except in sample 2 (Figure 4f). Si is contained in all samples except for samples 2 and 9 with concentrations ranging from 0.008% to 2.28%, a mean value of 0.311±0.701%. Zn is also noticed in all samples except in sample 6 with concentrations ranging from 0.003% to 1.41%, the mean value of 0.19 1±0.421%. Fe was present in seven samples with concentrations varying from 0.006% to 5.5%, a mean value of 1.028±2.006%. The remaining elements occur at a lower concentration except for sample 10 where Mg exists very close to that of Ca concentration at a concentration of 46%. Therefore, Ca, Zr, S, and Cl were detected in all analyzed stone samples, where these elements can be considered as core elements of kidney stones formation in Koya City.

The mean and SD statistical parameters indicate the risk of the development of kidney stones. The mean ± SD and the CV% values for the analyzed stone of core elements of Ca, Zr, S, and Cl were 91.033±14.041%, 0.498±0.134%, 0.173±0.105%, and 0.048±0.044% and 15%, 27%, 61%, and 91%, respectively. For the Ca element, the CV% value was lower than Zr, S, and Cl elements, so the mean variation is small. According to the results, calcium is the dominant element in all 12 stones. After Ca, zirconium, sulfur, chlorine, phosphorus, and aluminum are the elements with the highest percentage of mass present in kidney stones.

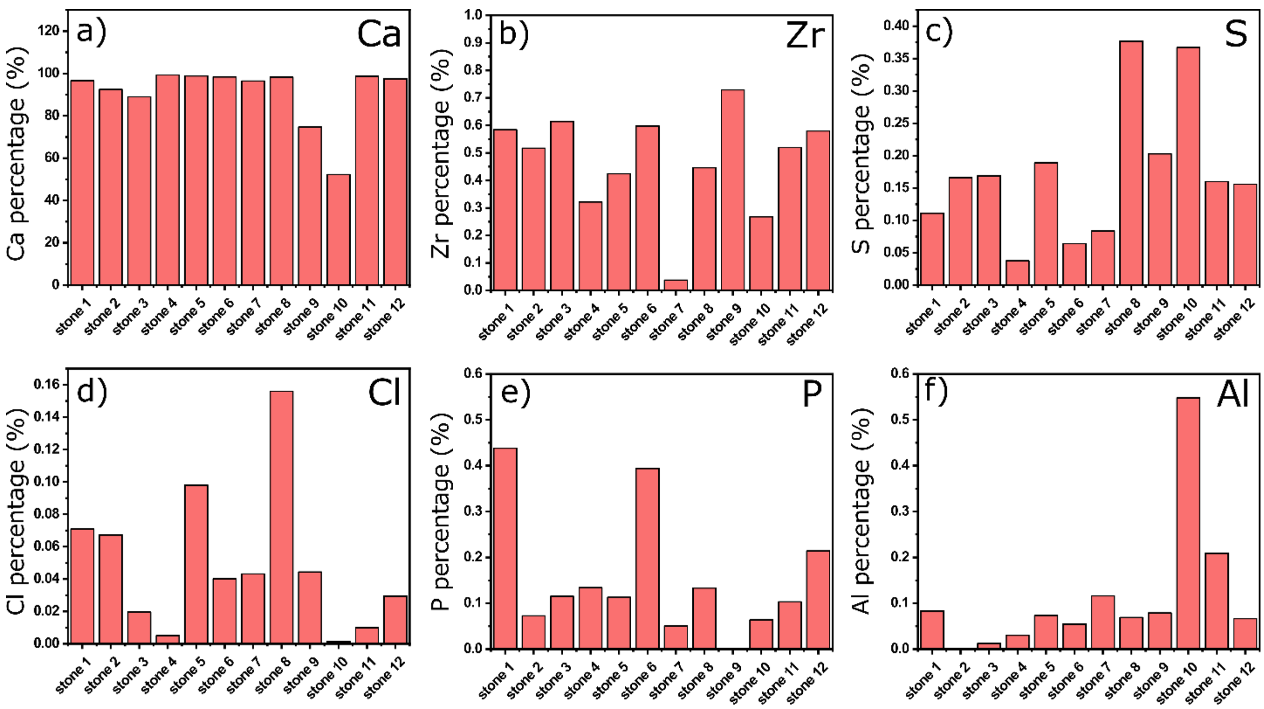

Figure 4. The percentage of mass concentrations of **a)** Ca element, **b)** Zr element, **c)** S element, **d)** Cl element, **e)** P element and **f)** Al element in kidney stone samples.

3.2 Diet Analysis

Diet factors play a vital role in kidney stone pathogenesis[19]. If the kidneys do not function properly, waste from the diet builds up in the blood rather than the kidneys removing it[20]. A diet rich in minerals raises the risk of developing kidney stones. To examine the risk factor and development of kidney stones, various types of foods and drinks consumed by the people in Koya city were examined such as vegetables, tea (black and green), coffee, meat, egg, nuts, and seeds.

3.2.1 Vegetables

Table 3s (in the supplementary file) represents the percentage of the relative mass concentration (%) of elements contained in various common vegetable types (hot green pepper, cabbage, chard, cucumber, dill, eggplant, leek, okra, onion, parsley, potatoes, radish, sweet green pepper, thyme, tomatoes, and zucchini) in Koya city, along with their statistical parameters shown in Table 4s. Moreover, Figure 5 illustrates the percentage of mass concentrations for the major elements in the vegetables. The core elements Ca, Zr, S, and Cl have been identified in all vegetable samples with different concentrations. Calcium (Ca) has the highest concentration in vegetables among the core elements, as in parsley (49.0%), and the lowest concentration in potatoes (0.0568%), with a mean value of 8.823±12.206% and CV%, equals 138%; Zr with a concentration ranging from 0.142% in the chard sample to 3.13% as in the zucchini sample with a mean value of 0.532±0.697% and CV% equals to 131%; S with a concentration ranging from 0.207% as in the sample of potatoes to 2.88% as in the sample of okra, with a mean value of 1.114±0.813% and CV% equals to 73% and Cl with a concentration ranging from 0.0867% in the potatoes sample to 5.8% in the leek sample with a mean value of 2.044±2.023% and CV% equals to 99%.

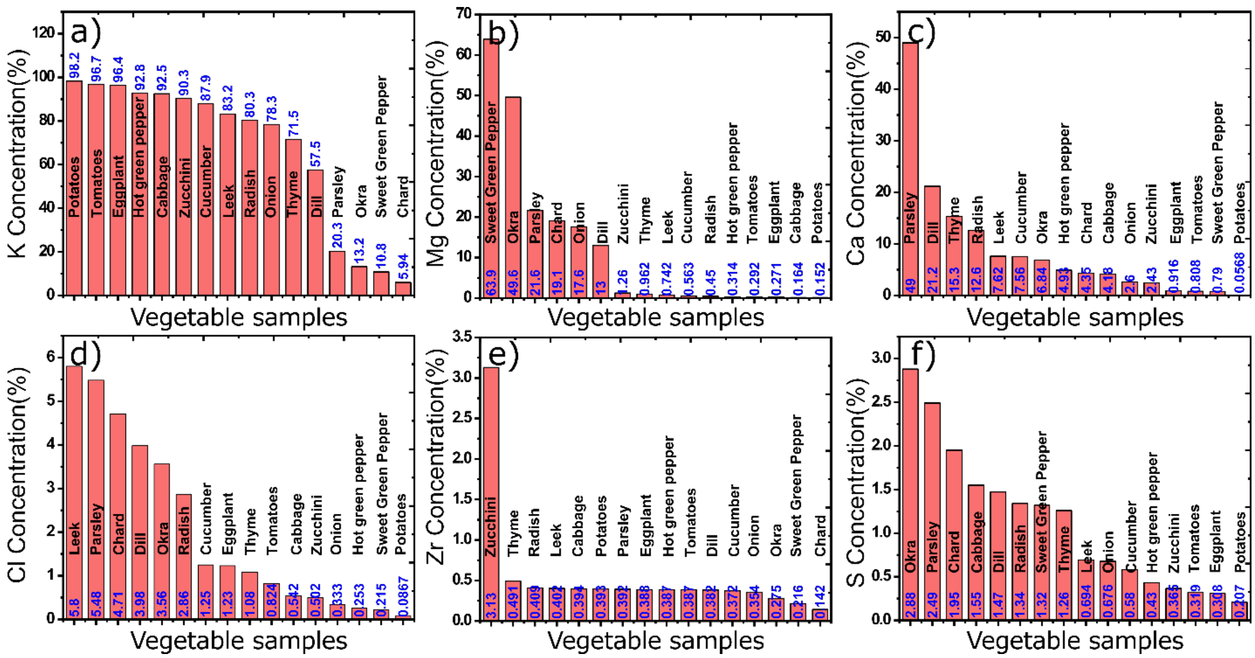

Figure 5. The mass concentrations of a) K element, b) Mg element, c) Ca element, d) Cl element, e) Zr element, and f) S element in vegetable samples.

According to Table 4s, the vegetable samples have a low mean of Ca (8.823%), high SD (12.206), and large CV(138%), thus results suggesting that the probability of kidney stone formation would be high. On the other hand, if both the mean and SD are high but with a low CV percentage, the probability of kidney stone formation would be relatively low.

Most vegetable samples have a high percentage of potassium. Only Parsley, Okra, sweet green pepper, and chard contain less potassium than other samples. In contrast, these four samples show a higher percentage of magnesium than the other samples. Apart from Parsley, other vegetable samples have a low percentage of calcium. In general, the three potassium, magnesium, and calcium elements are the most predominant elements in vegetable samples. After them, chlorine, zirconium, and sulfur are more present in samples. Leak, Parsley, and Chard are the three samples with the highest percentage of chlorine in the range of 4 to 6%, and among all samples, Zucchini has the highest percentage of zirconium (about 3%) compared to the others.

Based on the analysis obtained from kidney stones and the results from the vegetable samples, Parsley, Dill, and Radish show a higher mass percentage of calcium than others. Also, most samples have a high mass percentage of potassium, which is an element in kidney stones. Zucchini contains the most zirconium compared to the others, and a large number of samples contain sulfur, both of which are found in kidney stone samples.

3.2.2 Coffee and Tea

Table 5s gives information on the percentage of relative mass concentration (%) and the statistical parameters of elements in black-tea, coffee, and green-tea. They include the core elements Ca, Zr, S, and Cl, according to the analysis. The results of table 5s are presented in Figure 6a. Calcium (Ca) occurred in the black-tea sample at a high concentration (14.4%); in the green-tea sample appeared with a concentration of 6.11%. While for coffee its concentration is low 0.746%. The mean ± SD for Ca is 7.085±6.879% with CV% equal to 97%. The concentration of the other core elements Zr, S, and Cl ranged from 0.449% to 5.06%, 0.117% to 0.386% and 0.141% to 0.369%, respectively. The CV percentage for Zr, S, and Cl corresponds to 134%, 46%, and 59%, respectively.

Some research studies consumed certain drinks like coffee and tea, that are associated with increased excretion of urinary calcium and, might increase the risk of developing kidney stones[21-23].

3.2.3.Meat Analysis

Table 6s presents the percentage of element concentrations in the various meat samples of beef, chicken, and fish with their statistical parameters. The concentration of the core elements Ca, Zr, S, and Cl tend to range from 0.231% to 0.676%, 0.414% to 1.53%, 1.49% to 4.12% and 0.416% to 1.38%, respectively. The CV percentage is 48% for Ca, 80% for Zr, 64% for S, and 53% for Cl. These results show that beef meat contains more elements with a major and higher concentration than in fish and chicken; whereas, urinary stones form when there is a high level of minerals (Ca, Mg, P, Cl, Fe, Zn, and so on) in the urine[24]. The obtained results are shown in Figure 6b. Accordingly, like beverages, the predominant element in meat samples (especially in chicken and fish) is potassium.

3.2.4 Egg Analysis

The relative mass concentrations for the egg (yolk and glair) are shown in Table 7s. It demonstrates that calcium (Ca) in the yolk sample has appeared with a concentration of 1.61%. Zirconium (Zr) is also detected in both yolk and glair samples with a concentration of 0.126% and 0.372% with CV% equal to 70%. The other two core elements of sulfur (S) and chloride (Cl) in the glair sample are contained with concentrations of 2.79% and 0.528%. Additionally, Figure 6c indicates the percentage mass concentration of elements in glair and yolk samples.

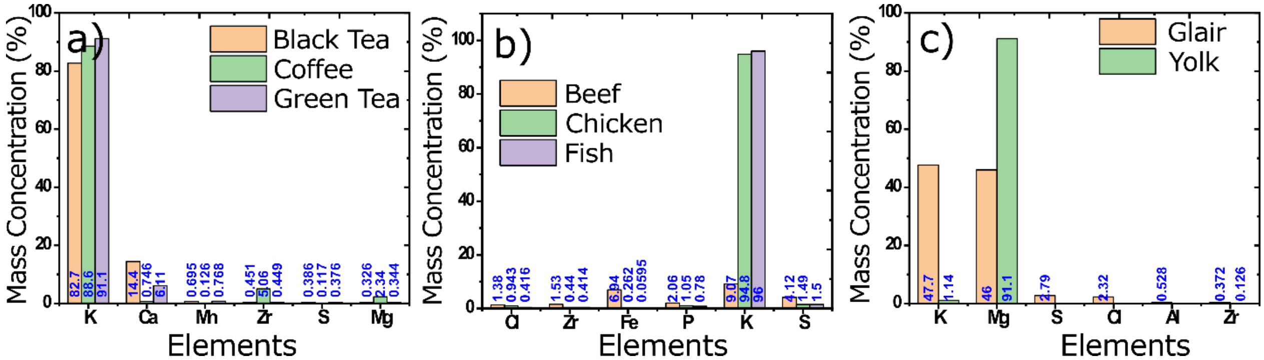

Figure 6. The percentage mass concentration of elements in **a)** Black tea, Coffee, and green tea. **b)** Meat: beef, chicken, and fish. **c)** Glair and yolk.

According to the results, beverages often have a high percentage of potassium and then calcium. Other elements show a lower mass percentage in beverages. By comparing the mass percentage of calcium, the highest weight percentages are in black tea (14.40%), green tea (6.11%), and coffee (0.74%), respectively. For meat samples, potassium has the highest mass percentage. Moreover, magnesium and potassium have the highest mass percentages for yolk and glair.

3.2.5. Nuts and Seeds

The relative mass percentage concentrations for some of the nuts and seeds (almond, chickpea, peanuts, pistachio, sunflower seeds, white pumpkin seeds, and yellow pumpkin seeds) are presented in Table 8s and Figure 7. Ca in the almond sample was found with a concentration of 1.63%, while in the yellow pumpkin seeds has not appeared. Zr has the highest concentration in pistachio at about 16.2% with a CV% value of 215%. Likewise, Cl appeared in some of these nuts and seeds but was not contained in almond and white pumpkin seeds. Besides, S shows the highest concentration in white pumpkin seeds at 5.61%. These results demonstrate that Zr has the highest percentage of CV, which increases the risk of kidney stone formation.

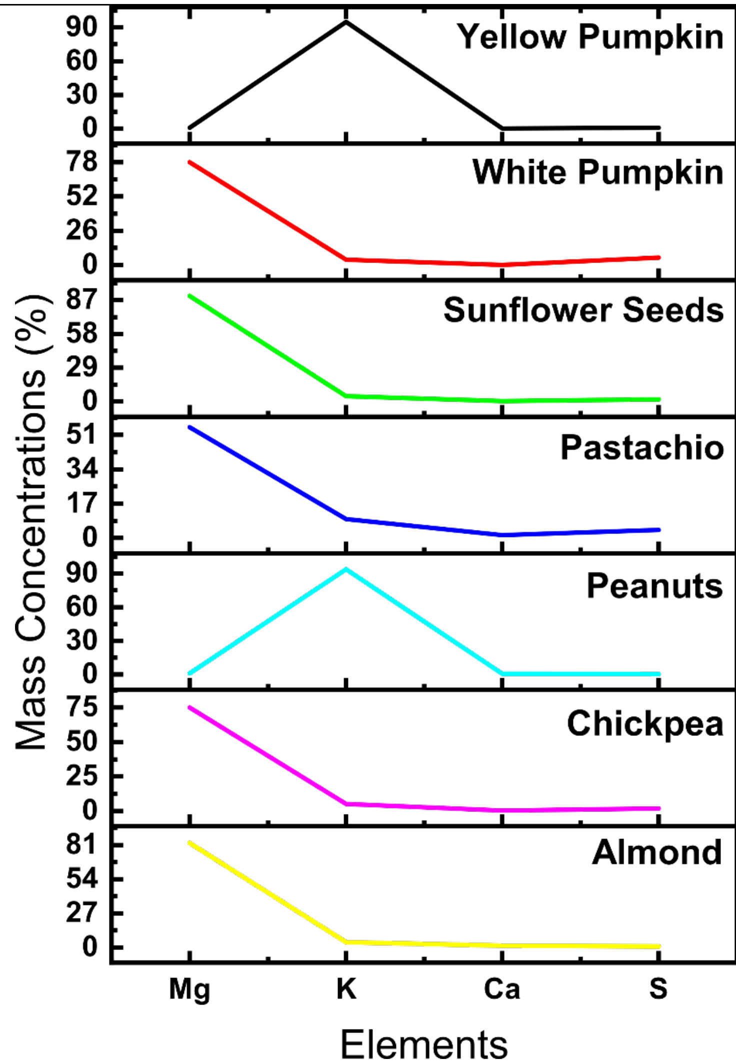

Figure 7. The percentage mass concentration of elements in nuts and seeds.

Figure 8 shows the results of the analysis of kidney stones and other diets. Figure 8a demonstrates a mapping diagram based on the mass percentage of trace elements in twelve kidney stones. The highest percentage, as previously discussed, is related to calcium. To see the percentage of other elements, the calcium is removed to better observe the percentage of other kidney stone elements in Figure 8b. Accordingly, zirconium, potassium, sulfur, and aluminum are the next dominant elements in kidney stone samples. Vegetable samples are high in potassium and then calcium, both of which are dominant elements in kidney stones (Figure 8c). In detail, chard, okra, parsley, and sweet pepper have the lowest percentage of potassium compared to others. However, Parsley and okra, with the highest mass percentage of calcium and potassium, will be a diet with the possibility of being resulted in kidney stone. Based on Figure 8d, all three beverage samples have significant calcium and potassium mass percentages. However, black tea has the most calcium, which is not good for the diet. For seeds, peanuts and yellow pumpkins have a high percentage of potassium (Figure 8e). By considering other elements, yellow pumpkin is mostly composed of calcium and potassium which can be considered a harmful diet for kidney stones.

Finally, according to Figure 8f, among meat samples, fish and chicken have the highest percentage of potassium, which is one of the elements in kidney stones.

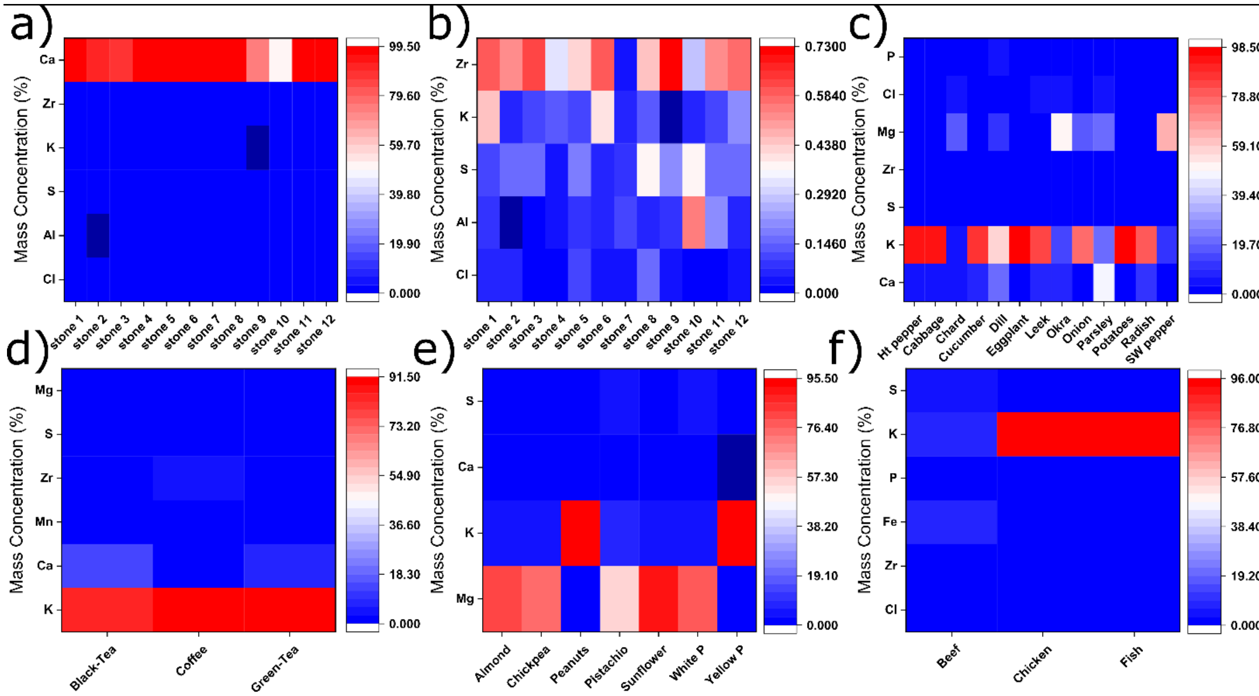

Figure 8. The relative mass concentration mapping for a) dominant elements of the kidney stones. b) dominant elements of kidney stone samples except calcium c) dominant elements of vegetable samples d) dominant elements of beverage samples e) dominant elements of seed samples and f) dominant elements of meat samples.

4. Conclusions

Various kidney stones were collected from Koya city hospital and the elements as Ca, Zr, S, and Cl were identified by the XRF technique. These elements are considered to be the core elements in the development of kidney stones in this area. Core elements are also contained in dietary products commonly eaten by Koya inhabitants. These results represent the association between daily dietary habits and kidney stone development. While the intake of such diets containing certain elements that increase the risk of kidney stones, these elements are necessary for the functions of the human body.

To understand the etiology of kidney stones for the prevention of recurrence, it is important to study their chemical composition, but genetic factors should also be considered. More regional-based studies are required to examine the direct association between dietary consumption and environmental exposure to these metals and the risk of kidney stone development, to complement this study.

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Supplementary file

Table 1S— The percentage of relative mass concentration for the kidney stone elements

%Elements	Stone 1	Stone 2	Stone 3	Stone 4	Stone 5	Stone 6	Stone 7	Stone 8	Stone 9	Stone 10	Stone 11	Stone 12
Ca	96.6	92.4	89	99.3	98.8	98.4	96.5	98.2	74.7	52.3	98.7	97.5
P	0.857	---	---	---	---	---	0.11	---	0.832	---	---	---
Zr	0.584	0.517	0.614	0.322	0.424	0.598	0.374	0.446	0.729	0.268	0.52	0.58
Eu	0.569	---	1.25	---	0.0876	---	---	0.152	3.53	0.0079	---	0.445
K	0.438	0.0727	0.115	0.134	0.113	0.394	0.0506	0.133	---	0.0638	0.103	0.214
Sc	0.238	---	---	---	---	---	0.212	---	---	---	---	---
Tb	0.156	---	1.13	0.0197	0.0114	0.201	---	0.091	---	---	---	0.184
Mg	0.112	---	---	0.0529	---	---	0.0787	---	---	46	0.138	0.081
S	0.111	0.166	0.169	0.0374	0.189	0.0643	0.084	0.377	0.203	0.367	0.16	0.156
Al	0.0833	---	0.0121	0.0302	0.0735	0.0545	0.116	0.0688	0.0788	0.548	0.209	0.0664
Cl	0.071	0.0672	0.0196	0.0051	0.098	0.0401	0.0432	0.156	0.0443	0.0013	0.0099	0.0294

Si	0.0545	---	0.0077	0.0135	0.0901	0.0519	2.28	0.0813	---	0.423	0.0617	0.0556
Cr	0.0398	0.0017	---	---	0.0012	0.0097	---	---	---	---	0.0031	0.0053
Zn	0.0345	0.335	0.271	0.0056	0.0032	---	0.0115	0.0149	1.41	0.004	0.0059	0.0067
Tm	0.0196	---	---	---	---	---	---	---	---	---	0.0087	0.0082
Er	0.0164	0.608	0.641	---	---	---	0.0068	---	---	---	0.0212	0.0089
Sn	0.0116	0.0069	0.0148	---	0.0038	0.0144	0.002	0.0038	0.0167	0.0041	0.0094	0.0061
Ac	0.0115	2.08	1.6	---	---	---	---	---	2.2	---	---	0.0069
Hg	0.0042	---	---	---	---	---	---	---	0.351	---	---	---
Fr	0.0036	0.159	0.108	---	0.002	---	0.0008	0.0168	0.363	---	0.0143	0.003
Pt	0.0034	---	---	---	---	---	---	---	0.602	---	0.0024	---
Pa	0.0025	---	---	---	0.0029	---	---	0.0093	---	---	0.0086	---
Au	0.0011	0.21	---	---	---	---	0.0009	---	0.535	---	0.0028	0.0031
As	0.0005	0.145	0.0736	---	---	---	---	---	0.381	---	---	---
Fe	---	0.669	0.923	---	---	---	0.0665	---	5.5	0.0062	0.0241	0.0135
Dy	---	0.528	0.827	---	---	0.0839	---	0.0287	2.86	---	---	0.0207
Co	---	0.444	0.485	---	---	---	---	---	---	---	---	---
Ta	---	0.342	0.332	---	---	0.0088	0.0059	0.0191	---	0.0018	0.0064	0.0094
Sr	---	0.305	0.275	0.0019	0.015	0.006	0.005	0.0127	0.561	0.0108	0.0125	0.0143
Re	---	0.292	0.231	---	0.0067	0.0079	0.003	0.0095	0.547	---	0.0066	0.0083
Cu	---	0.263	0.275	---	---	---	---	---	0.9	0.0013	---	---
Pb	---	0.223	0.107	---	---	0.0024	---	0.0085	---	---	0.0073	0.004
Br	---	0.129	0.0667	---	---	---	---	---	0.174	0.0005	0.0036	0.0005
Sm	---	---	1.09	---	0.0864	---	---	0.158	3.48	0.011	---	---
Hf	---	---	0.359	---	---	---	---	---	---	---	---	---
Ar	---	---	---	0.0713	---	0.0387	---	0.0454	---	---	---	0.594
Po	---	---	---	---	---	0.0013	---	0.0028	---	0.0003	---	---
Rn	---	---	---	---	---	---	---	0.0061	---	---	0.006	---
Pd	---	---	---	---	---	---	---	0.0004	---	---	---	---
I	---	---	---	---	---	---	---	---	0.013	---	---	---

Table 2S — Statistical parameters of elements in stones of the kidneys

Elements	SD	Mean	CV%
Ca	14.041	91.033	15
P	0.424	0.599	71
Zr	0.134	0.498	27
Eu	1.249	0.863	145
K	0.131	0.166	79

Sc	0.018	0.225	8
Tb	0.392	0.256	153
Mg	18.741	7.743	242
S	0.105	0.173	61
Al	0.150	0.121	1
Cl	0.044	0.048	91
Si	0.701	0.311	225
Cr	0.014	0.010	147
Zn	0.421	0.191	220
Tm	0.006	0.012	51
Er	0.315	0.217	146
Sn	0.005	0.008	61
Ac	1.091	1.179	93
Hg	0.245	0.177	138
Fr	0.122	0.074	164
Pt	0.345	0.202	171
Pa	0.003	0.005	62
Au	0.217	0.125	173
As	0.164	0.150	110
Fe	2.006	1.028	195
Dy	1.095	0.724	151
Co	0.028	0.464	6
Ta	0.152	0.090	168
Sr	0.186	0.110	169
Re	0.193	0.123	157
Cu	0.381	0.359	106
Pb	0.090	0.058	154
Br	0.074	0.062	120
Sm	1.472	0.965	153
Hf	N/A	0.359	N/A
Ar	0.271	0.187	145
Po	0.001	0.001	86
Rn	0.00007	0.006	1
Pd	N/A	0.0004	N/A
I	N/A	0.013	N/A

Table 3S — Percentage of relative mass concentration in vegetable samples

Elements %	Hot green pepper	Cabbage	Chard	Cucumber	Dill	Eggplant	Leek	Okra	Onion	Parsley	Potatoes	Radish	Sweet Green Pepper	Thyme	Tomatoes	Zucchini
K	92.8	92.5	5.94	87.9	57.5	96.4	83.2	13.2	78.3	20.3	98.2	80.3	10.8	71.5	96.7	90.3
Ca	4.93	4.18	4.35	7.56	21.2	0.916	7.62	6.84	2.6	49	0.0568	12.6	0.79	15.3	0.808	2.43
S	0.43	1.55	1.95	0.58	1.47	0.308	0.694	2.88	0.676	2.49	0.207	1.34	1.32	1.26	0.319	0.365
Zr	0.387	0.394	0.142	0.372	0.382	0.388	0.402	0.275	0.354	0.392	0.393	0.409	0.216	0.491	0.387	3.13
Mg	0.314	0.164	19.1	0.563	13	0.271	0.742	49.6	17.6	21.6	0.152	0.45	63.9	0.962	0.292	1.26
Fe	0.289	0.0456	0.126	0.115	0.388	0.0415	0.279	---	0.0382	0.279	0.113	0.385	12.6	6.25	0.0813	0.611
Cl	0.253	0.542	4.71	1.25	3.98	1.23	5.8	3.56	0.333	5.48	0.0867	2.86	0.215	1.08	0.824	0.502

P	0.209	0.297	---	0.729	---	0.0969	0.187	---	---	---	0.0289	0.094	---	0.628	0.305	---
Ar	0.139	0.101	---	0.0747	---	0.15	0.0382	0.0284	---	---	0.149	0.0909	---	---	0.111	---
Al	0.0554	0.0631	1.45	0.0766	0.88	0.0454	0.311	2.78	---	---	---	0.362	7.81	0.585	---	0.194
Ti	0.0476	---	0.0138	---	0.0427	---	---	---	---	0.0173	---	0.0463	---	0.0893	0.0549	---
Si	0.0434	---	1.67	0.556	0.806	0.0175	0.494	0.888	---	0.249	---	0.862	2.32	1.07	0.023	0.275
Zn	0.0329	0.0323	0.0069	0.031	0.0236	0.0166	0.025	---	0.0193	0.0178	0.0196	0.018	0.0187	0.0275	0.022	0.299
Cu	0.0222	0.0059	0.0055	0.0106	0.0107	0.0139	0.0166	0.0368	0.0101	0.01	0.011	0.0158	0.0057	0.0155	0.0132	0.104
Mn	0.0215	0.0143	0.0333	0.0245	0.0577	0.0104	0.0196	---	---	0.0468	0.0069	0.0258	0.0119	0.141	0.0174	0.116
Sr	0.0106	0.0522	0.0126	0.0467	0.0363	0.0211	0.0956	18.5	0.0194	0.105	0.0008	0.0757	0.0013	0.0945	0.0071	0.0471
Sn	0.0087	0.0083	0.004	0.0085	0.0092	0.0076	0.008	0.0135	0.0078	0.0094	0.0067	0.0088	0.0045	0.0114	0.0091	0.0651
Co	0.0044	---	0.0016	0.0039	0.0046	---	0.0035	---	---	0.0042	---	0.0063	---	---	---	0.0057
Ni	0.0037	---	0.0005	0.0056	0.0027	---	---	---	0.0013	0.0021	---	0.0025	---	0.003	0.0018	0.0398
Rb	0.0034	0.0044	0.0049	0.011	0.0062	0.0125	0.0151	0.0439	0.0031	0.0072	0.002	0.0036	0.0033	0.0039	0.0121	0.151
Pa	0.0014	---	---	---	0.0018	---	---	0.0032	---	---	0.0011	---	0.002	0.0047	---	---
V	---	0.004	0.0012	---	---	---	---	---	---	---	---	---	---	---	---	---
Br	---	0.0035	0.0018	0.0415	0.0048	0.0081	0.0187	0.0142	0.0054	0.017	---	0.0041	---	0.0029	0.0156	0.0353
Na	---	---	60.5	---	---	---	---	---	---	---	---	---	---	---	---	---
Sc	---	---	0.0266	---	0.079	---	---	0.0358	0.0354	---	---	---	---	---	---	---
Eu	---	---	0.0096	---	0.0221	0.0126	0.0267	0.585	---	0.0174	---	0.0306	---	0.0404	---	---
Dy	---	---	0.0042	0.0077	0.0126	---	0.0145	---	---	0.0144	---	0.0075	0.0049	---	---	0.0638
Tm	---	---	0.0027	---	0.007	---	0.0068	---	---	---	---	---	---	---	---	---
Cr	---	---	0.0005	0.001	---	---	---	---	---	0.0031	---	---	---	---	---	---
U	---	---	---	---	---	---	0.0013	---	---	---	---	---	---	---	---	---
Tb	---	---	---	---	---	---	---	0.378	---	---	---	---	---	---	---	---
Yb	---	---	---	---	---	---	---	0.16	---	---	---	---	---	---	---	---
Hf	---	---	---	---	---	---	---	0.12	---	---	0.0037	---	---	---	---	---
Rn	---	---	---	---	---	---	---	0.068	---	---	---	---	---	---	---	---
Fr	---	---	---	---	---	---	---	0.015	---	---	---	---	---	---	---	0.0011
Ta	---	---	---	---	---	---	---	0.008	---	---	---	---	---	---	---	0.01
Pb	---	---	---	---	---	---	---	---	---	---	---	0.001	0.001	---	---	---
As	---	---	---	---	---	---	---	---	---	---	---	0.0005	---	0.0009	---	---
Er	---	---	---	---	---	---	---	---	---	---	---	---	---	0.0074	---	---
Te	---	---	---	---	---	---	---	---	---	---	---	---	---	0.0018	---	---
Kr	---	---	---	---	---	---	---	---	---	---	---	---	---	0.0008	---	---
Au	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	0.0013

Table 4S — Statistical parameters of elements in vegetable samples

Elements	SD	Mean	CV%
K	34.306	67.24	51
Ca	12.206	8.823	138
S	0.813	1.114	73
Zr	0.697	0.532	131
Mg	19.325	11.873	161
Fe	3.459	1.442	240
Cl	2.023	2.044	99
P	0.241	0.286	85
Ar	0.044	0.098	46
Al	2.224	1.217	183
Ti	0.025	0.044	57
Si	0.681	0.713	96
Zn	0.071	0.040	176
Cu	0.023	0.019	124
Mn	0.040	0.039	104
Sr	4.614	1.195	386
Sn	0.014	0.011	121
Co	0.001	0.004	33
Ni	0.011	0.006	188
Rb	0.036	0.017	206
Pa	0.001	0.002	57
V	0.001	0.002	76
Br	0.012	0.013	95
Na	N/A	60.5	N/A
Sc	0.023	0.044	53
Eu	0.199	0.093	214
Dy	0.019	0.016	121
Tm	0.002	0.005	44
Cr	0.001	0.001	90
U	N/A	0.001	N/A
Tb	N/A	0.378	N/A
Yb	N/A	0.16	N/A
Hf	0.082	0.061	133
Rn	N/A	0.068	N/A
Fr	0.009	0.008	122
Ta	0.001	0.009	16
Pb	N/A	0.001	N/A
As	0.0002	0.0007	40
Er	N/A	0.007	N/A
Te	N/A	0.001	N/A
Kr	N/A	0.0008	N/A
Au	N/A	0.001	N/A

Table 5S — The relative mass concentration of elements in coffee and tea samples with their statistical parameters

%Elements	Black-Tea	Coffee	Green-Tea	SD	Mean	CV%
K	82.7	88.6	91.1	6.143	84.95	7

Ca	14.4	0.746	6.11	6.879	7.085	97
Mn	0.695	0.126	0.768	0.358	0.422	85
Zr	0.451	5.06	0.449	2.253	1.688	134
S	0.386	0.117	0.376	0.155	0.339	46
Mg	0.326	2.34	0.344	0.973	0.887	110
Ar	0.226	0.0182	---	0.146	0.122	120
Fe	0.190	0.926	0.194	0.351	0.406	86
Cl	0.161	0.369	0.141	0.115	0.197	59
P	0.0871	---	0.0834	0.121	0.155	78
Al	0.0775	0.0491	0.137	0.044	0.087	51
Ti	0.0727	---	---	N/A	0.072	N/A
Rb	0.0452	0.650	0.0477	9.730	5.110	190
Zn	0.0346	0.0939	0.0389	0.031	0.048	65
Gd	0.0332	---	0.0413	0.005	0.037	15
Cu	0.0284	0.0404	0.0259	0.014	0.025	57
Si	0.0201	0.333	0.0344	0.176	0.129	137
Dy	0.0162	0.0602	0.0138	0.021	0.029	73
Sr	0.0122	0.0937	0.0182	0.037	0.040	93
Ni	0.0097	---	0.0104	0.010	0.016	66
Sn	0.0097	0.110	0.0103	0.048	0.037	132
Co	0.0096	---	0.0091	0.0003	0.009	4
Br	0.0030	0.150	0.0032	0.070	0.058	121
Eu	---	0.0841	---	N/A	0.084	N/A
Hf	---	0.0103	---	N/A	0.010	N/A
Fr	---	0.0086	---	N/A	0.008	N/A
Sc	---	---	---	N/A	0.037	N/A
Er	---	---	---	N/A	0.032	N/A
U	---	---	---	N/A	0.007	N/A

Table 6S — The relative mass concentration of elements in meat samples

%Elements	Beef	Chicken	Fish	SD	Mean	CV%
Fr	1.96	---	---	N/A	1.96	N/A
Cl	1.38	0.943	0.416	0.482	0.913	53
Zr	1.53	0.44	0.414	0.636	0.794	80
Fe	6.94	0.262	0.0595	3.915	2.420	162
P	2.06	1.05	0.78	0.674	1.296	52
K	9.07	94.8	96	49.846	66.623	75
Ca	0.231	0.676	0.612	0.240	0.506	48
S	4.12	1.49	1.5	1.515	2.37	64
Zn	63	0.0532	0.0464	36.344	21.033	173
Er	1.51	---	---	N/A	1.51	N/A
Dy	0.838	---	---	N/A	0.838	N/A
Tb	0.149	---	---	N/A	0.149	N/A
Sn	0.0408	0.0099	0.0089	0.018	0.019	91
Pt	0.49	---	---	N/A	0.49	N/A
Rn	0.907	---	---	N/A	0.907	N/A
Pa	2.6	---	---	N/A	2.6	N/A
Tm	0.533	---	---	N/A	0.533	N/A
Hf	0.776	---	---	N/A	0.776	N/A

Au	1.02	---	---	N/A	1.02	N/A
Ta	0.883	---	---	N/A	0.883	N/A
Al	---	0.0824	---	N/A	0.082	N/A
Si	---	0.0593	---	N/A	0.059	N/A
Mg	---	0.0583	0.0998	0.029	0.079	37
Cu	---	0.0147	0.0078	0.004	0.011	43
Rb	---	0.0134	0.0045	0.006	0.008	70
Br	---	0.0125	0.0274	0.010	0.019	53
Po	---	0.0008	---	N/A	0.0008	N/A
Se	---	---	0.003	N/A	0.003	N/A
Sr	---	---	0.0028	N/A	0.002	N/A

Table 7S — The relative mass concentration of elements in the egg sample with its statistical parameters

%Elements	Glair	Yolk	SD	Mean	CV%
K	47.7	1.14	32.922	24.42	135
Mg	46	91.1	31.890	68.55	47
S	2.79	---	N/A	2.79	N/A
Cl	2.32	---	N/A	2.32	N/A
Al	0.528	---	N/A	0.528	N/A
Zr	0.372	0.126	0.173	0.249	70
Si	0.145	---	N/A	0.145	N/A
Fe	0.0386	0.0608	0.015	0.049	32
Br	0.0089	0.0012	0.005	0.005	108
Sn	0.0071	0.0017	0.003	0.004	87
Rb	0.0058	0.0003	0.003	0.003	128
Ti	0.0037	---	N/A	0.003	N/A
Cu	0.0035	0.0026	0.0006	0.003	21
Zn	0.0023	0.0336	0.022	0.017	123
Cr	0.001	---	N/A	0.001	N/A
Sr	0.0004	0.0003	0.00007	0.0003	20
Se	0.0003	0.0003	0	0.0003	0
P	---	5.92	N/A	5.92	N/A
Ca	---	1.61	N/A	1.61	N/A
Sc	---	0.0125	N/A	0.012	N/A
Dy	---	0.002	N/A	0.002	N/A
Er	---	0.0019	N/A	0.001	N/A
Ta	---	0.0009	N/A	0.0009	N/A

Table 8S — The relative mass concentration of elements in nuts and seeds samples with their statistical parameters

%Elements	Almond	Chickpea	Peanuts	Pistachio	Sunflower Seeds	White Pumpkin	Yellow Pumpkin	SD	Mean	CV%
Mg	82.7	75.2	0.941	54.9	90.6	78	0.895	38.342	54.748	70
Al	8.47	14.1	---	---	---	11.9	---	2.837	11.49	25
K	4.39	5.24	93.7	9.41	4.7	4.01	95.1	43.393	30.935	140
Ca	1.63	0.354	0.693	1.52	0.427	0.214	---	0.616	0.806	76
P	1.61	---	---	---	---	---	1.73	0.084	1.67	5
S	0.99	1.87	0.461	4.08	1.96	5.61	0.827	1.900	2.256	84

Zr	0.128	0.161	2.34	16.2	0.131	0.144	0.349	5.972	2.779	215
Fe	0.053	0.0311	0.534	6.58	0.0619	0.0742	0.315	2.426	1.092	222
Zn	0.0146	0.016	0.356	1.24	0.0292	0.0274	0.117	0.450	0.257	175
Mn	0.0144	0.0111	0.305	0.37	0.0181	0.0273	0.0603	0.153	0.115	134
Sc	0.0072	---	---	---	0.0045	0.0031	0.0088	0.002	0.005	44
Cu	0.0055	0.0051	0.107	0.648	0.0119	0.0052	0.0193	0.238	0.114	208
Rb	0.0022	0.0022	0.0377	0.202	0.0019	0.0028	0.0061	0.074	0.036	204
Dy	0.0021	---	---	0.406	---	0.0057	0.0092	0.200	0.105	189
Sr	0.002	0.0009	0.0124	0.512	0.0009	0.0003	0.0012	0.192	0.075	254
Sn	0.0018	0.0033	0.0445	0.119	0.0019	0.0015	0.0039	0.044	0.025	176
Hf	0.0016	---	---	0.0904	---	0.0014	0.0086	0.043	0.025	170
Pa	0.001	0.0006	0.0208	---	0.0007	---	0.0035	0.008	0.005	164
Ta	0.0009	---	0.0163	0.151	---	0.0013	0.0036	0.065	0.034	189
Cl	---	3.02	0.319	2.22	2.03	---	0.558	1.151	1.629	71
Br	---	0.0029	0.006	---	0.0003	0.0118	---	0.004	0.005	94
Ni	---	0.0008	0.0306	0.101	0.0014	0.0013	---	0.043	0.027	160
Er	---	---	0.0271	0.0799	---	---	---	0.037	0.053	70
Yb	---	---	0.0157	0.0314	---	---	---	0.011	0.023	47
Ar	---	---	0.0124	---	---	---	---	N/A	0.0124	N/A
Co	---	---	0.0036	0.117	---	0.0014	0.0027	0.057	0.031	184
Eu	---	---	---	0.785	---	---	0.0232	0.538	0.404	133
Tm	---	---	---	0.0891	---	---	---	N/A	0.089	N/A
Os	---	---	---	0.0585	---	---	---	N/A	0.058	N/A
Re	---	---	---	0.041	---	---	---	N/A	0.041	N/A
Te	---	---	---	0.0365	---	---	---	N/A	0.036	N/A
Cr	---	---	---	---	0.0009	0.0007	---	0.0001	0.0008	18
Po	---	---	---	---	0.0002	---	---	N/A	0.0002	N/A
Fr	---	---	---	---	---	0.0009	---	N/A	0.0009	N/A
Au	---	---	---	---	---	0.0007	0.0011	0.0002	0.0009	31