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Element contents of commonly consumed grain, pulse and legume seeds

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Abstract

P and K amounts of the seeds were defined to be between 3449 mg/kg (Beluga lentil) and 8080 mg/kg (white chia) to 2936 mg/kg (black rice) and 10603 mg/kg (mash bean), respectively. Also, Ca quantities of the seed samples vary between 87.1 mg/kg (whole rice) and 6681 mg/kg (white chia), Mg contents of the seeds were specified to be between 965 mg/kg (Beluga lentil) and 3540 mg/kg (black chia). As and Bi amounts of the seeds were characterized to be between 3.3 mg/kg (red bean) and 22.7 mg/kg (buckwheat) to 0.9 mg/kg (red bean) and 3.8 mg/kg (white chia), respectively. The highest Ba in seeds was established in black chia (28.2 mg/kg) and white chia (36.4 mg/kg) samples, and the Ba contents of other seed samples were stated below 2.6 mg/kg. Cd, Co and Cr quantities of the seeds were found below 0.2 mg/kg, 0.4 mg/kg and 0.8 mg/kg, respectively.

Keywords: pulses, cereal, legume seeds, elements, toxic elements, ICP-OES.

1. Introduction

Legumes, which are vital for a balanced diet because they increase their nutritional and phytochemical content, are one of the oldest human foods [1]. In addition, pulses are another group of grains belonging to the Leguminosae family, which forms a subgroup of legumes and produces edible seeds used for human and animal consumption [2]. Legumes, belonging to the Leguminosae family, are known as the second most important food crop after cereals in tropical regions and are inexpensive sources of plant protein and minerals compared to animal products [3]. Legumes such as beans, peas, lentils and peanuts, which are grown mainly for their edible seeds, belong to the "Leguminosae" family, also called "Fabaceae", and play an important role in human nutrition [4]. Since animal proteins are more expensive and scarce than proteins obtained from plant sources, the grains of legumes used as human food are widely used by vegetarians as a protein source instead of meat [5]. Legume seeds have a high importance in human consumption as they are considered a nutritious food and are a rich source of protein, fat, carbohydrates, vitamins and microelements [4,6]. The main components of legumes are protein (20-40%), carbohydrates (50-60%; the main component is starch), fat (2-3%), dietary fiber (0.7-6.2%), vitamins and minerals [7]. Pulses also contain valuable sources of protein, unsaturated fatty acids and minerals, and bioactive compounds [8-10,6]. Cereal, legume and herbal plant seeds are used for food and medicinal purposes [11], and their macronutrient content is considered essential for assessing their quality [12]. On the other hand, in addition to the need for mineral elements in large quantities for metabolic and developmental processes [13], mineral and polyphenol contents have been reported for different seeds and [11] reported that legumes are rich in potassium, calcium, magnesium, phosphorus and iron. Legumes have been reported to be suitable sources of iron, calcium, manganese and zinc according to contributions to the Dietary Reference Intakes [14]. More specifically, Indian rice has been reported to be rich in macro (calcium, potassium and

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sodium) and micro elements (iron and zinc) [15]. In addition to being a good source of minerals (calcium, iron, copper, zinc, phosphorus, potassium and magnesium) and vitamins, legumes are also a good source of PUFA (linoleic and linolenic acids) [16,17]. Since micronutrient deficiencies have increased in developed and developing countries in recent years [18], micronutrient deficiency has become a major public health problem known as "hidden hunger" in many parts of the world [19]. Fe and Zn deficiency in particular is a very important public health problem and has been reported to negatively affect the health, longevity and productivity of more than 4 billion people worldwide [20,21]. Although the proximate and mineral composition of pulses and legume seeds have been studied by many researchers, it is important to determine the mineral components of seeds in order to evaluate the nutritional quality of locally grown varieties, since the composition of seeds is affected by genetic and environmental factors. The aim of this study was to reveal the macro, micro and toxic element levels of widely consumed seeds of cereals, pulses and legumes.

2. Materials and method

2.1. Materials

Seeds were purchased from a local market in Konya and transported to the laboratory. Upon arrival, they were cleaned to remove foreign materials such as stones, soil, and leaves in 2023 (Fig. 1).

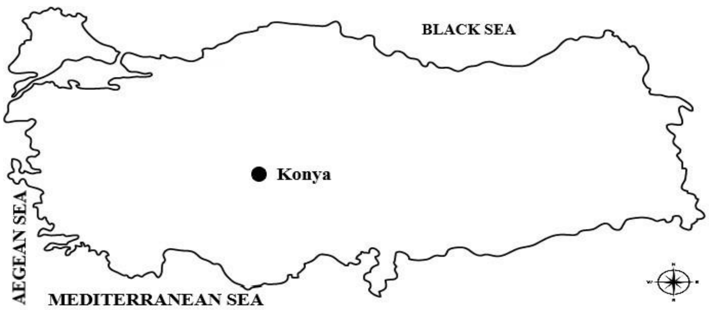

Figure 1. Locations where the vegetables used in this study were collected

2.2. Methods

2.2.1. Macro-, Micro-, and Heavy Metal Content Analysis of Seed Samples

Seed samples (0.2 g) were digested using a microwave system at 210°C and 200 PSI with 5 mL of concentrated nitric acid (HNO_3) and 2 mL of hydrogen peroxide (H_2O_2, 30% w/v). The resulting solutions were diluted to 20 mL with deionized water. Element concentrations in the seed samples were then analyzed using inductively coupled plasma optical emission spectrometry (ICP-OES) [22].

2.3. Statistical Analysis

The statistical analysis of the results was conducted using the JMP software. Differences between the data were determined by analysis of variance (ANOVA), with statistical significance set at $p < 0.01$ [23]. To examine the correlation between nutrient element contents in the seeds, a multivariate cluster analysis was performed using the PAST software to conduct Principal Component Analysis (PCA) [24].

3. Results and Discussion

3.1.Macroelement quantities of some grains and legumes

Macroelement quantities of some grains and legumes are displayed in Table 1. Differences were observed in macroelement contents depending on seed types. P and K amounts of the seeds were recorded to be between 3449 mg/kg (Beluga lentil) and 8080 mg/kg (white chia) to 2937 mg/kg (black rice) and 10603 mg/kg (mash bean), respectively. Also, Ca amounts of the seed samples vary between 87.1 mg/kg (whole rice) and 6681 mg/kg (white chia), Mg contents of the seeds were recorded to be between 965 mg/kg (Beluga lentil) and 3540 mg/kg (black chia). As seen in Table 1, the highest macroelement contents were established in chia samples. In general, it is thought that the cereal and legume seeds used in the study may be good sources of P and K.

3.2.The microelement contents of the grain and legume seeds

The microelement contents of the grain and legume seeds used in this study are depicted in Table 2. Microelement quantities of the seeds were found to be at lower levels than their macroelement quantities. Fe and Zn amounts of seed samples were established to be between 1.9 mg/kg (black rice) and 33.5 mg/kg (black chickpea) to 4.4 mg/kg (whole rice) and 36.4 mg/kg (white chia), respectively. While Cu contents of the seeds change between 0.8 mg/kg (whole rice) and 14.8 mg/kg (broad bean), Mn values of the seed samples were specified to be between 6.7 mg/kg (red bean) and 114.4 mg/kg (teff). In addition, the B amounts of seeds ranged from 0.9 mg/kg (quinoa) to 8.6 mg/kg (einkorn wheat). Black chia, white chia, beluga lentil and teff seeds are rich in Fe, Zn, Cu and Mn elements. In general, the Fe, Zn and Cu contents of whole rice, buckwheat and black rice were lower than those of other seeds. In addition, the seeds studied appear to be rich in Mn. Microelement amounts of legumes were found to be higher than cereals. The high Mn, Fe and Zn amounts of the seeds may be due to the fact that the soils where these plants grow are rich in these elements.

Table 1. Macro element contents of some cereal, pulses and legume seeds

Samples	P	K	Ca	Mg
	-------------------- (mg/kg) ---------------			
Black Chia	7528±37.5 B	6069±17.4 E	6268±38.3 B	3540±65.2 A
White Chia	8080±15.6 A	6454±33.5 D	6681±258.9 A	3248±49.5 B
Quinoa	3863±28.4 E	4439±33.1 F	362±6.6 G	1572±28.6 E
Beluga lentil	3449±43.8 F	7881±11.6 C	563±18.8 F	965±4.9 J
Broad beans	3558±24.4 EF	10636±50.2 A	572±19.3 F	986±3.3 J
Red bean	3732±25.5 EF	10598±25.4 A	475±3.6 FG	1397±41.9 F
Mash bean	3853±26.6 E	10603±38.4 A	825±22.9 E	1375±57.9 FG
Whole rice	3879±8.9 DE	2537±48.9 H	87±0.5 H	1162±30.1 HI
Buckwheat	4351±12.9 C	4435±99.1 F	126±2.8 H	2039±29.8 C
Einkorn wheat	3653±42.3 EF	3259±33.1 G	405±0.5 FG	1023±16.2 IJ
Teff	4243±41.5 CD	3237±82.3 G	1549±1.7 C	1721±27.9 D
Black rice	3827±60.2 E	2937±41.5 G	93±39.7 H	1290±27.9 FGH
Black chickpea	3837±45.8 E	8656±36.6 B	1092±17.5 D	1244±11.1 GH

A,B; $p<0.01$

Table 2. Microelement contents of some cereal, pulses and legume seeds

Samples	Fe	Zn	Cu	Mn	B
	-- (mg/ kg) --				
Black Chia	24.9±1.3 BC	30.6±1.2 B	13.7±0.2 B	76.2±0.6 B	1.9±0.1 G
White Chia	25.7±1.9 BC	36.4±1.5 A	14.5±0.2 AB	45.9±0.5 C	1.9±0.0 G
Quinoa	18.6±0.2 D	11.7±0.2 G	2.8±0.2 F	14.5±0.3 F	0.9±0.1 I
Beluga lentil	27.7±2.2 B	17.5±0.2 EF	5.4±0.4 D	12.5±0.2 G	4.1±0.0 D
Broad beans	18.2±0.6 D	22.5±0.3 D	14.8±0.9 A	8.5±0.2 I	0.7±0.1 I
Red bean	26.4±2.5 BC	16.3±0.4 F	6.8±0.0 C	6.7±0.3 J	4.9±0.3 C
Mash bean	23.7±0.7 C	18.5±0.2 E	6.8±0.1 C	8.5±0.1 I	1.5±0.1 H
Whole rice	3.1±0.0 F	4.4±0.2 I	0.8±0.0 H	22.7±0.5 E	8.4±0.4 A
Buckwheat	7.3±0.0 E	11.7±0.3 G	4.9±0.1 DE	11.5±0.3 H	5.8±0.2 B
Einkorn wheat	10.7±0.6 E	17.5±0.2 EF	2.6±0.0 F	23.2±0.3 E	8.6±0.3 A
Teff	17.7±0.4 D	22.5±0.3 D	4.5±0.0 E	114.4±0.8 A	4.4±0.0 CD
Black rice	1.9±0.1 F	6.5±0.2 H	1.7±0.5 G	23.3±0.3 E	2.7±0.0 F
Black chickpea	33.5±3.7 A	24.9±1.6 C	5.5±0.2 D	26.8±0.2 D	3.5±0.0 E

A,B; $p<0.01$

3.3.Toxic metal quantities of the grain and legume seeds

Toxic element quantities of the grain and legume seeds used in this study are defined in Table 3. The toxic metal established in the highest amounts in the seeds was As, followed by Bi, Se, Ni, Mo, Ba and Pb in decreasing order.

Table 3. Toxic elements of some cereal, pulses and legume seeds (mg/kg)

Samples	Se	Al	As	Ba	Cd
	mg/kg				
Black Chia	1.3±0.1 D	0.5±0.0 A	16.8±2.2 B	28.2±0.9 B	0.1±0.0 BC
White Chia	0.3±0.0 E	0.4±0.1 A	12.6±1.0 C	36.4±2.8 A	0.1±0.0 BCD
Quinoa	2.8±0.15 A	0.4±0.0 A	18.2±0.6 B	0.4±0.0 D	0.1±0.0 BC
Beluga lentil	1.4±0.0 D	0.4±0.0 B	24.8±3.3 A	2.4± 0.3C	0.1±0.0 BCD
Broad beans	1.2±0.1 D	0.4±0.0 B	10.5±0.2 CD	0.1±0.0 D	0.02±0.0 EF
Red bean	0.4±0.0 E	0.3±0.0 D	3.3±0.2 F	0.2±0.3 D	0.005±0.0 F
Mash bean	1.4±0.0 D	0.3±0.0 C	8.6±0.4 DE	0.6±0.0 D	0.2±0.0 A
Whole rice	2.5±0.1 B	0.4±0.0 B	18.4±0.3 B	0.2±0.04 D	0.02±0.0 EF
Buckwheat	2.4±0.3 B	0.5±0.0 A	22.7±0.3 A	0.1±0.0 D	0.1±0.0 BC
Einkorn wheat	1.9±0.1 C	0.5±0.0 A	12.4±0.2 C	1.6±0.0 CD	0.03±0.0 DEF
Teff	1.2±0.0 D	0.1±0.0 D	10.5±0.0 CD	0.9±0.0 CD	0.1±0.1 B
Black rice	1.1±0.1	0.3±0.0 C	11.2±0.3 CD	0.5±0.0 D	0.1±0.0 CDE
Black chickpea	1.2±0.0 D	0.3±0.0 C	7.2±0.0 F	0.8±0.0 CD	0.1±0.0 BC

Samples	Co	Cr	Mo	Ni	Pb
			mg/kg		
Black Chia	0.1±0.0 B	0.7±0.0 B	0.6±0.0 C	0.9±0.0 F	0.1±0.0 H
White Chia	0.1±0.0 E	0.7±0.0 A	0.7±0.1 C	2.3±0.1 BC	1.3±0.2 A
Quinoa	0.1±0.0 CD	0.6±0.0 BC	0.4±0.0 C	0.6±0.0 FG	1.2±0.1 A
Beluga lentil	0.1±0.0 EF	0.6±0.0 CD	2.4±0.2 B	1.7±0.0 E	0.9±0.0 C
Broad beans	0.4±0.0 A	0.5±0.0 F	1.2±0.1 C	1.7±0.0 E	1.1±0.0 B
Red bean	0.03±0.0 HI	0.4±0.0 G	0.7±0.0 C	0.3±0.0 H	0.3±0.0 G
Mash bean	0.1±0.0 DE	0.5±0.0 DE	24.5±1.6 A	3.7± 0.0A	0.7±0.0 DE
Whole rice	0.02±0.0 I	0.6±0.0 DE	0.8±0.0 C	0.6±0.4 G	0.8±0.0 CD
Buckwheat	0.1±0.0 BC	0.6±0.0 AB	0.7±0.0 C	2.4±0.0 B	0.6±0.0 EF
Einkorn wheat	0.1±0.0 EF	0.6±0.0 DE	0.6±0.0 C	0.7±0.0 FG	0.3±0.01G
Teff	0.1±0.0 GH	0.4±0.0 F	0.5±0.0 C	2.1±0.0 CD	0.6±0.0 EF
Black rice	0.02±0.0 I	0.5±0.0 F	0.9±0.0 C	2.1±0.1 BCD	0.6±0.0 F
Black chickpea	0.04±0.0 GHI	0.5±0.0 E	0.6±0.0 C	1.9±0.0 D	0.7±0.0 DE

A,B; $p<0.01$

As and Bi contents of the seeds were characterized to be between 3.3 mg/kg (red bean) and 22.7 mg/kg (buckwheat) to 0.9 mg/kg (red bean) and 3.8 mg/kg (white chia), respectively. In addition, Ba and Ni amounts of the seeds samples were established to be between 0.1 mg/kg (broad bean) and 36.4 mg/kg (white chia) to 0.3 mg/kg (red bean) and 3.7 mg/kg (mash bean), respectively. The highest Ba in seeds was assessed in black chia (28.2 mg/kg) and white chia (36.4 mg/kg) samples, and the Ba contents of other seed samples were determined below 2.6 mg/kg. While Pb quantities of the seeds vary between 0.1 mg/kg (black chia) and 1.3 mg/kg (white chia), Se contents of the seed samples ranged from 0.3 mg/kg (white chia) to 2.8 mg/kg (quinoa). Mo results of the seeds varied to be between 0.4 (quinoa) and 25.5 mg/kg (mash bean). Cd, Co and Cr amounts of the seeds were found below 0.2 mg/kg, 0.4 mg/kg and 0.8 mg/kg, respectively. Grembecka *et al.* [1] assessed 131 mg/100g and 93.8 mg/100g Ca, 163 mg/100g and 98.5 mg/100g Mg, 1.08 mg/100g and 0.95 mg/100g Na, 828 mg/100g and 652 mg/100g K, 480 mg/100g and 546 mg/100g P, 1.92 mg/100g and 2.78 mg/100g Zn, 0.75 mg/100g and 0.65 mg/100g Cu, 3.84 mg/100g and 10.5 mg/100g Fe, 1.28 mg/100g and 1.32 mg/100g mg/100g Mn in mung bean and lentil seeds, respectively [26] determined 265.35 Ca, 134.26 mg/100g Mg, 986.35 mg/100g K, 196.36 mg/100g P, 266.35 mg/100g Na, 37.17 mg/100g Mn, 5.65 mg/100g Fe, 2.86 mg/100g Cu, 17.12 mg/100g Zn and 0.16 mg/100g Se in red bean seeds. Grembecka *et al.* [1] determined 0.02, 0.03 and 0.02 Cr, 0.17, 0.1 and 0.19 Ni and 0.02, 0.02 and 0.02 mg/100g Co in bean, mung bean and lentil, respectively. The contents of K (7881.40 mg/kg) of beluga lentil was lower than the one reported by [27] (837 mg/100 g). [27] reported lower Fe values (6.6 mg/100 g) but our Zn values were found low compared to Zn content (4.2 mg/100 g) of Souci *et al.* (2002). According to [14], Fe content in dry lentils and beans amounted to 8.4 mg/100 g and 4.5 mg/100 g, respectively, and our Fe and Zn results in bean and lentil samples were low compared to these values. However, in our current research, Fe content in beans was 26.40 mg/kg, while [28] assessed almost three times higher Fe content of 6.25 mg/100 g. Calcium (Ca), which is the most abundant substance in the human body, plays a role in the process of tooth and bone formation, muscle physiology and blood clotting mechanism, along with phosphorus [29]. Copper and zinc, which play a vital role in the body during metabolism, serve as cofactors for a number of important metabolic enzymes [30, 31]. According to the composition of the mineral, pigeon peas in Indonesia, which have various mineral contents, have been reported to differ with the mineral contents of various other pigeon peas [32]. In addition to the level of minerals in plant raw materials depending on environmental and varietal factors, the mineral contents of plant products can also be affected by agricultural practices [33, 34]. To maintain the high quality of seeds usable in the food industry, agricultural practices need to be optimized, especially variable environmental factors such as temperature, drought and soil conditions. For this purpose, many researchers have demonstrated the effects of crop rotation on yield, weed and disease control, soil fertility and soil structure, and it has been reported that agronomic activities would be beneficial in this direction [35-37].

3.4.Principal Companent Analysis (PCA)

Macro (P, K, Ca and Mg) and micro levels of grain varieties (Black Chia, White Chia, Quinoa, Beluga lentils, Broad beans, Red beans, Bean puree, Whole rice, Buckwheat, Einkorn wheat, Teff, Black rice, Black chickpeas) Pearson correlation (r) between nutrient contents (Fe, Zn, Mn, Cu and B) is given in Figure 2. As shown in Figure 2, Pearson correlation analysis revealed both positive and negative relationships between the nutritional elements in the grains. Significant and moderately strong positive correlations ($p < 0.05$, r = 0.30-0.70) were observed between phosphorus (P) and copper (Cu) content in the cereal varieties (r = 0.652**). Additionally, there were significant and highly strong positive correlations ($p < 0.05$, $r > 0.70$) between calcium (Ca) (r = 0.975**), magnesium (Mg) (r = 0.962**), and zinc (Zn) (r = 0.715**) content.

While it was revealed that there were significant and moderately strong positive relationships between the K contents of the varieties and their Cu contents (r = 0.560**), it was stated that there were significant and high strong positive relationships between their Fe contents (r = 0.717**). When looking at the Ca content of grains; It was determined that there were significant and high strong relationships between Mg (r=0.915**), Zn (r=825**) and Cu (r=0.721**) contents. In addition, this study revealed that there are significant and moderately strong positive relationships between the Mg contents of the varieties and Zn (r = 0.637**) and Cu (r = 0.589**). When the Fe, Zn and Cu contents of the grains are considered, it was determined that there were significant and high strong relationships between Fe contents and Zn contents (r=0.714**) and Zn contents with Cu contents (0.817**), while Cu contents showed

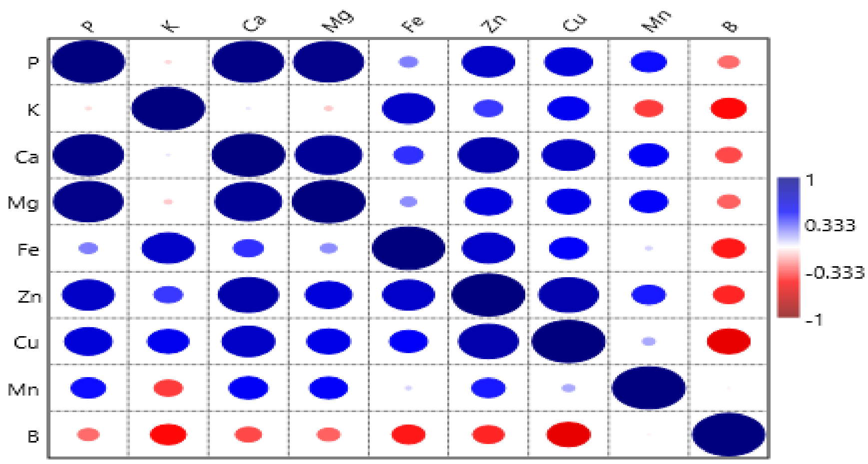

Figure 2. Macro (P, K, Ca and Mg) and micro levels of grain varieties (Black Chia, White Chia, Quinoa, Beluga lentils, Broad beans, Red beans, Bean puree, Whole rice, Buckwheat, Einkorn wheat, Teff, Black rice, Black chickpeas) Pearson correlation (r) between nutrient contents (Fe, Zn, Mn, Cu and B).

significant relationships with B contents (r=0.714**). r=-0.589**) was determined to create significant and negative, medium-strong relationships.

Pearson correlation (r) between heavy metal contents (Bi, Al, As, Ba, Cd, Co, Cr, Mo, Ni, Pb and Se) of grain varieties is given in Figure 3.

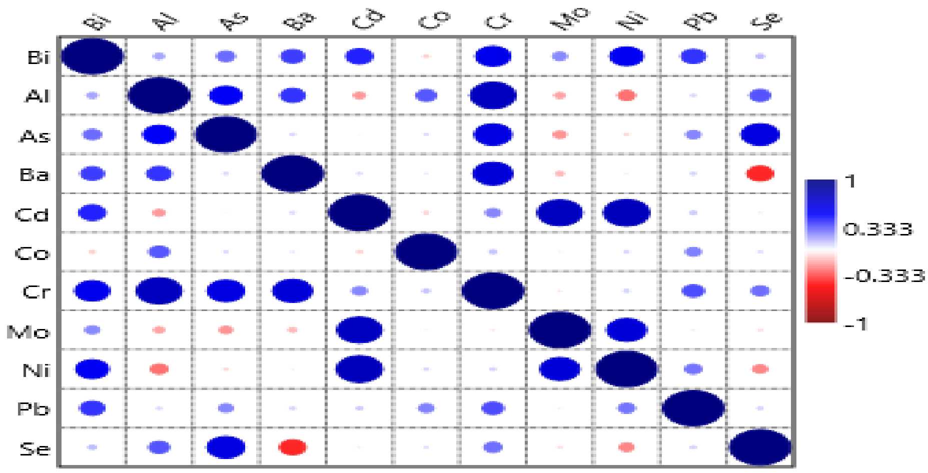

Figure 3. Pearson correlation (r) between heavy metal contents (Bi, Al, As, Ba, Cd, Co, Cr, Mo, Ni, Pb and Se) of grain varieties

As can be seen from examining the correlation between the heavy metal contents of grains, there is a positive relationship between the heavy metal contents of the varieties. When the Bi, Al and Ba contents of the cereal varieties are examined, it is revealed that there are significant and moderately strong positive relationships between Bi contents and Cr contents (r = 0.570**) and between Ba contents and Cr contents (r = 0.651**), while Al contents and Cr contents are found to be significant. It was determined that there were significant and high-strength positive relationships between their contents (r = 0.750**). While the As contents of the varieties create significant and moderately strong positive relationships with the Cr (r=0.612**) and Se (r=0.618**) contents, the Cd contents create significant positive relationships with the Mo (r=0.741**) and Ni (r=0.760**) contents. It was determined by Pearson correlation analysis that it had significant and strong positive relationships with its contents. It was also stated that there were significant and highly positive relationships between Mo contents and Ni contents of grain varieties (r=.0.651**). In this study on grain varieties, it was aimed to determine the strength and direction of the relationship between variable grain varieties and their nutritional element or heavy metal contents using Pearson correlation analysis. Thus, Pearson correlation tried to draw the best fit line on the data regarding grain types and nutrient element contents or grain types and heavy metal contents, and the Pearson correlation coefficient (r) revealed how far all these data points were from the best fit line [38].

4. Conclusion

The highest macroelement contents were detected in chia samples. In general, it is thought that the grains and legume seeds used in the study may be good sources of P and K. The microelements generally found in the highest amounts in the seeds were Mn, Fe and Zn, followed by Cu and B in decreasing order. In general, the Fe, Zn and Cu contents of whole rice, buckwheat and black rice were lower than those of other seeds. The toxic metal found in the highest amounts in the seeds was As, followed by Bi, Se, Ni, Mo, Ba and Pb in decreasing order.

Ethical Approval: Not applicable.

Competing Interests: The authors declare no competing interests

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