Zoltán RÉPÁS[1,2], Zoltán GYŐRI[1,2]

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Determination of the nutrient content of crops from different countries

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1. SUMMARY

The crops commercially available in Hungary show great variety in terms of their county of origin. According to out hypothesis, this diversity is also reflected in value of their nutrient content. In our experiments, the nutrient and mineral content of jasmine rice, lentils and beans from different areas of origin was determined, and the results were analyzed using descriptive statistical methods.

The aim of our work was to gather basic data from raw materials from different countries of the world, which can be compared with basic data from Hungary. During the evaluation of the results, a trend-like change in macronutrient amount was observed, while the mineral content of the crops was moderately or strongly variable in several cases. Based on our results, it is recommended that experts update basic data more frequently, given the increasingly globalized nature of the world, and take into account the variability of crops by country of origin.

[1] University of Debrecen, Faculty of Agricultural and Food Sciences and Environmental Management, Institute of Nutritional Science

[2] University of Debrecen, Doctoral School of Nutritional and Food Sciences

Zoltán GYŐRI	gyori.zoltan@unideb.hu	https://orcid.org/0000-0003-4169-0514
Zoltán RÉPÁS	zoltan_repas@yahoo.com	https://orcid.org/0000-0001-9463-1943

2. Introduction

The lentil, rice and dried bean varieties commercially available in Hungary show great variety in terms of their county of origin. Shoppers can choose from products from five continents on the shelves of a supermarket. This variability is also reflected in the range of raw materials supplied for communal catering. In order to design the right menu, which can even meet special nutritional needs, it is essential to know the nutrient content with sufficient accuracy, which also includes the mineral content. Food labeling only provides information on the main nutrients, but not on the mineral content. In the course of the study, the nutrient and mineral content of crops originating from different countries and appearing in the wholesale and retail trade in Hungary was determined.

3. General characterization of the studied crops

3.1. Jasmine rice

Rice (Orzyza sativa L.) has been a food since the Neolithic. It reached Europe through the ancient Greeks, Romans and then the Mohammedan peoples **[1]**. It was first categorized by Carl von Linné in the Species Plantarium in 1753 **[2]**. The geographical boundaries of current rice production are the latitudes of 53° north and 40° south. In 2018, the world's total rice production was 782 million tonnes. The largest rice-producing countries are China with 214.08 million tonnes/year, India with 172.58 million tonnes/year and Indonesia with 83 million tonnes/year. Rice production in Hungary was 55-68.5 thousand tonnes/year in the 1970s, 30-47 thousand tonnes/year in the 1980s, 10 thousand tonnes/year since the 1990s **[3]**. The 1000-grain weight of rice grains is between 12 and 54 g. The quality of rice can also be characterized by the profile index. This parameter characterizes the length and width of the grain, based on which it can be slender (3.0<), medium (3.0-2.1), hemispherical (2.1-1.1) and round (1.0>). Rice is a valuable and popular crop which is well reflected in its more than 8,000 varieties.

Outstanding among the varieties is the long-grained jasmine rice, which, when ready for cooking, has a soft texture and a pleasant aroma. Jasmine rice (KDML 105) produced in the northern and northeastern growing areas of Thailand has an outstanding aroma content **[4]** and has been bred from the Khao Dow Mali 105 and Kor Kho 15 varieties **[5]**. Its characteristic is that it grows only once a year, in the rainy season. As a result, the crop ripens at the same time, it is harvested at the same time, and the crop is placed on the market at the same time, resulting in a depressed commercial price. The producer can choose to store his crop (which results in storage costs) or sell it immediately at a lower profit. The nutrient content of jasmine rice is different from that of other rice varieties. According to the database of the US Department of Agriculture, Agricultural Research Service, Food Data Central, it has an energy content of 356 kcal, a protein content of 6.67 g/100g, a fat content of practically zero, and a carbohydrate content of 80 g/100 g **[6]**. According to the measurements of Chee-Hee Se et al., its energy content is 349 kcal, protein content is 6.98±0.16, carbohydrate content is 79.6±0.30, while the fat content is 0.26±0.07 g/100 g **[7]**. University of Arkansas student Mills and the instructor Wang in 2020 examined samples from nine varieties native to Thailand but grown in the USA **[8]**.

Their nutrient content measurement results were as follows.

- Protein content (g/100 g): 7.61±0.01; 7.65±0.01; 8.39±0.02; 10.89±0.15; 6.99±0.03; 7.87±01; 9.09±0.02; 6.87±0.00; 8.41±0.13;
- Fat content (g/100 g): 0.015±0.00; 0.19±0.00; 0.56±0.02; 0.54±0.01; 0.31±0.01; 0.43±0.01, 0.4±0.01; 0.26±0.01; 0.45±0.01.

The mineral content of rice varieties measured by other authors is shown in ***Table 1***.

Table 1. Mineral content of rice from different sources (mg/kg)

Mineral	Rice [27]				Rice [28]	Rice [29]			Rice [15]
Ca	98.75	75.8	85.6	76.3	119.5	51.9	64.5	78.1	160
Cu	4.1	4.5	5.55	6.41	9.96	3.7	2.6	4.7	0.37
Fe	31.5	10.5	16.45	3.2	5.4	23.5	1.83	2.49	2.8
K	482.65	268.45	265.85	341.35	804.83	2586.4	2687.8	2160.2	2300
Mg	171.3	83.5	155.25	139.55	194.8	403.1	403.2	302.1	1100
Mn	No data	No data	No data	No data	10.73	5.3	5.8	3.3	0.07
Zn	17	10.25	13.25	11.5	25.9	11.7	7.7	14	16
Na	57.4	51	68.85	41.44	20.78	51.9	64.5	78.1	100
Ca	98.75	75.8	85.6	76.3	119.5	3.7	2.6	4.7	160

3.2 Lentils

The lentil (LensCulinarisMedik. SSP. Culinaris) is one of the oldest cultivated plants of mankind. It was already cultivated in Central Europe during the Stone Age **[9]**. It is also mentioned in the Bible, in the first book of Moses (Moses 25:27-34), but stable carbon isotope studies have shown that it was also an important part of the diet in ancient Egypt **[10]**. Its botanical description in 1787 was carried out by Friedrich Kasimir Medikus, a German physicist and botanist **[11]**. It is currently grown on five continents, in several countries, including Hungary. According to the United Nations Food and Agriculture Organization (UN FAO), it was grown on about 4.3 million hectares between 2012 and 2014, with an annual world lentil production of 5 million tonnes. In 2017, the size of growing area has already reached 6.5 million hectares **[12]**. The world's largest lentil producers are Canada, India and the United States, but Australia is also among the emerging countries. In Europe, the largest lentil-producing countries are Russia, Spain and France. Canada accounts for 40% of world production, India is second with 22% and Turkey is third with 8.1%.

Several varieties of lentils are known. They can be distinguished on the basis of the size of the seed: large, medium and small seed, but also on the basis of the color variation of the seed: brown, yellow, red, black or green lentils. Some varieties have outstanding nutrient content. Masooregy is an Indian large seed red lentil variety. Cultivated by Bahauddin Zakariya University in Pakistan, Masoor 85 has a protein content of 30.41 g/100 g, while the protein content of NIAB Masoor is 30.6 g/100 g, which are outstanding values **[13]**.

The types of lentils commercially available in Hungary are distinguished according to the size and color of the lentil seeds.

In terms of nutrient content, lentils are a protein-rich crop. Comparing the measurement results of several authors, its protein content shows variability. Based on electronic data collection by Ganesan and Bajoun in 2017 from the database of the Department of Agriculture, Agricultural Research Service, Food Data Central operated by the government of the USA, the protein content of lentils is 24.44-25.71 g/100 g **[14]**. According to the New Nutrient Table (2005) edited by Imre Rodler, the protein content of lentils is 26 g/100 g, its carbohydrate content is 53 g/100 g, and the fat content is 1.9 g/100 g **[15]**.

In 2004, Wang and Daun examined lentil samples grown by several randomly selected Western Canadian producers. The average protein content of the large seed brown lentils examined by them was 27.3 g/100 g, its carbohydrate content was 44 g/100 g, and the fat content was 1.2 g/100 g, while the average protein content of the medium seed brown lentils was 25.9 g/100 g, its carbohydrate content was 44.8 g/100 g, and the fat content was 1.0 g/100 g **[16]**. The mineral content of lentils measured by other authors is shown in ***Table 2***.

Table 2. Mineral content of lentils (mg/100 g)

Mineral	**Lentils [15]**	**Large seed lentils (Laird variety) [16]**	**Medium seed lentils (Richlea variety) [16]**
P	420	465.5	568.4
Ca	68	64	81.3
K	840	976.4	1116.9
Mg	135	136.1	147.1
Na	7	No data	No data
Zn	3.5	4.4	4.3
Mn	1.55	1.7	1.9
Cu	0.75	1.2	1
Fe	6.5	8	7.7

3.3 Beans

Among legumes, the most important plants for the food industry belong to the Fabaceae family. These are peas, beans, lentils, lupine and peanuts.

Beans (Phaseolus vulgaris L.) belong to the family of Papilionaceae. They are native land is considered to be the areas of Mexico and Guatemala 500-1,800 m above sea level, and they came to Europe after the discovery of the New World. The oldest bean finds are almost 10,000 years old and were found in Peru **[17]**. They are characterized by a great richness of form, and there are several variants within the species. Their flowers have a well-developed, zygomorphic, characteristic butterfly shape with bilateral symmetry. The fruit is a multi-seeded, flattened or cylindrical pod. The pods contain 4 to 8 seeds, depending on the variety. The color of the seed is varied.

In Hungary, two species are grown: common beans, also known as garden beans (Phaseolus vulgaris L.), and creeper beans or butter beans (Phaseolus coccineus L.). World bean production (Phaseolus vulgaris L.) was 11.23 million tonnes in 1961 and 30.43 million tonnes in 2018, which means a nearly threefold increase. In 2018, the world's largest bean-producing country was India with 6.22 million tonnes, followed by Brazil with 2.62 million tonnes. The volume produced in Hungary has decreased significantly in the last 50 years: while in 1962 the amount of beans produced was nearly 31 thousand tonnes, by 1990 this number had decreased to 3,546 tonnes. The low point was 2010 with 545 tonnes. From 2014 to the present, the average production has been 1,500 to 1,700 tonnes/year **[3]**. The amount of nutrients found in beans depends on the variety, the climate, the growing area and the cultivation technology. Beans can be stored for years under appropriate conditions without damage **[18]**.

In terms of nutrient content, the most valuable component of ripe beans is protein. Bean proteins are made up of valuable essential amino acids such as lysine, methionine, cysteine and tryptophan.

The nutrient and mineral content of beans measured by other authors is shown in ***Table 3***.

Table 3. Nutrient and mineral content of beans from different sources (per 100 g)

Nutrient	Dried beans [15]	White beans [19]	Kidney beans [30]
Protein (g)	22.3	24.1	No data
Fat (g)	1	1.51	No data
Carbohydrate (g)	57.9	42.4	No data
Ash (g)	3.4	No data	No data
Water (g)	12.4	0	No data
P (mg)	410	523	439±46
Cs (mg)	100	229	92±37
K (mg)	1550	1470	1649±296
Mg (mg)	145	180	207±24
Na (mg)	8	No data	4.296±1.052
Zn (µg)	2800	3310	3199±365
Co (µg)	5	38.9	57±15
Cr (µg)	18	No data	28±11
Mn (µg)	2500	2200	1660±196
Ni (µg)	200	220	380±164
Cu (µg)	850	1140	841±105
Se (µg)	10	No data	No data
Fe (µg)	6600	No data	10094±1750

3.4 Sulfur-nitrogen ratio

The sulfur content of foods is not very often determined, although its amount is an important indicator of sulfur-containing amino acids. Sulfur occurs I the soil in organic and inorganic forms. The most important sulfides in the soil are FeS_2 (pyrite) and FeS, and the most important sulfates are gypsum ($CaSO_4 \cdot 2H_2O$) and anhydrite ($CaSO_4$). The amount of organically bound sulfur varies in direct proportion to and is strongly correlated with the humus content of the soil: r=0.84. The organic sulfur content of the soil varies from soil type to soil type **[31]**: in chernozem soils it is 75%, while in podzolic soils it is approximately 50%. The sulfur replenishment in different soil types also depends on air pollution and on industrial sulfur emission. Between 1972 and 1974, the amount of sulfur precipitating from the air due to air pollution in the central parts of Great Britain reaches 50 kg/year/ha **[38]**. In 1980, A. Martin compared the results measured by several authors over a period of 20 years and found that the amount of sulfur precipitating from the air varied by geographical area and season **[39]**. In 1988, J. Archer calculated the amount of sulfur in agricultural production areas in East England as generally at least 30 kg/year/ha, based on several measurements carried out on the 1970s **[36].** In the United Kingdom, sulfur dioxide emissions have been steadily declining for the last 50 years. Emissions today are about 3% of those measured in the 1970s **[40]**. Plants usually absorb most of the sulfur through the roots in the form of sulfate, or through the stomata of the leaves. The absorbed sulfate is reduced in several steps. It first reacts with ATP to form adenosine phosphosulfate (APS), while inorganic phosphate (P_{an}) is released from ATP:

$$SO_4^{2-} + ATP \rightarrow APS + P_{an}$$

With the help of ATP, APS is phosphorylated a second time to phosphoadenosine phosphosulfate. The sulfate thus bound is reduced to sulfite by an enzyme carrying a hydrogen atom, then it is then further reduced by NADPH to sulfide-S (S^{2-}), which reacts with serine to form cysteine **[32]**.

Sulfur occurs in plants in both inorganic and organic forms. There is no sharp boundary between the two fractions, sulfate is the S reserve of the plant. If the sulfur supply of crops is increased, the inorganic sulfur content will increase primarily, and organically bound sulfur to a lesser extent. The absorbed sulfur is stored by the plant in the form of sulfate, which is reduced to an organic form as needed. First, the plant meets its organic sulfur demand, only then the absorbed sulfur is stored **[33].** The greatest significance of sulfur is that it is a constituent of peptides, proteins and lipids, and a building block of sulfur-containing amino acids. Of the sulfur compounds, the amount of cysteine and methionine is significant. The presence of these is essential in various food and feed raw materials. The specific role of sulfur is manifested in enzymes and coenzymes containing the SH group. 90% of SH groups are linked to proteins in plants. In the case of sulfur deficiency, the protein synthesis of the plant is disturbed, the amount of soluble nitrogen compounds increases and the protein content decreases **[20]**. Then relationship between the elements can be demonstrated by statistical methods. In studies on bread wheat, a correlation of $r=0.73$ ($\alpha=0.01$) was measured in the relationship between the sulfur and nitrogen content **[21]**. In Poland, studies on beans (*Phaseolus vulgaris L.)* have been carried out for several years, during which the protein content of the crop was increased by 13.6% with adequate sulfur supply **[37]**. In Northern Germany, in a study on rapeseed, the nitrogen uptake of the plant was increased by 40% with adequate sulfur supply **[34]**.

As no comprehensive studies had been found in the literature by us regarding the composition of the individual crops, we consider it important to provide basic data on this element for the food raw materials studied as well.

4. Materials and methods

4.1. Raw materials

Samples were purchased in December 2020, by random subjective selection in various retail stores in Hungary. The selection criteria was for the samples to differ according to their country of origin or distributor. Seven types of brown lentils from five different distributors and countries of origin, four types of jasmine rice from four different distributors and three countries of origin, and four types of white beans from four different distributors and three countries of origin were analyzed and their nutrient contents were determined. Summary tables of the results, descriptive statistical analyzes and graphs were prepared in Microsoft Excel.

The samples analyzed are listed in ***Table 4*** based on their crop characteristics.

Table 4. Samples analyzed and their characteristics

Sample ID	Name	Characteristic	Country of origin
R1.	Rice	Jasmine	Cambodia
R2.	Rice	Jasmine	Thailand
R3.	Rice	Jasmine	Vietnam
R4.	Rice	Jasmine	Thailand
L1.	Lentils	Medium seed, brown	Russia
L2.	Lentils	Medium seed, brown	Ukraine
L3.	Lentils	Large seed, brown	Canada
L4.	Lentils	Large seed, brown	Poland
L5.	Lentils	Medium seed, brown	Poland
L6.	Lentils	Medium seed, brown	Turkey
L7.	Lentils	Medium seed, brown	Russia
B1.	Beans	White beans	Ethiopia
B2.	Beans	White beans	Ukraine
B3.	Beans	Pinto beans (Diana)	Hungary
B4.	Beans	White beans (Start)	Hungary

4.2. Analytical method

Analytical tests were performed on the basis of the food analysis guidelines of the Hungarian Standards Institution (HSI) and the Hungarian Food Codex at the Faculty of Agriculture, Food Science and Environmental Management Instrument Center of the University of Debrecen. Analytical methods are listed in ***Table 5***. To determine the protein content, the amount of nitrogen measured was multiplied by 6.25.

Table 5. Analytical methods

Parameter analyzed (unit)	Analytical method	Permitted analytical deviation
Moisture (m/m) %, drying, weighing	MSZ 6367-3:1983	±0.4 m/m%
Crude protein (m/m) %, Kjeldahl method	MSZ EN ISO 20483:2014	±0.3 m/m%
Carbohydrate (m/m) % Phenol-sulfuric acid method	Theoretical Foundations of Food Analysis I (1987) Chapter 3.7.2.3	±0.05 m/m %
Total dietary fiber (m/m) %, Enzymatic hydrolysis	Hungarian Food Codex 3-2-2008/Guideline no. 1 Annex I	±55 R
Sample preparation	SVM2 2011	No data
Ca (mg/kg) ICP-OES	MSZ-08-1783-26:1985	±10 % R
Cu (mg/kg) ICP-OES	MSZ-08-1783-34:1985	±10 % R
Fe (mg/kg) ICP-OES	MSZ-08-1783-31:1985	±10 % R
K (mg/kg) ICP-OES	MSZ-08-1783-29:1985	±10 % R
Mg (mg/kg) ICP-OES	MSZ-08-1783-27:1985	±10 % R
Mn(mg/kg) ICP-OES	MSZ-08-1783-32:1985	±10 % R
Na ((mg/kg) ICP-OES	MSZ-08-1783-30:1985	±10 % R
P (mg/kg) ICP-OES	MSZ-08-1783-28:1985	±10 % R
S (mg/kg) ICP-OES	MSZ-08-1783-38:1985	±10 % R
Zn(mg/kg) ICP-OES	MSZ-08-1783-33:1985	±10 % R

Note: "MSZ" means "Magyar Szabvány = Hungarian Standard"

Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) is a quantitative elemental analysis method, for which samples were prepared according to a study published by professors and lecturers of the University of Debrecen **[35]**.

4.3. Statistical method

Statistical analysis was performed using descriptive statistical analysis, and regression analysis was performed using Microsoft Excel.

5. Results and evaluation

5.1. Results of rice samples and their evaluation

The results of the nutrient analysis of the rice samples are shown in ***Table 6**,* and the descriptive statistical evaluation of the data is presented in ***Table 7***. The measurement results and their statistical evaluation of the mineral analysis are summarized in ***Table 8*** and ***9***, the measurement results demonstrated in ***Figures 1*** and ***2***.

Table 6. Nutrient content of the rice samples

Sample ID	R1	R2	R3	R4
Protein (m/m) %	6.47	6.68	6.86	7.04
Total carbohydrate (m/m) %	78.9	78.2	78.3	77.5
Dietary fiber (m/m) %	4.87	4.52	4.91	4.66

Table 7. Statistical evaluation of the nutrient content of rice samples

Nutrient m/m%	Average	Standard deviation	Standard error	Variance	Minimum	Maximum	Range	CV%
Protein	6.76	0.24	0.12	0.06	6.47	7.04	0.57	3.58
Total carbohydrate	78.25	0.60	0.30	0.35	77.49	78.94	1.45	0.76
Dietary fiber	4.74	0.18	0.09	0.03	4.52	4.91	0.39	3.86
N (Protein content/6,25)	1.08	0.04	0.02	0.00	1.04	1.13	0.09	3.58

Table 8. Measured mineral content of rice samples and their statistical analysis, Part 1

Mineral m/m%	Average	Standard deviation	Standard error	Variance	Minimum	Maximum	Range	CV%
Ca	334.25	23.51	11.75	552.5	307.8	356.8	49.00	7.03
K	710.71	142.81	71.40	20394	568.1	893.5	325.4	*20.09
Mg	112.83	11.57	5.79	133.9	103.8	129.5	25.74	*10.25
P	947.59	44.01	22.01	1937	910.3	1008	98.41	4.64
S	908.24	86.26	43.13	74418	837.5	1029	191.5	9.50

**Moderately variable*

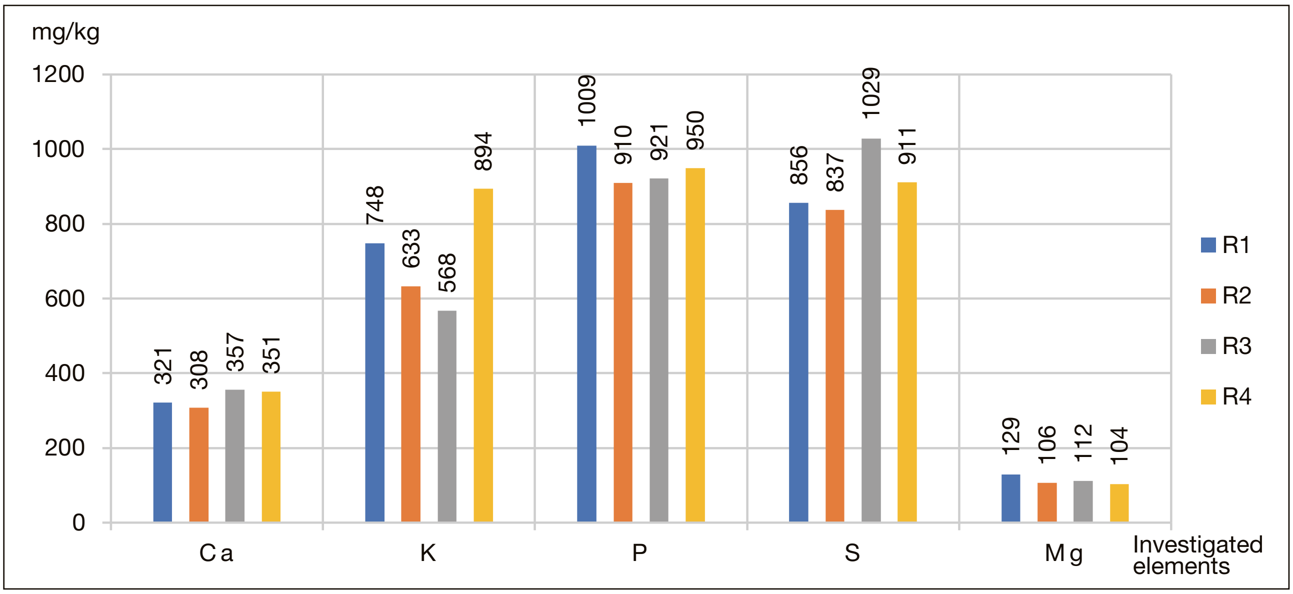

Figure 1. Measured mineral content of rice samples, Part 1

Table 9. Measured mineral content of rice samples and their statistical analysis, Part 1

Mineral m/m%	Average	Standard deviation	Standard error	Variance	Minimum	Maximum	Range	CV%
Mn	10.27	1.43	0.71	2.04	8.36	11.41	3.06	*13.92
Na	47.12	12.81	6.41	164.21	33.57	64.33	30.76	**27.19
Zn	15.97	1.43	0.72	2.06	14.01	17.44	3.43	8.98
Cu	4.25	0.5	0.25	0.25	3.78	4.94	1.16	*11.65
Fe	15.56	334.11	2.05	16.86	11.31	19.48	8.18	**26.43

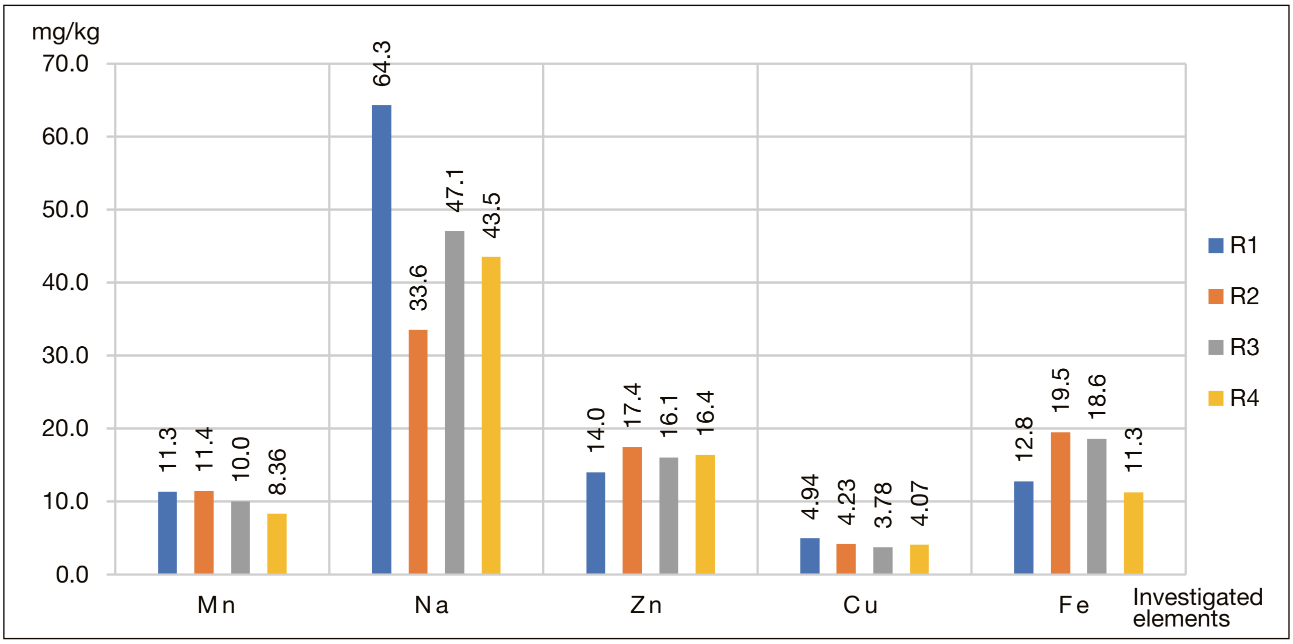

Figure 2. Mineral content of rice samples and their statistical analysis, Part 2

The protein (6.47-7.04 m/m%), carbohydrate (77.49-78.94 m/m%) and dietary fiber (4.52-4.91 m/m%) content of the rice samples was homogeneous. In the case of the samples tested, the mineral content exhibited moderate or high variability. The highest variability was observed when measuring the Na (CV%=27.19) and Fe (CV%=26.43) content. It is worth noting that the Na content was highest in the sample from Cambodia and lowest in the samples from Thailand, while the Fe content was highest in one of the samples from Thailand and lowest in the sample from Cambodia and another sample from Thailand.

5.1.1. Sulfur-nitrogen ratio

The relative S/N ratios of the rice samples are shown in ***Table 10***.

Table 10. Amount and ratio of sulfur and nitrogen

Sample	R1	R2	R3	R4
S (g/kg)	0.856	0.837	0.103	0.911
N (g/kg)	10.35	10.69	10.97	11.26
S/N	0.83	0.78	0.94	0.81
%	+6.4	No data	+20.5	+3.8

The fifth row of the table is based on the lowest ratio (R2) and shows the percentage difference from it.

The strongest correlation is found between samples R2 and R4; their country of origin is Thailand, but the final value is also close for sample R1. The largest deviation was found in the case of sample R3, with its country of origin being Vietnam. The correlation indicates the similar agrochemical characteristics of the soil and the cultivation area.

5.2. Results of lentil samples and their evaluation

The results of the nutrient analysis of the lentil samples are shown in ***Table 11***, and the descriptive statistical evaluation of the data is presented in ***Table 12***. The results and statistical evaluation of the mineral analysis are summarized in ***Tables 13 and 14 and Figures 3*** and ***4***.

Table 11. Nutrient content of the lentil samples

Amount of nutritient m/m%	L1	L2	L3	L4	L5	L6	L7
Protein	20.4	22.7	21.8	22.4	19.9	24.0	22.0
Total carbohydrate	56.9	55.3	55.8	54.8	55.3	53.5	56.7
Dietary fiber	18.8	19.4	19.1	19.7	18.8	20.1	19.5

Table 12. Statistical evaluation of the nutrient content of lentil samples

Nutrient m/m%	Average	Standard deviation	Standard error	Variance	Minimum	Maximum	Range	CV%
Protein	21.87	1.40	0.53	1.96	19.91	24.05	4.14	6.41
Total carbohydrate	55.48	1.17	0.44	1.38	53.46	56.86	3.40	2.11
Dietary fiber	19.35	0.49	0.19	0.24	18.76	20.14	1.38	2.55
N (Protein content/6,25)	3.50	0.22	0.08	0.05	3.19	3.85	0.66	6.41

Table 13. Mineral content of lentil samples and their statistical analysis, Part 1

Mineral m/m%	Average	Standard deviation	Standard error	Variance	Minimum	Maximum	Range	CV%
Ca	1081	81.09	30.65	6576	967	1202	235.3	7.50
K	8209	354.9	134.14	125956	7676	8656	980,0	4.32
Mg	1043	84.14	31.80	7080	941.3	1155	214.1	8.07
P	3832	509.7	192.6	259784	3258	4650	1391	*13.30
S	1775	149.2	56.40	22266	1570	1988	417.1	8.41

**Moderately variable*

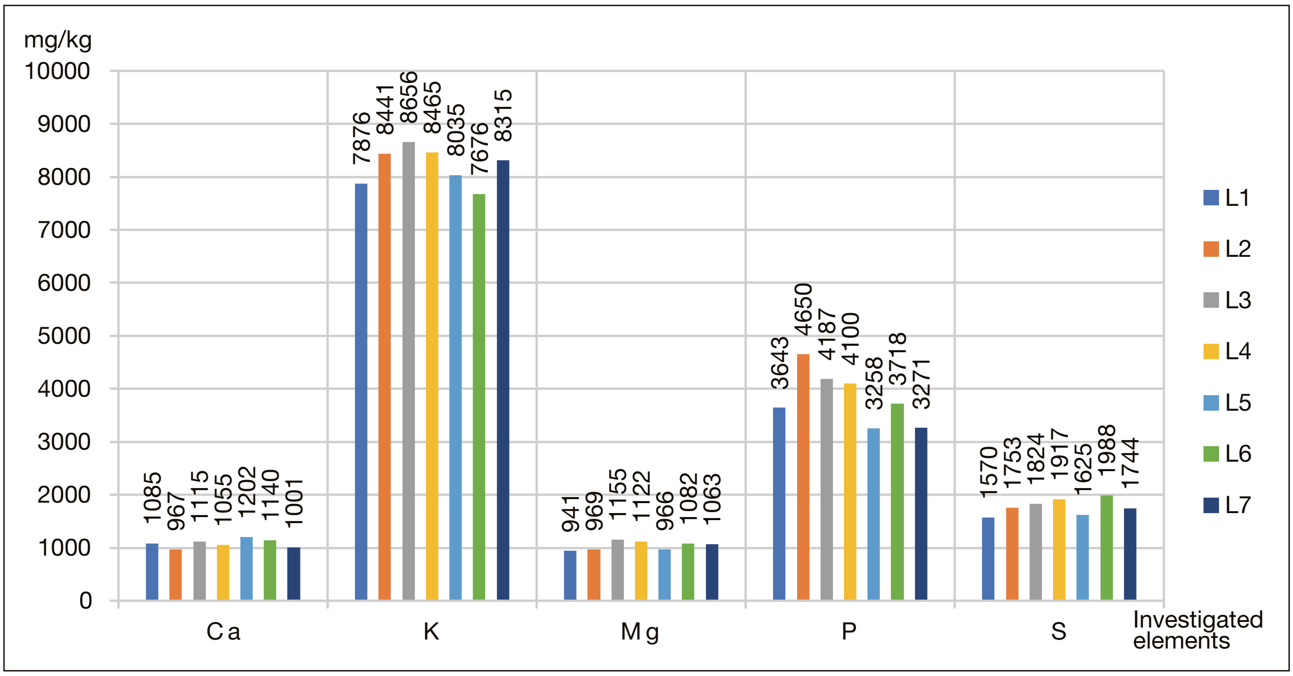

Figure 3. Measured mineral content of lentil samples, Part 1

Table 14. Mineral content of lentil samples and their statistical analysis, Part 2

Mineral m/m%	Average	Standard deviation	Standard error	Variance	Minimum	Maximum	Range	CV%
Mn	14.64	1.20	0.45	1.44	13.19	16.32	3.13	8.19
Na	54.87	5.0	2.00	28.11	45.24	60.32	15.08	9.66
Cu	11.57	1.23	0.47	1.52	9.76	13.13	3.37	*10.67
Fe	100.8	7.83	2.96	61.31	87.55	108.6	21.05	7.77
Zn	34.01	3.31	1.25	10.96	29.06	38.35	9.28	9.73

**Moderately variable*

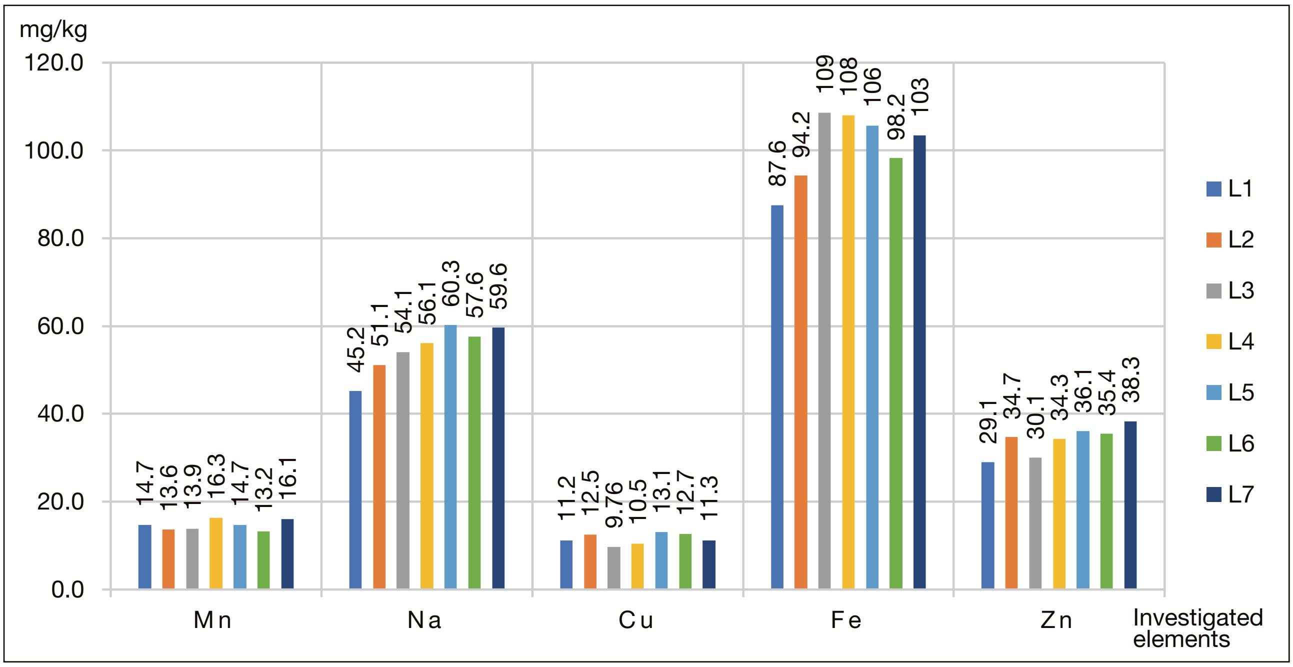

Figure 4. Measured mineral content of lentil samples, Part 2

In the case of the samples tested, several values showed moderate variability in terms of mineral content. The protein (19.91-24.05 m/m%), carbohydrate (53.46-56.86 m/m%) and dietary fiber (18.76-20.14 m/m%) content of the lentil samples was found to be statistically homogeneous, but there was a 15% difference between the lowest and highest values in percentage terms. Of minerals, phosphorus (CV%=13.3) and copper (CV%=10.67) exhibited moderate variability. The other minerals were statistically homogeneous. It is important to note that the amounts of Mg, Mn, Na, S and Zn were statistically homogeneous, but the values were in the upper part of the statistical range (CV%~10). The protein, carbohydrate and dietary fiber contents were all homogeneous.

The amount of phosphorus had the highest coefficient of variation. This value was lowest for the samples from Russia and Poland, while it was highest for the produce grown in Ukraine. In general, lentils grown in Canada and Poland had the highest mineral content, while it was lowest in the lentils grown in Russia and Ukraine. The relative S/N ratios of the lentil samples are shown in ***Table 15***.

Table 15. Sulfur-nitrogen ratios of the lentil samples

Sample	L1	L2	L3	L4	L5	L6	L7
S/N ratio	0.480	0.480	0.520	0.536	0.510	0.517	0.500
%	100	100	109	111	106	107	103

In the case of medium seed samples (L1, L2, L5, L6, L7), the values for samples L1, L2 and L7 were closest to each other. These samples came from Ukraine and Russia. In the case of samples L4 and L5, the cultivation area was the same, but sample L4 was large seed brown lentils, while sample L5 was medium seed lentils, the values of which were well separated from the values of other cultivation areas. Sample L3 (Canada) was also large seed lentils, with an S/N ratio different from the other values.

5.2.1. Regression analysis of sulfur-nitrogen ratio

Regression analysis of the amount of sulfur and nitrogen was performed only in the case of lentils, given the larger number of samples. Our regression statistics measurement data are shown in ***Table 16***, the line characteristic of the correlation and the equation of the line are shown in ***Figure 5***.

Table 16. Characteristic values of the regression analysis of S-N values (p=0.05)

Regression statistics	
r value	0.881909
r-squared value	0.777764
Adjusted r-square value	-1.4
Standard error	0.115765

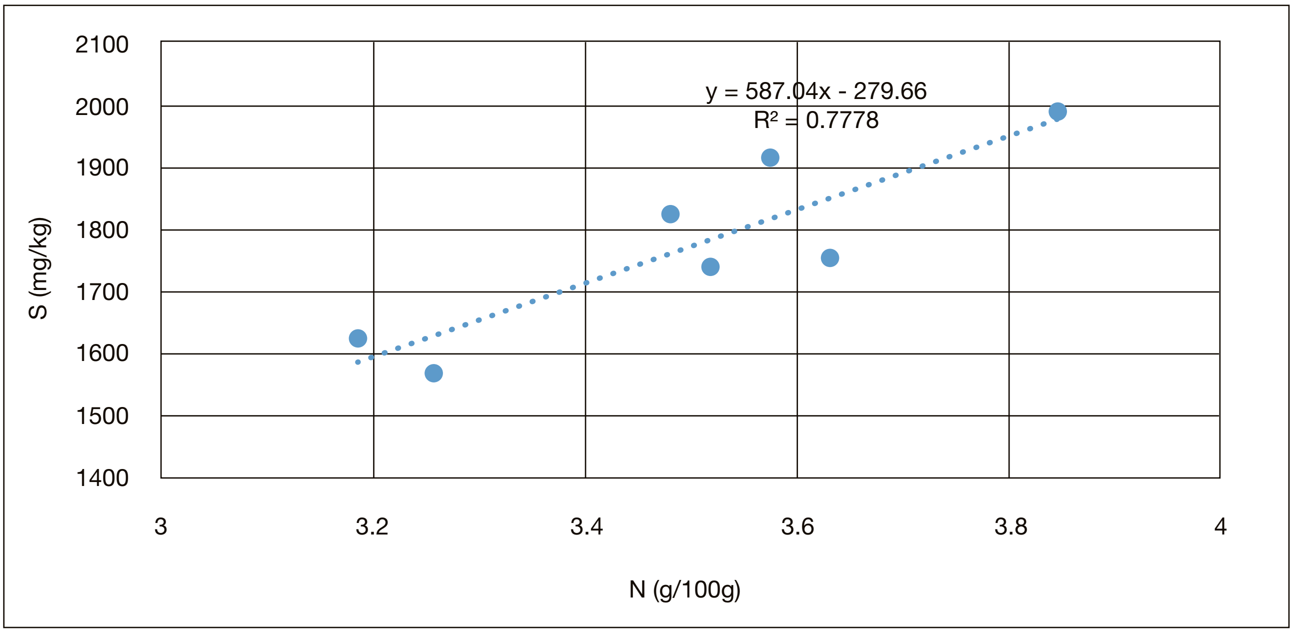

Figure 5. The line describing the correlation of S and N and its equation

The correlation between sulfur and nitrogen content can also be measured in wheat studies, and the correlation is r=0.7515 **[25]**, which affects the amount of cystine as a gluten component, and thus the quality o the finished product **[26]**.

5.3. Results of dried bean samples

The results of the nutrient analysis of the bean samples are shown in ***Table 17***, and the descriptive statistical evaluation of the data is presented in ***Table 18***. The results of the mineral analysis and their statistical evaluation are summarized in the ***Tables 19 and 20*** and demonstrated in ***Figures 6*** and ***7***.

Table 17. Nutrient content of beans

Component	B1	B2	B3	B4
Protein (m/m)%	20.0	18.8	No data	No data
Total carbohydrate (m/m)%	57.6	58.1	No data	No data
Dietary fiber (m/m)%	23.3	24.3	No data	No data

Table 18. Statistical evaluation of the nutrient content of bean samples

Nutrient m/m%	Average	Standard deviation	Standard error	Variance	Minimum	Maximum	Range	CV%
Protein (m/m)%	19.38	0.82	0.58	0.68	18.80	19.96	1.17	4.26
Total carbohydrate (m/m)%	57.85	0.42	0.30	0.17	57.55	58.14	0.59	0.72
Dietary fiber (m/m)%	23.80	0.75	0.53	0.56	23.27	24.33	1.06	3.15
N (Fehérjetartalom/6,25)	3.10	0.13	0.09	0.02	3.01	3.19	0.19	4.26

Table 19. Statistical evaluation of the measured mineral content of bean samples, Part 1

Minerals m/m%	Average	Standard deviation	Standard error	Variance	Minimum	Maximum	Range	CV%
Ca	2166	593.7	296.9	352499	1288	2597	1309	**27.41
K	15024	3177	1589	10095767	12911	19563	6742	**21.15
P	4915	819.3	409.7	671304	4256	5971	1715	*16.67
S	2105	327.4	163.7	109217	1810	2562	752.3	*15.55
Mg	1708	108.1	54.08	11699	1571	1831	260.0	6.33

**Moderately variable / **Highly variable*

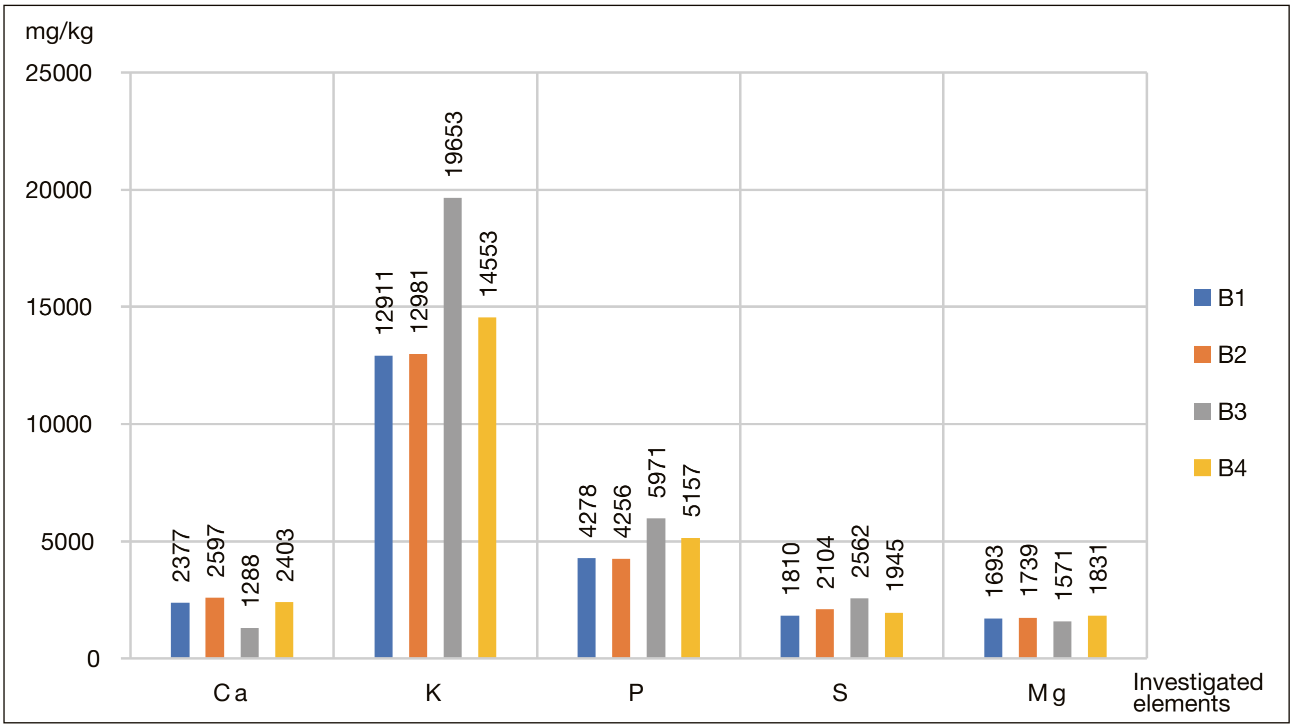

Figure 6. Mineral content of bean samples and their statistical analysis, Part 1

Table 20. Statistical evaluation of the measured mineral content of bean samples, Part 2

Minerals m/m%	Average	Standard deviation	Standard error	Variance	Minimum	Maximum	Range	CV%
Cu	9.75	2.09	1.05	4.37	7.03	12.13	5.10	**21.44
Fe	86.90	12.90	6.45	166.3	68.10	95.66	27.56	*14.84
Mn	14.99	2.40	1.20	5.77	12.30	17.81	5.51	*16.02
Na	62.29	13.98	6.99	195.4	54.50	83.20	28.70	**22.44
Zn	19.38	0.82	0.58	0.68	18.80	19.96	1.17	*19.26

**Moderately variable / **Highly variable*

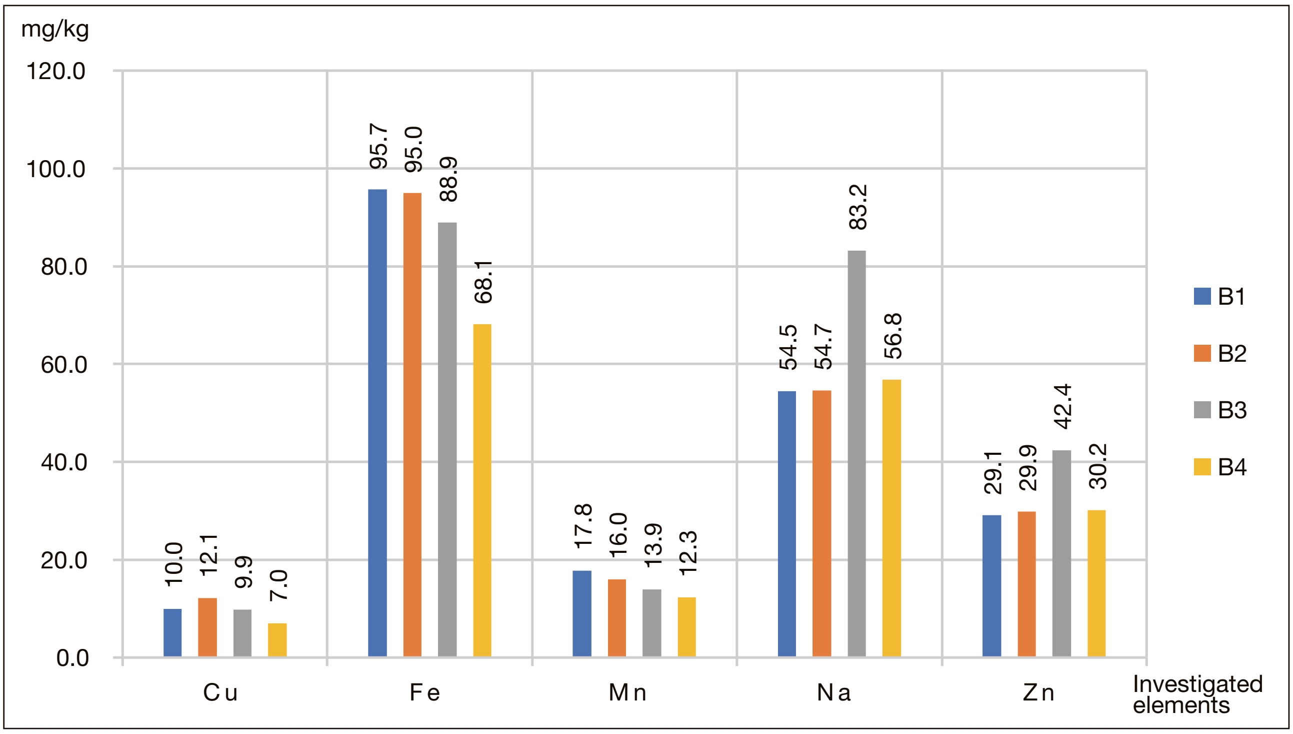

Figure 7. Mineral content of bean samples and their statistical analysis, Part 2

The protein (18.8-19.96 m/m%), carbohydrate (57.55-58.14 m/m%) and dietary fiber (23.27-24.33 m/m%) content of the white bean samples was statistically homogeneous, but with the exception of magnesium, the results showed moderate or high variability in terms of the amount of minerals. Moderately variable were the phosphorus (CV%=16.67), sulfur (CV%=15.55), iron (CV%=14.84), manganese (CV%=16.02) and zinc (CV%=19.26). Highly variable were calcium (CV%=27.41), copper (CV%=21.44), potassium (CV%=21.15) and sodium (CV%=22.44).

The highest mineral content was measured in the case of beans grown in Hungary, while the lowest was measured in the case of beans grown in Ethiopia and Ukraine.

5.4. Comparison of the measured values with the reference values

The measured data were compared with the values in the New Nutrient Table edited by Imre Rodler **[15]**. Percentage differences in the nutrient and mineral contents are shown in ***Table 21*** for rice, ***Table 22*** for lentils and ***Table 23*** for beans.

Table 21. Percentage differences in the nutrient and mineral contents of rice samples

Measured parameters	R1	R2	R3	R4	Average
Protein (m/m)%	-17.0	-14.3	-12.1	-9.8	-13.3
Total carbohydrate (m/m)%	1.2	0.3	0.4	-0.7	0.3
Ca (mg/kg)	100.9	92.3	123.0	119.4	108.9
Cu (mg/kg)*	1237*	1042*	921.7*	998.7*	1050*
Fe (mg/kg)*	355.8*	595.8*	564.5*	303.8*	455.0*
K (mg/kg)	-67.5	-72.5	-75.3	-61.2	-69.1
Mg (mg/kg)	-88.2	-90.3	-89.9	-90.6	-89.7
Mn (mg/kg)*	16068*	16205*	14192*	11840**	14576*
Na (mg/kg)	-35.7	-66.4	-52.9	-56.5	-52.9
P (mg/kg)	-64.0	-67.5	-67.1	-66.1	-66.2
Zn (mg/kg)	-12.4	8.9	0.5	2.3	-0.2

**Results with different orders of magnitude.*

The amounts of copper, iron and manganese differ by orders of magnitude from the values of the New Nutrient Table (data highlighted in brick red in ***Table 21***). After comparing the values in the New Nutrient Table with the results in ***Table 1***, measured by other authors (Cu=2.6-9.96 mg/kg, Fe=1.83-31.5 mg/kg and Mn=0.07-10.73 mg/kg), it can be stated that the difference is several orders of magnitude compared to the results found in international literature. Because of these differences, it is necessary and recommended to update available basic data periodically.

In the case of the samples, all samples had a lower protein content than the reference value, while all but one sample had a higher carbohydrate content than the reference value **[15]**. In terms of minerals, the amount of calcium was significantly higher, while the amounts of potassium, magnesium, sodium, phosphorus and zinc were less than the reference values **[15]**.

Table 22. Percentage of differences from the reference values in the nutrient and mineral contents of lentil samples ***[15]***

Measured parameters	L1	L2	L3	L4	L5	L6	L7	Mean
Protein (m/m) %	-21.7	-12.7	-16.3	-14.0	-23.4	-7.5	-15.5	-15.9
Total carbohydrate (m/m) %	7.3	4.4	5.3	3.3	4.4	0.9	7.1	4.7
Ca (mg/kg)	59.5	42.2	64.0	55.2	76.8	67.7	47.2	58.9
Cu (mg/kg)	49.7	66.3	30.2	39.7	75.1	68.9	50.0	54.3
Fe (mg/kg)	34.7	45.0	67.1	66.2	62.5	51.1	59.1	55.1
K (mg/kg)	-6.2	0.5	3.0	0.8	-4.4	-8.6	-1.0	-2.3
Mg (mg/kg)	-30.3	-28.2	-14.4	-16.9	-28.4	-19.9	-21.3	-22.8
Mn (mg/kg)	-5.3	-12.2	-10.3	5.3	-5.2	-14.9	3.8	-5.5
Na (mg/kg)	-35.4	-26.9	-22.7	-19.9	-13.8	-17.6	-14.8	-21.6
P (mg/kg)	-13.3	10.7	-0.3	-2.4	-22.4	-11.5	-22.1	-8.8
Zn (mg/kg)	-17.0	-0.9	-14.0	-1.9	3.2	1.2	9.6	-2.8

In the case of the lentil samples, the protein content was significantly lower, while the carbohydrate content was higher. Of minerals, the amounts of calcium, copper and iron were significantly higher, while the amounts of magnesium and sodium were significantly lower than the reference values **[15]**.

Table 23. Percentage of differences in the nutrient and mineral contents of bean samples

Sample ID	B1	B2	B3	B4	Mean
Protein (m/m) %	-10.5	-15.7	No data	No data	-13.1
Total carbohydrate (m/m) %	-0.6	0.4	No data	No data	-0.1
Ca (mg/kg)	137.7	159.7	28.8	140.3	116.6
Cu (mg/kg)	17.3	42.7	16.0	-17.3	14.7
Fe (mg/kg)	44.9	43.9	34.7	3.2	31.7
K (mg/kg)	-16.7	-16.3	26.8	-6.1	-3.1
Mg (mg/kg)	16.7	19.9	8.3	26.3	17.8
Mn (mg/kg)	-28.8	-36.1	-44.4	-50.8	-40.0
Na (mg/kg)	-31.9	-31.7	4.0	-29.0	-22.1
P (mg/kg)	4.3	3.8	45.6	25.8	19.9
Zn (mg/kg)	4.1	6.8	51.4	7.9	17.5

The protein content of the bean samples was on average 13.1% lower, and the carbohydrate content was slightly reduced. Of minerals, the amount of calcium was significantly higher, the amounts of iron, magnesium, zinc and phosphorus were higher, while the amounts of manganese and sodium were lower than the reference values **[15]**.

6. Summary, conclusions

In our measurements, on average, the protein content of the crops was lower and their carbohydrate content was higher than the corresponding reference values **[15]**. With respect to macronutrients, the change is the same as the change in the nutrient content of crops measured by other authors and associated with the climate change of Earth **[22, 23, 24]**. Strong variability was measured for several minerals. Based on our measurements, our hypothesis was accepted that the significant diversity of the crops by country of origin is reflected in their nutrient content. In the case of lentils, a correlation was found between the amounts of S and N (r=0.88). The S/N ratios observed were almost the same within countries or for neighboring countries, but were different for samples from different cultivation areas. Comparing the results of our measurements with the data in the New Nutrient Table, orders of magnitude differences were found **[15]**.

Based on our work, it is recommended that the variability of the nutrient and mineral contents is taken into account. Adequate nutrient knowledge of the raw materials is essential for accurate menu planning. Providing adequate nutrition for short- and long-term tasks, or for long-term health and availability, can be of great or even strategic importance to those performing work accompanied by high physical or mental strain (such as those working in law enforcement or members of the armed forces). The nutrients needed for these stresses can be provided by a natural diet, but knowledge and availability of accurate data is also a prerequisite.

It is recommended that changes in nutrient content according to the place of origin are taken into account already in the planning and execution phase of raw material procurement procedures.

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