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Determination and Evaluation of Minerals in Legumes Consumed in Vitória Da Conquista-BA

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Abstract

Legumes have played an important role in traditional diets in various regions of the world because they meet the recommended dietary guidelines for healthy eating. The present study aimed to determine and evaluate the mineral composition of legumes consumed in the municipality of Vitória da Conquista-BA using optical emission spectrometry with inductively coupled plasma. Minerals, calcium, magnesium, potassium, iron, manganese and zinc were determined in samples of chickpeas, soybeans, peas and lentils. An oxidizing mixture consisting of nitric acid and hydrogen peroxide was used for digestion of samples in a microwave oven. The concentration of minerals in the legumes indicated a small variation within the same type of sample. The results obtained revealed that the chickpea and soybean samples presented the highest mineral content of calcium, magnesium, and zinc among the analyzed samples. In addition, the study allowed the determination of the percentage contributions of each legume in relation to the Dietary Reference Intake for each nutrient. The principal component analysis showed that legume samples can be characterized according to differences in mineral contents. This work also suggests the importance of the analysis of other legume species and localities, as the consequence of the factors were associated with the chemical composition of the vegetables.

Subject Areas

Analytical Chemistry

Keywords

Chemical Analyses, Nutrition, Vegetables

1. Introduction

Humans require essential minerals for normal physiological functions and overall health. However, billions of people worldwide do not receive sufficient daily amounts of various minerals due to low concentrations and reduced bioavailability in commonly consumed staple food crops. Thus, food has been the subject of several studies due to its characteristic of essentiality to life (Valls *et al.*, 2010) [1].

Legumes are by definition grains contained in pods. They are divided into dried legumes, which include beans, chickpeas, soybeans, and lentils, and fresh legumes, such as peas and broad beans (Messina, 1999) [2].

Cultivated for thousands of years, legumes have played an important role in the traditional diets of many regions of the world (Caprioli *et al.*, 2010 [3]; Chung *et al.*, 2008 [4]). The inclusion of these vegetables in the daily diet has beneficial effects on the control and prevention of chronic metabolic diseases, such as diabetes mellitus and coronary heart disease (Sagratini *et al.*, 2009) [5].

From the nutritional point of view, legumes are characterized by being rich in slow-absorbing carbohydrates, fibers, proteins, B-complex vitamins, minerals such as calcium, iron, phosphorus, potassium and magnesium, and phytochemicals such as phenolic compounds (Ruiz *et al.*, 1996) [6].

The Brazilian Health Regulatory (Anvisa) defines the Dietary Reference Intakes (DRI) as the amount of protein, vitamins, and minerals that should be consumed daily to meet the nutritional needs of most individuals and groups of people in a healthy population. All DRI values are based on the RDA (Recommended Dietary Allowances), published in 1989 and indicated for all ages (infants, children, adults, and pregnant women) (Brasil, 1998) [7].

Cabrera *et al.* (2003) [8] state that of all foods, legumes provide more adequately the recommended dietary guidelines for healthy eating. Thus, the problem that undertracks the development of this study can be expressed in the following question: What is the percentage contribution of legumes such as peas, lentils, chickpeas and soybeans in relation to the DRI for the minerals calcium, magnesium, potassium, iron, manganese and zinc?

From this perspective, the present research is justified in the current social scenario, considering the extreme importance of the determination of macro and micro minerals in foods for nutritional and toxicological analyses, due to its participation in the numerous biochemical processes essential to human health. Thus, one can glimpse the importance of this study by considering that these inorganic substances have very important functions in the body and the lack or excess of them can generate imbalances in the health workforce (Ribeiro, 2004) [9].

Iron, manganese, and zinc are essential micro minerals for human health. In addition, these elements play an important role in human metabolism, and interest in these elements is increasing along with reports of relationships between trace element status and oxidative diseases (Pelus *et al.*, 1994 [10]; Fenema, 1993

[11]).

Calcium, potassium and magnesium are macro minerals whose daily need is greater than 100 mg. Its main functions are linked to the structure and formation of bones, regulation of body fluids and digestive secretions (Gibson, 2010) [12].

Because the chemical composition of crops varies according to the cultivars, soil and climatic conditions of the area, it is important to study the mineral constitution of food legumes such as chickpea, lentil, soybean and pea. Thus, the study of minerals in legumes represents a valuable field of research, indispensable for both the evaluation of safety and knowledge of their nutritional value.

Among the analytical techniques available to quantify the minerals present in legumes, inductively coupled plasma optical emission spectroscopy (ICP OES) is a powerful analysis technique that combines qualities such as high capacity for simultaneous and accurate determinations in short times over wide concentration ranges (Montaser, 1992) [13].

The reference values for minerals, recommended by the RDAs, are indicated for each type of individual (women, men, adults according to age, children, pregnant and lactating women). Thus, it is essential that the daily mineral recommendation is not the same for all individuals, considering that each human being is unique and individualized.

In view of the above, this study aimed to determine the concentrations of the macro minerals calcium, magnesium and potassium and of the micro minerals iron, manganese and zinc in legumes consumed in the municipality of Vitória da Conquista-BA, in order to highlight their nutritional importance, using optical emission spectroscopy with inductively coupled plasma (ICP OES). In addition, to investigate the percentage contributions of chickpea, soybean, pea and lentil samples, in relation to DRI for the determined minerals.

2. Material and Methods

This is an exploratory and experimental research, considering the proposed objectives and procedures performed for the acquisition of analytical data. From the point of view of the nature of the research, it fits into the quantitative research.

The subjects of this study consisted of samples of chickpeas, lentils, soybeans and peas. Four samples were acquired from each of the legumes, between March and April 2020, in the retail market of Vitória da Conquista-BA, totaling sixteen samples.

The municipality of Vitória da Conquista is located in the mid-south region of Bahia and has the following geographical coordinates: 14˚51'42.93"S Latitude and 40˚50'40.33"W Longitude. Due to its geographical location and economic diversity, Vitória da Conquista is a commercial and social center of great importance for the southwestern region of the state and north of Minas Gerais.

After acquiring samples of different brands, they were stored in plastic bottles and placed in a desiccator at room temperature.

The determination of the macro minerals calcium, magnesium and potassium and micro minerals iron, manganese and zinc was performed using an inductively coupled plasma optical emission—ICP OES (Vista Pro, Varian, Mulgrave, Australia). The instrumental parameters established for the determination of chemical species by ICP OES in high purity deionized water and in nitric acid 1% $v \cdot v^{-1}$ are presented in Table 1.

In this study, all reagents used were of high analytical degree. The solutions were prepared with deionized water, type I, ultrapure (resistivity 18.2 MΩ cm) obtained in the Milli-Q system (Millipore, Bedford, USA). The multielement solutions used were prepared from stock solutions containing calcium, magnesium, potassium, iron, manganese and zinc 1000 $mg \cdot L^{-1}$ (Merck, Darmstadt, Germany).

The decontamination of glassware, plastic bottles and materials in general was performed in an acid bath containing 10% $v \cdot v^{-1}$ nitric acid, for at least 12 h before use. Subsequently, the materials were washed with deionized water. For digestion of the samples, 30% $v \cdot v^{-1}$ hydrogen peroxide (Merck, Darmstadt, Germany) and nitric acid 70% $v \cdot v^{-1}$ (JT Baker) were used.

In a teflon bottle, 0.5000 ± 0.0001 g of the legume sample partially crushed into smaller grains was weighed. An oxidizing mixture consisting of 2.0 mL of concentrated nitric acid, 1.0 mL of hydrogen peroxide 30% $v \cdot v^{-1}$ and 5.0 mL of ultrapure water was then added. The bottle was sealed and placed in a microwave oven (Provecto Analytica, DGT 100 Plus) for digestion of the samples. After digestion, the contents were filtered and transferred to a 25.00 mL volumetric flask and measured with deionized water. The legume digests performed in microwaves were processed in triplicate according to the schedule described in Table 2.

Table 1. Instrumental parameters used in ICP OES.

Parameters	Conditions	
RF Generator (MHz)	40	
RF Power (KW)	1.3	
Plasma flow ($L \cdot min^{-1}$)	15.0	
Auxiliary gas flow ($L \cdot min^{-1}$)	1.5	
Nebulizer pressure (KPa)	200	
Diameter of injector tube (mm)	2.4	
Spray chamber	Cyclonic	
Nebulizer	Concentric type K	
Lines (nm)	Ca(II) 422.673	Fe (II) 238.204
	Mg(II) 285.213	Mn(II) 259.372
	K(II) 766.491 nm	Zn (II) 213.857

Source: authors.

Table 2. Microwave oven operating parameters for acid digestion of samples.

Step	Temperature (˚C)	Ramp (minutes)	Pressure (bar)	Time (minutes)	Power (%)
1	140	5	30	5	70
2	160	3	30	5	80
3	175	3	35	20	80
4	50	1	25	10	0
5	50	0	0	0	0

Source: Provecto Analyítica, 2008.

The evaluation of the results obtained after the determination of minerals by ICP OES was carried out with the aid of the *Past* 4.0 software, using principal component analysis (PCA). For this, the first step involved the construction of a 16 × 6 data matrix containing the results obtained for the concentration of each of the minerals.

3. Results and Discussion

Table 3 presents the concentrations (mg/100g of sample) found for macro and microminerals in lentil, peas, chickpea and soybean samples. The results of the analyses correspond to the gap between the minimum and maximum concentrations found for four different samples of each legume.

All determinations were performed in triplicate by inductively coupled plasma optical emission spectroscopy (ICP OES). From the use of this analytical technique it was possible to observe that the analyzed samples constitute important food species for the ingestion of some minerals essential to human health.

As shown in **Table 3**, the concentrations of minerals in legumes indicated a small variation in the same type of sample. The main sources that explain the variability in the composition of minerals may be related to soil, climatic conditions, seasonal variations, physiological status and legume maturity (Ramírez-ojeda, 2018) [14].

It is observed that the soybean and pea samples presented practically the same chemical composition, mainly in terms of microminerals iron, manganese and zinc, with little significant variations in the contents of macrominerals calcium, potassium and magnesium.

The lentil samples showed a lower mineral content when compared to other legumes. However, it was possible to observe that potassium concentration was higher in lentils when compared to peas, chickpea and soybean samples.

In general, among the minerals determined in the samples, manganese presented lower concentrations, while potassium was higher in content, followed by calcium and magnesium.

In view of the results obtained, it was possible to verify that the chickpeas samples presented higher concentrations of calcium, iron and zinc among the

Table 3. Concentration of minerals in the legumes analyzed (range and mean concentration in mg/100g of the sample for $n = 3$).

Mineral	Minerals Concentration (mg/100g of sample)			
	Lentil	Pea	Chickpeas	Soy
Calcium	51.02 - 59.34 (53.32)	114.21 - 135.65 (126.54)	197.32 - 210.12 (206.45)	127.33 - 146.54 (134.26)
Magnesium	4.51 - 5.11 (4.54)	4.23 - 4.81 (4.46)	4.67 - 5.27 (4.96)	4.81 - 5.63 (5.18)
Potassium	1142.44 - 1491.71 (1328.48)	1032.23 - 1156.87 (1093.67)	1159.11 - 1458.93 (1261.57)	1049.23 - 1326.77 (1187.65)
Iron	1.56 - 2.14 (1.68)	2.37 - 3.23 (2.94)	3.46 - 4.29 (3.78)	2.53 - 3.65 (3.11)
Manganese	1.61 - 2.43 (1.97)	2.32 - 3.18 (2.85)	1.69 - 2.76 (2.23)	1.57 - 2.53 (2.11)
Zinc	2.89 - 3.67 (3.43)	3.12 - 4.11 (3.68)	6.78 - 7.69 (7.34)	3.27 - 4.57 (3.84)

Source: authors.

legumes analyzed. These results corroborate the work developed by Viadel (2006) [15], Wang (2010) [16] and Hemalatha (2009) [17], which indicated chickpeas as an excellent source of iron and zinc.

The graphic representation of the principal components (PC) allowed the characterization of the minerals present in the different samples of legumes studied. The graphs of the first two axes of the principal components associated with each variable (calcium, magnesium, potassium, iron, manganese and zinc) are shown in **Figure 1**.

Through the principal component analysis (PCA), it was possible to observe the discrimination of the four groups of legumes analyzed: lentils, soybean, chickpeas and peas, as shown in **Figure 1(a)**. The first principal component (PC1) explains 52.43% of the total variance of the data. The most weight variables for PC1 are: calcium, magnesium, zinc and iron. The second principal component (PC2) accounts for 35.48% of the total variance. Thus, the first two principal components can explain the data describing 87.91% of the total variance.

The first principal component is mainly related to the minerals: calcium, magnesium, zinc and iron, while the second principal component is related to the minerals potassium and manganese. The score and loadings graphs (**Figure 1(a)** and **Figure 1(b)**) show that there is a separation between the samples of chickpeas, lentils and soybeans in the first principal component. While the second principal component separate the pea from the other legumes.

PCA revealed that soybean and chickpea samples have higher mineral contents than lentil and pea samples. The concentration of magnesium, zinc, calcium and

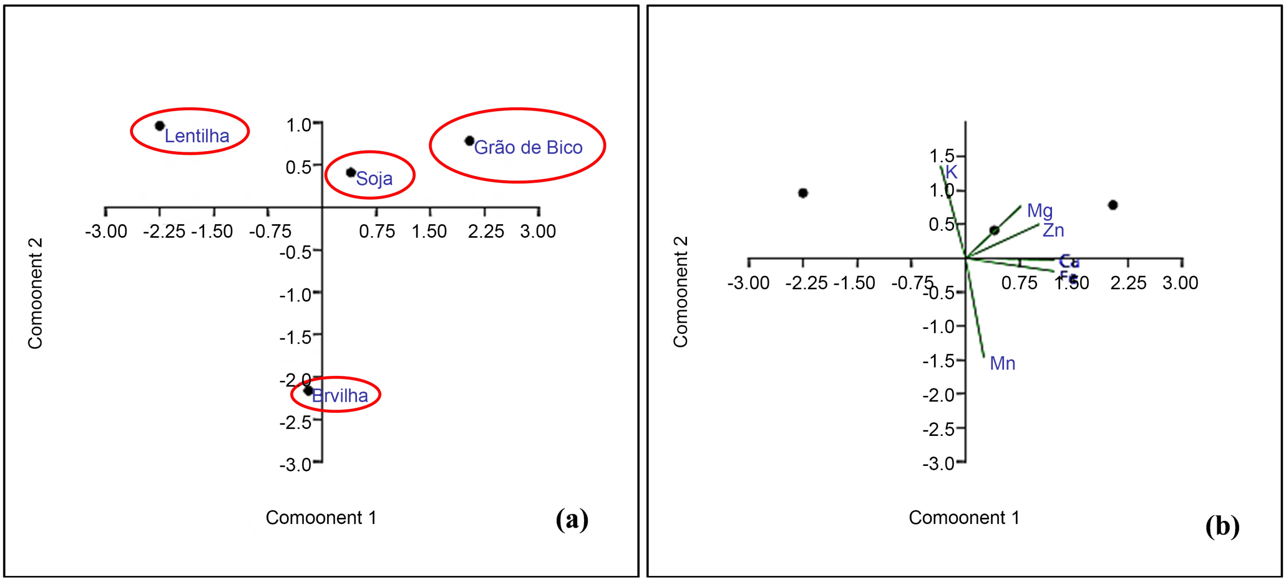

Figure 1. Graph scores (a) and loadings (b) in the analysis of principal components for mineral evaluation in legumes soybean, lentil, chickpeas and peas. Source: authors.

iron in soybean and chickpea samples are higher than in lentil and peas samples. These minerals play an important role in human metabolism, and interest in these elements is increasing.

As pinheiro *et al.* (2005) [18] identifies, magnesium is an essential nutrient for muscle, nerve activity and for many metabolic processes, and is also important in the formation of bones, teeth and proteins. The authors also state that calcium is responsible for the formation of bones, teeth and blood coagulation, while iron is an essential mineral for the formation and transport of hemoglobin, besides playing an important role in the transport of oxygen and carbon dioxide. According to Shils *et al.* (1994) [19], zinc participates in a variety of metabolic processes, including the synthesis or degradation of carbohydrates, lipids and proteins, and is necessary for the synthesis of deoxyribonucleic and ribonucleic acid.

In the first principal component (PC1), lentil samples have higher potassium content and pea samples have higher manganese content. Potassium is a nutrient needed to maintain osmotic pressure in interstitial fluids, facilitating water transport in tissues, while manganese acts as a constituent of enzymatic systems, whose concentration range varied from 2.32 - 3.18 g/100g of the sample in peas. It is important to note that in normal adults, its oral absorption is only about 3% of the dose ingested and remains constant, even when this intake is increased (Pinheiro *et al.*, 2005) [18].

The results obtained also allowed the determination of the percentage contributions of each of the legume samples analyzed in relation to the Dietary Reference Intakes (DRI) for each mineral (Brasil, 1998) [7]. These data, considering the nutritional requirements of an adult, are shown in **Table 4**.

According to the Ordinance No. 27 of January 13, 1998 of the Ministry of

Table 4. Percentage of dietary reference intakes (DRI) for an adult.

Parameter	% DRI compared to 100 g of the sample			
	Lentil	Pea	Chickpeas	Soy
Calcium	6.66	15.82	25.81	16.78
Magnesium	1.51	1.49	1.65	1.73
Potassium*	28.26	23.27	26.84	25.27
Iron	12.00	21.00	27.00	22.21
Manganese	39.40	57.00	44.60	42.20
Zinc	22.87	24.53	48.93	25.60

*Values related to AI (Adequate intake) due to the lack of RDA values. Source: authors.

Health (Brazil), for a food to be pointed out as a source of a specific mineral, it must provide at least 15% of the amount of the Dietary Reference Intakes (DRI) of this mineral, while to be considered high in content, this percentage should be at least 30% (Brasil, 1998) [7].

The results obtained showed that all the legumes evaluated provide the minimum content of potassium, manganese and zinc necessary to reach the Dietary Reference Intakes (DRI) of these minerals.

The acquired data also showed that the lentil, pea, chickpeas and soybean samples can be considered sources with high manganese sources, because these samples contributed with values between 39.40% and 57.00% in relation to the DRI for this nutrient. However, these same legumes cannot be considered sources of magnesium, since the samples provided a percentage of DRI in relation to 100 g of the sample lower than 2%.

Lentil samples have also demonstrated that they do not have the minimum levels indicated by the legislation to be considered sources of calcium and iron. In addition, the results showed that chickpea samples can be considered a food with high zinc content, because it provides a quantity greater than 30% of the Dietary Reference Intakes (DRI).

4. Conclusions

The information obtained through this study made it possible to obtain preliminary data on the content of macro and micro minerals in legumes consumed by the population of Vitória da Conquista-BA.

The results, when compared with the DRI, showed that the amount of minerals, potassium, iron, manganese and zinc present in legumes ensure the recommended daily needs, and can be used in the development of diet programs in different areas of knowledge. However, the same cannot be said about calcium and magnesium for some of the samples analyzed.

The principal component analysis provided a multivariate interpretation of the results, showing that legume samples are grouped according to differences in mineral contents.

In view of the study conducted and increasing consumption of legumes, as a result of its nutritional properties and beneficial effects, it is intended in later studies to analyze samples from other localities and different species of legumes, since the chemical composition of these vegetables may vary and present differences due to factors associated with cultivation and the environment.

Conflicts of Interest

The authors declare no conflicts of interest.

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