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Determination of mineral profiles in germinated legumes cowpea (*Vigna unguiculata*) and broad bean (*Vicia faba*)

Determinação do perfil dos minerais das leguminosas feijão de corda (*Vigna unguiculata*) e feijão fava (*Vicia faba*) germinadas

Determinación del perfil mineral de las legumbres frigol caupí (*Vigna unguiculata*) y frijol haba (*Vicia faba*) germinadas

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Abstract

The goal of this study was to assess the mineral profiles of cowpea (*Vigna unguiculata*) and broad bean (*Vicia faba*) during mature green (*in natura*), seed, and germination stages. Green beans and seeds were purchased, the later being germinated and immediately afterwards lyophilized and packaged. Analytes were determined using inductively coupled plasma optical emission spectroscopy (ICP-OES). Macro minerals K, P, and Mg exhibited the highest levels in legumes cowpea and broad bean. Among the micro minerals, Fe exhibited the highest amount in pigeon pea and lablab bean. There was a variation in mineral levels between the different stages of the beans, with a tendency to increase their concentrations after germination. No heavy metals were detected, with the exception of barium and strontium. The results indicated that the flours of cowpeas and broad beans, in general, met the National Health Surveillance Agency (ANVISA) recommendations for daily intake of macro and micro minerals. It is concluded that the flours of legumes in different stages can contribute as good sources of minerals to be included in individuals diets.

Keywords: Minerals; Legumes; Germination; *Vigna unguiculata; Vicia faba.*

Resumo

Este trabalho objetivou analisar o perfil de minerais dos feijões de corda (*Vigna unguiculata*) e fava (*Vicia faba*) nos estágios de maturação verde (*in natura*), semente e germinado. Para tanto, foram adquiridos os feijões verde e semente, sendo que estas foram germinadas e logo a seguir liofilizadas e envasadas. A determinação dos analitos foi realizada utilizando o ICP OES. Os macrominerais K, P e Mg apresentaram os maiores teores no feijão de corda e no feijão fava. Entre os microminerais, o Fe demonstrou o maior quantitativo nas duas variedades de feijões estudadas. Foi observada uma variação nos teores dos minerais entre os diferentes estágios dos feijões, com uma tendência de elevação da concentração após a germinação. Não foram detectados metais pesados, com exceção do Bário e Estrôncio. Os resultados mostraram que as farinhas dos feijões de corda e fava, de modo geral, atenderam as recomendações de ingestão diária, segundo a ANVISA, para os macrominerais e

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microminerais. Conclui-se que as farinhas das leguminosas nos diferentes estágios podem contribuir como boa fonte de minerais na dieta dos indivíduos.
Palavras-chave: Minerais; Leguminosas; Germinação; *Vigna unguiculata*; *Vicia faba.*

Resumen

Este trabajo tuvo como objetivo analizar el perfil mineral de las legumbres frigol caupí (*Vigna unguiculata*) y frijol haba (*Vicia faba*) en las etapas de maduración verde (*in natura*), semilla y germinadas. Para ello se adquirió frijol verde y semilla, que se germinó y luego se liofilizó y empacó. La determinación de los analitos se realizó mediante el ICP OES. Los macrominerales K, P y Mg mostraron los niveles más altos en frijoles caupí y frijoles haba. Entre los microminerales, el Fe mostró la mayor cantidad en las dos variedades de frijol estudiadas. Hubo variación en los niveles de minerales entre las diferentes etapas del frijol, con tendencia a incrementar la concentración luego de la germinación. No se detectaron metales pesados, a excepción del bario y el estroncio. Los resultados mostraron que las harinas de judías verdes y habas, en general, cumplieron con las recomendaciones de ingesta diaria, según ANVISA, para macrominerales y microminerales. Se concluye que las harinas de legumbres en diferentes etapas pueden aportar como buena fuente de minerales en la dieta de los individuos.
Palabras clave: Minerales; Legumbres; Germinación; *Vigna unguiculata*; *Vicia faba.*

1. Introduction

Legumes are plants whose grains are contained in pods, the best known of which are beans, lentils, peas, beans, chickpeas, and soybeans. They are divided into two groups: (a) dried, which includes beans, chickpeas, soybeans, and lentils; and fresh, including peas and broad beans. Legumes have high protein content. They are sources of food energy, and represent an important component of the human diet in different regions of the world. In some countries, especially developing ones, they are the only protein source in the diets. In Brazil, the most consumed legume is common bean (*Phaseolus vulgaris* L.). The northeast region is currently the largest consumer of common bean in Brazil considering all species of cultivated legumes followed by peas (*Pisum sativum* L.) and lentils (*Lens culinaris*) (Correa, 2016; Motta *et al*., 2016; Sei, 2014).

In addition to being one of the main sources of iron, beans are also considered to have significant nutritional value. As this food is easy to access and prepare, Brazil has become one of the largest consumers and producers of common beans (*P. vulgaris* L.). Broad bean (*Vicia faba*), popularly known as fava bean, wild bean, or even Italian broad bean, belongs to the family Fabaceae. It is an important source of protein for humans in various parts of the world due to its nutritional value (Wang *et al.*, 2011). In Chile, this legume is grown for human consumption as a fresh and frozen vegetable (ODEPA, 2012). It is little cultivated in Brazil, but of great importance in Europe, particularly in Italy. Broad beans (*Vicia faba*) are a potential source of protein, dried seeds of bean contain 20 – 28% crude protein and the amino acids are moderately well balanced with especially high lysine content (Saini *et al*., 2001).

According to Baginsky *et al*. (2013), due to its chemical composition, broad bean assists in the prevention of heart diseases and reduction of blood glucose levels. The results obtained by these authors indicated differences in phenolic compounds between different varieties of immature *Vicia faba* L. seeds.

Cowpea (*Vigna unguiculata* L. Walp.) is another legume highly valued in the diet of populations living in the north and northeast regions of Brazil, and has a considerable protein value. It was introduced in Brazil in the second half of the 16th century by Portuguese colonists through the State of Bahia, being botanically classified as belonging to the class of Dicotyledonea, family Fabaceae, subfamily Faboideae and genus *Vigna* (Lovato *et al.*, 2018). According to Freire Filho *et al*. (2011) considering the national average of the period from 2005 to 2009, cowpea contributed with 37,53% of the harvested area, 15,48% of the production and had a productivity that corresponded to 42,20% of the national one.

In addition to proteins, minerals are also found in legumes in significant concentrations. These nutrients are important inorganic elements for many functions in the human body, and the concentrations of these elements in beans can vary according to the species. They are classified into macro minerals, which are required in greater quantities by the body, such as sodium, potassium, calcium, magnesium and phosphorus, and micro minerals, such as cobalt, copper, iodine, fluorine, molybdenum, selenium, chromium, iron, and zinc, which are essential for balanced human nutrition, and required in small amounts by the human body (Silva, Martins & Borges, 2017).

Legumes, in addition to being consumed in the ‘green’ stage and dry, can also be consumed after germination. In this process, endogenous reactions can favor the nutritional value of the grains, including mineral concentrations. Germination occurs after physiological maturation, in which the seeds have to recover physically quickly from drying, during the hydration stage, intensively resuming their metabolism, completing essential cell events to allow the development of the embryo, and prepare for subsequent seedling growth (Benevides *et al*., 2013; Nonogaki, 2014).

Thus, the goal of the present study was to assess the profile of minerals, and the concentrations of oxalates and tannins in legumes *Vigna unguiculata* and *Vicia faba*, during three stages, namely *in natura*, seed, and after germination.

2. Methodology

This is an explanatory experimental study, carried out in the UNEB bromatology laboratory. The approach is qualitative-quantitative, whose method of procedure is experimental (Pereira et al., 2018).

Samples of cowpeas (*Vigna unguiculata*) and broad beans (*Vicia faba*) in the green and seed stages were acquired at a family farming site, in the Municipality of Sapeaçú, State of Bahia, Brazil. The seeds were sent to the Food Technology Laboratory and the Bromatology Department of the Life Sciences Department, State University of Bahia, Salvador, State of Bahia, Brazil, where they were cleaned, germinated, and lyophilized.

The germination of the legume seeds was carried out under controlled conditions at the laboratory of the State University of Bahia, according to the method proposed by Berni & Canniatti-Brazaca (2011), with adaptations. Initially, 2 kg of seeds from each legume were selected, washed, and sanitized using sodium hypochlorite solution (1% active chlorine) for fifteen minutes. Subsequently, they were washed with excess water to remove sodium hypochlorite residue, and left immersed in deionized water for eight hours (hydration phase).

Germination took place in glass flasks with a proportion of 1/3 of grains with respect to the volume of the flasks, at room temperature and ambient light. Every eight hours, for three days, 400 ml of deionized water was added twice, with gentle agitation for washing and hydrating the grains. After three-day germination, the germinated seeds were washed, and the excess water was removed. The legume samples *in natura* (green stage) and germinated were previously frozen in an ultra-freezer, at - 40°C, and then subjected to lyophilization in a freeze dryer (Mod LIOTOP 101), under pressure of 150 μm Hg/-50°C, according to the manufacturer's guidelines. The lyophilized samples, as well as the dried seeds, were crushed using a hammer mill (Grindomix-GM200) and packed in airtight glass jars.

Mineral determination was carried out in partnership with the Chemistry Department of the Federal Institute of Bahia, Salvador, State of Bahia, Brazil. The lyophilized and crushed samples were initially packed in glass jars and covered with plastic film (PVC). All pots were

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previously decontaminated (5% soap bath/8 hours and 20% HNO_3 bath (v/v/24 h)) and kept in a desiccator until obtaining microwave-assisted acid digestion. To that end, we used 1,0 mL of nitric acid, 1,0 mL of hydrochloric acid, 3,0 mL of hydrogen peroxide, 5,0 mL of water, and 500 mg of the sample. The heating program chosen consisted of four steps, namely: 90°C/6 min; 90°C/4 min; 190°C/18 min and 190°C/7 min. The power (1000 W) and pressure (45 bars) were the same throughout the process. The volume of the digested mixture was adjusted to 15,0 mL using ultrapure water, and the solutions were stored in previously decontaminated Falcon tubes (50 mL).

For the determination of the analytes using inductively coupled plasma optical emission spectroscopy (ICP-OES), we prepared a multi-element solution of 40,00 $mg.L^{-1}$ with the elements As, Ba, Cd, Cr, Co, Cu, Fe, Mn, Mo, Ni, Pb, Se and Zn. The analytical curve was prepared in 2,0 mol L^{-1} HNO_3. The concentrations ($mg.L^{-1}$) of the analytes for the curve were As, Ba, Cd, Cr, Co, Cu, Fe, Mn, Mo, Ni, Pb, Se and Zn (0,05; 0,10; 0,30; 0,50; 0,70; 1,00; 1,50; 2,00; 2,50; 3,00 and 4,00, respectively). However, the concentrations of the other elements, i.e., Mg, Na, Ca, and P ($mg.L^{-1}$) for the curve were: 1,00; 5,00; 10,0; 15,0; 20,0; 30,0; 40,0; 60,0; 80,0; 100,0 and 120,0, respectively.

The operating conditions of ICP-OES were: power = 1300 W; signal integration time = 1 s; plasma gas flow = 5 $mL.min^{-1}$; auxiliary gas flow = 1,5 $mL.min^{-1}$; nebulization gas flow = 0,70 $mL.min^{-1}$; sample pump flow = 0,70 mL min^{-1}. The sample was placed in a cyclonic chamber and Gern Cone TM nebulizer - Low Flow. The selected nuclear (I) and ionic (II) lines were: I 188,979; Ba II 233,527; Ca II 317,933; Cd I 228,802; Cu I 324,752; Cr II 267,716; Fe II 238,204 (259,939); Pb II 220,353; P I 213,517; Mo II 202,031; Mn II 257,610; Mg II 279,077; Na I 589,592; Ni II 231,604; Se I 196,026; Zn II 213,857; K 766,490; Sr 421,552.

3. Results and Discussion

Table 1 illustrates the data obtained assessing the mineral profile of cowpea and broad bean samples during the green (*in natura*), seed and germinated stages.

Table 1. Mineral profile of cowpea (*Vigna unguiculata*) and broad bean (*Vicia faba*).

Minerals	COW NAT (mg/Kg)	COW SEE (mg/Kg)	COW GER (mg/Kg)	BRO NAT (mg/Kg)	BRO SEE (mg/Kg)	BRO GER (mg/Kg)
Cu	3.40±1.02	2.66±0.62	4.05±0.50	3.42±1.02	2.79±0.04	2.72±0.13
Ni	2.79±1.00	1.05±0.26	3.44±0.40	1.50±0.40	0.69±0.10	0.63±0.28
Zn	44.11±4.22	42.91±7.12	47.82±4.96	27.71±7.42	23.54±1.32	24.79±0.94
Ba	-	-	-	2.29±1.71	2.70±0.41	4.33±0.56
Sr	2.11±0.49	0.89±0.30	3.09±0.06	1.99±0.95	0.94±0.15	3.20±0.29
K	13016.5±0.80	15575.9±1.89	14232.1±1.11	10548.5±1.74	14041.5±0.18	13464.1±0.32
Na	35.21±10.16	25.98±12.18	39.99±7.54	25.41±5.19	14.74±1.32	28.58±3.41
Fe	85.05±19.04	69.178±7.81	95.88±13.08	85.05±0.14	67.32± 0.14	68.90± 0.14
Mg	6736.52±2057.67	5827.13±655.93	8730.40±114.36	3611.32±715.35	3818.00±56.89	3945.89±92.18
Ca	78.00±11.29	55.24±6.79	61.90±2.21	58.77±14.58	41.11±2.70	70.05±4.26
Mn	20.80±6.58	15.78±1.88	16.61±1.53	15.95±3.26	15.50±0.082	-
P	7215.44±998.46	8849.38±479.39	5489.81±532.77	3954.77±622.35	3891.56±255.48	5491.27±586.81

Note: COW NAT = green cowpeas; COW SEE = cowpea seeds; COW GER = germinated cowpeas; BRO NAT = green broad beans; BRO SEE = broad bean seeds; BRO GER = germinated broad beans.
Source: Authors (2020).

Table 1 indicates that the concentrations of micro minerals iron (Fe), manganese (Mn), copper (Cu), zinc (Zn) and nickel (Ni) varied according to the different stages. Fe was the mineral that stood out the most, followed by Zn and Mn.

With respect to the different stages of the assessed grains, in general terms, there was an increase in the levels of micro minerals after germination. Fe, Zn, Cu and Ni exhibited a reduction in the seeds, and an increase after germination. However, Mn content decreased during the seed stage and remained practically constant after germination. In the broad beans, the levels of Fe, Zn, Cu, and Ni exhibited similar behavior, whereas Mn did not vary in the three stages of this bean. Benevides *et al*. (2017) affirmed that this process is characterized by different changes in the distribution of secondary metabolites, the mobilization of reserve proteins stored in cotyledons, and changes in the composition of soluble amino acids.

Germination conditions, such as light and temperature, are determining factors in the development of aroma, flavor, and humidity in the germinated seeds. In turn, these factors determine physical and chemical changes, such as the composition of soluble carbohydrates, contents of phytate and minerals, and vitamin C levels, changing the nutritional value and the functional food character of legumes (Nonogaki, 2014).

The data obtained in the germinated cowpeas are in line with those of the study conducted by Francisqueti & Souza (2014), who stated that the germination process possibly enhanced nutrient content in foods-including minerals and thus improving their nutritional quality, since this process induces the dephosphorylation of the antinutrient phytic acid, making minerals more bioavailable. However, regarding broad beans, the results were discrepant, which may have been influenced by species and cultivation conditions, among other factors. It is important to highlight that the nutritional composition of the germinated grains still requires further clarification, considering that this proximate composition of the food may vary after this process according to the grains and the germination conditions.

Table 1 illustrates that, in general, in the seed stage, i.e., at its maximum physiological maturation, the concentrations of minerals were reduced. According to Pedroso *et al*. (2008), there is a tendency of reduced seed quality after physiological maturity, which may have influenced the reduction of the micro minerals concentrations in the seeds assessed in the present study.

Carvalho & Nakagawa (2000) reported that seeds that are not yet mature do not result in vigorous seedlings, such as those that would be obtained from seeds harvested at the physiological maturity stage. The development and maturation process of seeds starts right after fertilization, and involves a series of physical, physiological, biochemical, and molecular changes. This process is characterized by reduction in the moisture content of the seeds (drying), increase in the size of seeds during development, and increase in dry mass content, represented by the accumulated reserves in the form of different compounds such as, carbohydrates, proteins, and lipids. However, since physiological maturity, there is a tendency of reduced seed quality, whose deterioration speed is influenced by environmental factors, especially those predominant in the final stage of maturation (Pedroso *et al*., 2008).

Santos (2016) assessed the concentrations (mg/kg) of Cu, Fe and Zn in five samples of broad beans (*in natura*) and found a variation in levels for different minerals, namely: Cu (2.50 ± 0.17 to 4.30 ± 0.34 mg/kg); Fe (31.61 ± 2.06 to 47.03 ± 1.57 mg/kg); and Zn (17.60 ± 0.70 to 29.30 ± 0.16 mg/kg). These Cu and Zn values are similar to the concentrations found for broad beans (*in natura*) in the present study. Only the concentrations of Fe reported by the author were lower than the concentrations found in our research.

With respect to macro minerals, the contents of phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg) also exhibited very different results (Table 1). K had the highest concentration, followed by P and Mg; whereas Ca and Na exhibited much lower values in the two legumes. The high concentration of K, P and Mg found in legumes was possibly due to soil fertilization. The comparison between cowpeas and the broad beans indicated that the former had a higher content of P, K and Mg during the three stages.

Pereira *et al*. (2015) stated that most soils in Brazil had insufficient nutrient reserves to supply the amount required by crops, thus making fertilization an indispensable practice, associated with favorable environmental conditions and adequate soil and crop management, at all production stages to maintain bean productivity. Thus, a way to perform this fertilization effectively, without compromising the development of the plants and the environment, is using organic fertilization. To that end, organo mineral fertilizers such as NPK fertilizers, also called macro elements and are used, because they are composed of Nitrogen (N), Phosphorus (P) and Potassium (K), being absorbed in large quantities by plants (Cruz; Pereira & Figueiredo, 2017; Rabelo, 2015).

The variation in the concentration of macro minerals in the three stages for each bean variety indicated that K exhibited an increase in the seed stage, followed by a decline in the green (*in natura*) stage. Ca exhibited a slight decline in the seed stage, with subsequent increase after germination in cowpeas. In broad beans, Ca, P and Na had a decline in the seed stage, with subsequent increase after germination. Still, in the broad beans, K content increased in the seed stage and remained constant after germination, whereas Mg increased in the seed stage and after germination.

Cowpeas also exhibited higher nutritional value concerning macro minerals in comparison to broad beans that are essential for body structure, maintenance of body acid-base and water balance, transmembrane potential for cellular functions, nerve conduction, and muscle contraction (Cozzolino, 1997).

Frota *et al*. (2010) used cowpea flour (*Vigna unguiculata*) for preparing bakery products and found the following mineral concentrations: P - 4,370 mg/kg; Fe – 45,02 mg/kg; Mg - 472 mg/kg and Zn – 37,04 mg/kg. The total contents of Fe, Mg and Zn reported by these authors for cowpeas were lower than those found in the present study, with the exception of P. Frota *et al*. (2010) reported that, in the process of preparing food products, the contents of P, Fe, K, Mg and Zn increased significantly with the addition of cowpea flour, indicating that it can contribute to the enrichment of minerals in various food products.

Among the legumes studied by Iqbal *et al*. (2006), cowpea had the following concentrations: Na - 1,020 mg/kg; P - 3,030 mg/kg; Ca - 1,760 mg/kg; Fe - 26 mg/kg; Cu - 97 mg/kg; Mg - 48 mg/kg; Zn - 51 mg/kg; Mn - 17 mg/kg; K - 12,800 mg/kg. Na, Ca and Cu values reported by the authors showed higher concentrations. The values of P, Fe, Mg were lower. The concentrations found by Iqbal et al. for Zn, Mn and K were similar to those obtained in the present study.

Frota, Soares, & Areas (2008) studied the mineral composition of *Vigna unguiculata* and found Na contents of 2,040 mg/kg. According to the authors, Na concentrations were not significant in cowpeas. P content was 5,100 mg/kg; Fe - 68 mg/kg; Mn - 15 mg/kg; Ca - 1,400 mg/kg; Zn - 41 mg/kg and K - 14,300 mg/kg. Na and Ca values reported by these authors were also higher and the value of Mg was lower than the value observed in the present study. The concentrations found for Fe, Zn, Mn, K and P by the authors were similar to those obtained in our study.

The National Health Surveillance Agency (ANVISA) RDC Resolution nº. 269 of September 22nd 2005 (Brasil, 2005), considering the need to update the values of recommended daily intakes (RDI) of proteins, vitamins and minerals, approved the "Technical Regulation on Recommended Daily Intakes (RDI) of Proteins, Vitamins and Minerals". This resolution establishes that the daily requirement of Fe is 9 mg for children and 14 mg for adults. Therefore, if Fe content of cowpea seeds is around 70 mg/kg, which is equivalent to 7 mg/100 g, children and adults would be ingesting 100 g of this flour per day, thus supplying their bodies with 77,8 or 50% of their Fe needs, respectively.

It is important to highlight that iron deficiency anemia is characterized by a decrease in the concentration of Fe and consequently of the hemoglobin, is one of the main nutritional deficiencies, especially in developing countries. It affects mainly children, older adults, and women during pregnancy and postpartum, which, depending on the severity, can have a deleterious effect on the mother and the fetus. This way, its intake, as recommended, is of great relevance, considering that this is one of the most abundant minerals in the body, participating in the synthesis of hemoglobin and myoglobin, in addition to being a cofactor in a series of enzymatic reactions (Azaredo *et al*., 2013; Brandão *et al*., 2011).

The need for Zn is 7 mg in adults and 5,6 mg in children (ANVISA, 2005). Considering the consumption of 100 g of germinated cowpea flour, this amount will supply 68,5% of the RDI in adults and 85,5% in children. It should be noted that zinc deficiency has been associated with impaired growth and reproduction, immune disorders, and a variety of other symptoms (Adeyeye; Oyarekua & Adesina, 2014). Cruz & Soares (2011) stated that, in some stages of life, the needs for this mineral are increased, as in pregnancy, childhood, puberty, and senility.

After iron, zinc represents the most abundant micro mineral distributed in the human body, found in large quantities in all tissues. This mineral is an enzymatic cofactor that plays a catalytic, structural, and regulatory role for metalloenzymes, and is also involved in the physiology of insulin. However, even though the insulin-zinc complex is not entirely necessary for hormonal action, the removal of Zn from such a complex reduces insulin activity due to changes that occur in the structure of this hormone. Thus, zinc supplementation not only accelerates and increases the magnitude of hormone binding to the receptor, but also inhibits the degradation of insulin by the liver, either *in vivo* or *in vitro* (Mattoso, 2013; Mezzomo & Nadal, 2016; Pedroza & Queiroz, 2011).

Regarding potassium, ANVISA does not mention RDI; however, the World Health Organization (WHO) recommends a potassium intake equal to or greater than 3,500 mg/day for adults and children. In this case, cowpea seeds supply 44,3% in 100 g of flour/day; whereas this percentage is 40% in broad bean seeds. Potassium is responsible for the reduction of intracellular sodium through the sodium/potassium pump, and induces a decrease in blood pressure by increasing natriuresis, decreasing renin and norepinephrine, and increasing prostaglandin secretion. Its deficiency (hypokalemia) is characterized as a serious health problem, which can promote the mortality of patients who have kidney complications (Vavruk *et al*., 2012).

For copper, the recommendation of food consumption for adults and children, according to the RDI by ANVISA (2005), is 0,9 and 0,44 mg/day, respectively. Thus, germinated cowpeas provide a more satisfactory percentage in comparison to broad beam seeds, with percentages of 44,4 and 28,8% of daily intake, respectively. Deficiency of this mineral in the body can cause several problems, such as complications in the nervous system. There is evidence that, due to the reduction in serum copper levels, there is a possible depletion of antioxidant activity in the human body and susceptibility to infections (Akinyele & Shokumbi, 2015; Gobato, 2012; Macêdo *et al*. 2010).

The need for Mn is 2,3 mg in adults and 1,5 mg in children (ANVISA, 2005). The consumption of 100 g of germinated broad bean flour is able to supply 73,9% of the RDI in adults and 113% in children. This micro mineral has some functions in the body, such as, for example, activation of enzymes for the metabolism of carbohydrates and cholesterol, and participation in the regulation of glucose tolerance. Its deficiency in the body can interfere with bone formation and, thus, compromise growth, in addition to causing lower glucose tolerance and alteration in the metabolism of carbohydrates and fats (Nascimento & Gonzalez, 2018; Silva, Martins & Borges 2017).

The RDI of these minerals in the legumes under study suggests that, in addition to being considered an important source of proteins, fibers, and carbohydrates, they should also be observed as a source of some inorganic micronutrients, with emphasis on daily consumption.

Among the minerals considered to be contaminants in food, aluminum (Al), argon (Ar), barium (Ba), beryllium (Be), cadmium (Cd), lead (Pb), molybdenum (Mo) and nickel (Ni) are considered heavy metals involved in food poisoning, which can cause neurological damage, cell oxidative stress, DNA damage, changes in glucose or calcium metabolism, and can also interfere with some essential elements. In the present study, only Ba was detected in broad beans, with reduced concentrations in the seed stage and after germination. Strontium (Sr) was detected in the two beans assessed, increasing its concentrations in the seed stage and after germination. The other contaminating minerals (Al, Cd, Pb, Mo and As (arsenic) did not reach the detection limit of ICP-OES (<0,01 mg/kg) and, therefore, were not detected. Possibly, the contaminating minerals detected in these legumes came from agricultural practices, such as the use of contaminated irrigation water, addition of metal-based fertilizers and pesticides, industrial emissions, transportation, harvesting processes, and storage, among others. This way, variations of these elements between the legume species may have been influenced by the aforementioned agricultural practices (Adeyeye *et al*., 2014).

Leite & Zampieron (2012) analyzed the sensitivity of common bean (*Phaseolus vulgaris*) in soils contaminated with heavy metals of industrial and domestic origin. The analysis performed by these authors, via scanning electron microscopy (SEM), indicated that there had been no changes. The analysis using energy-dispersive X-ray spectrometry (EDS) indicated that the beans did not absorb heavy metals, being selective regarding the absorption of nutrients in any of their parts. Therefore, it is suggested that the general population should be aware of the origin of the food consumed, in order to avoid possible ingestion of contaminants, such as heavy minerals of anthropogenic origin.

4. Conclusions

It is concluded that the mineral profiles of cowpeas and broad beans varied according to the green (*in natura*), seed and after germination stages, and that these legumes had satisfactory mineral concentrations (macro and micro minerals), during the different stages, generally meeting the RDI provided by ANVISA. No heavy metals were detected in the legumes assessed in the present study, with the exception of Barium and Strontium. It is suggested that the flours produced with these legumes in their different stages can contribute as good sources of minerals in the diet of individuals. They can be considered as another alternative to be used in food formulations, thus contributing to the reduction of mineral deficiencies in individuals.

With this study, it is expected to increase the incentive for more research and experiments that propose the technical, practical and scientific visualization of nutritious beans capable of improving human food.

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