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Determination of heavy metals in the roasted and ground coffee beans and brew

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Some compounds present in coffee beans can affect consumer health. The present study determines the content of heavy metal in coffee cultivated in the Cerrado Mineiro region (Alto Paranaíba – MG, Brazil), to compare the values found with the legal standards and check how these metals are extracted from the respective infusions. Fifty samples of coffee beans were analyzed, taken from the Alto Paranaíba region, MG, Brazil. Determination and quantification were done by recording the values from the atomic absorption spectrophotometer for the metals mentioned: cadmium (Cd), chromium (Cr), copper (Cu), manganese (Mn), nickel (Ni), lead (Pb), and zinc (Zn). The Cr concentrations presented earlier the limit allowed by law in 66% of the coffee samples. And 74% of the samples contained Pb in higher than permissible concentrations. For all the infusions, the metals evaluated were found in lower concentrations and were less significant with respect to the maximum permissible daily intake, except for Pb were quantified very high levels. Only seven of the 50 coffee samples revealed results with levels that were quantified to be within the legally stipulated standards. The Pb and Cr metals were found to have the highest percentage of leaching in the coffee infusions.

Key words: Coffee powder, chemical contaminants, law, drink, leaching.

INTRODUCTION

Coffee culture greatly influences world trade. In 2015, the total coffee production was about 143 million bags (International Coffee Organization, 2016), whereas the world consumption in 2014 was 149 million bags, implying an enormous demand for coffee (International Coffee Organization, 2015). Coffee is consumed mostly for its sensory characteristics, besides various other social and economic factors (Carvalho et al., 2016).

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At present, Brazil ranks first in the world as a coffee producer and exporter and is the second largest consumer, after the United States (International Coffee Organization, 2015, 2016). The Brazilian output in 2015 reached 43 million bags (of 60 kg each) of processed coffee, nearly 31% of the global production (International Coffee Organization, 2016). It therefore becomes crucial to assess the quality of the bean and infusion Brazilian coffee.

Heavy metals are the most evaluated elements in food or any other product due to their ability to accumulate in the food chain (Silva et al., 2007). The maximum levels to which they are present therefore becomes the standard of quality across the world (Malik et al., 2008). As these elements are stable, they remain in the environment, accumulating in the soil (Hseu et al., 2010) due to the weathering process of rocks and soil formation, environmental conditions, technological practices and/or chemical usage (Ashu and Chandravanshi, 2011; Selinus, 2006).

Some metals are biologically crucial in low concentrations for living organisms, including copper (Cu), chromium (Cr), cobalt (Co), manganese (Mn), nickel (Ni), zinc (Zn); however, because elements such as arsenic (As), cadmium (Cd), lead (Pb), mercury (Hg), titanium (Ti) and uranium (U) are not essential and exert harmful effects on different parts of the biosphere, they are termed toxic metals (Schmidt et al., 2009).

The coffee plants can absorb these metals and store them in the roots or transport them into the shoots and grains (Silva et al., 2007). The heavy metals vary in concentration in the different plant tissues, and normally, the grains contain lesser concentrations than the vegetative plant parts (Bettiol and Camargo, 2006). On reaching the coffee beans, these metals form the vehicles of contamination for humans inducing adverse health effects like severely decreased neurological and hepatic functions, as well as mutagenesis and carcinogenesis (Matés et al., 2010).

The leaching of each element present in the roasted and ground coffee samples and their infusions can differ (Stelmach et al., 2013), which makes it crucial to also assess the values of these elements in the beverage. Therefore, it is important to assess the dietary exposure for risk evaluation (Noël et al., 2012).

The present study provides a more detailed determination of the contents of cadmium, chromium, copper, manganese, nickel, lead and zinc in coffees cultivated in the Cerrado Mineiro region (Alto Paranaíba – Minas Gerais, Brazil), to compare the values found with the legal standards and check how these metals are extracted from the respective infusions.

MATERIALS AND METHODS

A total of 50 coffee Arabica (*Coffea arabica* L.) samples were collected from the farms and in the coffee marketing centers of the municipalities of Alto Paranaíba region, Minas Gerais, Brazil (Figure 1), including Carmo do Paranaíba (n = 21), Rio Paranaíba (n = 13), Serra do Salitre (n = 11) and Tiros (n = 5).

In each property, 10 samples from the same lot were collected with a coffee sampler. Then the material was homogenized and a 500 g portion was sent for heavy metal analysis. Analyses were performed in two replicate.

The coffee beans were put through a medium roasting process (120 to 150°C/7 to 8 min) utilizing a gas roaster (ROD-bel brand, TP2-L model, São Paulo, SP, Brazil). The samples were later crushed to 3.5 meshin the electric grinder (Probat Leogap brand, model M-50, Curitiba, PR, Brazil).

The coffee infusion was prepared as a beverage using roasted and ground coffee in boiling hot water (95 to 100°C) and filtering, in the ratio of 12 g of powder to 100 ml of water (Teixeira et al., 2016). Subsequently, 25 ml of the beverage prepared by volume was concentrated in a greenhouse with good circulation and air exchange (Tecnal brand, TE-394/2 model, Piracicaba, SP, Brazil) at 60°C, to make approximately 2.5 ml of the final volume.

The roasted and ground coffee samples and their infusions were mineralized by wetting, using a mixture of nitric and perchloric acids in a 3: 1 ratio. Then, the elements cadmium (Cd), chromium (Cr), copper (Cu), manganese (Mn), nickel (Ni), lead (Pb) and zinc (Zn) were analyzed in the samples (Gomes and Oliveira, 2011).

Readings were recorded from the fast sequential atomic absorption using the spectrophotometer (Varian brand, AA240FS model, Mulgrave, Vic, Australia) with atomization in flame air/acetylene flow at 13.3 L min^{-1}/2.9 L min^{-1} for Cr and 13.5 L min^{-1}/2.0 L min^{-1} for the other elements. A hollow cathode mono elementar lamp (HCL) was used as the radiation source. The electrical current intensities used were of the order of 7 mA (Cr), 5 mA (Mn, Pb and Zn), and 4 mA (Cd, Cu and Ni). Measurements were taken for the following wavelengths (nm): 228.8 Cd, 357.9 Cr, 324.7 Cu, 279.8 Mn, 232.0 Ni, 217.0 Pb, and 213.9 Zn (Onianwa et al., 1999).

The percentage of extraction of the method varies from 92 to 97%. The metal content found was compared to the standards established by Brazilian legislation in force (Brazil, 2013, 1965).

Statistical analysis

Standard curves of each of the white samples analyzed were drawn to determine the various concentrations. The elements of the reagents and samples were also analyzed the patterns of using the elements. Descriptive statistics were used to analyze the data.

Correlation analysis (Pearson) between cadmium, chromium, copper, manganese, nickel, lead and zinc concentrations in roasted and ground coffee samples and in the infusion prepared from these samples was performed.

RESULTS AND DISCUSSION

Manganese, copper and zinc are the heavy metals found in high concentrations in all the roasted and ground coffee samples (Table 1), concurring with the results of Santos and Oliveira (2001), Grembecka et al. (2007) and Ashu and Chandravanshi (2011).

The Southern Common Market Group (Mercosul) (Brazil, 2013) and European Commission (European Commission Regulation, 2008) have established regulations although not limited to these three elements in coffee. The maximum permissible amounts of 50 mg/kg for zinc and 30 mg/kg for copper in general foods

Figure 1. Location of the headquarters of the municipalities where samples of coffee were collected.

Table 1. Maximum concentration, mean and minimum metal roasted and ground coffee samples.

Metals	Cd	Cr	Cu	Mn	Ni	Pb	Zn
			Concentrations (mg/kg)				
Maximum	0.10	1.50	17.18	39.78	1.95	1.58	55.83
Minimum	0.03	0.05	0.70	9.808	0.03	0.03	5.53
Mean	0.01	0.34	10.38	19.44	0.70	0.75	6.62
Medium	0.00	0.23	11.09	18.16	0.64	0.78	6.42
Standard deviation	0.01	0.30	2.52	4.32	0.38	0.33	2.26

(Brazil, 1965) are according to Decree n° 55871 established on 26 March, 1965. Morgano et al. (2002) identified an average manganese content of 31.77 mg/kg in all the raw coffee samples and an average content of 30.33 mg/kg for only the coffee samples from the Alto Paranaíba region– MG, values more than those of the average concentration reported in this study.

One of the roasted and ground coffee samples, corresponding to 2% of the samples showed a higher concentration of zinc than the maximum (50 mg/kg) set by the Brazilian legislation (Brazil, 1965) (Figure 2).

Zinc concentrations for the remaining roasted and ground coffee samples ranged from 5.55 to 14.42 mg/kg. Morgano et al. (2002) reported average concentrations similar to those found this study, the average concentration of zinc raw coffee being about 8.33 mg/kg and that for the samples of the Alto Paranaíba region – MG of 7.04 mg/kg. Grembecka et al. (2007) also recorded values around these with the average concentrations of zinc 9.5 mg/kg for the Arabica coffee samples. Santos et al. (2009) estimated the metal content in two coffee farms in the state of Bahia, Brazil, and reported mean values of 25 and 45 mg/kg for zinc, greater than those found in most of the samples analyzed in this study. Ashu and Chandravanshi (2011) also reported zinc values higher than those in this study, (19 mg/kg) in the commercial roasted coffee samples.

All the roasted and ground coffee samples analyzed revealed copper concentrations below the maximum legal value (30 mg/kg) set by the Brazilian legislation (Brazil, 1965). These concentrations approximate the amounts reported by Santos et al. (2009) in the coffee produced in two places in Bahia (7.15 and 14.9 mg/kg). On comparison of all the samples, Morgano et al. (2002)

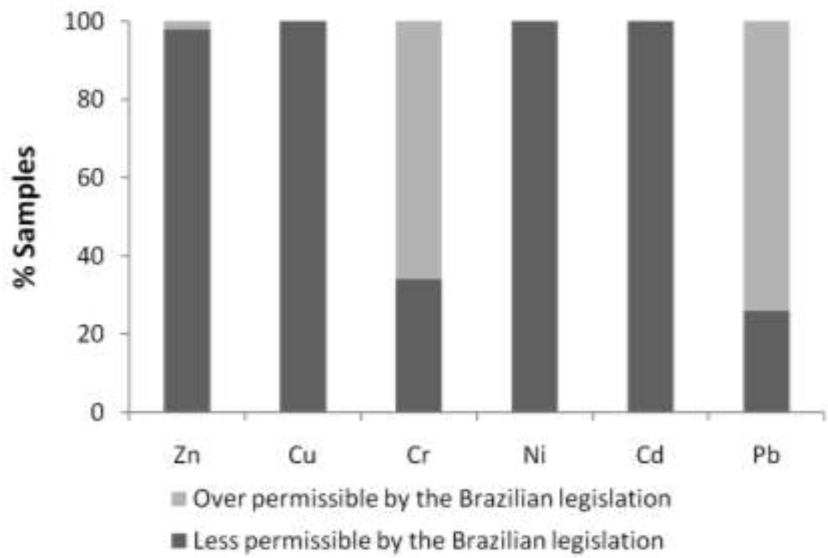

Figure 2. Percentage of roasted and ground coffee samples with metal content less than and higher than the permissible mount set by the Brazilian legislation (Brazil, 2013, 1965).

reported copper with medium values but higher than this study (29.86 mg/kg), although limited only to the samples from the Alto Paranaíba region – MG; the mean value (14.17 mg/kg) showed results similar to those of the current study.

The elements that occur in the lower concentrations or which are undetected in the samples include nickel, chromium, lead and cadmium, among which the latter were found in only 20% of the 50 samples of the roast and ground coffee analyzed. Lead and cadmium rank among the most toxic of the inorganic contaminants. The maximum permissible limit for cadmium set by the regulations of Mercosul (Brazil, 2013) and the European Union (European Commission Regulation, 2008) is 0.1 mg/kg. Lead has been established within the limits of 0.5 and 0.2 mg/kg in the Mercosul regulations (Brazil, 2013) and the European Union (European Commission Regulation, 2008), respectively

The cadmium element was identified in ten roasted and ground coffee samples, none of which exceeded the maximum limit specified by the European Union and Mercosul regulations. The cadmium concentrations in all ten samples ranged from 0.025 to 0.1 mg/kg. Santos et al. (2009) found cadmium concentrations higher than the limit drawn by the European Union and Mercosul regulations (0.1 mg/kg) in the coffee samples produced in the two different properties in Bahia state (0.70 and 0.75 mg/kg).

Lead as an element was absent only in one of the analyzed roast and ground coffee samples. Values ranging from 0.075 and to 1.575 mg/kg were detected in the samples. In fact, 74% of the 50 roasted and ground coffee samples analyzed contained lead concentrations higher than the maximum permitted under Brazilian law and Mercosul regulations (Brazil, 2013) (0.5 mg/kg), some containing almost three times the value (Figure 2). In 86% of analyzed samples of roasted and ground coffee, the element lead was in concentrations above the permitted by the regulations of the European Union (European Commission Regulation, 2008) (0.2 mg/kg). Lead is highly toxic and gets accumulated in the body. The main adverse effects of this metal on health are neurological, hematological, endocrinological, cardio-vascular, gastrointestinal and hepatic systems also affects growth, reproduction and development, and contains a carcinogenic potential (Moreira and Moreira 2004). Thus, to preserve consumer health, none of the high lead level samples could be sold in the market.

For the presence the chromium and nickel elements in coffee beans no maximum levels have been legally specified. Brazilian law permits a maximum of 0.1 mg/kg for chromium and 5 mg/kg for nickel in the general foods (Brazil, 1965). Chromium was absent in 14 of the 50 samples analyzed. However, in 66% of the roasted and ground coffee samples (Figure 2), the chromium concentration was over 0.1 mg/kg, the maximum set by the Brazilian legislation (Brazil, 1965), and the sample having the highest concentration contained greater than 15 times the maximum established. Santos et al. (2009) did not identify any chromium originating from the coffee samples of Bahia.

One sample not showed the presence of nickel while the other roasted and ground coffee samples contained nickel concentrations below 5 mg/kg, as per the requirements of Brazilian law (Brazil, 1965). Morgano et al. (2002) reported a similar trend for the raw coffee samples of the Alto

Table 2. Maximum, minimum and mean concentrations (mg / 50 ml) of metal present in a cup (50 mL) of coffee infusions.

Concentration	Cd	Cr	Cu	Mn	Ni	Pb	Zn
Maximum	0.0030	0.0025	0.0122	0.0373	0.0514	0.0120	0.1292
Minimum	0.0001	0.0001	0.0122	0.0132	0.0002	0.0002	0.0045
Mean	0.0001	0.0011	0.0002	0.0229	0.0011	0.0021	0.0131
Medium	0.0000	0.0011	0.0000	0.0221	0.0000	0.0000	0.1025
Standard deviation	0.0002	0.0005	0.0005	0.0047	0.0020	0.0024	0.0059

Paranaíba region – MG, in a concentration of 1.21 mg/kg. However, the overall average reported by Morgano et al. (2002), considering all the raw coffee samples, was 4.76 mg/kg, higher than those found in the coffee samples of the Alto Paranaíba region – MG and very near to the maximum permissible amount stipulated by Brazilian law (5 mg/kg) (Brazil, 1965). Metals are soil contaminants and are present in this resulting from atmospheric deposition or due to its incorporation, intentional or not, in the soil. Metals are non-biodegradable and due to their poor mobility in the soil they can remain in the superficial layers, in contact with the plant roots over longer time periods. When food crops absorb these metals, they easily enter the food chain, causing harmat all levels (Schmidt et al., 2009; Magna et al., 2013).

On comparing the results of this study with those in the literature, some differences in the concentrations were observed for certain elements. It is well known that rocks are the natural sources of all chemical elements existing on earth (Selinus, 2006). The elements released by rock weathering occur first in the soil and are then transported to the rivers and ground water. In the soil, plant roots absorb them and they thus enter the food chain (Silva et al., 2007). However, these elements naturally occur in equal distribution across the earth's surface and can cause problems when they occur either in very low concentrations (deficiency) or in very high amounts (toxic) (Selinus, 2006).

Studies on soils from the Alto Paranaíba region (MG, Brazil) show the presence of heavy metals (Fernandes et al., 2007; Neto et al., 2009). As there is no legal standard for acceptable limits of heavy metals for the State of Minas Gerais, for comparison purposes, we will use the guideline values of quality, prevention and intervention established by the Environmental Sanitation Technology Company of São Paulo (Fernandes et al., 2007). These studies showed that the levels of Cd (0 to 16.22 mg/kg) and Cr (175.13 to 960.00 mg/kg) were higher than the intervention value for agricultural activity (Cd: 3 mg/kg; Cr: 150 mg/kg). The other metals (Cu: 0 to 56.00 mg/kg; Ni: 9.18 to 32 mg/kg; Pb: 0 to 26.46 mg/kg; Zn: 16.00 to 34.20 mg/kg) were below or very close to the established value of prevention (Cu: 60 mg/kg; Ni: 30 mg/kg; Pb: 72 mg/kg; Zn: 300 mg/kg) (Fernandes et al., 2007; Neto et al., 2009).

The elements of copper, manganese, nickel and zinc are vital to the development of the coffee culture, being applied to the soil or to the leaf and are thus present in the beans, as evident in this study. Further, some elements are pesticide active ingredients used in cultivation. Copper, for instance, finds use as a fungicide in coffee culture as copper hydroxide, copper oxychloride, copper sulfate and/or copper EDTA, which facilitates the absorption of this element by plants, which justifies its presence in bean.

Water used in irrigation can be a source of heavy metal carriers. Silva et al. (2006) evaluated the levels of heavy metals in the waters of the Paranaíba River and found levels above that allowed by the legislation for Cu in 35.71% of the samples, for Zn in 28.57% of the samples and for the Pb in 68, 29% of the samples. The mean Pb content found (0.2611 mg/kg) was about 5 times higher than the value allowed by Brazilian legislation (0.05 mg/kg) (Silva et al., 2006). Rivers are accumulating points of pollutants, receiving pollution from landfills and various anthropogenic activities that develop along river basins (Ferreira and Rosolem, 2011).

The metal contamination also occurs due to human activities, either through waste mining, steel industry, cosmetics industry, or agriculture. The contamination that affects the agricultural areas is now a major problem because many pollutants somehow perform essential roles in economic activities, such as pesticides and fertilizers, and many of these products can remain in the soil and water, contaminating food (Souza et al., 2014).

It should be emphasized that the results were obtained from a single composite sample and had an exploratory and preliminary character. Definitive conclusions about these higher levels should be taken with caution and should be preceded by a more intense analysis of the collection points with problems, from a larger number of samples.

Reports on the maximum, minimum and average concentration of metals in coffee infusions made from the 50 roasted and ground coffee samples, are listed in Table 2. From the values reported for the metals in coffee infusion, the metal content (mg) in a 50 ml cup of coffee was calculated.

Table 3 shows the percentage of extraction (leaching) of the average of the metal in the ground and roasted coffee sample infusions, considering the ratio of the drink

Table 3. Average percentage of leaching metals from roasted and ground coffee samples for coffee infusions (6 g/50 ml infusion).

Metals	Cd	Cr	Cu	Mn	Ni	Pb	Zn
Extractions (%)	26.00	53.45	0.32	19.63	26.13	46.85	28.69

prepared. The elements leached showed higher chromium and lead content, with about 50% of the quantity present in the roasted and ground coffee being a leached infusion. These elements were found in most of the roasted and ground coffee samples in concentrations higher than the maximum established by Brazilian law (Figure 2). This justifies the high percentage of leaching, resulting in an increased concentration of these elements in the coffee infusions.

The element showing the least leaching was copper. Stelmach et al. (2013) reported an average of 6.3% of copper leaching. This low degree of extraction was most likely because of a complex formation of this ion with the strong coffee matrix (Stelmach et al., 2013). Cadmium, manganese, nickel and zinc showed leaching percentages between 20 and 30% (Table 3). Grembecka et al. (2007) reported that the element manganese had a leaching potential of 24% of the roast and ground coffee beans for infusion, similar to theresults of this study. Stelmach et al. (2013) identified an average leaching of 41.93% for the same element. Chromium and lead in this study revealed higher leaching percentages, because they possessed a lower interaction with the coffee matrix.

According to Padovani et al. (2006), the maximum tolerable intake - UL (Tolerable Upper Intake Level) of certain elements is calculated chiefly with respect to age and sex (also considering pregnancy and lactation). UL refers to the highest value of prolonged and everyday intake of a nutrient that apparently presents no risk of ill health effects to almost all the individuals irrespective of gender or the stage in life.

Considering, on average, a daily consumption of four cups of coffee (Arruda et al., 2009), the quantity of manganese ingested via the coffee infusion will be 0.0916 mg/day, comfortably less than the value set as the maximum tolerable limit for this metal, which is 11 mg/day (Padovani et al., 2006). The daily intake of four cups of coffee contributes 0.83% of the maximum daily intake set for manganese. Noël et al. (2012), in their evaluation of 30 coffee samples, arrived at an average manganese concentration of 0.662 mg/kg in the brewed coffee. When only one cup (50 ml) is considered, this value will be 0.0331 mg/50 ml, a little above than the average identified in this study, hovering close to the maximum values noted.

The daily zinc intake from the consumption of four cups per day of coffee from the coffee samples analyzed in the current study is about 0.0524 mg/day, indicating 0.13% of the maximum tolerable intake for this metal (40 mg/day) (Padovani et al., 2006). On analyzing the presence of metals in various products in France, Noël et al. (2012) arrived at a mean value of 0.01425 mg/50 ml for zinc in the coffee, almost identical to the findings of this study.

Copper metal was found in only one of the 50 coffee infusion samples at a concentration of 0.0122 mg/50 ml. The maximum tolerated limit for copper has been set at 10 mg/day (Padovani et al., 2006). Although, high copper concentrations are present in the roasted and ground coffee beans (Table 1), it was almost never detected in the coffee infusions, revealing an average of less than 1% leaching. Noël et al. (2012) found an average copper concentration of 0.0945 mg/50 ml on evaluating 30 coffee infusion samples.

Chromium however, revealed a unique pattern, quite different from that of the other elements. It occurred in higher concentrations of the brew when compared with the quantities present in the roasted and ground beans for a few samples. Ashu and Chandravanshi (2011) reported similar behavior for the elements of cobalt, zinc and manganese. In the coffee infusions, chromium was not identified in only two roasted and ground coffee samples. Santos and Oliveira (2001) detected chromium in only one of the 21 instant coffee samples studied by the authors. Noël et al. (2012) had earlier reported the chromium concentration to be 0.0023 mg/50 ml on average in coffee infusion. The permissible chromium intake for adults is 50 to 200 µg/day (0.05 to 0.2 mg/day) (World Health Organization, 2000). Although, most of the roasted and ground coffee samples analyzed showed a chromium concentration above the maximum set by the Brazilian legislation (0.1 mg/kg) (Brazil, 1965), the daily consumption of four cups of coffee would account for 4.4 µg chromium, corresponding to 2.2% of the allowable total intake (maximum of 200 mg/day).

According to Padovani et al. (2006), the maximum daily nickel intake is 1 mg/day. As it was identified in only eight coffee infusion samples, nickel was ingested in small amounts via the coffee intake. The nickel concentration on average in the coffee brewed in this study was less than that found by Noël et al. (2012), which was around 0.0041 mg/50 ml of the coffee infusion. Santos and Oliveira (2001) found no nickel at all in the 21 samples of soluble coffee analyzed.

Lead and cadmium are highly toxic elements; therefore, their consumption should be as minimal as possible. The maximum permissible limit for cadmium set by the "Joint FAO/WHO Expert Committee on Food Additives" is 7 µg/kg body weight/week (Food and Agriculture Organization/World Health Organization, 2004). Thus, for a 70 kg adult human being the maximum daily intake

Table 4. Pearson correlation matrix of analyzed metals present in roasted and ground coffee and coffee infusions.

Correlation	Mn r	Zn r	Cu r	Cr r	Ni r	Cd r	Pb r	Mn i	Zn i	Cu i	Cr i	Ni i	Cd i	Pb i
Mn t	1.000													
Zn t	0.040	1.000												
Cu t	0.510	0.104	1.000											
Cr t	0.024	0.015	0.027	1.000										
Ni t	0.240	0.169	0.284	0.706**	1.000									
Cd t	0.028	0.054	0.101	0.206	0.241	1.000								
Pb t	0.062	0.172	0.230	0.186	0.124	0.060	1.000							
Mn b	0.744	0.135	0.430	0.054	0.228	0.049	0.081	1.000						
Zn b	0.111	0.059	0.009	0.110	0.052	0.052	0.011	0.204	1.000					
Cu b	0.037	0.024	0.035	0.182	0.272	0.058	0.080	0.008	0.237	1.000				
Cr b	0.033	0.144	0.272	0.335	0.183	0.063	0.351	0.048	0.054	0.053	1.000			
Ni b	0.100	0.030	0.067	0.008	0.143	0.142	0.105	0.074	0.307	0.532	0.048	1.000		
Cd b	0.321	0.052	0.534	0.063	0.217	0.315	0.141	0.254	0.127	0.021	0.244	0.047	1.000	
Pb b	0.367	0.120	0.380	0.157	0.047	0.084	0.110	0.252	0.079	0.084	0.326	0.362	0.570	1.000

Correlation coefficients (R) followed by ** are greater than 0.60 and are significant by the t-test at the 1% probability level. r: Metals present in roasted and ground coffee; i: Metals present in the coffee infusions.

would be 70 mg. Therefore, the daily consumption of four cups of coffee will imply the ingestion of 0.4 µg of cadmium. This is a low value and accounts for 0.57% of the maximum daily cadmium intake, considering the overall average (0.0001 mg/50 ml). On analysis of the samples separately, the cadmium consumption may be much higher, achieving 17.1% (sample containing cadmium concentration of 0.003 mg/50 ml infusion of coffee). However, most of the samples analyzed (60%) did not show the presence of cadmium. Santos and Oliveira (2001) detected no cadmium in any of the 21 samples of instant coffee analyzed.

Lead was identified in 23 coffee infusions, corresponding to 46% of the samples, and in these samples the concentration of this element ranged of 0.0004 mg/50 ml to 0.0121 mg/50 ml. The maximum permissible lead intake is 25 µg/kg body weight/week (250 µg/day, for an adult human being weighing 70 kg). Consumption of the coffee samples would imply the ingestion of large quantities of this element, although absent in more than half the samples. Four cups of such coffee consumed could contribute to nearly 3.36% of lead ingestion, reaching 19.36% if the sample with the highest lead concentration of lead is consumed. This is a very crucial value, as coffee is a beverage consumed over a few days by volume when compared with other foods. Santos and Oliveira (2001) identified no presence of lead in 21 samples analyzed for soluble coffee.

Pearson correlation coefficients were estimated for the concentrations of metals present in roasted and ground coffee samples and infusions (Table 4). Among the same element, only the correlation for manganese was significant, that is, samples that contained higher concentrations of this metal in the roasted and ground coffee, also presented in their infusions, evidencing that this metal is quite soluble/leachable. In the analyses between metals, only the correlation between chromium and nickel was significant for roasted and ground beans. This indicates that the terrors of these two elements in the samples are directly proportional.

Conclusions

The chromium and lead elements in some samples are found in concentrations higher than the legal permissible extent. With respect to the maximum allowed, chromium and lead concentrations according to Brazilian law, only 14% of the samples analyzed are within the established norms. In the face of this contamination, new studies are needed to analyze the soil and the water used in the irrigation of these properties and in less disturbed areas to allow more adequate comparisons with the contents naturally present in soil and water.

There is a variation in the amount of extracted heavy metals for coffee infusions, due to differential interaction with the organic matrix. Most metals extracted chromium and lead, which were already in great amounts in roasted and ground coffee, contributing to a high content of these elements in infusions.

Conflict of Interests

The authors have not declared any conflict of interests.

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