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Determination of trace elements in commercially available instant coffees

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Abstract This paper presents results regarding the determination of essential toxic microelements in different instant coffee brands used to prepare coffee. The authors used flame atomic absorption spectrometry (FAAS) to determine the content in Fe, Mn, Zn, Cu, Pb and Cd in five instant coffee brands – Amigo, Doncafee, Jakobs Kronung, Jacobs Velvet and Nescafe Brasero purchased from supermarkets in Timisoara, Romania. Results point to moderate contents in Fe (42.2-159 mg/kg), Mn (19.1-54.1 mg/kg), and Zn (13.3-56.7 mg/kg) and to small amounts of Cu (0.75-7.19 mg/kg). Pb and Cd, elements with high toxicity, were not identified.

Key words

trace element, minerals, instant coffee, FAAS

Coffee, a drink from roasted coffee beans, is one of the most common drinks of the world. Known mainly for its aroma, taste, specific flavour and energising effect, it also contains important nutrients and antioxidants such as carbohydrates, lipids, nitrate compounds, vitamins, minerals, alkaloids, phenol compounds, etc. [13, 15]. Its nutrition and therapeutic features are due to its chemical compounds that meet human body physiological requirements, among which mineral microelements [9, 10, and 16].

Instant or soluble coffee is a derivative of roasted coffee beans [23]: therefore, its distribution of minerals matches generally the mineral profile of roasted coffee beans assortments.

Literature supplies numerous data regarding the concentration of minerals in most coffee brands, as well as the analytic methods and techniques used to analyse them [3, 7, 8, 10, 11, 14, 17, 18]. These references show that coffee brands used to prepare coffee contain important amounts of macro elements and moderate amounts of essential microelements such as Fe, Mn, Cu, Zn, Al, Co, Ni, Se, Cr, etc. heir distribution in different instant coffee assortments is uneven since their concentration depends on several factors among which the nature of the mineral, the coffee assortment, the soil and climate conditions of the area of origin, the processing technology, etc. [3, 4]. Besides these essential elements, some coffee brands also contain considerable amounts of toxic minerals Pb, Cd, Hg, etc. [1]. We need to know the mineral profile of these coffee brands to assess their mineral supply and to identify possible toxic mineral compounds [22].

References regarding the concentration of microelements in instant coffee are scarce. To note, however, the studies conducted by Dos Santos et al., 2001 [5]; Farah, 2012 [6]; Oliveira et al., 2012 [17]; Szymczycha-Madeja et al., 2015 [21]; Hernández et al., 2017 [12].

The chemical composition of instant coffees reflects the composition of the mix, the roasting method, and the method used to extract and concentrate the drink. The content in caffeine in instant coffee (2.5-5 g/100 g) depends primarily on the mix composition and on the extraction method. The goal of the producers of instant coffee is to develop instant coffee preparations with a chemical composition similar to that of roasted coffee beans. In general, instant coffee contains polysaccharides (50-60 g), proteins (12.6-21 g), lipids (0.2-1.6 g), minerals (8.8-10 g), oligosaccharides (5.2-7.4 g) and moisture up to 5% (2.7%-3.5%) [6].

To note the study carried out by dos Santos et al. [5] on the content in such essential toxic minerals as Na, K, Mg, Al, P, S, Ca, Mn, Fe, Ni, Cu, Zn, Cd, Sb, Pb, Cr

and Sn in 21 types of instant coffee from different coffee brands (Café Pelé, Gran Classic, Nescafé Matinal, Nescafé Tradição, Café do Ponto Freeze-dried, Café do Ponto Descafeinado, Café Solúvel Parmalat, Ariscafé, Café Solúvel Iguaçu, Café Solúvel Eldoro, Café Solúvel Diana and Bassil Coffee): 32.500-45.800 mg/kg in K; 2.120-4.150 mg/kg in Mg; 1.160-1.890 mg/kg in Ca; 322-1.743 mg/kg in Na; <5-233 mg/kg in Al; 14.0-450 mg/kg in Fe; 6.4-18 mg/kg in Sn; 3.62-27.9 mg/kg in Mn; 3.17-15.17 mg/kg in Zn; 0.54-2.33mg/kg in Cu; <2.5 mg/kg in Ni; <1 mg/kg in Pb; <0.25 mg/kg in Cd; <0.1 mg/kg in Cr.

Analysing the concentration of nine minerals – Ca, Mg, K, Na, P, Fe, Mn, Cr and Ni in 49 samples of instant coffee and coffee substitutes, Oliveira et al. [17] have found out that they are rich in K, Mg and P (> 1.000 mg/kg) and that they contain moderate amounts of Na, Ca and Fe (>10 mg /kg) and traces of Cr and Ni.

Hernández et al. [12] found similar results regarding the content in Na, Mg, P, S, K, Ca, Cr, Mn, Fe, Cu, Zn, Br, Rb, and Sr in the instant coffee brand "Nescafé Dolca" through X-ray Fluorescence (XRF), i.e. microelement concentrations between 1.2 mg/kg (Cu) and 72 mg/g (Fe). According to these authors, the mineral profile of Nescafé Dolca is characterised by an increasing trend: Cu (1.2 mg/kg) ≤ Cr (1.7 mg/kg) < Zn (5.2 mg/kg) < Sr (9.2 mg/kg) < Mn (14 mg/kg) < Rb (18 mg/kg) < Br (32 mg/kg) < Fe (72 mg/kg).

These data show that mineral concentration has a strong unevenness depending on the nature of the elements and on the coffee type. The mineral profile (mean values) of different instant coffee types is characterised by a decreasing variation: K >> Mg > Ca > Na > Al > Fe > Mn ≅ Sn > Zn > Cu ≅ Ni > Sb > Pb > Cd > Cr.

The objective of this study was to determine the concentration of essential and toxic trace element in different instant coffee brands used to prepare coffee to better know their mineral supply and to identify possible toxic mineral compounds. To do so, the authors used flame atomic absorbance stereoscopy to determine the content in Fe, Mn, Zn, Cu, Pb and Cd in five instant coffee types – Amigo, Doncafee, Jakobs Kronung, Jacobs Velvet and Nescafe Brasero – purchased from supermarkets in Timisoara, Romania.

Material and Method

2.1. Apparatus

- Analytic scales DENVE INSTRUMENT-Germany, model TP 2014;
- Thermal regulation calcination oven Nabertherm model 6/11;
- Thermal regulation electric stove;
- Flame atomic absorption spectrometer Varian 280 FS.

2.2. Reagents

- Natric acid Merck, 65 % (ρ = 1.39 g/cm^3) to prepare the solution of nitric acid 0,5 N;
- Multi-element concentrated standard solution (1 g/L) Merck-Germany to prepare

work samples in concentrations covering the concentration span of studied microelements;

- Distilled water;
- Laboratory utensils: Berzelius glasses 150 ml, porcelain crucibles, rated balloons (100

and 50 mL), pipettes, rated cylinder 50 ml), filter paper.

Reagents used in the assay are chemical reagents p.a. Glassware and laboratory utensils used in the experiments were cleaned with chromium mix and rinsed with distilled water.

2.3. Procedure

To reach our goals, we sampled five instant coffee brands marketed by supermarkets in Timisoara, Romania – Amigo, Doncafee, Jakobs Kronung, Jacobs Velvet and Nescafe Brasero – used frequently to prepare coffee. These instant coffee samples were packaged by their producers in bags containing about 1.8 g of produce. From these five sample, we prepared five work samples of 2 g each that we identified as Instant 1, Instant 2, Instant 3, Instant 4 and Instant 5.

Determining microelements in instant coffee brands was done in two steps: mineralising coffee samples by calcination, followed by solubilising inorganic matter in nitric acid HNO_3 0.5 N and measuring mineral absorbance from the acid solution [9, 10].

Instant coffee samples (2 ± 0.0002 g each) were calcinated at 550^{0}C in a Nabertherm calcination oven in two sessions of four hours each. The ashes were then treated with 20 mL solution of HNO_3 0.5 N and evaporated (on the electric stove) until almost dry. This was done two times after which it was reduced with small portions of 15 mL of HNO_3 0.5 N and with distilled water through filtering to 50 mL.

Measuring element absorbance in the clear solution of 50 mL was done with a Varian 280 FS Spectrometer in air-acetylene flame. For certainty results we used, for each element, a control sample of known concentration. The work parameters of the apparatus – wave length, burner height, etc. – were chosen in accordance with the recommendations of the apparatus manufacturer. Together with measuring sample absorbance and under the same work conditions, we also determined calibration solution absorbance.

Total concentration of analysed microelements was determined with the formula:

$$C\ [mg/kg] = \frac{a}{m}$$

where:

a – concentration of the element measured by the apparatus (mg/l);

m – work sample weight (g).

Results and Discussions

Experimental results from the analysis of essential and toxic microelements in five studied instant coffee triple samples are shown in Table 1 below.

Table 1

Trace element content (mean values) in some brands of instant coffee

Coffee brand	Trace element, mg/kg					
	Fe	**Mn**	**Zn**	**Cu**	**Pb**	**Cd**
Instant 1	159	54.1	18.5	7.19	ND	ND
Instant 2	9.6	40.0	26.7	2.27	ND	ND
Instant 3	42.2	34.7	15.5	0.75	ND	ND
Instant 4	67.6	26.2	13.3	0.81	ND	ND
Instant 5	60.9	19.1	17.6	1.31	ND	ND
Average	***84.7***	***34.8***	***16.18***	***2.47***	***ND***	***ND***

As shown in Table 1 above, the distribution of Fe, Mn, Zn, Cu, Pb and Cd in the instant coffee samples analysed (identified as Instant 1 to Instant 5) is uneven: it depends on the nature of the element analysed and on the coffee brand studied.

The concentration of the analysed elements varies within wide limits: 0.75 mg/kg (Cu in Instant 3) and 159 mg/kg (Fe in Instant 1). Pb and Cd, elements with a strong toxic character, were not identified under work conditions (their concentration in all studied samples was below detection limits) (ND).

Iron (Fe), an essential microelement involved in oxygen binding, transport and release [10], is the best represented of all analysed elements, with a concentration of 9.6-159 mg/kg. The richest coffee brand in Fe was Instant 1 (159 mg/kg), while the lowest content of Fe was in Instant 2 (only 9.6 mg/kg). The other instant coffee brands had relatively close concentrations of Fe: 42.2 mg/kg (Instant 3), 60.9 mg/kg (instant 5) and 67.6 mg/kg (instant 4).

Manganese (Mn), an essential microelement acting as an activator of enzyme and as a component of metalloenzymes [19], was determined in lower concentrations than Fe (mean value: 34.8 mg/kg) but higher than those of Zn and much higher than those of Cu. Mn concentration intervals ranged between 19.1 mg/kg (Instant 5) and 54.1 mg/kg. Though Mn concentration in the five instant coffee brands had the same size order, we noted that Instant 1 was the richest in Mn. The other instant coffee brands had smaller amounts of Mn decreasing almost evenly: 40.0 mg/kg (Instant 2) > 34.7 mg/kg (Instant 3) > 26.2 mg/kg (Instant 4) > 19.1 mg/kg (Instant 5).

Zinc (Zn), an essential microelement playing a role in maintaining the health of the reproductive and immune systems [20], was determined in concentrations between 13.3-26.7 mg/kg, with an average of 16.18 mg/kg for the five instant coffee brands. Zn was determined in lower concentrations than Fe and Mn, but in higher concentrations than Cu. Instant 2 was the richest instant coffee in Zn; the other instant coffee brands had lower but close concentrations of Zn: 18.5 mg/kg (Instant 1), 15.5 mg/kg (Instant 3), 133 mg/kg (Instant 4), and 17.6 mg/kg (Instant 1).

Copper (Cu), a microelement essential for the proper functioning of some enzymes and participating in energy production, in bonding collagen and elastin, in maintaining blood vessels healthy, in bone formation, in iron fixing, in noradrenalin production, in adrenalin formation [2], had the lowest concentrations of all analysed microelements. Cu distribution in the analysed instant coffee samples was clearly uneven: it ranged between 0.75 mg/kg (Instant 3) and 7.19 mg/kg (Instant 1). Taking into account these concentration levels, we can say that Instant 1 was the richest instant coffee brand in Cu, closely followed by Instant 2 (2.27 mg/kg). Instant 5, Instant 4 and Instant 3 had lower yet close Cu concentrations: 1.31, 0.8, and 0.75 mg/kg, respectively.

Zincn and *copper*, though microelements essential for a normal functioning of the human body, can have side effects in concentrations above normal limits. Food legislation regulates Zn and Cu though the Minister's Order No. 975 from December 16, 1998 [24]. According to this act, maximum Zn and Cu concentrations in coffee are limited to 30 mg/kg and 10 mg/kg, respectively. Zn and Cu concentrations in the instant coffee brands we analysed show no risk of toxicity: 13.3-26.7 mg/kg in Zn and 0.75-7.19 mg/kg in Cu.

Lead (Pb) and **Cadmium (Cd)**, also called heavy metals [1], are metal elements with a strong toxic character whose concentrations in coffee are limited to maximum 1 mg/kg and 0.01 mg/kg, respectively [24]. All instant coffee brands analysed contain these elements in very low concentrations below detection limits and below maximum limits admitted, which makes them Pb and Cd toxicity-free.

Conclusions

The concentration of different mineral elements in different instant coffee brands reflect the composition of the coffee mix used to produce them; they show a decreasing variation (mean values): K >> Mg > Ca > Na > Al > Fe > Mn ≅ Sn > Zn > Cu ≅ Ni > Sb > Pb > Cd > Cr.

The distribution of Fe, Mn, Zn, Cu, Pb and Cd in the instant coffee brands analysed is uneven: it depends on the nature of the element and on the coffee brand. The concentrations of the elements analysed varies largely between 0.75 mg/kg (Cu in Instant 3) and 159 mg/kg (Fe in Instant 1).

Results point out moderate contents in microelements: Fe (42.2-159 mg/kg), Mn (19.1-54.1 mg/kg), Zn (13.3-56.7 mg/kg) and small amounts of Cu (0.75-7.19 mg/kg). Pb and Cd, elements with strong toxicity, were not detected under the conditions of the current experiment.

In conclusion, we emphasise the need to know the mineral profile of these instant coffee brands in order to get aware of their mineral supply and to detect possible potentially toxic mineral elements.

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