

Characterization and study of the essential mineral components of Spanish commercial herbal products and their infusions

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Summary

The popularity of herbal infusions is increasing in recent years, mainly because of their health benefits. There are few studies about macroelements and microelements in the different commercial herbal infusions present in the market. The aim of this study was to determine the concentration of some macroelements (Ca, K, Mg and Na) and microelements (Fe, Cu, Mn and Zn) in twenty samples of herbal infusions, and compare them with tea. Most of the relationships between the mineral elements were positive. The extraction rate was uniform for all the samples. By comparison with tea, the only significant difference was in Ca concentration, which was much lower in tea infusion. Also, as a whole, Mn concentration was much higher in tea. A wide variability was observed both in dry materials and in herbal infusions. The profile of mineral elements was similar in most samples and remained in the herbal infusions. K and Ca were the predominant macroelements, and Fe and Mn the predominant microelements. Fe was the least soluble, and Cu, Zn and Na the most soluble.

Keywords

herbal infusion; mineral composition; extraction rate; atomic absorption spectrometry

The growing awareness about health and quality of life has promoted the search for food products with scientifically tested healthy properties. Since ancient times, traditional healers prescribed mixtures of medicinal plants and currently the resurgence of the use of these plants has promoted their industrial production for public consumption [1]. The role of medicinal plants has been re-valued due to the knowledge of the contained phytochemicals, and their possible effects on health. The consumers use these herbal infusions with medicinal properties as hypocholesterolemic, hypotensive, anti-osteoporosis or diabetes-preventing [2], also as alleviating stress, fatigue, insomnia, anxiety, nervousness [3] or simply for their organoleptic properties “to give water a better taste” [4]. The water intake that involves the herbal infusion consumption contributes to body hydration [5] including some minerals in order to maintain good health [6]. The herbal infusions have low contents of energy and nutrients, even though, from a nutritional point of view, they can contribute to mineral intake. Determination of

mineral elements in herbal infusions is important to judge their nutritional value and to prevent any probable ill-effects [7].

In Europe, market trends have changed in recent years. The almost exclusive commercialization of black tea (*Camellia sinensis*) is now turning to alternatives based on herbs and aromatic plants, with more variety of tastes or with medicinal properties (diuretic, relaxing, anti-inflammatory), scientifically proved as herbal infusions [8].

Regarding the Spanish trade of herbal infusions and the data provided by Mercasa in 2009 [9], there is a much higher consumption of herbal infusions than tea. Chamomile leads this area, followed by a range of “wellbeing infusions”, which are the subject of this study.

This rise in sales of these products has resulted in a proliferation of “Tea shops” and other establishments dedicated to herbal infusions. In spite of this development in Europe and all over the world during recent years, numerous studies were devoted to health benefits of these products [7, 10–13] but only few data are available on the con-

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centration of minerals in herbs and their infusions [13–19]. Many studies about the mineral content in black tea were carried out but there are few studies about macroelements and microelements in the different commercial herbal infusions in the market. Moreover, the transfer of these mineral elements to the infusion has not been determined.

Keeping in view all this information, the aim of the present study was to characterize and to determine the concentration of essential elements (Cu, Zn, Fe, Mn, Mg, Ca, Na and K) in the raw materials and the corresponding herbal infusion of

a variety of representative herbal infusion samples in the Spanish market.

MATERIALS AND METHODS

Samples and sample preparation

Twenty types of herbal infusions were purchased from several markets of Madrid, Spain in 2011. Tab. 1 summarizes the information declared on the labels. Samples were analysed in triplicate. Each box contained 15–20 infusion bags

Tab. 1. Label information in packed herbal infusions studied.

Sample	Trade-mark	Type	Composition	Boiling time [min]	Bag weight [g]
1	A	Lemongrass	Lemongrass	5	1.7
2	A	Esbel tea multiinfusion	Mate, nettle, crisp mint, peppermint, balm, blackberry leaves and centaurea	5	2
3	A	Breathes well multiinfusion	Fennel, sage (15%), orange peel, liquorice root, ginger, cinnamon, eucalyptus, thyme and daisies	5–8	2
4	A	Non-stress multiinfusion	Melissa, chamomile, lime blossom, mint, sage, verbena, lavender and natural flavour of plum	5–8	1.7
5	A	Sleep well multiinfusion	Rooibos, melissa, honeybush, anise, cinnamon, liquorice, hops, blackberry leaves, cardamom and lotus (2%)	5–8	2
6	B	Rooibos with cinnamon, cardamom, ginger	Rooibos (88%), cinnamon (7%), cardamom and ginger	3–5	1.5
7	B	Digestive infusion without theine	Chamomile (35%), rooibos (25%), mint (16%), anise (12%), liquorice and lemongrass	3–5	1.5
8	B	Infusion relax without theine	Orange blossom and lemongrass	3–5	1.5
9	B	Infusion without theine	Lemongrass, apple (20%), fennel, mint (10%), elder (7%), chicory root, mallow leaves (5%), lemon peel and flavour	3–5	1.5
10	B	Herbal infusion	Lemongrass, hibiscus, pomace, rosemary, ginger (6%), guarana (2%), beet and pieces of raspberry (1%)	3–5	1.5
11	B	Herbal infusion	Lemongrass, mint (35%), natural flavour of lime, natural flavour of lemon, lime (1%) and aloe vera extract (0.5%)	3–5	1.5
12	A	Digestive multiinfusion	Rooibos, chamomile (15%), anise, fennel, crisp mint, peppermint, liquorice root and blackberry leaves	5–8	2
13	A	Digestive infusion	Chamomile (65%), mint (20%), anise (10%) and anise flavour (5%)	5	1.5
14	A	Relax infusion	Tile (25%), orange blossom (25%), lemongrass (25%) and melissa (25%)	5	1.5
15	B	Flavoured infusion without theine	Pomace (58%), cinnamon (9%), flavours, hibiscus (7%), liquorice, malic acid, citric acid, rose hip and dehydrated cream	3–5	2
16	B	Flavoured infusion without theine	Pomace, flavours, citric acid, liquorice, rose hip, hibiscus, chicory, peaches (0, 9%) and maracuya (0.1%)	3–5	2
17	B	Flavoured infusion without theine	Pomace, apple, currant leaves, rose hip, citric acid, lemon peel (5%), hibiscus, flavours, chicory and grapefruit (0.5%)	3–5	2
18	B	Flavoured infusion without theine	Rose hip, rooibos (30%), hibiscus (24%) and raspberry flavour and pieces (3%)	3–5	1.5
19	C	Digestive concentrated infusion	Mint concentrated (89%), liquorice root (7%), fennel concentrated (2%) and fennel fruits (2%)	1–4	2.2
20	C	Breathe infusion	Thyme (25%), eucalyptus (25%), rosemary (25%) and peppermint (25%)	5	1.5

containing between 1.5 g and 2 g, except sample 19 which had 2.2 grams. Herbal infusions were prepared following the instructions on the label, with 250 ml of boiling distilled water.

All the polyethylene and glass materials were treated with HNO₃ (10%), and then rinsed with distilled water. All the analyses were performed in triplicate.

General characterization

The density measurement was carried out using a pycnometer, comparing the density of the infusion with the density of pure water at 20 °C [20]. The pH value was measured with a pH-meter Crison micro pH-2000 (Crison Instruments, Barcelona, Spain), previously calibrated with buffer solutions (pH 4.00 and pH 7.00). Moisture was determined in the dry sample by the method of weight loss by evaporation in an oven at (100 ± 2) °C until constant weight [21].

Ash determination

For the determination of ash in dry material, an amount of 0.3 g was ignited in a microwave muffle furnace (Milestone MLS-1200 Pyro, Milestone, Shelton, Connecticut, USA) at 550 °C for 12 h or until the collection of white ash, following the method used by MATEOS-APARICIO et al. [22]. For the determination of ash in herbal infusion, 50 ml of each herbal infusion were evaporated to dryness and handled as above for the dry material.

Determination of mineral concentration

The ash residue was solubilized in 2 ml of HCl (50%): HNO₃ (50%) (1:1; v/v), and then filtered through an ash-free, acid-washed filter paper [22]. Afterwards, it was diluted to 25 ml with distilled water and stored in a polyethylene bottle. All reagents used were of analytical grade (Merck, Darmstadt, Germany).

Mineral elements were quantified by atomic absorption spectrometry (AAS) in a Perkin Elmer Analyst 2000 (Perkin Elmer, Waltham, Massachusetts, USA), using a flame as nebulizer with air-acetylene and a hollow cathode lamp. For each element, wavelength (λ) conditions and calibration curves are shown in Tab. 2.

Standard solutions of each element (Ca, Na, Mg, K, Fe, Cu, Mn, Zn; Panreac, Barcelona, Spain) were prepared by dilution of the stock solution (1000 mg·l⁻¹) with distilled water. To determine Na and K, CsCl was added as a matrix modifier to prevent interferences caused by the ionization of the alkaline elements when air-acetylene flame is used. At quantification of Ca and Mg, O₃La₂ was added to prevent the interferences caused by the phosphates of the sample. The addition of O₃La₂ results in Ca and Mg oxides, which are dissociated into free atoms. The microelement determination was carried out directly.

Validation of the methodology

Validation of the methodology was carried out by checking the precision and accuracy of the data. Accuracy tests were carried out by adding known amounts of standard solutions of the corresponding mineral element. The recoveries were for all mineral elements between 94.3% and 105.8%. Ten assays of the same sample were performed to carry out the precision test. The coefficient of variation obtained was never above 5%. This shows that the accuracy and precision of the applied method were satisfactory. The limits of detection (*LOD*) and quantification (*LOQ*) were determined and are presented in Tab. 2.

Statistical analysis

The analytical data were analysed using SAS statistical programme 9.1 (SAS Institute, Cary, North Carolina, USA). The description of each

Tab. 2. Calibration curve parameters and wavelength conditions of the equipment for 8 elements studied.

Element	Line	R ²	λ [nm]	SLIT	Matrix modifier	LOD [$\mu\text{g}\cdot\text{ml}^{-1}$]	LOQ [$\mu\text{g}\cdot\text{ml}^{-1}$]
Cu	$y = 0.0612x - 0.006$	0.9999	342.7	0.7	–	0.0040	0.0132
Mn	$y = 0.0969x - 0.001$	0.9998	279.5	0.2	–	0.0074	0.0247
Fe	$y = 0.0318x - 0.0011$	0.9997	248.3	0.2	–	0.0075	0.0250
Zn	$y = 0.1559x - 0.0382$	0.9919	213.8	0.2	–	0.0037	0.0122
Na	$y = 0.0055x - 0.1159$	0.9992	330.2	0.2	CsCl	0.0090	0.0300
K	$y = 0.0025x - 0.0384$	0.9942	766.5	0.7		0.0072	0.0241
Ca	$y = 0.0688x - 0.0179$	0.9988	422.7	0.7	O ₃ La ₂	0.0053	0.0177
Mg	$y = 0.0059x - 0.0172$	0.9999	285.2	0.7		0.0028	0.0094

SLIT – a system of lenses, mirrors and apertures (slits) that define and focus the radiation beam, and a monochromator that separates the narrow-band radiation of wavelength, *LOD* – limit of detection, *LOQ* – limit of quantification.

variable was obtained and the developed correlation matrix showed the relationship between all the parameters analysed. Hierarchical cluster analysis was also performed to determine if there were any significant groups of samples with same characteristics.

Results are expressed as mean values \pm standard deviation.

RESULTS AND DISCUSSION

General characterization

Tab. 3 shows the general characteristics of the samples, the densities of all samples were around 1 g·ml⁻¹. The highest density was detected in samples 13, 14 and 19, the last one corresponded to the triple concentrated infusion. The data are consistent with the high levels of dry residue and ash.

The pH value in the infusions was fairly homogeneous, in most samples ranged from 5.42 (sample 6) to 6.49 (sample 20). Samples 13, 14, 16 and 18 had a relatively acid pH with values from 3.25 to 3.39. These values are due to the addition of organic acids (citric or malic acid) in samples 15, 16 and 17, or the presence of raspberry [23] in sample 18.

The Spanish legislation [24] establishes a maximum of moisture of 15% for this kind of products to ensure a good preservation, as this is a limiting factor for microbial growth. None of the samples exceeded this level. The values ranged between 4.4% (sample 19) and 8.9% (sample 3), although most of the samples had a moisture content between 6% and 8%. The elaboration of these products involves a drying step [25], which was reflected by the determined low moisture of the samples.

Ash determination

The ash values obtained were between 2.1% (sample 16) and 12.8% (sample 19). This range of values is in line with current legislation in Spain, which establishes a maximum of 14% of ash. The sample 19 had by far the highest ash content, which probably corresponds with triple concentration specified on the label, and so this sample is not comparable with the others. Sample 2 had also a high content of ash (11%). Flavoured infusions (samples 15, 16, 17 and 18) had low ash content, along with the Rooibos infusion (sample 6), with values around 2–3%.

KARTIKA et al. [16] determined the mean percentage of ash from the species *Camellia sinensis* (average of green and black tea) estimating a value of 6.3%. Comparing the average values of the ana-

Tab. 3. General characteristics of herbal infusions.

Sample	Density [g·ml ⁻¹]	pH	Moisture [%]	Ash [%]
1	1.001	6.01	7.1	8.5
2	1.000	5.47	6.9	10.1
3	1.001	5.81	8.9	7.5
4	1.001	5.73	8.2	8.8
5	1.000	5.74	8.8	4.6
6	1.001	5.42	7.3	2.6
7	1.000	5.88	7.0	8.6
8	1.002	5.98	7.6	10.3
9	1.000	5.93	6.8	7.3
10	1.001	5.82	6.4	6.6
11	1.001	6.01	6.5	7.7
12	1.001	5.68	8.0	6.0
13	1.002	3.25	6.7	11.0
14	1.001	3.25	7.1	10.1
15	1.000	5.68	7.4	2.3
16	1.001	3.34	7.5	2.1
17	1.000	4.67	5.7	2.5
18	1.001	3.44	7.2	3.8
19	1.001	5.68	4.4	12.8
20	1.001	6.49	4.7	6.7

lysed samples (6.7%) with the average value of tea, the ash contents were in the same order. Despite this, due to the wide variability in the ash values in our samples, 65% of those outweighed the average value of tea and the remaining 35% were of much lower values, in particular the group of flavoured infusions and the Rooibos.

Macroelements

The results given in Tab. 4 show that the concentration of the elements analysed in this study varied among the samples, both for the dry material as for the herbal infusion. Regarding the macroelements, there were two remarkable, K and Ca, with mean values of 21.65 mg and 16.33 mg per bag respectively. In almost all the samples the profile was K > Ca > Mg > Na. A similar profile was obtained by MALIK et al. [13] for mate, rooibos, honeybush and chamomile, and by GALLAHER et al. [14] for dandelion leaf, echinacea herb, peppermint leaf, red raspberry leaf, red clover leaf, European blueberry leaf and Siberian ginseng root. Exceptionally, Na was higher in samples 7, 13 and 6. The last sample was rooibos, and the others were digestive infusions.

The total concentration of macroelements varied between samples, and a relationship between the macroelement concentration and the composition of the dry material could not be established. It must be taken into account that each herbal infusion contained a variety of plant spe-

Tab. 4. Macroelements in raw materials and herbal infusions.

Sample	Ca		Mg		Na		K	
	Raw material [g·kg ⁻¹]	Infusion [mg·ml ⁻¹]	Raw material [g·kg ⁻¹]	Infusion [mg·ml ⁻¹]	Raw material [g·kg ⁻¹]	Infusion [mg·ml ⁻¹]	Raw material [g·kg ⁻¹]	Infusion [mg·ml ⁻¹]
1	14.0 ± 0.4	0.017 ± 0.001	2.5 ± 0.0	0.009 ± 0.001	1.2 ± 0.0	0.006 ± 0.000	13.0 ± 0.1	0.067 ± 0.002
2	14.0 ± 0.1	0.035 ± 0.002	5.6 ± 0.3	0.026 ± 0.001	1.7 ± 0.2	0.017 ± 0.001	18.1 ± 0.4	0.111 ± 0.006
3	11.0 ± 0.5	0.021 ± 0.002	2.8 ± 0.3	0.013 ± 0.001	1.1 ± 0.2	0.012 ± 0.002	13.6 ± 0.9	0.069 ± 0.000
4	12.2 ± 0.3	0.016 ± 0.002	2.7 ± 0.2	0.003 ± 0.002	2.7 ± 0.1	0.003 ± 0.001	16.4 ± 0.2	0.046 ± 0.005
5	6.4 ± 0.7	0.014 ± 0.001	1.8 ± 0.2	0.011 ± 0.002	1.3 ± 0.5	0.006 ± 0.003	9.5 ± 0.7	0.031 ± 0.005
6	2.0 ± 0.7	0.009 ± 0.009	0.6 ± 0.0	0.002 ± 0.001	2.5 ± 0.1	0.005 ± 0.002	3.3 ± 0.2	0.008 ± 0.002
7	9.7 ± 0.8	0.022 ± 0.003	2.6 ± 0.1	0.014 ± 0.001	4.9 ± 0.3	0.017 ± 0.002	12.8 ± 0.7	0.070 ± 0.008
8	15.9 ± 0.8	0.014 ± 0.003	3.5 ± 0.3	0.009 ± 0.002	0.5 ± 0.0	0.004 ± 0.001	14.2 ± 0.9	0.047 ± 0.004
9	10.1 ± 0.1	0.016 ± 0.002	2.5 ± 0.2	0.009 ± 0.003	0.8 ± 0.1	0.001 ± 0.001	11.8 ± 0.5	0.048 ± 0.004
10	6.4 ± 0.1	0.024 ± 0.004	2.8 ± 0.1	0.012 ± 0.001	1.0 ± 0.4	0.005 ± 0.002	13.4 ± 0.3	0.067 ± 0.009
11	7.9 ± 0.3	0.019 ± 0.002	3.4 ± 0.2	0.013 ± 0.001	1.3 ± 0.1	0.008 ± 0.001	16.7 ± 2.0	0.057 ± 0.003
12	7.4 ± 0.1	0.017 ± 0.001	3.3 ± 0.2	0.012 ± 0.001	1.8 ± 0.2	0.008 ± 0.000	11.6 ± 0.3	0.053 ± 0.013
13	11.4 ± 0.1	0.021 ± 0.002	3.8 ± 0.1	0.011 ± 0.001	5.7 ± 0.5	0.040 ± 0.001	17.8 ± 0.3	0.086 ± 0.006
14	16.2 ± 1.1	0.016 ± 0.001	3.9 ± 0.1	0.009 ± 0.001	0.7 ± 0.4	0.004 ± 0.001	14.4 ± 0.5	0.060 ± 0.003
15	3.3 ± 0.1	0.008 ± 0.001	0.8 ± 0.0	0.003 ± 0.002	0.3 ± 0.1	0.000 ± 0.001	4.9 ± 0.2	0.011 ± 0.000
16	2.3 ± 0.2	0.007 ± 0.002	0.6 ± 0.1	0.003 ± 0.001	0.2 ± 0.1	0.000 ± 0.001	4.1 ± 0.4	0.012 ± 0.001
17	5.5 ± 0.1	0.012 ± 0.001	1.1 ± 0.1	0.005 ± 0.002	0.5 ± 0.2	0.006 ± 0.01	4.6 ± 0.3	0.021 ± 0.001
18	8.1 ± 0.2	0.012 ± 0.002	3.1 ± 0.0	0.007 ± 0.001	1.5 ± 0.2	0.005 ± 0.000	10.1 ± 0.4	0.016 ± 0.001
19	15.1 ± 0.4	0.046 ± 0.003	5.4 ± 0.1	0.030 ± 0.001	1.7 ± 0.2	0.027 ± 0.002	29.3 ± 0.6	0.165 ± 0.007
20	11.8 ± 0.3	0.013 ± 0.001	3.5 ± 0.1	0.009 ± 0.000	2.1 ± 0.4	0.003 ± 0.002	9.7 ± 0.4	0.033 ± 0.004

cies, and also other factors could influence the results, such as effects of irrigation, fertilization, climate, etc.

The samples with the highest concentration of macroelements were samples 2 and 19. Samples 6, 15, 16 and 17 had the least concentration of macroelements, the three last samples belonging to flavoured infusions and sample 6 to rooibos. Sample 6 (rooibos) had a different profile than the other samples: Na > K > Mg > Ca. The concentrations of macroelements in the herbal infusions were similar to their contents in the dry material. The most abundant element in almost all samples was K and the profile of macroelements was maintained in the herbal infusions.

Na/K coefficient for the herbal infusions

Sodium and potassium are indispensable elements for the electrolyte balance in the human body and are associated with blood pressure. The Na/K coefficient determined from the values of the recommended daily amounts is 0.3 (600mg Na per day and 2000mg K per day) [26]. The values of Na/K coefficient for all the samples were between 0 (samples 15 and 16) to 0.64 (sample 6). All samples contained less sodium than potassium. The low value of Na/K ratio was due to the high concentration of potassium in most samples. Only samples 6 and 13 had a high value of this ratio (0.64 and 0.46, respectively).

Microelements

The major microelement was Fe, followed by Mn, Zn and finally Cu (Tab. 5). The same profile was determined by MALIK et al. [13], GALLAHER et al. [14], LOZAK et al. [15] and BASGEL et al. [18] for similar species of herbs as chamomile, rooibos and mate. Fe was the highest in sample 13 (1162.48 µg per bag), and it was also abundant in samples 4, 7, 8 and 13. The levels

of Fe in samples 4, 7 and 13 can be attributed to the contents chamomile, which contains high amounts of this element. Our results are consistent with the data on Fe in chamomile samples obtained by BASGEL et al. [18] and MALIK et al. [13], who detected $502 \text{ mg}\cdot\text{kg}^{-1}$ and $467 \pm 115 \text{ mg}\cdot\text{kg}^{-1}$, respectively. Mn was the highest in sample 2, which contained mate. According to the research of TENORIO et al. [19] and MALIK et al. [13], mate contains high amounts of this element.

The samples with least concentrations in microelements, similar to macroelements, were rooibos (sample 6) and flavoured infusions (samples 15, 16, 17 and 18). The profiles were again maintained in the herbal infusion, which is similar to results of several previous studies [14, 15–18].

Within all the elements studied, Ca was the highest macroelement detected and Fe the highest microelement. Our research showed that one cup (250ml) of these herbal infusions may provide up to 1.4% of recommended daily allowance (RDA) for Ca and 1.4% RDA for Fe [27]. Based on the RDA for adults living normal lifestyles, these herbal infusions may contribute to the daily uptake of elements to supplement a normal diet.

Comparison with tea

Due to the close relation between tea and herbal infusions, we have compared our data of herbal infusions with those provided by GALLAHER et al. [14] concerning minerals in the dry matter and infusion of *Camellia* species. In this comparison, the only significant macroelement difference was in Ca, which was much lower in the tea infusion ($0.0037 \pm 0.002 \text{ mg}\cdot\text{ml}^{-1}$). The rest of the parameters were within the same range of values, for both tea and herbs, and for their infusions. Regarding micro-

Tab. 5. Microelements in raw materials and herbal infusions.

Sample	Fe		Cu		Mn		Zn	
	Raw material [$\text{mg}\cdot\text{kg}^{-1}$]	Infusion [$\mu\text{g}\cdot\text{ml}^{-1}$]	Raw material [$\text{mg}\cdot\text{kg}^{-1}$]	Infusion [$\mu\text{g}\cdot\text{ml}^{-1}$]	Raw material [$\text{mg}\cdot\text{kg}^{-1}$]	Infusion [$\mu\text{g}\cdot\text{ml}^{-1}$]	Raw material [$\text{mg}\cdot\text{kg}^{-1}$]	Infusion [$\mu\text{g}\cdot\text{ml}^{-1}$]
1	133.8 ± 24.8	0.258 ± 0.030	20.3 ± 1.5	0.047 ± 0.008	47.8 ± 2.4	0.057 ± 0.2	30.8 ± 5.1	0.093 ± 0.006
2	211.0 ± 7.36	0.289 ± 0.017	15.0 ± 8.3	0.206 ± 0.028	430.6 ± 33.8	1.200 ± 0.075	51.1 ± 1.6	0.295 ± 0.046
3	202.3 ± 19.5	0.257 ± 0.066	11.0 ± 4.1	0.099 ± 0.038	65.5 ± 6.4	0.138 ± 0.001	43.4 ± 1.8	0.247 ± 0.043
4	331.3 ± 23.0	0.196 ± 0.093	7.7 ± 0.5	0.028 ± 0.006	64.4 ± 1.9	0.066 ± 0.009	44.6 ± 3.4	0.125 ± 0.016
5	122.3 ± 7.7	0.132 ± 0.028	2.0 ± 0.1	0.108 ± 0.050	153.2 ± 3.0	0.310 ± 0.006	37.7 ± 2.3	0.178 ± 0.033
6	83.4 ± 10.5	0.052 ± 0.020	7.7 ± 1.3	0.004 ± 0.002	77.9 ± 0.3	0.080 ± 0.012	17.4 ± 5.7	0.051 ± 0.013
7	519.5 ± 26.4	0.514 ± 0.026	6.7 ± 0.2	0.210 ± 0.171	64.6 ± 0.8	0.135 ± 0.004	29.8 ± 2.3	0.181 ± 0.012
8	572.2 ± 46.2	0.409 ± 0.043	15.1 ± 2.3	0.030 ± 0.011	77.5 ± 1.4	0.081 ± 0.006	39.6 ± 0.4	0.152 ± 0.015
9	294.1 ± 14.7	0.314 ± 0.038	10.9 ± 4.7	0.041 ± 0.006	48.5 ± 2.1	0.067 ± 0.004	36.1 ± 1.6	0.138 ± 0.039
10	218.0 ± 3.0	0.388 ± 0.025	16.3 ± 8.7	0.146 ± 0.098	194.3 ± 8.2	0.780 ± 0.014	33.2 ± 0.8	0.225 ± 0.024
11	303.1 ± 13.2	0.254 ± 0.001	11.0 ± 1.5	0.065 ± 0.029	55.4 ± 4.8	0.114 ± 0.003	34.4 ± 2.2	0.179 ± 0.034
12	203.1 ± 20.6	0.340 ± 0.011	13.2 ± 7.3	0.116 ± 0.033	51.0 ± 0.3	0.118 ± 0.005	30.3 ± 0.8	0.284 ± 0.006
13	775.0 ± 54.5	0.566 ± 0.039	9.9 ± 1.9	0.045 ± 0.009	75.3 ± 1.2	0.119 ± 0.005	27.7 ± 0.9	0.200 ± 0.010
14	333.9 ± 29.2	0.299 ± 0.041	8.6 ± 1.2	0.054 ± 0.031	61.1 ± 0.5	0.080 ± 0.009	30.0 ± 1.9	0.144 ± 0.018
15	89.2 ± 8.7	0.228 ± 0.010	3.6 ± 3.3	0.025 ± 0.019	39.5 ± 0.3	0.150 ± 0.009	12.1 ± 2.4	0.098 ± 0.009
16	84.5 ± 17.1	0.300 ± 0.006	3.4 ± 2.1	0.093 ± 0.058	22.0 ± 0.1	0.111 ± 0.006	20.7 ± 1.3	0.123 ± 0.000
17	61.8 ± 1.3	0.324 ± 0.048	3.9 ± 0.0	0.196 ± 0.003	29.2 ± 0.2	0.156 ± 0.006	13.1 ± 1.2	0.116 ± 0.009
18	82.2 ± 5.9	0.256 ± 0.013	3.2 ± 1.2	0.066 ± 0.003	161.1 ± 8.2	0.490 ± 0.004	21.0 ± 1.3	0.079 ± 0.009
19	258.9 ± 8.6	0.547 ± 0.039	7.7 ± 0.9	0.235 ± 0.021	82.4 ± 2.1	0.289 ± 0.009	36.6 ± 1.2	0.200 ± 0.057
20	279.7 ± 17.2	0.277 ± 0.001	5.8 ± 1.5	0.072 ± 0.004	304.2 ± 8.8	0.498 ± 0.047	25.2 ± 1.6	0.082 ± 0.007

Tab. 6. Correlation matrix of herbal infusion parameters.

	Density	pH	Ash	Ca		Mg		Na		K		Fe		Cu		Mn		Zn	
Density	1.000			DM	ER	DM	ER	DM	ER	DM	ER	DM	ER	DM	ER	DM	ER	DM	ER
pH		1.000																	
Ash			1.000																
Ca	DM			1.000															
	ER			-0.573	1.000														
Mg	DM			0.791	0.534	1.000													
	ER						1.000												
Na	DM							1.000											
	ER								1.000										
K	DM									1.000									
	ER										1.000								
Fe	DM											1.000							
	ER												1.000						
Cu	DM													1.000					
	ER														1.000				
Mn	DM															1.000			
	ER																1.000		
Zn	DM																	1.000	
	ER																		1.000

DM – dry material contained in a bag, ER – extraction rate.

elements, Mn level was much higher in tea ($1103 \pm 17,8 \text{ mg}\cdot\text{kg}^{-1}$) and its infusion ($1861 \pm 83 \text{ mg}\cdot\text{l}^{-1}$), being 10–15 times higher in the majority of samples. Sample 2 was the only that contained a high amount of Mn ($430.6 \text{ mg}\cdot\text{kg}^{-1}$), due to the presence of mate [19], but still did not reach half of the content in tea.

Extraction rates

The extraction rate of each element was calculated on the basis of the content of the element in the raw material and its concentration in the herbal infusion. Zn and in particular Cu were the most soluble elements reaching rates of 74.8% and 87.7% respectively, as shows Fig. 1. The least soluble was Fe (23.0%), which is in agreement with the results of GALLAHER et al. [14].

Statistical analysis

The correlation matrix of all the parameters analysed is presented in Tab. 6. The most significant correlations were observed between macro- and microelements. Also noteworthy is the direct relationship between pH and the ash, attributable to the low value of ash in flavoured infusions group, in which organic acids are added to enhance the flavour.

Most of the relationships between the mineral elements were positive, so direct correlations were observed between Ca and Mg of the dry material used to make the herbal infusions, and also with K, Fe, Cu and Zn. K in turn claimed direct correlations with Fe, Cu, and significantly with Zn ($p < 0.0001$) contents of the dry material. Among the microelements, the strongest relationship was between Mn and Zn.

Keeping in view the extraction rate, a negative correlation between Ca of the bag/Ca extraction rate was noteworthy, indicating that the higher Ca content was in the plant product, the less it will be extracted to the infusion. A similar pattern was observed between Fe content of the dry material and Fe extraction

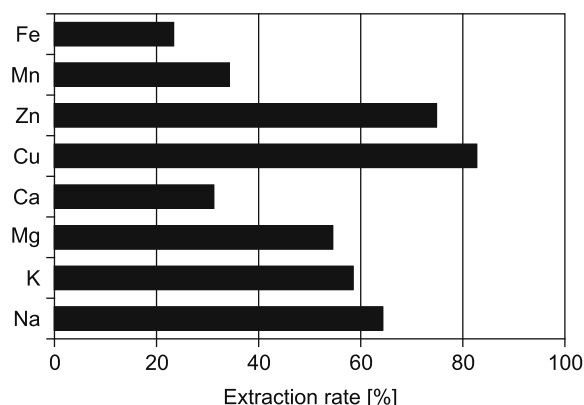


Fig. 1. Extraction rates of herbal infusions.

rate. On the other hand, there was a highly positive correlation between K extraction rate/K of the dry material, and a remarkable direct relationship was also observed between the extraction rates of Fe-Mn and Cu-Mn.

Regarding the cluster analysis, for the macroelements (Fig. 2), we could determine that, in cluster 2, where samples 2 (Esbel tea multiinfusion) and 19 (digestive triple concentrated) are included, there is a high amount of Mg and K, higher than all the other samples. In cluster 3 (sample 6, rooibos and sample 13, digestive infusion), there is a high amount of Na. In cluster 4 containing samples 5 (sleep well infusion), 6 (rooibos), 15, 16 and 17 (flavoured infusions), the values of K, Ca and Mg are below average, thus we could say that these are samples with a poor concentration of macroelements. For cluster 1 containing the majority of samples, there are no significant characteristics.

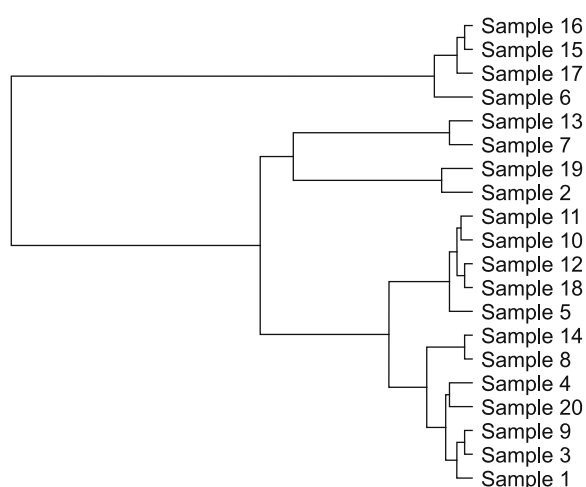


Fig. 2. Hierarchical cluster analysis – dendrogram for macroelements.

For microelements and pH (Fig. 3), we can determine that, in cluster 1 formed by almost half of the samples, Cu and Fe are above the overall average. In cluster 3 formed by practically the other half of the samples, Fe, Zn and Cu are below the overall average, as well as pH.

CONCLUSIONS

A wide variability was determined, both in dry material and in herbal infusions, for concentration of minerals. This was due to the wide variety of herb species that the samples were composed of. The profile of mineral elements was similar in most samples and remained in the herbal infusions. K and Ca were the predominant macroelements, and Fe and Mn were the predominant microelements. Only sample 6 (rooibos) presented a different profile with a high concentration of Na. The mineral composition of these products was similar to tea. The extraction rates were uniform for all the samples: Fe was the least soluble, while Cu, Zn and Na were the most soluble. The reason for the different solubility of individual mineral elements could not be established. The group classified as digestive infusions were the only samples that showed higher similarity between each other. Based on the results of cluster analysis, samples 5, 6, 15, 16 and 17 could be considered as containing very poor amounts of essential minerals. Sample 2, for both macro- and microelements, was excluded from the majority of groups and so it was very different from the rest of the samples. Overall, the study showed that the herbal infusions could be a valuable source of certain mineral elements in

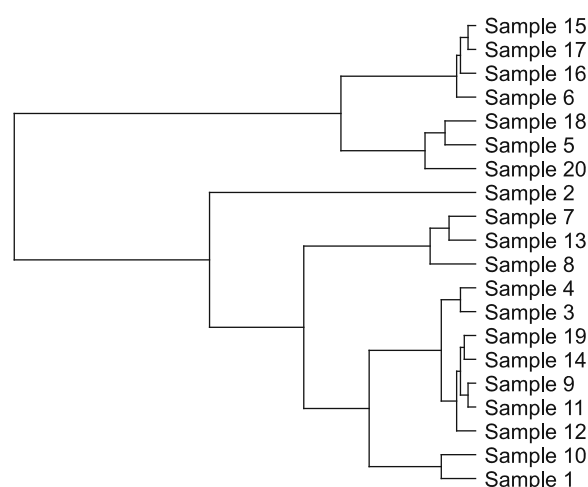


Fig. 3. Hierarchical cluster analysis – dendrogram for microelements.

the human diet. This study represents a contribution to the knowledge of the content of minerals in herbs and their transfer to herbal infusions.

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