Food Chemistry 130 (2012) 702–709

Contents lists available at ScienceDirect

Food Chemistry

journal homepage: www.elsevier.com/locate/foodchem

Intra- and interspecific mineral composition variability of commercial instant coffees and coffee substitutes: Contribution to mineral intake

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A R T I C L E I N F O

Article history:
Received 9 March 2011
Received in revised form 14 June 2011
Accepted 26 July 2011
Available online 3 August 2011

Keywords:
Soluble coffees
Coffee substitutes
Coffee surrogates
Minerals
High-resolution continuum source atomic absorption spectrometry

A B S T R A C T

The present paper reports the amount and estimated daily mineral intake of nine elements (Ca, Mg, K, Na, P, Fe, Mn, Cr and Ni) in commercial instant coffees and coffee substitutes ($n = 49$). Elements were quantified by high-resolution continuum source flame (HR-CS-FAAS) and graphite furnace (HR-CS-GFAAS) atomic absorption spectrometry, while phosphorous was evaluated by a standard vanadomolybdophosphoric acid colorimetric method.

Instant coffees and coffee substitutes are rich in K, Mg and P (>100 mg/100 g dw), contain Na, Ca and Fe in moderate amounts (>1 mg/100 g), and trace levels of Cr and Ni. Among the samples analysed, plain instant coffees are richer in minerals ($p < 0.001$), except for Na and Cr. Blends of coffee substitutes (barley, malt, chicory and rye) with coffee (20–66%) present intermediate amounts, while lower quantities are found in substitutes without coffee, particularly in barley.

From a nutritional point of view the results indicate that the mean ingestion of two instant beverages per day (total of 4 g instant powder), either with or without coffee, cannot be regarded as important sources of minerals to the human diet, although providing a supplementation of some minerals, particularly Mg and Mn in instant coffees. Additionally, and for authentication purposes, the correlations observed between some elements and the coffee percentage in the blends, with particular significance for Mg amounts, provides a potential tool for the estimation of coffee in substitute blends.

1. Introduction

Coffee has a relevant importance in human society for at least 1200 years (Muriel & Arauz, 2010) and is amongst the most economically important agricultural products in international trade, particularly in developing countries, representing the main source of income for millions of people worldwide (Pendergrast, 2009). Coffee fills approximately 400 billion cups a year and is estimated to be regularly consumed by more than 40 percent of the world's population (Fitter & Kaplinsky, 2001). Its widespread consumption is due primarily to the sensorial characteristics achieved, followed by a variety of factors of both social and economic nature. Although some negative effects have been suggested over decades, including addiction, reproductive and cardiovascular adverse effects, increased susceptibility to certain cancers, etc. (Higdon & Frei, 2006). Recent investigations increasingly suggest that regular coffee consumption (about 2–4 cups per day) is associated with substantially lower mortality risk, colorectal cancer development, hepatic injury and cirrhosis, as well as degenerative, progressive and chronic diseases (including Alzheimer's and Parkinson's disease, type 2 diabetes and coronary heart disease) (Alves, Casal, & Oliveira, 2009; Debry, 1994; Higdon & Frei, 2006; Milon, Guidoux, & Antonioli, 1988, chap. 4; Nkondjock, 2009; Tan, Fook-Chong, Lum, Chai, Chung, et al., 2003).

Coffee beverages are usually prepared with *arabica* beans, plain or blended with *robusta* beans, the two most important commercial coffee species. Coffee is available to consumers as roasted grain, ground or soluble/instant powder. Instant coffee is more practical and "clean" to prepare, which is an important factor in consumer preferences (Geel, Kinnear, & Kock, 2005). In the production of instant coffee, *robusta* coffee is preferred since, in addition to its economical attractiveness, the extraction yield of soluble solids in the manufacturing process is superior to *arabica* coffee (Clarke & Macrae, 1987, chap. 6). According to the European Coffee

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doi:10.1016/j.foodchem.2011.07.113

Report (2009), soluble coffee exports and imports to and from non-European destinations represent currently around 39 and 41 thousand tons per year in Europe, respectively. Also according to this report, the soluble coffee consumption in Europe has been relatively stable in the last few years, being particularly important in Eastern Europe and in the UK.

Coffee substitutes or surrogates are prepared from roasted vegetables, being used to produce a product that, in the presence of hot water, results in a drink similar to coffee. People look increasingly for these products due their inferior or absent caffeine content and because they are cheaper than coffee. They can be commercialised in the form of roasted cereal or, more frequently, as soluble powders based on mixture of several cereals, often with some percentage of soluble coffee. In Portugal, they are based mostly on roasted chicory and some cereals, namely barley, rye and their malts, thus contributing for energy and nutritional intake, with a large amount of important bioactive substances, essential to the proper functioning of the body (Milon et al., 1988, chap. 4).

Food minerals play an important role in human nutrition. On the basis of the relative amounts in the human body and quantities needed per day (more or less that 100 mg/day), essential minerals are usually classified into macro and microelements (Nabrzyski, 2007, chap. 5). These minerals are critical for the growth and formation of bones, synthesis of vitamins, enzymes and hormones, as well as for the healthy functioning of the nervous system, blood circulation and cellular integrity, if maintained at required levels (McDowell, 2003).

Several reports regarding the mineral composition of instant coffees are found in literature. Gillies and Birkbeck (1983) estimated the daily mineral intake by ingestion of instant coffee samples using atomic absorption spectrometry. In 1998, a market survey was performed in the UK on the concentrations of metals and other elements in selected snack and convenience foods, including instant coffee samples (MAFF, 1998). The levels of seventeen elements were determined in Brazilian soluble coffees by inductively coupled plasma atomic emission spectrometry (Santos and de Oliveira, 2001) while Grembecka, Malinowska, and Szefer (2007) analysed fourteen elements in coffee samples marketed in Poland, including some instant coffee ones. Minor surveys were also performed in five brands of instant coffee powder available in the Indian market by atomic absorption spectrometry (Suseela, Bhalke, Kumar, Tripathi, & Sastry, 2001), in eight brands of soluble/instant coffee commercialised in Mexico and United States by neutron activation analysis (Vega-Carrillo, Iskander, & Manzanares-Acuna, 2002), and two samples from Pakistan (Zaidi, Fatima, Arif, & Qureshi, 2006) evaluated by the same methodology.

Although coffee substitutes should theoretically be also regarded as good sources of some minerals, only one study (Suseela et al., 2001) reported the mineral content for chicory-blended coffee ($n = 4$). Furthermore, only a limited number of studies were published concerning the application of a promising technique very recently developed, high-resolution continuum source atomic absorption spectrometry (with flame – HR-CS-FAAS- or graphite furnace detection – HR-CS-GFAAS), in food matrices, namely in yogurt, wine, beans, grain products and mineral waters (Welz et al., 2010).

The aim of this work was (i) to evaluate the content of some minerals in instant coffee-based and coffee substitutes samples, (ii) to estimate the daily mineral intake promoted by the consumption of theses beverages in order to study their nutritional significance, and (iii) to provide an analytical tool for the estimation of coffee in instant coffee substitute blends. This study also included the characterisation of the analytical performance of high-resolution continuum source atomic absorption spectrometry when applied to instant coffees and coffee substitutes.

2. Materials and methods

2.1. Reagents

A Milli-Q water purification system (Millipore, Molsheim, France) was used to obtain ultrapure water (18.2 MΩ cm^{-1} resistivity) for quantitative analysis. Standard solutions of Ca, Mg, Fe, Mn, Cr and Ni were prepared from the correspondent 1000 mg/l stock solutions (Panreac, Barcelona, Spain). K, Na and P standard solutions were obtained by potassium chloride (99.5%, Riedel-de Haën, Seelze, Germany), sodium chloride (99.8%, Riedel-de Haën, Seelze, Germany) and potassium dihydrogen phosphate (99.5%, Riedel-de Haën, Seelze, Germany) dissolution in ultrapure water, respectively. Standards and samples were acidified with 1% (v/v) suprapur hydrochloric (for HR-CS-FAAS analyses, Sigma–Aldrich, Steinheim, Germany) or nitric acid (for HR-CS-GFAAS determinations, Sigma–Aldrich, Steinheim, Germany), except for P analysis. For quantification by HR-CS-FAAS, cesium chloride 1% (w/v; Sigma–Aldrich, Steinheim, Germany) was used as ionisation chemical suppressor. For Cr and Ni analyses by HR-CS-GFAAS, the applied matrix modifier was 0.05% (v/v) $Mg(NO_3)_2 \cdot 6H_2O$ (p.a; Panreac, Barcelona, Spain).

The colour development reagent for P determination was prepared as described in 4500-P standard (Greenberg, Clesceri, & Eaton, 1992) by the addition of ammonium molybdate tetrahydrated (99.0%, Merck, Darmstadt, Germany) and ammonium

Table 1
Identification and labelled composition of the samples under study.

Sample	Composition (%)				
	Barley	Chicory	Malt	Rye	Coffee
Instant coffees					
1–8	–	–	–	–	100
Mixtures with coffee					
9	–	50	–	–	50
10	–	50	–	–	50
11	–	60	–	–	40
12	–	60	–	–	40
13	–	60	–	–	40
14	–	66.7	–	–	33.3
15	–	80	–	–	20
16	55	25	–	–	20
17	x	x	–	–	20
18	x	x	–	–	20
19	x	x	–	–	20
20	55	25	–	–	20
21	x	x	–	–	20
22	x	x	–	–	20
23	55	25	–	–	20
24	55	25	–	–	20
25	55	25	–	–	20
Mixtures without coffee					
26	40	x	30	5	–
27	35	25	35	5	–
28	35	25	35	5	–
29	35	25	35	5	–
30	35	25	35	5	–
31	35	25	35	5	–
32	35	25	35	5	–
33	x	x	x	x	–
34	x	x	x	x	–
35	x	x	x	x	–
36	x	x	x	x	–
37	x	x	–	x	–
38	x	x	–	x	–
Chicory					
39	–	100	–	–	–
Barley					
40–49	100	–	–	–	–

x: no detail given on the amounts.