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Transition rates of selected metals determined in various types of teas (*Camellia sinensis* L. Kuntze) and herbal/fruit infusions

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Sambucus nigra
Tea
Aluminium
Arsenic
Cadmium
Copper
Lead
Mercury

A B S T R A C T

Teas and raw materials used as ingredients of herbal and fruit infusions (HFI) were analysed by means of ICP-MS for their content of aluminium, arsenic, cadmium, copper, lead and mercury in the dry product and in the infusion. Samples of tea (*Camellia sinensis* L. Kuntze) were selected to include different origins, types (black, green), leaf grades (whole leaf, broken, fannings, dust) and manufacturing techniques (orthodox, "crush, tear, curl"). The selected HFI raw materials (chamomile, elderberries, fennel, hibiscus, mate, peppermint, rooibos and rose hip) cover the most important matrices (flower, fruit, seed, herb, leaf) and reflect the economic significance of these HFI materials in trade. Infusions were prepared under standardised conditions representing typical household brewing.

Transition rates for the investigated metals vary significantly but are mostly well below 100%. We propose default transition rates for metals to avoid overestimation of exposure levels from tea/HFI consumption.

1. Introduction

Tea (*Camellia sinensis* L. Kuntze) is the second most widely consumed beverage after water, with 4.6 million tons consumed worldwide in 2013 (ITC, 2014). An overview on per capita tea consumption for the EU population is given in Table 1 (German Tea Association/Deutscher Teeverband e.V., 2015).

Apart from its hydration properties, the health benefits of tea have also been attributed to its flavonoid polyphenol content, which accounts for approximately 30% of the dry weight of the tea leaf. Epidemiological studies have associated tea consumption with the prevention of several chronic and degenerative diseases including cancer.

HFI are prepared from of dried plants or parts of plants (e.g. fruits, flowers, leaves, roots, bark) that do not originate from the tea bush, i.e. *Camellia sinensis* L. Kuntze. They are intended for use by brewing with freshly boiling water. In Europe, more than 400 different plant parts are used as ingredients for the preparation of HFI (THIE, 2015). Single ingredient products as well as blends of different herbs and/or fruits are available on the market.

In recent years, HFI have become increasingly popular throughout Europe as part of a well-balanced diet: they contain no sugar, have almost no calories and offer a vast range of different flavours. HFI ingredients are subject to growing scientific interest due to their richness in polyphenols and other functional constituents. Many of them have therefore been studied with respect to their antioxidative properties (Joubert, Gelderblom, Louw, & de Beer,

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Table 1
EU inhabitants with highest per capita tea consumption (German Tea Association).

	3 year-average consumption 2012–2014 L/year/per head
UK	201
Ireland	173
Poland	94
NL	53
Sweden	34
Austria	32
Czech Rep.	32
Germany	28
Denmark	27

Reference:
German Tea Association/Deutscher Teeverband e.V., "Hitliste der Teetrinker" of 28th October, 2015.
Figures are based on:

- London "Annual Bulletin of Statistics 2015".
- EUROSTAT, Brussels.
- DeStatis, Wiesbaden.
- German Tea Association, Hamburg "membership survey 2015″.

Table 2
Sample information.

ID	HFI	Botanical name	Matrix type	
CAM	Camomile FC	*Matricaria recutita* L.	Herb	
ELD	Elderberries FC	*Sambucus nigra* L	Fruit	
FEN	Fennel FC	*Foeniculum vulgare* Mill.	Volatile oil rich	
HIB	Hibiscus FC	*Hibiscus sabdariffa* L.	Acidic	
MAT	Mate FC	*Ilex paraguariensis* A. St.-Hil.	Roasted/ smoked	
PEP	Peppermint FC	*Mentha* × *piperita* L.	Volatile oil rich	
ROO	Rooibos FC	*Aspalathus linearis* (Burm. f.) R. Dahlgr.	Herb	
ROS	Rose hip FC	*Rosa canina* L.	Fruit	
ID	Teas	Leaf grade	Origin	Type of manufacturing
BLT1	Black tea	Leaf; OP	Vietnam	–
BLT2	Black tea	Broken leaf; BOP	China	Orthodox
BLT3	Black tea	Broken leaf; FBOP	Vietnam	Orthodox
BLT4	Black tea	Broken leaf; BOP	India, Assam	Orthodox
BLT5	Black tea	Fannings	China	Orthodox
BLT6	Black tea	Fannings	China	CTC
BLT7	Black tea	Fannings	South India	CTC
BLT8	Black tea	Dust	South India	CTC
BLT9	Black tea	Dust	Java	CTC
BLT10	Black tea	Dust	Rwanda	CTC
BLT11	Green tea	Leaf	China	Orthodox
BLT12	Green tea	Leaf	China	Orthodox
BLT13	Green tea	Fannings	Vietnam	Orthodox
BLT14	Green tea	Fannings	China	Orthodox
BLT15	Green tea	Fannings	China	CTC

2008). Tea and HFI also offer a healthy choice of beverages for the 2 L of fluid that make the minimum recommended daily intake for an adult (EFSA, 2010).

Various concentrations of the selected elements (Al, As, Cd, Cu, Hg, Pb) may be found in tea or HFI ingredients due to their natural occurrence in soil and water or to emissions from human activities, such as mining, farming (mineral fertilisers) or industrial production. Given the different physicochemical properties of these elements it is necessary to take their specific transition rates into consideration in order to make a reliable assessment of potential consumer exposure as a result of tea or HFI consumption.

Most of the levels of the selected elements reported for tea in the literature refer to the dried raw materials and rarely to the infusions. An extensive review article on "Trace elements in tea leaves, made tea and tea infusion" (Karak & Bhagat, 2010) summarises data published in the literature over the last 50 years, including aluminium, arsenic, cadmium, copper and lead in tea under various conditions.

A product group that covers a broad spectrum of different plant materials, the HFI have not been studied as extensively as tea and there is therefore less data available in the literature. One important survey based on 109 herbs traded in the EU including tea and most of the herbs investigated in our study was published by Gasser and co-authors who compiled data for lead and cadmium obtained from 7100 samples and for mercury from 2500 samples and calculated 90th percentiles (Gasser, Klier, Kühn, & Steinhoff, 2009). The Canadian Food Inspection Agency conducted a survey for the presence of metals in tea (black, green, oolong, white) and blends of HFI (CFIA, 2010). This study covers both tea and HFI, determining relevant metals in the dry products by means of the same analytical protocol. It did not, however, investigate the content of metals in the infusions of teas and HFI.

The aim of our study was to determine the levels of aluminium, arsenic, cadmium, copper, lead and mercury in different types of tea (*Camellia sinensis* L. Kuntze), in HFI raw materials and in the respective infusions in order to establish transition rates. The elements were selected on the basis of their potential health effects. Efforts were made to select tea and HFI samples which contained higher levels of the metals of interest, ensuring detectable metal levels in the infusions. The infusion procedure was performed under standardised conditions and was designed to reflect typical conditions of household brewing.

2. Material and methods

2.1. Sampling

Tea samples (*Camellia sinensis* L. Kuntze) were selected to cover different origins, main types (black, green), typically traded leaf grades (whole leaf, broken, fannings, dust), as well as the predominant manufacturing techniques (orthodox and "crush, tear, curl" (CTC)) (refer to Table 2 for details of the samples). HFI ingredients were selected to represent the most important matrices (refer to Table 2) and the economic significance of the HFI material in trade. All HFI samples were fine cuts (FC), i.e. with a particle size of 0.2–6 mm. All samples analysed in this study were provided by companies organised under the roof of the association Tea & Herbal Infusions Europe (THIE, formerly known as European Tea Committee (ETC) and European Herbal Infusions Association (EHIA)). The samples do not represent consumer ready products but are raw materials offered to the companies from suppliers all over the world. The criterion for the sample selection was a possibly high content in the metals of interest.

2.2. Sample preparation

All samples were analysed in duplicate and two independent infusions were prepared. All of the chemicals used were of