Preparing the coffee drink through coffee pod machines: Do we drink aluminum?

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ABSTRACT

1. Introduction

Coffee is an important raw material in the global economy, becoming one of the most valuable products in our daily life. In fact, coffee drink is one of the most consumed and appreciated beverages in the world due to its organoleptic properties (odor and taste), and, mainly, for presenting potential effects on human health, such as antioxidant (Espinelli Junior, Da Silva, Bastos, Furlong & Carapelli, 2020; Verzelloni, Tagliazucchi, Del Rio, Calani & Conte, 2011), and physiological and psychological properties, with the stimulating effect being the most desired to improve the ability to concentrate, increase body energy, as well as reducing drowsiness and tiredness (Lima, Pereira, Abrahão, Duarte & Paula, 2010; Esquivel & Jiménez, 2012).

The roasted coffee bean has a very complex chemical composition, and it is estimated there are more than 2000 components - such as caffeine, minerals, phenolic compounds, amino acids, diterpenes, chlorogenic acids, sterols, β-carbolines, among many others - some of these responsible for positively interfering with cognitive and psychomotor performance, as well as delaying the development of certain diseases, including type II diabetes, asthma, alcoholic cirrhosis and some types of cancer (Espinelli Junior et al., 2020; Alves, Casal & Oliveira, 2009).

Besides organic compounds, more than 30 different elements can be found in green, roasted, ground coffees and infusions. These elements can be divided into three groups: macronutrients, micronutrients, and trace elements. Some of the trace elements, for example, aluminum, present in coffee (Koch, Pougnet & Villiers, 1989; Santos & Oliveira, 2001) or its infusions at excessive levels, can be toxic to health (Santos &

Oliveira, 2001; Exley, 2016) and therefore the concentrations of these elements in the final product and during coffee production must be strictly controlled to verify information about exposure to these elements.

The launch of the coffee capsule segment gave rise to innovation and sophistication associated with this product, changing the habits of the consumers, and also the coffee taste. The high amount of coffee flavors offered in capsules aroused the curiosity of consumers to try more than 25 different flavors grouped into aromatic families, intensities, and varieties (Nespresso, 2018). The search for quality products, fast preparation, and mono portions, which provide a differentiated experience, transformed this coffee segment into one of the greatest growth potentials in the Brazilian coffee market, and worldwide (ABIC, 2019).

As it is a natural product with beneficial and protective actions, at first, moderate coffee consumption does not, in general, seem to be contraindicated (Alves, Casal & Oliveira, 2009). However, in view of preparation for consumption under conditions of high temperature and pressure (up to 19 bar, in fact, the highest in the market) (Nespresso, 2019) submitted by home espresso machines, and also due to the fact that the product packaging can also contribute to the contamination and introduction of elemental impurities, the hypothesis of this work arises that such conditions may foster transfer of aluminum from metallic seals to coffee drink, once these seals are perforated by the machine during the coffee extraction (Pohl, Stelmach, Welna & Szymczycha-Madej, 2012; Vega-Carrillo, Iskander & Manzanares-Acuna, 2002). To this end, the presence and magnitude of aluminum when the coffee drink is prepared using coffee pod machines are evaluated in this work through three different samples, including capsule seals, coffee powder, and the own coffee drink using the technique of ICP-MS (Inductively Coupled Plasma Mass Spectrometry), such as the evaluation of the parameters aimed at the optimization of the sample preparation conditions.

2. Experimental

The coffee capsules were acquired in a local market (Nespresso stores). The coffee drink (Arpeggio flavor) was prepared along this work using the Nespresso® *Essenza Mini* machine, equipped with a unique extraction system that guarantees pressure up to 19 bar and prepared as espresso (40 mL per cup). Deionized water was used to prepare the coffee drink. Subsequently, three kinds of samples (capsule seals, coffee powder and coffee drink) were treated differently using a microwave-assisted acid decomposition process and five types of diluted samples were analysed by ICP-MS: unused metallic seals (pre) and those perforated after coffee extraction (post), unused coffee powder (pre) and extracted ones (post) and, finally, a pool of coffee drink . For quality control purposes, the method for microwave decomposition of coffee powder was applied to the certified reference material (SRM 1568a rice flour) for trueness check. For coffee drink samples the standard addition method was used (before being subject to a microwave-assisted acid decomposition process) to construct the analytical curve and to validate the method. For capsule seals, several sample preparation procedures were evaluated and the most representative microwave-assisted sample decomposition protocol (results statistically identical at the 99.5% confidence level) were applied. Figure 1 illustrates the workflow with the general steps of the experimental procedure.

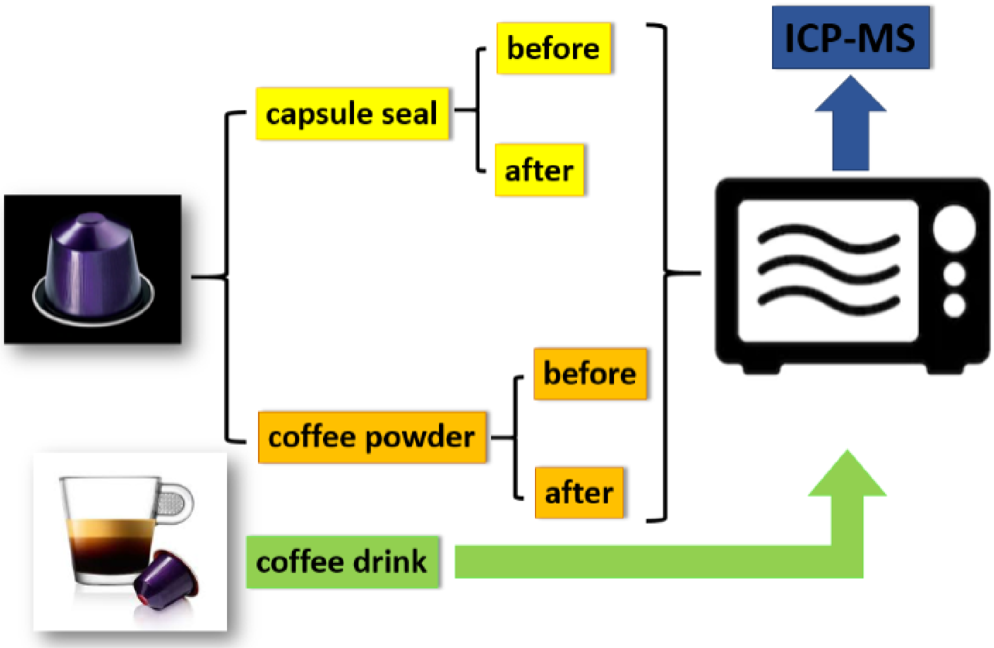

Figure 1. General outline of the experimental workflow to evaluate the aluminum concentration in the coffee powder, capsule seal, and coffee drink, so as to get insight into the aluminum sources.

3. Results and discussion

Table 1 summarizes all the aluminum concentrations determined in the coffee-related samples evaluated through this work. In fact, the highest aluminum content (*ca.* 80 %) is found in the metallic seal of the capsules, and this sample is contributing to the incorporation of *ca.* 0.001% aluminum in the powder after coffee drink preparation through the coffee pod machine. However, it is curious that despite the high aluminum concentration in the capsule seal, only 0.46 mg kg^{-1} of aluminum was found in the coffee beverage. A possible explanation for this fact is that coffee ground is adsorbing most of the leached aluminum from the capsule seal during coffee drink preparation, thus, resulting in low aluminum concentration in the coffee infusion. Our results corroborate this hypothesis, since an increase of *ca.* 6 mg kg^{-1} of aluminum is observed in the coffee grounds after beverage preparation through the coffee machine, thereby, suggesting that coffee ground is acting as a natural adsorbent. In fact, coffee powder waste has been extensively employed as a biosorbent for removing several contaminants from aqueous media, including toxic metals (Cherdchoo, Nithettham, Charoenpanich, 2019; Alvarez, Pastrana, Lagos & Lozada, 2018; Babu, Reddy, Kumar, Ravindhranath & Mohan, 2018; Anastopoulos, Karamesouti, Mitropoulos & Kyzas, 2017).

Table 1. Al concentrations in the three types of samples as determined by ICP-MS and percentage leached from the metallic seals to coffee powder, and coffee drink.

Samples[1]	**Metallic seals (n=4)**		**Coffee powder (n=3)**		**Coffee drink[2] (n=10)**
Portion	Pre	Post	Pre	Post	Post
Concentration	(80±2.5)[3]	(79.4±1.1)[3]	(2.5±0.9)[4]	(8.5±1)[4]	(0.46±0.08)[5]
Leachate (%)	---		(0.001)		(7.67)

[1]All samples came from the same batch; [2]Prepared without cleaning, as usually done by the consumers; [3]Values as % (m/m); [4]Values as mg kg^{-1}; [5]Values as mg L^{-1}.

Additionally, based on the *Agense Française de Securité Sanitaire des Aliments*, the packaging and utensils marketed for food storage are usually responsible for the migration from 4 to 12 mg of the metal per kg of food. In fact, the value found *ca*. 6 mg kg^{-1} is inside this range. The Environmental Protection Agency (EPA) has recommended a secondary maximum contaminant level (SMCL) of 0.05 to 0.2 mg L^{-1} of aluminum in drinking water, which is significantly lower than the aluminum concentration found in the coffee drink (*ca*. 0.46 mg L^{-1}). However, and considering espresso coffee, it is really difficult for one adult to drink one liter of this beverage per day. Taken into account the recommendation from the European Food Safety Authority (EFSA), the range of weekly intake of aluminum in adults ranges from 0.2 to 1.5 mg/kg bw/per week. Considering our results in the coffee drink (*ca*. 460 µg L^{-1}), and a maximum amount of 5 cups of espresso/day (40 mL each), this represents 91.8 µg Al/day. By taking an adult weight of 70 kg, the aluminum content is then 1.31 µg/kg bw/day, being this result far from the range preconized by EFSA. It is interesting to note that all data refer to the total amount of aluminum, without considering the percentage of bioaccessibility. In fact, the bioaccessible pools of aluminum in the body from coffee drink prepared from coffee pod machines may be significantly lower than the total aluminum content in the beverage.

In addition to this test, in order to demonstrate that, in fact, there is aluminum leaching from the capsule to the drink consumed, the coffee drink prepared at high pressure by the coffee machine was analyzed along that obtained by the conventional filtration system (at environmental pressure). The contents of aluminum of the drinks prepared by filtration and coffee machine were 407 ± 7 and 459 ± 8 μg L^{-1} Al, respectively. This result indicates an increase of *ca*. 13 % of the aluminum content when the coffee is prepared with a coffee pod machine against that of the filtration system. This difference in aluminum concentration in the beverage could be, in fact, due to the high pressure used by the Nespresso machine (19 bar) for coffee drink preparation, providing a better extraction, not only for those organoleptic organic compounds but also for unwanted aluminum, as quantified through ICP-MS.

4. Conclusions

The main objective of this work consisted of the development of accurate methodologies for sample decomposition and quantification of coffee-borne aluminum when the coffee drink is prepared through coffee pod machines. It was clear that the coffee drink prepared through these machines, at high pressures, contributes to the increase of aluminum in the beverage (*ca*. 13%), compared to that from conventional filtration systems at environmental pressure. Although the capsule seals are a great source of aluminum, and the process for coffee drink preparation through coffee machines damage such seals, the leaching of aluminum from the seal to coffee drink is only marginal, acting the particles of the coffee powder as natural sorbents for aluminum. From our results, and their comparison with those preconized by some food and environmental protection agencies, it is easy to rationalize that a daily normal consumption of coffee drink (*ca*. 5 cups of espresso/day) prepared from these machines does not represent a serious health risk of aluminum contamination by coffee consumers.

Anyway, the reuse of coffee powder as recommended in a diversity of propaganda is of great concern, once the increase of aluminum content is *ca*. 3.5 times higher in the power after coffee drink preparation by coffee pod machines, and thus this potential recycling strategy should be discouraged.