



Assessment of cadmium and lead in commercial coconut water and industrialized coconut milk employing HR-CS GF AAS



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ABSTRACT

In this work, an analytical method for the determination of Cd and Pb in natural coconut water samples, industrialized coconut water samples and coconut milk using high-resolution continuum source graphite furnace atomic absorption spectrometry (HR-CS GF AAS), after minimum treatment of the sample was developed. The analytical method was applied to 46 samples collected in Salvador, Bahia (Brazil). The ranges of concentrations obtained were: 0.42–18.72 $\mu\text{g L}^{-1}$ Cd and < 0.70–36.32 $\mu\text{g L}^{-1}$ Pb for natural coconut water samples ($n = 14$); < 0.06–1.49 $\mu\text{g L}^{-1}$ Cd and 6.57–29.02 $\mu\text{g L}^{-1}$ Pb for industrialized water coconut samples ($n = 16$); and < 0.10–5.93 ng g^{-1} Cd and < 0.85–22.41 ng g^{-1} Pb for coconut milk samples ($n = 16$). For all samples, Cd and Pb concentrations were below the maximum tolerated values recommended by Brazilian Health Surveillance Agency (Agência Nacional de Vigilância Sanitária, ANVISA).

1. Introduction

Coconut water and coconut milk are products extracted from coconut fruit (*Cocos nucifera* L.). Coconut water corresponds to 25% of fruit weight, and is composed of 93% water and 5% sugars, vitamins, minerals and proteins. The water is an alternative beverage, healthier than many soft drinks, since it has low levels of carbohydrates and fats (Carvalho, Pinheiro, Pereira, Borges & Magalhães, 2012; Froehlich, 2015). Coconut milk is defined as an emulsion extracted from coconut pulp, comprising (in % w w⁻¹): 54.1 water, 32.2 fat, 4.4 protein and 8.3 carbohydrate (Saikhwan et al., 2015). Although these foods are consumed widely in many countries, few studies have been performed to evaluate the presence of potentially toxic elements in these matrices, such as cadmium and lead.

In recent years, several studies have evaluated contamination of foods with Cd and Pb, due to their harmful effects. In Brazil, the Brazilian National Health Surveillance Agency (Agência Nacional de Vigilância Sanitária, ANVISA) regulates maximum values for toxic elements in foods (ANVISA, 2013).

Cadmium can be obtained as a by-product from zinc and lead ores (EFSA, 2009). In the human body, this element can damage most cells, blocking cell respiration via essential enzyme systems. Cd bioaccumulates in the lungs, spleen, endocrine glands, liver and kidneys (Andresen & Küpper, 2013; Wu, Li, Chen, Zheng, & Hou, 2012). Pb also affects

different organs and biological systems in humans, due to its capacity to inhibit or mimic the action of Ca and interact with proteins. It can induce changes in blood electrolytes (Ca, K, Na and P), affect the metabolism of minerals (Al, Cu, Mn, Si and Zn), vitamins (B1, PP [B3], B12 and C) and amino acids, carbohydrates and lipids (with inhibition of enzymes containing an SH group), protein synthesis, and production of some hormones (Paoliello & Chasin, 2001). Exposure to Pb can occur through soil, air, food and paint (Saryan & Zenz, 1994).

Several analytical techniques are used to determine Cd and Pb in food matrices. Among these, graphite furnace atomization atomic absorption spectrometry (GF AAS) has been applied most due to its high sensitivity and low detection limits (De Oliveira, Peres, Felsner, & Justi, 2017; Dos Santos, Quináia, & Felsner, 2018; Fang & Zhu, 2014; Ghorbani, Akbarzade, Aghamohammadhasan, Seyedin, & Lahoori, 2018; Hernández-Martínez & Navarro-Blasco, 2012; Huang, Pan, Wu, Han, & Chen, 2014; Yao et al., 2018). However, high-resolution continuum source graphite furnace atomic absorption spectrometry (HR-CS GF AAS) has advantages over line source (LS) AAS, such as more efficient background correction, several strategies to correct spectral interference, a better signal-to-noise ratio and a radiation source that emits a broad wavelength range (Zong, Parsons, & Slavin, 1998). This allows the use of a unique radiation source for the determination of analytes and simultaneous determination, in some cases (Welz, 1999; Welz, Becker-Ross, Florek, & Heitmann, 2005; Welz, Becker-Ross,

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Florek, Heitmann, & Vale, 2003).

High-resolution continuum source flame atomic absorption spectrometry (HR-CS F AAS) was used in the sequential determination of Cd and Pb in vegetable oils (Trindade, Dantas, Lima, Ferreira, & Teixeira, 2015), and simultaneously determination of Cd, Fe and Sn in canned-food samples (Leão, Junior, Brandão, & Ferreira, 2016). More recently, HR-CS GF AAS and direct solid sample analysis was employed for the simultaneous determination of Fe and Ni in vegetables (Pozzatti, Nakadi, Vale, & Welz, 2017). Also, another study proposed two methods for determination of Cd in vinegar employing GF AAS, the optimization step was performed using two-level full factorial and Box–Behnken designs, being that a new multiple response function was established (Junior, Silva, Leão, & Ferreira, 2014).

Some studies have suggested that it is not possible to determine the presence of lead using the 217.0 nm line because of interference caused by phosphate molecules (Borges et al., 2006, 2014). However, HR-CS AAS technique uses software that allows measurement and storage of reference spectra for diatomic molecules with rotational fine structure that coincide temporally and spectrally with the analyte, so it is possible to perform background correction using least-squares background correction (LSBC) (Welz, Vale, Pereira, Castilho, & Dessuy, 2014).

The aim of this study was to develop an analytical method for determination of Cd and Pb in coconut water (natural and industrialized) and coconut milk using HR-CS GF AAS. Sample preparation procedures were simple: dilution with HNO₃ for the coconut water samples, and ultrasound-assisted extraction of the coconut milk samples. To the best of our knowledge, a simple and rapid method for the determination of Cd and Pb in natural and industrialized coconut water and coconut milk has not been reported previously.

2 Materials and methods

2.1 Reagents and solutions

All solutions were prepared using deionized water with resistivity of 18.2 MΩ cm, obtained from a Purelab Elga® (Elga, United Kingdom, UK) purification system. All reagents used were of analytical grade: 14 mol L⁻¹ distillate nitric acid (Merck, Darmstadt, Germany) and 30% (m m⁻¹) hydrogen peroxide (Merck, Darmstadt, Germany).

Prior to the experiments, all materials used (glassware, plastic bottles, etc.) were washed with mild detergent and submerged in 10% v v⁻¹ HNO₃ solution for a period of 24 h. Then, the materials were washed with deionized water and dried at room temperature.

Standard solutions containing 4 μg L⁻¹ Cd and 20 μg L⁻¹ Pb were prepared by appropriate dilution from stock solutions containing 1000 mg L⁻¹ of each element (Specsol, Quimilab, São Paulo, Brazil) in 0.5% (v v⁻¹) nitric acid.

A chemical modifier solution of 0.1% (m v⁻¹) Pd was prepared by appropriate dilution of stock solution of 1% (m v⁻¹) Pd (Specsol, Quimilab, São Paulo, Brazil) in 0.5% (v v⁻¹) HNO₃. A chemical modifier solution containing 1% (m v⁻¹) NH₄H₂PO₄ was also used. A standard solution of 4000 mg L⁻¹ P was used to obtain a reference spectrum, which was used to correct spectral interference caused by PO bands for Pb determination in natural and industrialized coconut water samples, using least-squares background correction (LSBC).

2.2 Samples

Samples (46) were acquired in Salvador city, Bahia, Brazil: 14 natural coconut water samples, 16 industrialized coconut water samples and 16 coconut milk samples. Natural coconut water samples (coded as AN) were acquired from small outlets located at various points throughout the centre of Salvador city. These samples were purchased in disposable cups, and immediately transferred to decontaminated 50 mL polyethylene flasks before being stored in a refrigerator for analysis.

The industrialized coconut water samples (coded as AI), a total of eight different brands (numbered 1–8), were purchased in supermarkets in Salvador city. For each brand, two samples were acquired and designated A and B. Coconut milk samples (coded L) were also purchased in supermarkets in Salvador city; a total of 11 different brands were identified as 1 to 11 and their varieties, specifically traditional (T), light (L) and low fat (R).

Certified reference material (CRM) for wastewater (BCR-713) provided by the Institute for Reference Materials and Measurements (IRMM, Geel, Belgium) was used for evaluation of the accuracy and precision of the analytical method.

2.3 Sample preparation

For the coconut water samples, 5 mL of each sample were diluted 1:1 with 1% (v v⁻¹) nitric acid solution. Coconut milk samples were extracted using the method described by Santos et al. (2014). Briefly, ca. 1.0 g was measured in a 50 mL volumetric flask with 20 mL of 1.0 mol L⁻¹ HNO₃. This mixture was sonicated for 10 min and then centrifuged for 5 min at 2000 rpm. After filtration, the solution was analysed by HR-CS GF AAS.

2.4 Instruments

All measurements were performed using an HR-CS GF AAS (ContraAA 700 model, Analytik Jena, Jena, Germany). The radiation source was a high-intensity XBO 301 xenon short-arc lamp (GLE, Berlin, Germany) operating with a nominal power of 300 W in hot-spot mode. This equipment had a double monochromator, which consisted of a pre-dispersing prism monochromator and a high-resolution echelle grating monochromator, and a detection system that consisted of a charge-coupled device (CCD) array. Pyrolytically coated graphite tubes with an integrated platform (Analytik Jena AG, Jena, Germany) were used. Argon gas with a minimum purity of 99.998% and a flow rate of 2.0 L min⁻¹ (White Martins, São Paulo, Brazil) was used as purge and protective gas in all heating program steps, except for atomization. Absorbance signals were obtained using the central pixel plus adjacent ones (CP ± 1) and an integration time of 3 s. The atomic lines at 217.0005 and 228.8018 nm were used for Cd and Pb measurements, respectively.

A 75D ultrasonic bath from VWR (Cortland, New York, USA) and a centrifuge (model MA-1810, Marconi, Piracicaba, São Paulo, Brazil) were used for the Cd and Pb extraction from coconut milk samples.

2.5 Determination of Cd and Pb by HR-CS GF AAS

To determine Cd and Pb, an aliquot of 20 μL of the diluted sample (coconut water) or extract (coconut milk) was injected into the graphite tube with 5 μL of 30% (m m⁻¹) H₂O₂ and 5 μL of the chemical modifier. The mixture was subjected to the GF heating program shown in Table 1. For Cd determination, the concentration of 1% (m v⁻¹) Pd was used as chemical modifier, whereas 1% (m v⁻¹) NH₄H₂PO₄ was used as modifier for Pb determination. All determinations were performed in

Table 1

Graphite furnace heating program used to determine Cd and Pb in coconut water and coconut milk samples employing Pd and NH₄H₂PO₄ as chemical modifiers, respectively.

Stage	Temperature (°C)	Ramp (°C s ⁻¹)	Hold time (s)	Ar flow rate (L min ⁻¹)
Drying 1	110	3	10	2
Drying 2	140	5	20	2
Pyrolysis	900	100	20	2
Atomization	1700	3000	3	0
Clean	2450	500	4	2

triplicate, and blank solutions were prepared using the same procedure as the samples.

A standard solution containing 4000 mg L⁻¹ phosphorus was used to obtain a reference spectrum, which was applied to correct the spectral interference, using LSBC.

3. Results and discussion

3.1 Correction of spectral interference using LSBC for Pb determination

The molecule of PO causes interference in determination of Pb at the 217.0 nm line. Background correction using LSBC facilitates subtraction of the PO spectrum (Borges et al., 2014; Dessuy et al., 2008; Welz et al., 2002, 2005). Thus, in our work, LSBC was used to correct spectral interference caused by PO bands in the determination of Pb in natural and industrialized coconut water samples.

3.2. Validation

The validation of the analytical method ensures that the results obtained are reliable and the methodology developed meets requirements for their application. In this work, the analytical method was in-house validated according to the following criteria: selectivity, limit of detection (LoD), limit of quantification (LoQ), accuracy, precision and characteristic concentration (Food and Agriculture Organization of the United Nations, 1998).

3.2.1. Selectivity

According to International Union of Pure and Applied Chemistry (IUPAC), selectivity is the degree to which an analytical method can quantify the analyte accurately in the presence of interference. The selectivity can be evaluated through the quantitative measure the selectivity index s_a/s_b , where s_a is the sensitivity of the method (slope of the calibration function) and s_b the slope of the response independently produced by a potential interferent, provides a quantitative measure of interference (Thompson, Ellison, & Wood, 2002).

In this work, to evaluate the calibration curve of the analytical method used to determine Cd and Pb, the slope was obtained for aqueous standards in 0.5% (v v⁻¹) HNO₃, and compared with the slope of the calibration curve obtained with analyte addition. The calibration curves were obtained across concentration ranges from blank solution to 4 µg L⁻¹ for Cd, and from blank solution to 20 µg L⁻¹ for Pb. No significant differences were observed between these slopes at a 95% confidence level. Therefore, determination of Pb and Cd in coconut water and coconut milk samples could be performed using only a calibration curve with aqueous standards prepared in 0.5% (v v⁻¹) HNO₃.

3.2.2. Limits of detection and quantification

The limits of detection (LoD) and of quantification (LoQ) were obtained using expressions $3S_b/b$ and $10S_b/b$, respectively, where S_b is the standard deviation of 10 measures of the analytical blank and b is slope of the calibration curve (Thomsen, Schatzlein, & Mercurio, 2003). The values of LoD and LoQ obtained for Cd were 0.02 and 0.06 µg L⁻¹ for coconut water, and 0.03 and 0.10 ng g⁻¹ for coconut milk, respectively. For Pb, LoD and LoQ were 0.20 and 0.70 µg L⁻¹ for coconut water, and 0.26 and 0.85 ng g⁻¹ for coconut milk, respectively.

3.2.3. Accuracy

Due to the lack of a CRM for coconut water, accuracy of the analytical method in determining Cd and Pb by HR-CS GF AAS after a dilution was confirmed by analysis of wastewater (BCR-713). The CRM was analysed in the same way as samples, and the results are shown in Table 2. Agreement between the values found and the certified values was 108 ± 14% for Cd and 102 ± 11% for Pb. A statistical *t*-test ($t_{\text{calculated}}$ for Cd = 2.31 and Pb = 0.86) was used to compare the values found experimentally with certified values at a 95% confidence level

Table 2

Results of the determination of Cd and Pb in wastewater (BCR-713) by HR-CS GFAAS.

Elements	Certified value (µg L ⁻¹)	Found value (µg L ⁻¹)	Agreement (%)	<i>T</i> -test
Cd	5.1 ± 0.6	5.5 ± 0.7	108 ± 14	2.31
Pb	47 ± 4	48 ± 5	102 ± 11	0.86

Results expressed as average ± confidence interval ($n = 3$) at 95% confidence level//*T*-test value is 4.30 for 95% confidence level.

($t_{\text{critical}} = 4.30$). This statistical test revealed there were no significant differences between certified values and values found experimentally.

Accuracy of the proposed method for determining Cd and Pb was also evaluated through addition and recovery tests in coconut water and coconut milk samples, using three fortification levels (Table 3). Recoveries varied from 98.2 (± 2.2) % to 105.9 (± 1.4) % for Cd and from 93.7 (± 2.3) % to 99.9 (± 0.5) % for Pb for the industrialized coconut water samples. For the coconut milk samples, recoveries varied between 97.7 (± 0.4) % and 110 (± 3.5) % for Cd and between 91.3 (± 2.3) % and 95.0 (± 1.0) % for Pb. These values are acceptable, based on the ranges recommended by the Association of Official Analytical Chemists (AOAC, 2002), which is 70–125% for µg L⁻¹ concentrations (AOAC, 2002).

3.2.4. Precision

The precision of an analytical procedure expresses the degree of scattering between a series of measurements obtained from multiple sampling of the same homogeneous sample under the prescribed conditions. The precisions was evaluated through repeatability, that were expressed in relative standard deviation (RSD%). To determine these parameters five fractions of the same sample were assessed applying the procedure under evaluation. The values of these determinations are presented in Table 4, and the average relative standard deviation did not exceed the value of 5.3%. So, the results obtained showed a satisfactory agreement with good precision.

3.2.5. Characteristic concentration

The operating conditions of the instruments can be evaluated by comparing the characteristic concentration (C_0) value or characteristic mass (m_0) with the value supplied by literature (Welz & Sperling, 1999). It's defined as the concentration or mass of the element that produces 1% absorbance (0.0044). It is determined by ratio between 0.0044 and inclination of the analytical curve (slope or sensitivity) (Welz & Sperling, 1999). The experimentally obtained of the characteristic values for the elements Cd and Pb were 0.06 µg L⁻¹ and 0.50 µg L⁻¹, respectively. Comparing the values obtained with the values suggested by literature, 0.06 µg L⁻¹ for Cd and 0.65 µg L⁻¹ for Pb, it can be observed that they have good agreement with each other.

3.3. Application in coconut water and coconut milk samples

The analytical method was applied to quantify Cd and Pb concentrations in 14 natural coconut water samples, 16 industrialized coconut water samples and 16 coconut milk samples. The results are shown in Table 5.

Concentration ranges for natural coconut water samples, in µg L⁻¹, were: 0.27–18.72 (Cd) and < 0.70–36.32 (Pb). Only sample AN5 contained Pb below the LoQ of the method (< 0.7 µg L⁻¹). For all samples, Pb concentrations were higher than Cd concentrations, especially sample AN2, which contained 18.72 µg L⁻¹ Pb. However, this value was below the maximum level of 20 µg L⁻¹ stipulated by Brazilian legislation. For both elements, in this work, the values were below the maximum permitted values according to Resolution No. 42/2013 by ANVISA (ANVISA, 2013).

Table 3

Values of recoveries obtained for Cd and Pb determination in coconut water and coconut milk samples after addition and recovery test.

Addition and recovery test					
Cd recovery/%			Pb recovery/(%)		
Added($\mu\text{g L}^{-1}$)	Coconut water	Coconut Milk	Added($\mu\text{g L}^{-1}$)	Coconut water	Coconut milk
1.0	98.2 \pm 2.2	110.0 \pm 3.5	5.0	99.9 \pm 0.5	91.3 \pm 2.3
2.5	105.9 \pm 1.4	97.7 \pm 0.4	7.5	93.7 \pm 2.3	95.0 \pm 1.0
4.0	101.7 \pm 3.1	99.2 \pm 2.0	25	98.4 \pm 2.5	93.2 \pm 0.3

Results expressed as average \pm standard deviation (n = 3).**Table 4**

Average, standard deviation (SD) and relative standard deviation (RSD) for the analysis of five replicates of the industrialized coconut water sample and coconut milk.

Coconut water ($\mu\text{g L}^{-1}$)			Coconut milk (ng g^{-1})		
Samples	Cd	Pb	Samples	Cd	Pb
1	0.882	22.28	1	2.98	7.90
2	0.932	24.09	2	2.83	7.65
3	0.923	23.34	3	2.73	7.33
4	0.918	24.38	4	2.99	7.17
5	0.882	25.71	5	2.89	7.32
Average	0.907	23.96	Average	2.88	7.47
SD	0.024	1.27	SD	0.11	0.30
RSD (%)	2.6	5.3	RSD (%)	3.8	4.0

For the industrialized coconut water samples, Cd and Pb concentrations varied in the ranges < 0.06 to $1.49 \mu\text{g L}^{-1}$ and 6.57 to $29.02 \mu\text{g L}^{-1}$, with average values of 0.70 and $19.54 \mu\text{g L}^{-1}$, respectively. Only samples AI3A and AI3B contained Cd concentrations below the LoQ ($< 0.06 \mu\text{g L}^{-1}$). To assess whether there were significant differences between lots A and B, one-way analysis of variance (ANOVA) was applied at 95% confidence level. Pb concentrations in samples AI2A and AI2B were excluded, because these values were visually different from the other data. The statistical test indicated no significant difference between values for Cd and Pb in the two lots.

Tavares (2010) determined Pb and Cd concentrations in 12 industrialized coconut water samples by LS AAS after dilution with 10% (m v^{-1}) Triton X-100. In all the analyses samples, Cd concentrations

were below the LoQ of the method ($< 1.0 \mu\text{g L}^{-1}$). For Pb, only one sample contained any significant amounts ($4.91 \mu\text{g L}^{-1}$), whilst other samples presented concentrations below the LoQ of the method ($< 2.0 \mu\text{g L}^{-1}$).

The concentrations determined for the coconut milk samples were in the following ranges (ng g^{-1}): < 0.10 to 5.93 for Cd and < 0.85 to 22.41 for Pb, with average values of 1.91 for Cd and 10.20 for Pb. Cd concentrations in samples L2, L4T, L6, L7 and L10 were below the LoQ ($< 0.10 \mu\text{g L}^{-1}$). For samples L3T, L3L, L4T, L5T and L9T, Pb concentrations were also below the LoQ ($< 0.80 \mu\text{g L}^{-1}$). Concentrations for all coconut milk samples, for both elements, were below the maximum limit permitted (LMP) according to ANVISA Resolution No. 42 (2013).

Santos et al. (2014) determined Pb and Cd concentrations in coconut milk samples by ICP OES after decomposition in a closed-vessel microwave oven. Cd concentrations in the samples were below the LoQ ($< 0.334 \text{ng g}^{-1}$) of the proposed method, whereas Pb concentrations were in the range 0.022 to 0.27ng g^{-1} . The concentrations obtained for Pb were higher than those determined in this work.

The presence of these contaminants in industrialized coconut water and coconut milk could be attributed to the use of inorganic fertilizers in coconut agriculture. According to Jiao, Chen, Chang, and Page (2012), fertilizers may contain contaminants from the raw materials and intermediate reagents used in their manufacture. Some agencies, such as the Brazilian Ministry of Agriculture, Livestock and Supply (Ministério da Agricultura, Pecuária e Abastecimento, MAPA), have established maximum levels for contaminants in fertilizers. Through MAPA Normative No. 27 from June 2006, the LMP for Cd and Pb are 4

Table 5

Concentration of Cd and Pb in natural and industrialized coconut water and coconut milk samples.

Natural coconut water/ $\mu\text{g L}^{-1}$			Industrialized coconut water/ $\mu\text{g L}^{-1}$			Coconut milk/ ng g^{-1}		
Sample	Cd	Pb	Sample	Cd	Pb	Sample	Cd	Pb
AN1	0.49 \pm 0.02	5.52 \pm 0.28	AI1A	1.01 \pm 0.01	16.59 \pm 0.15	L1	2.89 \pm 0.10	7.33 \pm 0.29
AN2	18.72 \pm 0.32	28.38 \pm 1.31	AI1B	0.90 \pm 0.10	17.15 \pm 0.65	L2	< 0.10	3.00 \pm 0.16
AN3	0.34 \pm 0.01	25.53 \pm 0.19	AI2A	0.87 \pm 0.04	20.79 \pm 1.10	L3T	5.93 \pm 0.01	< 0.85
AN4	0.27 \pm 0.02	32.26 \pm 0.64	AI2B	0.56 \pm 0.01	8.91 \pm 0.12	L3L	1.01 \pm 0.02	< 0.85
AN5	0.42 \pm 0.01	< 0.70	AI3A	< 0.06	8.88 \pm 0.07	L3R	2.36 \pm 0.14	5.59 \pm 0.02
AN6	1.72 \pm 0.06	9.58 \pm 0.26	AI3B	< 0.06	6.57 \pm 0.09	L4L	0.33 \pm 0.03	4.14 \pm 0.09
AN7	0.75 \pm 0.05	2.54 \pm 0.02	AI4A	0.92 \pm 0.02	24.09 \pm 1.14	L4T	< 0.10	< 0.85
AN8	0.72 \pm 0.03	6.46 \pm 0.22	AI4B	0.69 \pm 0.04	22.01 \pm 0.04	L5T	2.09 \pm 0.16	< 0.85
AN9	0.70 \pm 0.01	9.15 \pm 0.06	AI5A	0.27 \pm 0.01	18.25 \pm 0.16	L5R	0.83 \pm 0.07	16.48 \pm 0.17
AN10	2.28 \pm 0.01	6.72 \pm 0.19	AI5B	1.49 \pm 0.03	20.02 \pm 0.46	L6	< 0.10	13.34 \pm 0.02
AN11	0.61 \pm 0.03	4.41 \pm 0.22	AI6A	0.55 \pm 0.02	24.34 \pm 0.26	L7	< 0.10	15.27 \pm 0.47
AN12	13.33 \pm 0.49	36.35 \pm 0.16	AI6B	0.71 \pm 0.02	23.45 \pm 0.97	L8	0.78 \pm 0.07	5.40 \pm 0.41
AN13	3.52 \pm 0.44	22.26 \pm 0.63	AI7A	0.71 \pm 0.01	21.78 \pm 0.71	L9T	2.20 \pm 0.22	< 0.85
AN14	0.72 \pm 0.01	24.36 \pm 0.05	AI7B	0.58 \pm 0.01	23.37 \pm 0.29	L9R	1.54 \pm 0.30	22.41 \pm 0.96
			AI8A	0.35 \pm 0.01	27.42 \pm 0.16	L10	< 0.10	< 0.85
			AI8B	0.24 \pm 0.01	29.02 \pm 0.80	L11	1.02 \pm 0.07	9.07 \pm 0.14
Average	3.19	16.42	Average	0.70	19.54	Average	1.91	10.20
Median	0.72	9.58	Median	0.70	21.29	Median	1.54	8.20
Standard deviation	5.61	11.97	Standard deviation	0.33	6.58	Standard deviation	1.55	6.38
Minimum	0.27	< 0.70	Minimum	< 0.06	6.57	Minimum	< 0.10	< 0.85
Maximum	18.72	36.35	Maximum	1.49	29.02	Maximum	5.93	22.41

and 20 mg kg⁻¹, respectively (MAPA, 2006).

Due to the potential for food contamination by toxic elements from soil, Souza et al. (2014) and Molina, Aburto, Calderón, Cazanga, and Escudey (2009) developed methods for the determination of contaminants, including Cd and Pb in fertilizers by ICP OES. Currently, there have been only a few studies published on products consumed in Brazil, most of them on macronutrients and organic species, which justifies the importance of the present work.

4. Conclusion

The proposed analytical method presented precision, accuracy, LoD and LoQ appropriate to determine Cd and Pb in natural and industrialized coconut water and coconut milk by HR-CS GF AAS, being suitable for applying Brazilian legislation (ANVISA).

Dilution and extraction procedures were employed to prepare the samples with minimum manipulation, reducing the risk of contamination and loss of volatile analytes, and reducing consumption of corrosive reagents and generated less waste.

Concentrations found for Cd and Pb in the analyses samples were below the LMP allowed for food by ANVISA. In the literature, there are few studies on the determination of contaminants in the matrices studied. Thus, this work contributes preliminary data on the presence of contaminants in these foods.

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