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Short Report

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Fit-for-Purpose MIP OES Method to Meet the Requirements of the Brazilian Regulations for K and Na in Coconut Water, and Nutritional Assessment

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The Brazilian regulations for processed coconut water establish the range concentrations of Na and K, being necessary high-throughput analytical methods, as microwave-induced plasma optical emission spectrometry (MIP OES) for quality control. Samples of natural (green and mature) and processed coconut water were treated by acid decomposition assisted by microwave radiation before their MIP OES analysis. Recoveries for Na and K were 103 and 95%, whereas the relative standard deviation (RSDs) were 7.6 and 1.3%, respectively. The limit of detection (LOD) was 1.77 mg kg^{-1} for K and 2.31 mg kg^{-1} for Na. Na and K were determined in the ranges of, respectively, 27-490 and 1,600-3,500 mg L^{-1} in natural samples, whereas in processed samples the ranges were 26-168 and 814-2,054 mg L^{-1}. K-means cluster analysis identified a group of processed samples with compositions similar to green coconut water. All the processed samples were in accordance with the established regulation, except one dehydrated sample for which K content was below the accepted range. Natural coconut water is an excellent source of K in the diet as its daily consumption can supply more than 20% of the recommended daily ingestion of K for adults and 30% for children.

Keywords: coconut water, sodium, potassium, Brazilian regulations, MIP OES

Introduction

Coconut water is the liquid part of the coconut (*Cocos nucifera* L.) endosperm, found in the hermetic inner cavity of the fruit. It is a refreshing drink widely consumed in several parts of the world, especially in tropical countries with large coastal zones where palm trees are abundant,[1] such as Brazil. The regular consumption of this natural drink can benefit the health, considering the high levels of essential elements, vitamins, amino acids, antioxidants, and phytohormones; and its low calorie and fat content.[1,2]

The most abundant compounds in coconut water are soluble sugars, such as fructose, glucose, and sucrose.[3,4] The second most abundant constituents are essential elements, which could reach levels of 1% (m/v) of coconut water, mainly sodium, potassium, magnesium, and calcium.[5] A marked characteristic of coconut water is its high potassium content, acting as a "natural isotonic" in some disease conditions or by athletes who consume this beverage for sports practices. The World Health Organization (WHO),[6] for example, recommends the ingestion of coconut water in cases of acute diarrhea to restore the potassium contents not achieved by ingestion of home-made oral rehydration salts (ORS), a solution prepared by adding half of a small spoon of salt sodium chloride (approximately 2.5 g) and 6 small spoons of sugar (approximately 30 g).

The increase in coconut water consumption and popularity gave rise to processed products, which should, ideally, preserve its nutritional and organoleptic properties, and extend its shelf-life without deterioration and external contamination.[7] As a result, a large variety of processed coconut water is commercially available in markets worldwide. With the processing, adulterations of this

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beverage with preservatives, water, juice fruits, sugar, milk proteins, emulsifiers, and natural or artificial colorants and sweeteners were reported.[8]

Then, in Brazil, a country where coconut water is popular, in 2020, the Ministry of Agriculture, Livestock, and Supply[9] established a new classification and quality standards for coconut water, and their respective analytical parameters, with the publication of the normative instruction No. 9 of January 30. According to this normative, coconut water is classified into five types: whole, standardized, reconstituted, dehydrated, and concentrated. Whole coconut water refers to the beverage in its natural concentration, without dilution and the addition of water or sugars, whereas in the standardized coconut water it is allowed the addition of concentrated or dehydrated coconut water and sugars in concentrations lower than 0.5 g *per* 100 mL. The reconstituted coconut water is defined as the beverage obtained from concentrated or dehydrated coconut water by adding drinking water and/or whole coconut water; the addition of sugar is permitted until 0.5 g *per* 100 mL. The dehydrated coconut water is defined as the product obtained in the drying process of whole coconut water, which presents moisture content equal to or lower than 5.0%. Finally, the concentrated coconut water is the product obtained from a process of whole coconut water concentration, without the addition of water and with a minimum soluble solids content of 30%. This normative also established the alcoholic and soluble solids contents, the pH, and the minimum and the maximum concentrations of sodium and potassium. For whole, standardized, reconstituted, and dehydrated coconut water reconstitution, the minimum and maximum Na concentrations are 20 and 300 mg L^{-1}, respectively, whereas for K these limits are 1,400 and 2,300 mg L^{-1}, respectively. For concentrated coconut water, only the minimal contents are established for both elements, and these values are 30 and 2,100 mg L^{-1} for Na and K, respectively.

Recently, the levels of essential elements, including Na and K, were determined in coconut water by inductively coupled plasma mass spectrometry (ICP-MS).[10] The authors reported Na concentrations in the range 80-294 mg L^{-1}; and K in the range 1,920-2,446 mg L^{-1}. In Brazil, the elemental composition of coconut water was extensively studied by Sousa *et al.*[11-13] The authors analyzed natural and bottled coconut water for the determination of Ca, Mg, Mn, Fe, Zn, and Cu by inductively coupled plasma optical emission spectrometry (ICP OES). However, Na and K were not reported. Thus, considering the new Brazilian regulations and the rise of the number of processed coconut water brands, newer data is necessary. In addition, high-throughput analytical methods should be proposed to be further used for quality control of Na and K concentration in processed coconut water samples.

The MIP OES is a multi-elemental analytical technique that uses a nitrogen plasma as an atomizer and this is the main differential of this technique, as nitrogen is cheaper than the other gases normally used to generate the plasma in other emission or mass spectrometry techniques, such as the argon gas used in ICP OES or ICP-MS, or less dangerous than acetylene or nitrous oxide used in techniques of atomic absorption (AA).[14] Pinto *et al.*,[15] for instance, determined the contents of Al, Ca, Cd, Cr, Cu, Fe, Hg, K, Mg, Na and Zn in chicken breast samples using MIP OES after a treatment performed in a block digester equipped with a reflux system, whereas Sá *et al.*[16] determined trace elements in meat by MIP OES after solid-phase extraction. Infant cereal samples were analyzed for the estimation of the total content and bioaccessible fractions of thirteen elements, including essential and potentially toxic trace elements.[17]

The aim of this work is to evaluate the suitability of MIP OES to be applied to Na and K determination in natural and processed coconut water to verify if their contents are in accordance with the Brazilian regulations. With the application of the method to analyze samples marketed in Brazil, a nutritious and risk assessment was conducted considering the recommended daily intake (RDI) of K and the maximum recommended intake (MRI) of Na.

Experimental

Instrumentation

The analytical measurements of Na and K were performed in a microwave-induced plasma optical emission spectrometer (4200 MP AES, Agilent Technologies, Melbourne, Australia), assembled with a Hammer's design, operated at fixed conditions of 2.45 GHz, 1,000 W, plasma gas flow rate at 20 L min^{-1} and auxiliary gas flow rate at 1.5 L min^{-1}. The plasma formed in a vertically arranged quartz torch was of nitrogen, and this gas came from a nitrogen gas generator (Model 4107, Agilent Technologies, Melbourne, Australia) powered by compressed air (ISO 8573e1:2010 Class 8.4.3). Yttrium (VHG-LABS, Manchester, NH, USA), at 371.029 nm, was used as internal standard. The MIP OES operating conditions are shown in Table 1.

For sample treatment (coconut water and reference certified material), a microwave-assisted digestion system (Multiwave GO, Anton Paar, Graz, Austria), equipped with sensors for temperature monitoring was used. For volume measurements, adjusted volume micropipettes (Eppendorf, New York, NY, USA) were employed, and

Table 1. MIP OES operating conditions for the determination of Na and K

Parameter	Condition
Nebulizer	Inert ETFE OneNeb®
Spray chamber	glass, double-pass
Viewing position / m	0
Read time / s	3
Background correction	auto
Wavelength / nm	Na: 589.592 (atomic) K: 769.897 (atomic)

for mass determination, an analytical balance (Sartorius, Göttinger, Germany) was used.

All the laboratory glassware and polypropylene tubes (Corning, NY, USA) were decontaminated in 10% v/v nitric acid bath for at least one day and rinsed with ultrapure water previously to their use.

Chemical reagents, solutions, and samples

All reagents used were of analytical grade and all the solutions were prepared with ultrapure water (18.2 MΩ cm) obtained from a system of water purification (Millipore, Bedford, MA, USA). Calibration standards were prepared by diluting mono-elemental stock standards of Na and K (1,000 mg L^{-1}), acquired from VHG-LABS (Manchester, NH, USA), as well as the stock solution of the internal standard (Y). Nitric acid (65% m/m) was purchased from Merck (Merck, Darmstadt, Germany).

Samples of natural (green and mature) and processed coconut water were acquired at the local markets of Niteroi (State of Rio de Janeiro, Brazil), between the years 2021-2022. In total, 21 coconut water samples were analyzed, 6 natural (3 from green coconut and 3 from mature coconut), and 15 processed coconut water, of which 7 were classified as whole, 6 as reconstituted, 1 as standardized, and 1 as dehydrated, according to the Brazilian regulation.[9] The natural green and mature coconut water samples were identified by the letters “G” and “M”, respectively, whereas the processed samples were named by the letter “P”, followed by the numbers which were randomly attributed. For the extraction of coconut water from the natural samples, a cut was made in the coconut with the aid of an electric saw until the solid endosperm, and then a polypropylene micropipette tip was used to finish drilling the solid endosperm until reaching the liquid endosperm (coconut water). The electric saw did not come into contact with the samples to avoid metallic contamination. All the samples were analyzed in triplicate (n = 3).

The certified reference material (CRM) tomato leaves (1573a) was acquired from the National Institute of Standards and Technology (NIST, Gaithersburg, Maryland, USA).

Sample treatment

The coconut water samples were treated by acid decomposition assisted by microwave radiation. Samples of 10 g of coconut water were placed inside the Teflon® microwave vessels and added 2.5 mL of 65% m/m nitric acid. The mixture was then submitted to a controlled heating program: heat from room temperature until 180 ºC in 18 min and held in this temperature for 10 min. After reaching room temperature, the decomposed samples were transferred to 50.0 mL volumetric flasks and the volume was made up with ultrapure water. In the CRM analysis, a mass of approximately 0.25 g was weighed and added 2.5 mL of 65% m/m nitric acid and 10.0 mL of ultrapure water (in order to make it similar to coconut water treatment) and submitted to the same microwave temperature program. The volume of the CRM solution was also made up to 50.0 mL with ultrapure water. Lastly, all samples were diluted 20 fold in ultrapure water, resulting in total dissolved solids (TDS) and pH values of approximately 4,800 mg kg^{-1} and 2.4, respectively.

Method validation

Accuracy was evaluated by analyzing the CRM tomato leaves (NIST, 1573a) and by performing assays of analyte addition and recovery. In the recovery assays, two fortification levels were evaluated, considering the mean analyte content of the samples: for Na, 50% (0.5 mg L^{-1}) and 100% (1.0 mg L^{-1}); for K, 10% (0.2 mg L^{-1}) and 50% (10 mg L^{-1}). Precision was expressed as the relative standard deviation (RSD) obtained from the analysis of 7 replicates of the CRM. Quantification was performed by external calibration using aqueous elemental standard in the ranges of 0.5-10.0 mg L^{-1} for Na and 0.5-25.0 mg L^{-1} of K. The limits of detection (LOD) and quantification (LOQ) were calculated based on the suggested equation by Jankowski and Reszke.[18]

Statistical treatment

Descriptive statistics were conducted on the K and Na concentrations data. All the statistical computing was performed with R (version 4.0.5)[19] and R-Studio (version 2021.09.02).[20] The unsupervised hierarchical clustering analysis (HCA) and the non-hierarchic cluster analysis by K-means with seed-points established as set.seed (1,2,3) were conducted on the data using the Euclidean average distance method, and the NbClust package in R which relies on 24 known indexes was employed to obtain the group number.

Results and Discussion

Method validation

Despite the wide applicability of MIP OES for food analysis, for coconut, no MIP OES analytical method was found. The necessity of Na and K determination in this beverage became evident after the publication of the updated Brazilian regulations regarding Na and K concentrations,[9] demanding the use of high-throughput analytical methods to verify if the commercial samples are in accordance with the current legislation.

The determination of easily ionizable elements (EIE) can be troubling in analytical techniques which use plasma or flame as atomizers. The presence of these elements can affect plasma robustness and modify its conditions, by diminishing the energy available for vaporization, dissociation, and atomization processes. Additionally, EIE may cause a matrix effect and interfere with the determination of other elements. However, nitrogen plasma can achieve lower temperatures than argon plasma, since N_2 is diatomic and the rotational and vibrational effects are accounted for in the excitation process. Consequently, N_2 plasma electron density (ca. 10^{13} cm^{-3}) is 100 times lower than in Ar plasma (ca. 10^{15} cm^{-3}),[14] which can favor the determination of Na and K elements by MIP OES.

For the determination of EIE Na and K by MIP OES, several analytical performance parameters were assessed. Regarding accuracy, evaluated by using the CRM tomato leaves, the following K and Na concentrations (mg kg^{-1}) were obtained, respectively: 25,382 ± 321 and 140 ± 11. The certified concentrations for both elements were, in order, 26,760 ± 480 (mg kg^{-1}) and 136.1 ± 3.7 (mg kg^{-1}). As we did not have a CRM similar to coconut water, assays were spiked with Na and K. Recovery percentages were suitable for quantitative purposes, and situated between 96-104% (Na) and 92-101% (K). The use of CRM guarantees the quality of the accuracy results generated by the laboratory, whereas the accuracy for Na and K determination in coconut water was evaluated by performing the assay of analyte addition and recovery. Regarding precision, an RSD of 1.3% was obtained for K and 7.6%, for Na. Using the equation suggested by Jankowski and Reszke,[18] the method LODs calculated were 2.31 and 1.77 mg kg^{-1}, for Na and K, respectively. Considering LOQ = 3.3 LOD, the method LOQ resulted were 7.62 and 5.84 mg kg^{-1}, for Na and K, respectively. The coefficient of determination was higher than 0.99 for both analytes.

The internal standard Y were used for precaution, to compensate for eventual changes in detector response fluctuations due to instrumental drift and non-spectral interferences, such as transport and ionization interferences.

The analytical features showed that the MIP OES is suitable for the simultaneous determination of Na and K in coconut water samples. The accuracy and precision were in accordance with the Association of Official Agricultural Chemists (AOAC)[21] criteria for method validation.

The LOD and LOQ also indicated that the method can be applied for the determination of Na and K in lower concentrations than those found in coconut water. Thus, the use of MIP OES is an alternative to achieve a more accessible routine analytical method when compared with other multi-elemental techniques, such as ICP OES or ICP-MS. However, as nitrogen plasma is colder than argon plasma, this technique is more prone to matrix-related interferents, as well as interferences caused by the presence of easily ionizable elements.[22,23] For the minimization of matrix interferences, a sample treatment in which the sample organic matter is decomposed, or a procedure of analyte extraction is normally required, allowing the determination of elements in several food samples by MIP OES. Another limitation of MIP OES is the sample uptake rate, which is restricted to 1 L min^{-1}, compromising the homogeneity of the matrix and the obtaining of reproducible data. Then, the decomposition procedure is important to guarantee this homogenization prior to aerosol introduction into the plasma. In addition, when consuming coconut water part of the solid endosperm is ingested with the liquid endosperm, and the present work aimed to reproduce the total Na and K concentration during ingestion.

The use of MIP OES for the determination of Na and K can also represent an alternative to the use of flame photometry. Despite its lower cost, flame photometry is monoelemental, and the determination of Na and K could not be performed in one single run. Besides, the linear range of flame photometry is limited to a narrow range. Thus, the analysis of samples with different concentrations could demand the dilution of the samples, diminishing the method analytical frequency, considering the time required to analyze the samples.

Analysis of natural and processed commercial samples

The MIP OES method was applied for the analysis of 21 samples of commercial coconut water, being 6 natural samples and 15 processed samples. Priority was given to the analysis of processed samples, which are subject to the Brazilian normative for classification and quality standards of coconut water.[9] The concentrations of Na and K determined are shown in Figures 1 and 2, respectively.

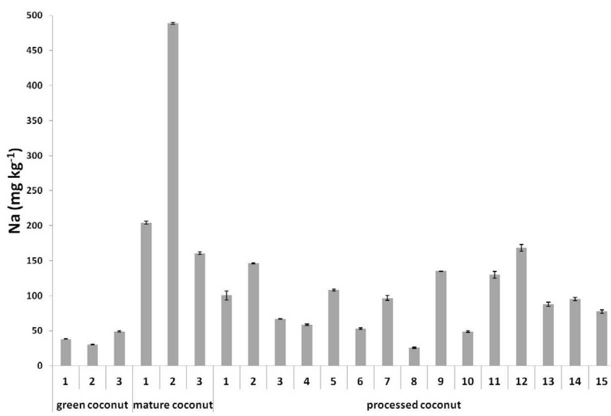

Figure 1. Sodium contents (average ± standard deviation) determined in natural and processed coconut water (n = 3) sold in Brazil.

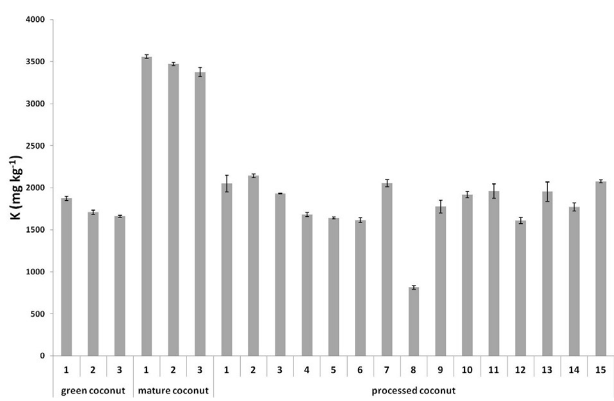

Figure 2. Potassium contents (average ± standard deviation) determined in natural and processed coconut water (n = 3) sold in Brazil.

The concentrations of Na in the natural coconut water samples were in the range of 27-490 mg L^{-1}, whereas in the processed samples the Na concentrations were lower, in the range of 26-168 mg L^{-1}. Regarding the natural samples, green coconut water presented a lower Na concentration than the mature samples, suggesting a preconcentration of the nutrients over the maturation period, due to the conversion of liquid to solid endosperm. The nutrient concentrations of coconut water vary over the period of maturation.[8,10] For Na, an increase in its concentration was observed with the increase of the maturity time,[10] which is in agreement with the results obtained in this work. In their revision, Yong *et al.*[24] also pointed out a similar tendency, with the raise of Na concentrations over the maturation period and varied K concentrations.

The processed samples presented intermediate Na concentrations between the natural green and mature coconut water. In these samples, a large variation of Na concentrations was observed. In the label's composition, some processed samples declared the addition of sodium hydrogen sulfite or ascorbic acid as antioxidants. However, the samples which declared these additives were not the samples with the highest Na concentration. The processed samples with the highest Na concentrations were samples 2 and 12. The processed sample 2 was declared as "organic" by the manufacturer, being the only sample to bring this information.

According to the results of Figure 2, K was determined in the natural coconut water samples in the range of 1,600-3,500 mg L^{-1} and the range of 814-2,054 mg L^{-1} in the processed samples. Regarding the variations of K contents, a profile similar to the Na contents one was observed, with green natural samples presenting a lower K concentration than the mature samples and intermediate K concentrations in the processed samples. Kunar *et al.*[10] pointed out that K concentrations increase in the initial stages of maturation and decrease over the maturation period.

The WHO indicated the consumption of green coconut water to restore K levels in cases of acute diarrhea and, in a general way, the majority of studies also analyzed the beverage obtained from green young coconuts in comparison with mature coconut water.[6] The preference for green coconut water is probably related to the better organoleptic characteristics of young green coconut water and not related to the K contents.[8,10]

Statistical approach

Sodium and K concentrations in the samples were described in Table 2 regarding their mean, median, maximum and minimum values, and 1st and 3rd quartiles. In both cases, the proximity of the mean and median values indicates a homogeneous distribution of the concentrations, which is expected in biochemically regulated metabolites. The data were standardized and were normally distributed, with values of 0.78 (K) and 0.68 (Na) for the Shapiro-Wilk test at 95% confidence.

The mature coconut waters introduce heterogeneity, which difficulted the application of HCA. The highest index score (12 indexes of 24) was observed for 3 groups, being (1) M2, (2) M1 and M3 and (3) the other samples, which was unsatisfactory for sample grouping. Consequently, the non-hierarchic cluster analysis by K-means was applied for the association of natural and processed samples without excluding data.

A multivariate cluster analysis was conducted with the objective to observe groups that would discriminate between the natural and industrial samples. The K-means cluster analysis has been used on the database of element concentrations in groundwaters, with the advantage of improving the within-group homogeneity.[25] The silhouette,

Table 2. Descriptive statistical analysis of the coconut waters

	K / (mg kg^{-1})	Na / (mg kg^{-1})
Minimum	791.3	25.02
1st quartile	1,674	52.4
Median	1,900	92.9
Mean	2,031	112.8
3rd quartile	2,094	135.2
Maximum	3,592	490
Mean ± sd (group 2)	3,469 ± 111	182 ± 24
Mean ± sd (group 3)	1,907 ± 186	110 ± 30
Mean ± sd (group 4)	1,610 ± 351	43 ± 12

sd: standard deviation.

total within the sum of square (wss), and gap statistics methods are employed for groups numbering in K-means analysis and resulted respectively in 3, 4, and 5 groups. The wss method was chosen because it introduced an additional group and 4 groups were also suggested by 5 indexes of the NbCluster package when performing an HCA, whereas none recommended 5 groups. Using this technique, the mature coconut samples were discriminated into two groups (1 and 2), being group 1 composed only by M2, and group 2 by M1 and M3. This discrepancy is due to the variation in the nutrient concentrations during the maturation process, as pointed out in other works.[10] The industrial samples are divided into two groups (3 and 4) which are mostly differentiated by their Na concentrations (Figure 3). The samples which are closer to the natural "mature" coconut water samples groups have higher Na average concentration (group 3, Table 2). Samples P4, P6, and P10 showed compositions similar to the green coconut water samples and were gathered in group 4. The sample P8, which is dehydrated, was located outside from the group 4 centroid, due to its lower concentrations of Na and K when compared with the other samples.

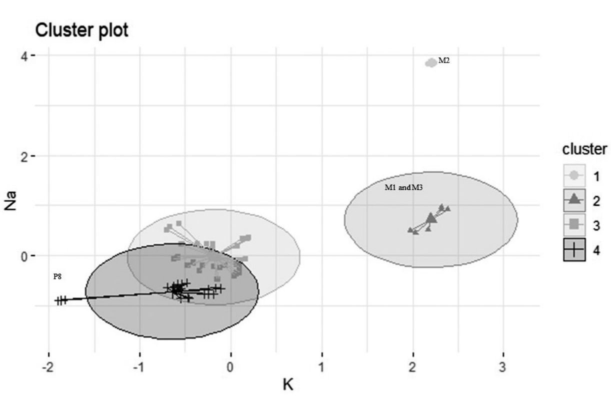

Figure 3. K-means cluster analysis for coconut water sample discrimination. Group 1: M2 (mature), group 2: M1 and M3 (mature); group 3: P1, P2, P3, P5, P7, P9, P11, P12, P14, P13, P14, and P15 (processed); and group 4: G1, G2, G3 (green), P4, P6, P8, and P10 (processed).

Comparison of the determined levels in coconut water with the Brazilian regulations

For the comparison of the Na and K levels determined in the processed coconut water with the concentration declared by the manufacturers on the product labels and the acceptance range according to the Brazilian normative (20-300 mg L^{-1} for Na and 1,400-2,300 mg L^{-1}),[9] "candlestick" graphics were used, which are represented in Figures 4 (for Na), and Figure 5 (for K). In these charts, the concentration range accepted by the normative are represented as fine lines; the color of the bars indicates if the determined concentration is higher or lower than the declared concentration, whereas the height of the bars indicates the proximity of the determined concentration with the declared concentration by the manufactures (taller bars indicate that the determined level is farther from the declared value, whereas a lower height indicates that the determined value is closer to the declared value). In cases in which there is a dash, there was no value declared on the label. These samples are identified with the symbol * on the x-axis.

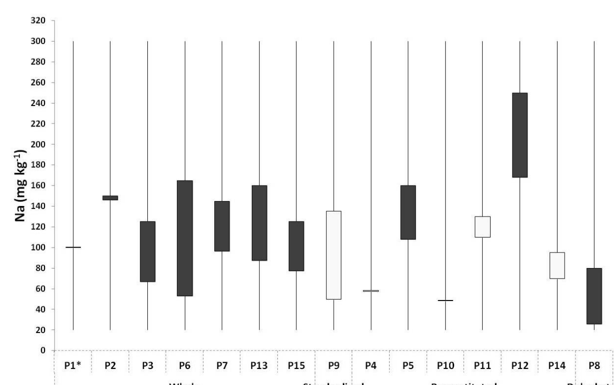

Figure 4. Comparison of the determined Na contents with the label's declared contents, and the normative Na range according to Brazilian regulations.[9] Legend: * [Na] not declared; colorless bar: [Na] determined > [Na] declared; dark gray bar: [Na] determined < [Na] declared.

According to Figure 4, all the processed analyzed samples presented Na concentration within the accepted range of the Brazilian normative. Nine samples presented Na concentrations lower than the concentrations declared, whereas 3 samples presented concentrations higher than the informed Na concentrations. Only two samples (P4 and P10) presented concentrations equal to the declared levels. These results suggest the necessity of a more adequate quality control of the lots sold.

For K, as represented in Figure 5, the majority of the samples were in the K concentration range established by the Brazilian legislation. However, in one sample (P8), classified as dehydrated, K levels were not in accordance

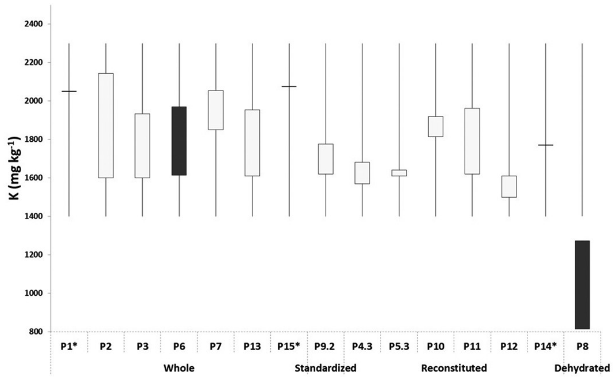

Figure 5. Comparison of the determined K contents with the label's declared contents, and the normative K range according to Brazilian regulations.[9] Legend: * [K] not declared; colorless bar: [K] determined > [K] declared; dark gray bar: [K] determined < [K] declared.

with legislation, and the determined levels were lower than the declared K content. Nevertheless, most of the analyzed samples (10) presented K concentrations higher than the declared concentration, in a contrary situation observed for Na. Only 2 samples presented K contents higher than the declared levels, and, two samples presented K concentrations very similar to the declared contents.

Contribution of coconut water to the recommended daily intake of K and the maximum recommended intake of Na

The WHO recommends a maximum recommended intake (MRI) of 2 g of Na *per* day, corresponding to 5 g of sodium chloride *per* day.[26] According to WHO instructions, for children from 2 to 15 years old, the MRI should be adjusted downwards according to children's energy requirements relative to adults. For K, the recommended daily intake (RDI) is 90 mmol *per* day, corresponding to 3,510 mg of K *per* day for adults older than 16 years.[27] For children between 2-15 years old, the recommendation is also to consider the energy needs of children relative to adults. In both instructions,[26,27] the recommendation is to ingest Na and K in a molar fraction of approximately 1.

In Brazil, specific normative or regulations about the minimum or the maximum quantities of Na and K that should be ingested were not found. However, in the Normative Instruction No. 75 of October 8 of 2020 from the National Health Surveillance Agency from Brazil[28] about the nutritional labeling of packaged foods, the daily reference values (DRV) to be considered are 2,000 mg for Na and 3,500 mg for K, which are similar to the MRI of Na and the RDI of K recommended by the WHO.[26,27] The National Institutes of Health (NIH, Office of Dietary Supplements) from the USA recommends the RDI of K for men, women, pregnant and lactating women according to their age (birth to 6 months, 7-12 months, 1-3 years, 4-8 years, 9-13 years, 14-18 years, 19-50 years, and 51 years or older).[29] Using these data from NHI, the contribution of the consumption of one cup (200 mL) of natural and processed coconut water to the RDI of K was calculated for all groups, except for babies of 0-6 months, since in this age group the exclusive feeding with human breast milk is recommended.[30] The results are presented in Table 3.

According to Table 3, the daily consumption of natural coconut water can supply more than 20% of the RDI of K for adults, more than 30% for children, and more than 80% for babies older than 7 months. These results indicated that natural coconut water is an excellent source of K in the diet. For the consumption of processed coconut water, the contributions to the RDI of K are lower when compared with natural coconut water, but they are also significant, reaching more than 12% of the RDI for adults, more than 18% for children, and more than 50% for babies. It is important to stress that these contributions were calculated considering the total contents of K in the analyzed samples. However, in a more adequate nutritious evaluation, the bioaccessibility and bioavailability should be estimated by considering the process occurring in the human gastrointestinal tract and the mechanisms of intestinal absorption.[32,33]

For Na, no specific values of MRI according to age groups were found. However, as Na concentrations in

Table 3. Contribution of the consumption of 200 mL of coconut water *per* day to the recommended daily intake[31] of potassium (K)

Type of coconut water	Contribution to recommended daily intake / %							
	Natural				Processed			
Age group	Men	Women	Pregnant	Lactating	Men	Women	Pregnant	Lactating
19 years or older	9.7-21.1	12.7-27.6	11.4-24.8	11.8-25.7	4.7-12.7	6.1-16.6	5.5-14.9	5.7-15.4
14-18 years	11.0-23.9	14.3-31.2	12.7-27.6	13.2-28.7	5.3-14.4	6.9-18.8	6.1-16.6	6.3-17.3
9-13 years	13.2-28.7	14.3-31.2	–	–	6.3-17.3	6.9-18.8	–	–
Children (men/women)								
4-8 years	14.3-31.2				6.9-18.8			
1-3 years	16.5-35.9				7.9-21.6			
7-12 months	38.3-83.5				18.4-50.2			

natural and processed coconut water was not high when compared to other processed foods, it is estimated that the consumption of one cup of natural coconut water *per* day can contribute to 5% of the MRI of Na for adults. For children, naturally, the contribution is higher. And, following the same tendency as K, the intake of this processed coconut water would contribute less to the MRI of Na than the natural samples.

Conclusions

The MIP OES showed to be a suitable technique to be used for Na and K determinations in coconut water in the face of the updated Brazilian regulations. The majority of analyzed samples were in accordance with the Brazilian normative in relation to their Na and K concentrations. Only one dehydrate sample presented K levels lower than those preconized by the Brazilian legislation. In addition, in most of the samples, the determined Na and K contents were not in accordance with the declared label's contents. For Na, the majority of samples presented a lower concentration than the declared concentration. For K, an inverse behavior was observed and most of the samples presented higher levels than the declared. These results indicated the necessity of a more adequate quality control and, in this sense, the analytical method using MIP OES is a useful tool since this multi-elemental technique is more affordable when compared with other multi-elemental techniques.

The nutritional evaluation indicated that coconut water showed to be an excellent source of K in the diet that can provide more than 20% of the RDI of K for adults and 30% for children with the consumption of one cup *per* day, considering the total contents of K in the samples. Further evaluation of the bioaccessibility and the bioavailability of these micronutrients in coconut water are future research needs.

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