

Multielemental Determinations in Chocolate Drink Powder Using Multivariate Optimization and ICP OES

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ABSTRACT: In this work multivariate experiments were conducted to optimize the operating conditions for inductively coupled plasma optical emission spectrometry (ICP OES) for multielemental determinations in chocolate drink powder. The operating conditions were investigated using a 2³ central composite design, where the variables studied were radio frequency power, nebulization flow rate, and auxiliary argon flow rate. The effects of these parameters on plasma robustness and on signal to background ratio (SBR) were considered in parallel, allowing the evaluation of robustness and detectability using few and fast experiments to select the best conditions for the determination of the analytes. In this case, the proposed experiments were applied to the optimization of a method aimed at the determination of Al, Ba, Cd, Co, Cr, Cu, Fe, Mg, Mn, Mo, Ni, P, Pb, V, and Zn in chocolate drink powder. The compromise conditions that allowed obtaining a robust and sensitive analytical method were radio frequency power of 1200 W, nebulization flow rate of 0.6 L/min, and auxiliary argon flow rate of 0.3 L/min. Using these conditions, recoveries between 95 and 105% and relative standard deviations lower than 5% were obtained for the majority of the analytes. The proposed method was successfully applied to the analysis of 15 samples of chocolate drink powder. The highest concentrations of metallic species were found in diet and light products.

KEYWORDS: ICP OES, multivariate optimization, chocolate drink powder

INTRODUCTION

Inductively coupled plasma optical emission spectrometry (ICP OES) is a remarkable technique for the determination of inorganic elements in a huge variety of analytical samples. Among the properties that made ICP OES so successful are its high sensitivity, wide range of linearity, low limits of detection, low susceptibility to chemical interferences, and the possibility of multielement detection, the last being, perhaps, the most important feature of this technique.^{1,2}

Besides its wide applicability, the optimization of the operating conditions in ICP OES is not a simple task, because it is highly dependent on which analytes will be determined and the overall aim of the optimization.² For multielemental determinations, which represent the majority of cases, compromise conditions are usually chosen. Plasma robustness, calculated as the Mg(II) (280.270 nm)/Mg(I) (285.213 nm) emission intensity ratio, must be monitored to obtain a plasma operating under robust conditions,³ when the analytical signals are not significantly affected by the nature of the matrix or elemental concentrations,^{3,4} whereas the signal to background ratio (SBR) must be considered when low limits of detection are desirable.² Several papers described plasma robustness and the SBR as responses for operating condition optimization in ICP OES,^{5–8} but most of them performed the experiments in a univariate way, which does not allow the evaluation of the interactions between the parameters, and thus it may not be appropriate for choosing the optimal conditions. There are few literature reports describing multivariate experiments to evaluate the operating conditions in ICP OES.^{9–11} Santos et al.,⁹ in a recent study, evaluated the influence of acid concentration, radio frequency power, and nebulization flow rate in the determination of uranium, whereas Lopes et al.¹⁰ applied multivariate techniques in the optimization of a method

for the determination of As and Se using ICP OES and a hydride generator. In both works the researchers used the analytical signals as responses in experimental designs, which was shown to be adequate considering that the authors carried out the determination of only a few analytes, not taking advantage of the multielementarity that the technique of ICP OES provides. Froes et al.,¹¹ on the other hand, applied an experimental design in the optimization of an ICP OES method for the determination of 13 metallic elements in fruit juice, considering as responses the analytical signals for each of the elements, generating in this way a large amount of data. In all of these works that applied multivariate techniques for the optimization of an ICP OES method, the analytical signals were considered as responses, only allowing the evaluation of the detectability of the method. In this way, additional experiments needed to be made to optimize others parameters, such as plasma robustness, considering that a robust method that presents good detectability at the same time is desirable, mainly in multielemental determinations.

When using multivariate experiments, it is possible to evaluate more than one response in parallel or simultaneously. In this case, the optimization of the operation conditions in ICP OES was performed in a multivariate form and considering two parameters as responses, plasma robustness and SBR, in parallel. The optimized conditions were then applied with the aim of determining inorganic elements in chocolate drink powder. Chocolate drink powders are a type of food widely consumed throughout the world and, in Brazil, the situation is

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not different, where they are consumed by people of all ages and, in some cases, on a daily basis. The great acceptability of chocolate drink powder by consumers is attributed to their sensory and nutritional characteristics as well as to their practicality and convenience.¹² It is important to mention that, in addition to being utilized for flavoring beverages, chocolate drink powders are also used in cakes, candies, and ice creams, showing the importance of the development of analytical methods for this type of sample. Despite its large consumption, however, there are few literature reports regarding the analysis of chocolate drink powder,^{12,13} and these papers mostly consider the analysis of chocolate^{14,15} and chocolate milk beverages.¹⁶ In this context, the proposed multivariate experiments were applied to evaluate the ICP OES experimental parameters for the simultaneous determination of Al, Ba, Cd, Co, Cr, Cu, Fe, Mg, Mn, Mo, Ni, P, Pb, V, and Zn in chocolate drink powder.

MATERIALS AND METHODS

Instrumentation. The analytical measurements were made with an ICP OES, model Optima 3000 DV (Perkin-Elmer, Norwalk, CT, USA), equipped with a solid-state segmented array charge-coupled device (SCD) detector, an Echelle grating, a peristaltic pump, a crossflow nebulizer coupled to a Scott spray chamber, and a quartz demountable plasma torch with a central tube injector having a 2.0 mm internal diameter. A shear gas interface (N₂) was used to strip off the cool plasma recombination area. The equipment was operated in the axial configuration. The operational parameters used for the analytical measurements were radio frequency power of 1300 W, nebulization flow rate of 0.8 L/min, auxiliary argon flow rate of 0.5 L/min, plasma argon flow rate of 15.0 L/min, sample flow rate of 1.0 L/min, and read delay of 30 s. The wavelengths (nm) used for each element were 308.215(I) for Al, 233.527(II) for Ba, 214.440(II) for Cd, 228.616(II) for Co, 205.560(II) for Cr, 324.752(I) for Cu, 238.204(II) for Fe, 279.077(II) for Mg, 260.568(II) for Mn, 202.031(II) for Mo, 232.003(I) for Ni, 213.617(I) for P, 220.352(II) for Pb, 292.402(II) for V, and 213.857(I) for Zn, I and II being atomic and ionic lines, respectively.

Reagents and Samples. Analytical grade reagents and deionized water (Milli-Q Water Purification System, Millipore, Bedford, MA, USA) were used throughout. The laboratory glassware was kept overnight in a 10% v/v HNO₃ solution and rinsed with deionized water.

The analyte solutions were prepared from 1000 mg/L standards solutions in 0.2% v/v HNO₃ (Merck, Darmstadt, HE, Germany). Appropriate dilutions were made for the preparation of the multielemental standards, which were stored in polyethylene flasks under refrigeration.

Argon with a purity of 99.996% (White Martins, São Paulo, SP, Brazil) was used in the analytical measurements.

The samples of chocolate drink powder were purchased in the local market of Campinas, State of São Paulo, in Brazil. Using the proposed method, 15 different samples of chocolate drink powder, designated by letters A–O, were analyzed. Samples A, C, F, H, I, J, M, N, and O are conventional products, samples B, D, and L are light products, sample E is a diet product, sample G is an organic product, and sample K is a soy-based product. Sample A was used for method optimization. Under the optimized conditions, each sample was analyzed in triplicate.

Sample Treatment. A microwave digestion system ETHOS 1 (Milestone, Sorisole, BG, Italy), equipped with closed polytetrafluoroethylene vessels and sensors for temperature and pressure control was used for sample treatment, according to the following procedure: 0.25 g of the sample was accurately weighed into polytetrafluoroethylene vessels, to which were added 3.0 mL of 65% v/v nitric acid (Merck), 1.5 mL of hydrogen peroxide 30% v/v (Merck), and 3.5 mL of deionized water. The closed vessels were then placed inside the microwave oven, and the decomposition was carried out according to

the heating program, in which the sample was initially heated from room temperature to 80 °C in 6 min (hold for 4 min), then to 140 °C in 3 min (hold for 5 min), and finally to 180 °C in 5 min (hold for 10 min). Subsequently, the samples were left to cool, transferred to individual 25.0 mL volumetric flasks, and diluted with deionized water, followed by quantitation by ICP OES. For each sample, this procedure was carried out in triplicate.

Method Optimization. The optimization of operating conditions was carried out in a multivariate form, varying the conditions for sample A. The variables evaluated were radio frequency power (studied in levels of 1200, 1300, and 1400 W), nebulization flow rate (0.6, 0.8, and 1.0 L/min), and auxiliary argon flow rate (0.3, 0.5, and 0.7 L/min).

The central point of the experimental design was based on the conditions recommended by the equipment manufacturer for aqueous solutions.

To obtain a robust and sensitive analytical method, the plasma robustness was calculated as the Mg(II) (280.270 nm)/Mg(I) (285.213 nm) emission intensity ratio for the sample,³ and the SBR was calculated as the emission intensity for Mn (260.568 nm) in the sample divided by the blank signal. These two answers were considered in parallel to reduce the number of experiments required for the evaluation of the robustness and the detectability of the method. Pareto charts were built for both plasma robustness and SBR. They were obtained by loading the data of Table 1 into StatSoft (Statistica 7) software.

Table 1. Experimental Design Used for the Optimization of the Operating Conditions

	variable	(−1)	0	(+1)	
(a)	radio frequency power (W)	1200	1300	1400	
(b)	nebulization flow rate (L/min)	0.6	0.8	1.0	
(c)	auxiliary argon flow rate (L/min)	0.3	0.5	0.7	
expt	a	b	c	Mg(II)/Mg(I) ratio	SBR for Mn
1	−1	−1	−1	9.0	415.3 ± 3.1
2	+1	−1	−1	9.5	24.7 ± 0.3
3	−1	+1	−1	3.5	308.1 ± 3.4
4	+1	+1	−1	4.2	64.5 ± 1.0
5	−1	−1	+1	9.2	363.4 ± 3.4
6	+1	−1	+1	9.9	303.4 ± 1.9
7	−1	+1	+1	3.4	770.6 ± 2.3
8	+1	+1	+1	4.3	1139.1 ± 9.2
9	0	0	0	6.4	322.7 ± 0.8
10	0	0	0	6.3	378.5 ± 5.7
11	0	0	0	6.4	329.3 ± 2.1

Experiments of analyte addition and recovery were set, at three levels of concentration and in triplicate for each spike level, to evaluate the accuracy of the method. The analyte concentrations added are described in Table 2.

In the selected experimental conditions the limits of detection (LOD) were calculated as $(3 \times \text{RSD} \times \text{BEC})/100$ and the limits of quantification (LOQ) as $(10 \times \text{RSD} \times \text{BEC})/100$ as suggested by

Table 2. Analyte Concentrations Added for the Addition and Recovery Studies

analyte	addition 1 (mg/L)	addition 2 (mg/L)	addition 3 (mg/L)
Mg, P	5.0	15.0	25.0
Al	0.20	0.60	4.00
Fe	0.20	2.50	5.00
Zn, Mn	0.05	0.15	0.30
Cd, Cr, Cu, Ba, Pb, Mo, Ni, V, Co	0.01	0.02	0.10

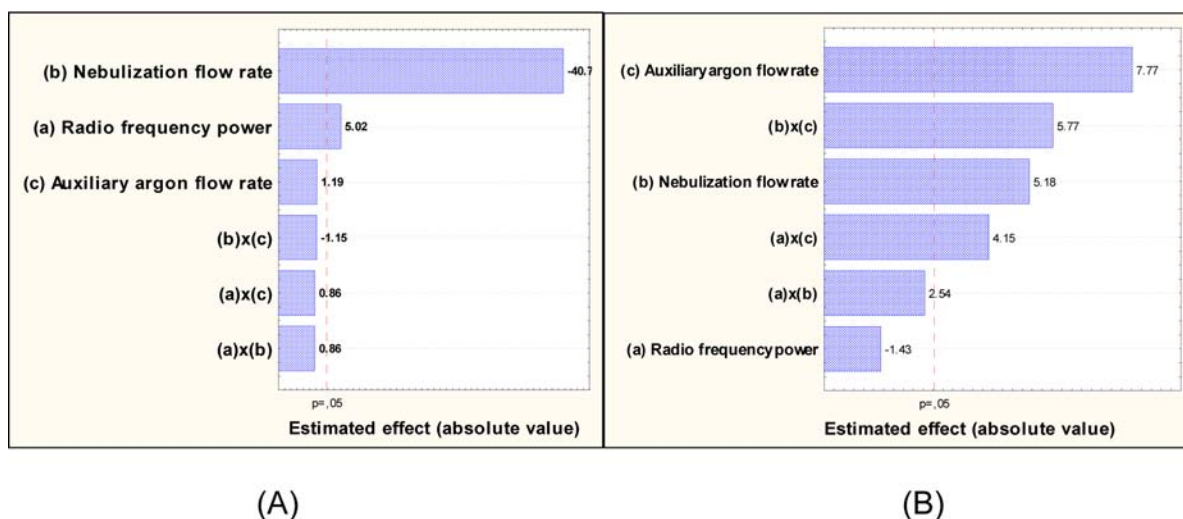


Figure 1. Pareto charts obtained for plasma robustness (A) and for Mn SBR (B).

Thomsen et al.,¹⁷ where RSD means relative standard deviation and BEC means background equivalent concentration obtained for 10 measurements of the blank.

RESULTS AND DISCUSSION

Optimization of Operating Conditions. The results obtained in the experimental design, as well as the two

Table 3. Recoveries Obtained for the Analytes^a in Chocolate Drink Powder Using the Optimized Conditions

element	recovery (addition 1)/%	recovery (addition 2)/%	recovery (addition 3)/%	mean recovery \pm s/%
Al	101	103	103	102 \pm 1
Ba	100	98	95	98 \pm 3
Cd	96	100	103	100 \pm 3
Co	99	99	100	99 \pm 1
Cr	103	102	102	102 \pm 0
Cu	105	100	97	101 \pm 4
Fe	100	101	99	100 \pm 1
Mg	89	100	99	96 \pm 6
Mn	101	99	100	100 \pm 1
Mo	106	99	102	102 \pm 4
Ni	105	100	101	102 \pm 3
P	101	100	102	101 \pm 1
Pb	119	120	102	114 \pm 10
V	108	108	103	106 \pm 3
Zn	105	101	103	103 \pm 2

^aThe concentration added are those described in Table 2.

responses considered, the emission intensities for the Mg(II)/Mg(I) ratio and for Mn (260.568 nm) SBR, are presented in Table 1. In each condition the analyses were made in triplicate.

As can be observed from the Pareto charts (Figure 1), for the plasma robustness only nebulization flow rate and radio frequency power are statistically significant at the 95% confidence interval, the nebulization flow rate being the most significant parameter. It was observed that lower values of nebulization flow rate provide higher values of the Mg(II)/Mg(I) ratio, as well as higher radio frequency power, as previously pointed out.¹²

Table 4. Limits of Detection (LOD) and Quantification (LOQ) Obtained for the Determination of Minerals in Chocolate Drink Powder by ICP OES

element	LOD (mg/kg)	LOQ (mg/kg)
Al	0.69	2.29
Ba	0.03	0.10
Cd	0.02	0.08
Co	0.06	0.19
Cr	0.06	0.20
Cu	0.10	0.35
Fe	0.03	0.10
Mg	0.46	1.52
Mn	0.01	0.03
Mo	0.10	0.34
Ni	0.24	0.79
P	0.90	2.98
Pb	0.63	2.09
V	0.07	0.22
Zn	0.04	0.12

According to previous papers,^{3,4} a plasma is considered to be robust when values of the Mg(II)/Mg(I) ratio >10 are obtained, whereas a value >8 is considered a robust plasma condition.^{18,19} In this case, for the chocolate drink powder, the highest value of the Mg(II)/Mg(I) ratio obtained was 9.9.

For the SBR, the auxiliary argon flow rate (*c*), the nebulization flow rate (*b*), and the interactions $b \times c$ and $a \times c$ are statistically significant. The highest SBR values were obtained when using the highest levels of the three parameters studied, as shown in Table 1. This means that under these conditions the method presents higher detectability and lower limits of detection are obtained; however, plasma robustness is not adequate, making this condition not suitable for carrying out the analytical determinations.

The choice of monitoring the SBR for Mn as a response in the optimization process was based on the fact that the method presents higher sensitivity for the determination of this element, for which lower limits of detection are generally obtained. In this way, the SBR for Mn is a good choice for monitoring the instrumental conditions in ICP OES, considering that any plasma oscillation could be easily noticed in the Mn signal. Other works have already used the SBR for

Table 5. Concentrations Found of Minerals in Chocolate Drink Powder^a

element (wavelength/nm)	A (mg/kg)	B (mg/kg)	C (mg/kg)	D (mg/kg)	E (mg/kg)	F (mg/kg)	G (mg/kg)	H (mg/kg)
Al (308.215)	32.74 ± 1.83	44.35 ± 2.82	2.27 ± 0.39	27.97 ± 7.44	100.45 ± 8.92	19.42 ± 3.31	24.73 ± 4.97	17.89 ± 1.09
Ba (233.527)	3.18 ± 0.27	5.02 ± 0.25	2.27 ± 0.05	4.90 ± 0.35	8.58 ± 0.57	2.25 ± 0.07	2.52 ± 1.06	2.07 ± 0.04
Cd (214.440)	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
Co (228.616)	<0.19	0.23 ± 0.01	<0.19	0.28 ± 0.01	0.51 ± 0.01	<0.19	<0.19	<0.19
Cr (205.560)	<0.20	1.70 ± 0.04	<0.20	<0.20	4.79 ± 0.24	0.57 ± 0.02	<0.20	0.89 ± 0.01
Cu (324.752)	4.60 ± 0.14	7.42 ± 0.55	3.55 ± 0.16	9.05 ± 0.74	17.50 ± 1.57	3.73 ± 0.25	5.21 ± 2.08	3.19 ± 0.02
Fe (238.204)	103.26 ± 1.85	233.42 ± 4.54	6.13 ± 0.23	71.78 ± 4.13	535.34 ± 15.54	141.78 ± 2.30	54.79 ± 8.98	160.05 ± 4.85
Mg (279.077)	1376.40 ± 26.84	2846.63 ± 54.66	64.38 ± 2.27	1241.27 ± 41.88	2675.97 ± 26.91	754.12 ± 28.05	878.19 ± 44.87	523.61 ± 5.89
Mn (260.568)	7.51 ± 0.73	11.54 ± 0.76	6.60 ± 0.17	10.74 ± 0.79	23.97 ± 1.81	17.71 ± 3.04	5.73 ± 2.01	6.20 ± 0.11
Mo (202.031)	<0.10	2.35 ± 0.04	0.11 ± 0.01	2.28 ± 0.05	5.41 ± 0.10	1.01 ± 0.06	1.70 ± 0.04	1.11 ± 0.15
Ni (232.003)	<0.79	<0.79	<0.79	<0.79	<0.79	<0.79	<0.79	<0.79
P (213.617)	1139.18 ± 18.74	2309.16 ± 45.18	89.75 ± 2.65	1721.22 ± 43.81	3658.60 ± 36.84	3369.50 ± 139.85	1258.45 ± 64.73	731.63 ± 8.19
Pb (220.353)	<2.09	<2.09	<2.09	<2.09	<2.09	<2.09	<2.09	<2.09
V (292.402)	<0.22	<0.22	<0.22	<0.22	<0.22	<0.22	<0.22	<0.22
Zn (213.857)	9.23 ± 0.54	16.28 ± 0.52	0.77 ± 0.05	17.30 ± 0.86	163.64 ± 13.00	72.22 ± 2.96	12.22 ± 0.89	7.29 ± 1.04
element (wavelength/nm)	I (mg/kg)	J (mg/kg)	K (mg/kg)	L (mg/kg)	M (mg/kg)	N (mg/kg)	O (mg/kg)	
Al (308.215)	10.94 ± 1.02	10.38 ± 0.97	56.28 ± 0.56	24.09 ± 0.33	14.90 ± 1.02	9.89 ± 0.16	9.22 ± 0.45	
Ba (233.527)	2.19 ± 0.22	2.00 ± 0.06	4.51 ± 0.33	5.83 ± 0.26	2.07 ± 0.04	1.27 ± 0.02	1.54 ± 0.14	
Cd (214.440)	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	
Co (228.616)	<0.19	<0.19	<0.19	0.34 ± 0.01	<0.19	<0.19	<0.19	
Cr (205.560)	0.46 ± 0.02	<0.20	0.41 ± 0.05	0.21 ± 0.02	0.26 ± 0.02	<0.20	<0.20	
Cu (324.752)	5.76 ± 0.60	3.35 ± 0.17	7.72 ± 0.86	11.73 ± 0.39	3.15 ± 0.07	1.61 ± 0.16	2.57 ± 0.29	
Fe (238.204)	108.95 ± 3.72	27.40 ± 2.53	116.90 ± 3.33	240.56 ± 1.78	44.69 ± 2.38	70.70 ± 3.26	18.60 ± 1.10	
Mg (279.077)	825.63 ± 14.91	439.09 ± 4.84	1850.03 ± 34.14	1530.47 ± 11.68	479.60 ± 19.71	254.91 ± 1.03	373.74 ± 19.95	
Mn (260.568)	7.41 ± 0.65	4.21 ± 0.18	15.57 ± 1.17	13.00 ± 0.39	5.52 ± 0.10	3.68 ± 0.15	4.31 ± 0.26	
Mo (202.031)	0.61 ± 0.03	0.76 ± 0.01	0.94 ± 0.01	2.76 ± 0.03	0.89 ± 0.05	0.48 ± 0.03	0.74 ± 0.02	
Ni (232.003)	<0.79	<0.79	<0.79	<0.79	<0.79	<0.79	<0.79	
P (213.617)	3036.24 ± 48.75	589.90 ± 9.08	7630.16 ± 172.11	2211.43 ± 14.84	623.30 ± 26.70	439.53 ± 1.31	500.24 ± 26.66	
Pb (220.353)	<2.09	<2.09	<2.09	<2.09	<2.09	<2.09	<2.09	
V (292.402)	<0.22	<0.22	<0.22	<0.22	<0.22	<0.22	<0.22	
Zn (213.857)	67.20 ± 25.38	5.76 ± 0.49	30.53 ± 1.00	116.62 ± 0.69	5.68 ± 0.50	30.12 ± 0.68	5.12 ± 0.39	

^aThe values represented using < could not be quantified in the samples because they are below the limit of quantification of the method.

Mn to optimize an ICP OES method,^{6,20} obtaining a more adequate condition for the determination of metals in other types of samples. Thus, considering both plasma robustness and SBR, the compromise conditions chosen for the analytical determinations in chocolate drink powder were radio frequency power of 1200 W, nebulization flow rate of 0.6 mL/min, and auxiliary argon flow rate of 0.3 mL/min, conditions in which is obtained a robust method with adequate detectability. It is interesting to point out the improvement obtained using these conditions compared with those recommended by the manufacturer (experiments 9–11), showing the importance of the optimization of operating conditions according to the matrix being analyzed. In addition, the results obtained show that univariate experiments are not appropriate to optimize the operating parameters of ICP OES when SBR is under evaluation. Considering the responses of SBR together with plasma robustness, it is possible to choose the best condition for the analytical determinations using a few simple experiments and considering that a robust and sensitive method is desirable. Despite the number of papers already published about the optimization of the ICP OES operating conditions,^{6,7,21} the approach of the present work is innovative because the majority of the studies did not consider plasma robustness and SBR, in parallel, as responses in multivariate studies. Considering only one of the monitored parameters, the optimum conditions would be different from the compromise conditions chosen, as demonstrated in this work. In addition, the use of SBR and plasma robustness could be a good alternative in the optimization process of an ICP OES method. The monitoring of these two responses could provide better results than the use of the limit of detection and precision.

Analytical Features. To evaluate the accuracy of the method in the compromise conditions chosen, addition and recovery studies were carried out at three levels of concentration and in triplicate (Table 2) for sample A. The recoveries obtained in each level are shown in Table 3. The recoveries were, in general, between 95 and 105%, showing adequate accuracy for the majority of the elements. The limits of detection (LOD) and quantification (LOQ) for the analytes obtained with the compromise conditions are presented in Table 4. The correlation coefficients of the analytical curves presented values of at least 0.998, whereas the RSDs were, in general, <5%. Considering these figures of merit, the proposed method can be applied for the determination of Al, Ba, Cd, Co, Cr, Cu, Fe, Mg, Mn, Mo, Ni, P, Pb, V, and Zn in chocolate drink powder.

Analytical Determinations. Using the optimized operating conditions, 15 samples of chocolate drink powder were analyzed in triplicate. The concentrations obtained for each analyte and the standard deviations are presented in Table 5. As can be observed, chocolate drink powders present, in general, high amounts of nutrients such as P and Mg and also other metallic species essential for human health, such as Mn, Zn, and Fe.²² Potentially toxic elements such as Cd and Pb, for instance, were not found in significant concentrations. Among the samples analyzed it is possible to observe that sample E, a diet product, presented the highest concentrations for Al, Ba, Co, Cr, Cu, Fe, Mn, Mo, and Zn, whereas the highest concentration of Mg was found in sample B, a light product. Therefore, in general, the light and diet products presented the highest concentrations of the analytes, except for P. It is interesting to note that the amounts of other elements, such as Co, were quantified only in the samples of light and diet products. The

highest concentration of P was found in sample K, a soy-based product, probably due to the addition of tricalcium phosphate as an antihumectant reagent, besides the fact that soybean is a cereal rich in phosphorus, which can be stored in the form of phytic acid.^{23,24} When the samples analyzed in this work were compared with those analyzed by Pedro et al.¹³ the concentrations found for Mg, P, Cu, and Zn were similar. On the other hand, the concentrations found for Fe are quite different, being lower in the samples analyzed in this work. Metallic species such as Mo and Cr¹³ were found in only some of the samples analyzed. Moreover, this work evaluated the presence of other elements such as Al, Cd, Ba, Ni, V, As, and Co, considering that there are no studies regarding the determination of these metallic species in chocolate drink powder in the literature.

Little information about the mineral content of this type of sample is reported on the product labels. The majority of the samples reported only the concentration of sodium, whereas in some samples it is possible to find information about the concentrations of Ca, Fe, and Mg. Information about the amount of other elements such as P, Zn, and Mn is scarce on the labels, highlighting the lack of information about the mineral content of this type of food for consumers. In this case, the concentrations found are in agreement with the information reported by manufacturers for those elements for which information about the concentration is available.

The proposed method was applied to the analysis of 15 different samples of chocolate drink powder. According to the results, the light and diet products presented the highest concentrations of the elements studied, except P, which was found in a higher concentration in a soy-based product.

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Notes

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