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Article

Development of an Analytical Method for the Determination of Metals in Chicken Breast by Microwave Induced Plasma Optical Emission Spectrometry (MIP-OES)

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An analytical method for the determination of Al, Ca, Cd, Cr, Cu, Fe, Hg, K, Mg, Na and Zn in breast of conventional, country and Christmas chicken and turkey samples using microwave induced plasma optical emission spectrometry (MIP-OES) technique was developed. Samples were decomposed in a digester block with a reflux system under conditions optimized using a central composite design as it follows: 2 g of sample, in 7.5 mL of HNO_3 during 180 min at 160 °C. The accuracy was evaluated by the analysis of standard reference material SRM 1546 meat homogenate (94 to 108%) and also by addition and recovery tests (80 to 121%). The highest concentrations, in mg kg^{-1}, of Al (2.77), Ca (88.3), Cu (1.99), Fe (3.65), K (3236), Mg (292.62) and Na (312.03) were found in the breast of conventional chicken sample. Zinc presented high value in the breast of turkey sample (10.6 mg kg^{-1}). However, the found concentrations were lower than the daily consumption limit established by supervisory agencies and reference limits from Brazilian legislation. Cadmium, Cr and Hg presented values below limit of quantification. In this way, it is evident that chicken breast should be consumed in a complementary way in a healthy diet.

Keywords: chicken breast, acid decomposition, metals, MIP-OES

Introduction

According to the Brazilian Animal Protein Association (ABPA), few countries in the world have the propensity that Brazil naturally achieved to be recognized internationally as the "Barn of the World" due to extensive grain fields with fertile land and an exceptionally favorable climate. Brazil has also compromised itself as a partner in food security in several countries around the world.[1]

Since the 1980s, the meat segment in Brazil has been very dynamic in relation to production, consumption and foreign trade. Particularly noteworthy is the poultry sector, which has expanded both in terms of slaughter and exports, as it is very competitive and integrated with the foreign market.[2] Approximately 70% of the Brazilian chicken exports are concentrated in the Southern part of the country (Santa Catarina and Rio Grande do Sul states).[1,2]

Chicken meat, besides being tasty, has other attractive features, such as affordable prices and high nutritional content.[3,4] According to the United States Department of Agriculture (USDA),[5] chicken meat and offals are rich in protein as well as in vitamins, and present minerals such as Ca, Fe, Mg, P, K, Zn, Mn and Se. The low-fat content of chicken breast meat is also another important reason for those seeking a healthier diet.[6-8]

According to the ABPA report,[1] the chicken meat *per* capita consumption in 2017 reached 42.07 kg a year. Due to the high consumption of chicken meat and also to the increase in exports, there is a requirement regarding the food security of chicken meat. Generally, chickens and turkey are reared in intensive farms and their feeding can contain additives. In this way, the mineral content of meat varies depending on the breed, rearing, diet, cut and carcass processing.[9]

Food composition data are important for estimating the adequacy of essential nutrient intake and for assessing the risks of exposure, mainly from the ingestion of potentially toxic elements. Food intake is a mean of exposure to metals because they are naturally constituents of foodstuffs, but it can also happen by environmental contamination or contamination during processing.[9] The elements can be classified as non-essential (Al, As, Cd, Pb, Hg, etc.) and essential (Fe, Mn, Cu, Zn, Se, among others). Potentially

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toxic elements can be harmful even at low concentrations when ingested over a long period of time. An interesting case is found for the As. Hunter[10] in a report mentions that As can be considered as a micronutrient in animals and Zheng *et al.*[11] related an interaction of As with Se. The recommended daily intake of As should be smaller than Se (40 µg *per* day). The essential elements may also produce toxic effects when ingested in excess.[12,13] The literature reports few studies of chicken meat that evaluates the metal concentrations. Hu *et al.*[14] determined trace metals (Cu, Zn and As) in fresh chicken meat products. Menezes *et al.*[15] evaluated the bioaccessibility of Ca, Cu, Fe, Mg and Zn in beef, pork and chicken samples. Wu *et al.*[16] evaluated the concentration of trace elements as Cd, Hg, Pb, As, Cr, Cu, Fe, Zn, etc. in chicken meat products by inductively coupled plasma mass spectrometry (ICP-MS).

The quantification of metals in food samples is usually carried out by atomic spectrometry techniques. The microwave induced plasma optical emission spectrometry (MIP-OES) provides multi-element analysis and sequential measurements. Can be highlighted due to low operational cost, since the plasma is maintained through nitrogen removed from the atmospheric air and does not require flammable or expensive gases such as acetylene, nitrous oxide or argon, besides exhibits limits of detection close to the techniques of flame atomic absorption spectrometry (FAAS) and inductively coupled plasma optical emission spectrometry (ICP-OES).[17-20]

The sample preparation is the most important step of a chemical analysis and there is no universal procedure that can be used in samples of different compositions. Thus, it is typical of the field of analytical chemistry to perform sequential studies on new systems and/or sample preparation methods in order to expand their working capacity. Reflux systems for acid decomposition have recently been applied, providing satisfactory results for the determination of metal and volatile elements in different samples.[21-24] The cold finger (reflux system) provide a larger surface area for the condensation and allow the formation of the absorber solution film for better retention of the volatile species. In this way, losses of analyte by volatilization and reposition of acids are avoided, increasing the efficiency of decomposition.[21]

Considering the importance of chicken meat food security, the present study aims to develop an analytical method for the quantification of Al, Ca, Cd, Cr, Cu, Fe, Hg, K, Mg, Na and Zn in chicken breast samples (conventional chicken, country and Christmas chicken and turkey) by MIP-OES. The acid decomposition with the reflux system was employed and the best conditions were optimized using a central composite design (CCD).

Experimental

Instrumentation

The measurements were carried out using a 4200-MIP-OES (Agilent Technologies, Melbourne, Australia) equipped with a nitrogen generator model 4107 (Melbourne, Australia). The nebulizer flow rate was variable for each analyte (Table S1, Supplementary Information (SI) section). Two sample introduction systems were employed: a double-pass cyclonic chamber and the inert OneNeb nebulizer and also a multimode sample introduction system (MSIS) that allows simultaneous nebulization and vapor generation. All measurements were performed in triplicate. The integration time was 10 s and the stabilization time was 15 s. Instrumental parameters such as nebulizer gas pressure and viewing position were automatically optimized, for each analyte separately, using the instrument software (MP Expert). The background correction was performed automatically by the software.

For sample decomposition, a digester block was employed (MA-4025 model, Marconi, Piracicaba, SP, Brazil). In each digester tube, a cold finger with continuous water recirculation (ca. 15 ºC) was introduced to avoid losses by volatilization of analytes and reagents, as described in a previous work.[21] More details of the reflux system can be found in Figure S1 (SI section).

Reagents and samples

All reagents used were of analytical grade. Solutions used were prepared with deionized water obtained by a water distiller MA078 (Marconi, Piracicaba, SP, Brazil) and subsequently deionized by passing through a column CS1800 (Permution, Curitiba, PR, Brazil). Calibrations solutions were prepared from a multielement standard solution 6 for ICP (Sigma Aldrich, Buchs, Switzerland) containing 100 mg L^{-1} of each analyte. The nitric acid (Synth, Diadema, SP, Brazil) was purified by doubly subboiling distillation in a quartz system (Marconi, model MA-075, Piracicaba, SP, Brazil). For multimode sample introduction system was used $NaBH_4$ 0.5% (m/v) in NaOH 0.5% (m/v). For carbon analysis was used a stock solution of dextrose (Synth, Diadema, SP, Brazil). A standard reference material SRM 1546 Meat Homogenate produced by the National Institute of Standards and Technology (NIST, Gaithersburg, MD, USA) was used for accuracy evaluation. The SRM 1546 is a mixture of pork, mechanically-separated chicken, ham, salt, sucrose, water, and spices.

Samples of conventional chicken, country chicken, Christmas chicken and turkey were acquired in a local

supermarket of Pelotas, RS, Brazil. At the laboratory, the samples were initially cut, the breast was separated and homogenized using a blender (non-contaminated kitchen mixer), put into clean plastic containers and frozen at –16 °C. Chicken breast samples were defrosted just before the sample preparation step. All results were expressed in wet mass.

Optimization procedures

The optimal conditions for acid decomposition procedure were performed by factorial design experiments considering the following variables: HNO_3 volume, decomposition time and decomposition temperature (Table S2, SI section). For the method development, a conventional chicken breast sample was used, and the sample mass was fixed in 2 g. The variables ranges were based on preliminary experiments. A central composite design (CCD) was applied (2^3 factorial, with three central points and six axial points) providing a total of 17 randomly performed experiments. Also, the residual carbon was determined because is an important parameter to evaluate the sample decomposition efficiency, besides being an essential criterion to be controlled depending on the instrumental technique employed.[25] All results were analyzed using the software Statistica® 7.0,[26] considering a significance level of 90%. For these optimizations, the conventional nebulization for sample introduction into the plasma was employed.

Sample preparation procedure

Aliquots of 2 g of chicken breast samples were weighed directly into a glass digester tube, and 7.5 mL of 65% HNO_3 (m/m) was added. The reflux system was then coupled to the digester tubes, and the mixture was heated in a digester block at 160 °C during 180 min. The decomposition was considered complete when the entire sample was dissolved. After cooling, the resulting solution was transferred to a polypropylene flask and filled up to a volume of 50 mL with deionized water. For analysis, the solutions were diluted two times. All samples were prepared in triplicate, and analytical blanks were prepared using the same procedure.

Figures of merit evaluated in this work were: limits of detection (LOD), limits of quantification (LOQ), linearity and accuracy. The procedures were performed in compliance with the INMETRO guide.[27] The linear range employed for Al, Ca, Cd, Cr, Cu, Fe, Hg, K, Mg, Na and Zn was: 0.5 to 5.0 mg L^{-1} (conventional nebulization) and 10 to 250 μg L^{-1} (multimode sample introduction system) and for C, 0.05 to 1.0%. For the elements that were not determined in the SRM 1546 (Al, Cd, Cr, Cu and Hg), the addition and recovery tests were applied at three concentration levels: 0.75; 2.5 and 4.0 mg L^{-1} for conventional nebulization and 20; 65 and 170 μg L^{-1} for the multimode sample introduction system. The difference between the concentration averages found for the metals in the breast samples were evaluated by the Tukey's test, with a significance level of 5%. The statistical analysis was performed using the Origin software tool.[28]

Results and Discussion

Optimization of decomposition procedure

The best conditions for acid decomposition with reflux system of chicken breasts were selected using factorial design experiments considering the following variables: HNO_3 volume, temperature of digester block and decomposition time. The matrix of the full factorial design containing the data for Al, Ca, Cu, Fe, K, Mg, Na and Zn, as well as intensity as the analytical response, is shown in Table S3 (SI section). Also, are presented the results for C concentration that was used in order to evaluate the efficiency of the sample decomposition.

The results evaluated using a Pareto chart (Figure S2, SI section), demonstrated that for Al, Cu, Fe, K and Zn no variable was statistically significant considering a 90% confidence level. Considering the significant variables only, an analysis of variance (ANOVA) was applied for Ca, Mg, Na and C (Table S4, SI section). The results showed that the models are significant and adequate to describe the results through the surface response graphics, as is evident by the *F* value calculated.

The Figure 1 shows the generated surface response graphics at the levels studied for each analyte and the Figure 2 shows the surface response graphics obtained for C. For Ca (Figure S3, SI section), was observed that the interaction between the variables HNO_3 volume and decomposition time were statistically significant; for Na, only the variable HNO_3 volume and for Mg, the temperature of digester block. All variables were statistically significant for C. The analysis of surface response graphics indicated that highest intensity was obtained in the follow conditions: 7.5 mL of HNO_3 for Na and Ca; decomposition time of 180 min for Ca and C and, temperature of digester block at 160 °C for Mg and C.

In general, a longer time allows better results in the sample decomposition process. When the decompositions were performed in less than 180 min, an incomplete decomposition was observed. The intermediate volume of 7.5 mL of HNO_3 allowed us to obtain a clear solution,

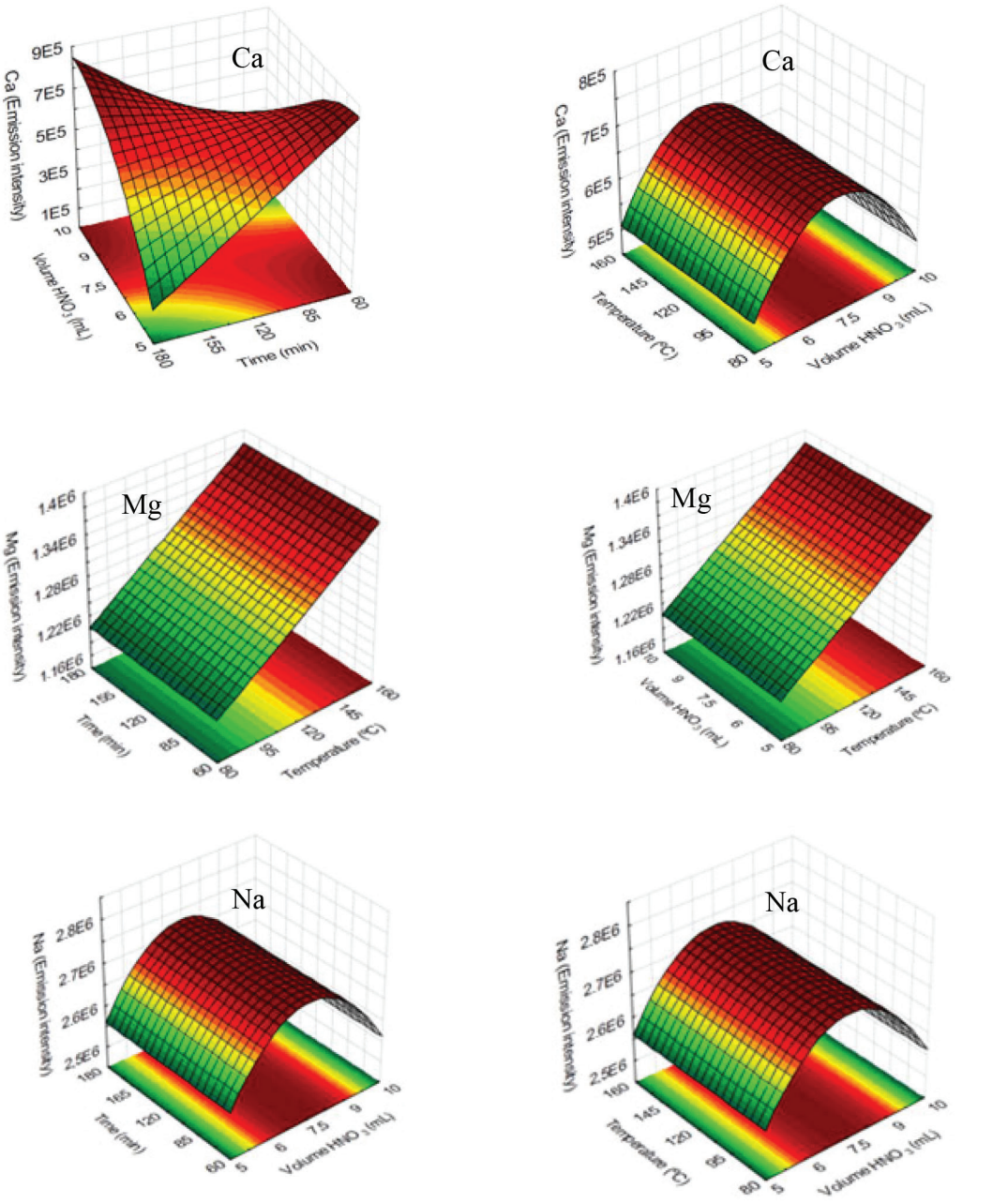

Figure 1. Surface response obtained from the central composite design for Ca, Mg and Na determinations.

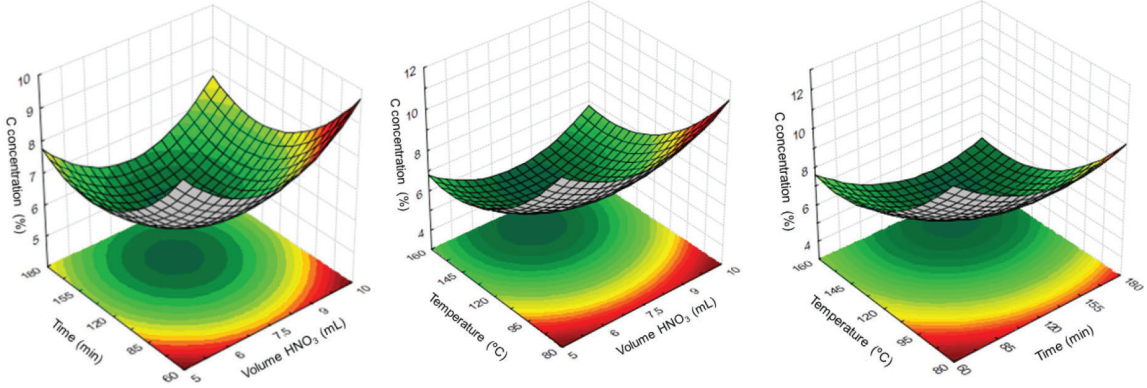

Figure 2. Surface response obtained from the central composite design for C.

ready to be analyzed in MIP-OES. The ideal temperature was 160 °C, also ensuring the boiling point of the HNO_3, which is approximately 120 °C and ensuring the breakdown of the bonds between the analyte and proteins in the case of Zn and Cu[29] or with lipids,[30] allowing the analytes to be free in solution. These conditions are confirmed by the study of C, where lower C concentrations were found under these conditions (trial 8 on Table S3, SI section).

Since no variables were statistically significant for Al, Cu, Fe, K and Zn, the same conditions of acid decomposition employed for Ca, Mg and Na were used in order to standardize the method. The accuracy of the method was evaluated with the use of standard reference material, as well as the addition and recovery test.

Analytical results

Figures of merit for the determination of the analytes Al, Ca, Cd, Cr, Cu, Fe, Hg, K, Mg, Na and Zn in chicken breast samples by MIP-OES were obtained from calibration curves data and the two sample introduction systems were used: conventional nebulization and MSIS (Tables S5 and S6, respectively, SI section).

The linear range for conventional nebulization was 0.5-5.0 mg L^{-1} and for multimode sample introduction system it was 10-250 µg L^{-1}. For both systems, the calibration curves presented a linear correlation coefficient > 0.99, indicating good linearity. The limits of detection and quantification obtained are adequate for the determination of metals in chicken breast samples. The multimode system presented better values probably because the chemical generation of vapor occurs simultaneously with the nebulization. The generation of hydrogen, from the reducing agent, increases the plasma energy and consequently improves the emission for hydride and nonhydride-forming elements and the sensitivity, as can be observed by the angular coefficients values of the obtained curves.[20]

The limits of detection obtained using the conventional nebulization and considering the sample mass were lower those reported by Menezes *et al.*[15] and Ogbomida *et al.*[31] that determined the concentration of metals by ICP-OES in crude protein in beef, pork and chicken after microwave-assisted digestion and in tissue chicken by ICP-MS, respectively.

The accuracy of the method was evaluated using standard reference material with matrix similar to the samples and the results (considering the sample wet) are shown in Table 1. The results were submitted to the statistical test (*t*-test, 95% confidence level) and no significant differences between the results were observed, for both sample introduction systems. The recovery range for the conventional nebulization was between 94 to 103% (with good accuracy) and relative standard deviation value (RSD) lower than 8.6%, also attesting to a good precision. For the multimode system, the recovery range was 94 to 108% and RSDs were lower than 6.8%. Sodium could not be determined through the MSIS because sodium borohydride is introduced into the system during the analysis.

Table 1. Analytical results of the concentrations for Ca, Fe, K, Mg, Na and Zn in SRM 1546 using a conventional nebulization (CN) and multimode sample introduction system (MSIS)

Analyte	Concentration[a]		
	Certified value / (mg kg^{-1})	CN / (mg kg^{-1})	MSIS / (mg kg^{-1})
Ca	360 ± 130	340 ± 15	338 ± 5
Fe	10.17 ± 0.35	10.35 ± 0.32	10.51 ± 0.55
K	2490 ± 210	2564 ± 140	2681 ± 86
Mg	178.1 ± 4.8	182.4 ± 3.49	173.1 ± 3.03
Na	9600 ± 1100	9776 ± 514	ND
Zn	17.88 ± 0.35	17.60 ± 1.52	18.22 ± 1.24

[a]Average ± standard deviation for n = 3; ND: not determined; CN: conventional nebulization; MSIS: multimode sample introduction system.

For Al, Cd, Cr, Cu and Hg the accuracy was assessed through the addition and recovery test by adding three levels of the inorganic standards concentration to a chicken breast sample using both sample introduction system. All the samples were spiked prior to the decomposition procedure. In some cases, the concentrations of these analytes on SRM presented lower values than the first point of the calibration curve. The results are shown in Tables 2 and 3. The recoveries for conventional nebulization ranged from 80 to 108% and for MSIS ranged from 80 to 121% showing good accuracy. The precision was verified, and the values of RSDs were lower than 8.8%.

After establishing the sample preparation method, breast from conventional chicken, country chicken, Christmas chicken and turkey were analyzed using the conventional nebulization and multimode sample introduction system. The obtained concentrations for Al, Cd, Cr, Cu, Fe, Hg, K, Mg, Na and Zn are shown in Table 4. The RSDs values were lower than 11.8%, confirming the good precision of analysis. The results were submitted to the Tukey's test at the 95% confidence level, comparing similarity/difference between nebulization methods (column) or comparing element values in the same nebulization method for different samples (line).

The knowledge about food composition is essential for quality control, for the assessment of essential nutrients

Table 2. Concentrations of Al, Cd, Cr, Cu and Hg measured by MIP-OES in conventional chicken breast sample after the additions of analytes using conventional nebulization

Addition	Measured[a] / (mg kg^{-1})	Recovery / %
	Al	
0	2.77 ± 0.02 (0.4)	–
37.5	39.9 ± 0.5 (1.2)	99
125	132.7 ± 3.0 (2.2)	104
200	212.4 ± 2.2 (1.0)	105
	Cd	
0	< 0.02[b]	–
37.5	32.9 ± 2.9 (8.8)	88
125	115.4 ± 3.7 (3.2)	92
200	173.2 ± 9.8 (5.6)	87
	Cr	
0	< 0.014[b]	–
37.5	35.0 ± 1.7 (4.9)	93
125	129.9 ± 7.9 (6.1)	104
200	195.2 ± 11.8 (6.1)	98
	Cu	
0	1.99 ± 0.20 (9.9)	–
37.5	39.7 ± 1.0 (2.5)	100
125	133.4 ± 3.9 (2.9)	105
200	208.1 ± 8.0 (3.8)	103
	Hg	
0	< 3.32[b]	–
37.5	30.0 ± 0.9 (3.1)	80
125	100.4 ± 1.1 (1.1)	80
200	215.9 ± 0.2 (0.1)	108

[a]Average ± standard deviation (relative standard deviation) for n = 3; [b]LOQ in mg kg^{-1}.

Table 3. Concentrations of Al, Cd, Cr, Cu and Hg measured by MIP-OES in conventional chicken breast sample after the additions of analytes using MSIS

Addition	Measured[a] / (mg kg^{-1})	Recovery / %
	Al	
0	2.77 ± 0.05 (1.8)	–
1.0	3.89 ± 0.01 (0.3)	112
3.25	6.17 ± 0.08 (1.2)	105
8.5	13.05 ± 0.07 (0.6)	121
	Cd	
0	< 15.03[b]	–
1.0	0.81 ± 0.01 (1.7)	81
3.25	2.63 ± 0.09 (3.5)	81
8.5	7.26 ± 0.36 (5.0)	85
	Cr	
0	< 1.49[b]	–
1.0	1.15 ± 0.07 (6.4)	115
3.25	3.43 ± 0.03 (0.8)	105
8.5	8.77 ± 0.25 (2.8)	103
	Cu	
0	1.86 ± 0.11 (5.9)	–
1.0	2.67 ± 0.02 (0.9)	81
3.25	4.76 ± 0.01 (0.2)	89
8.5	10.69 ± 0.21 (2.0)	104
	Hg	
0	< 0.87[b]	–
1.0	0.82 ± 0.01 (1.7)	82
3.25	2.87 ± 0.08 (2.7)	88
8.5	7.99 ± 0.29 (3.6)	94

[a]Average ± standard deviation (relative standard deviation) for n = 3; [b]LOQ in µg kg^{-1}.

intake and for the evaluation of exposure risks resulting from the metals ingestion. According to the results of the present study, the order of the elements found in the chicken breast was K > Na > Mg > Ca > Zn > Fe > Al > Cu. Concentrations of Cd, Cr and Hg were below the limit of quantification.

Among the investigated metals, the highest concentrations were found in the conventional chicken for Al, Ca, Cu, K and Mg. This may be due to the way of raising conventional chicken, if given by a greater anthropogenic action. For Zn, the highest concentrations were found in turkey breast sample. The highest Na values were found in the breast of turkey and Christmas chicken, because these samples were already spiced when purchased.

Andrade *et al.*[32] evaluated the concentration of Cu and Zn in conventional chicken breast samples and found 0.48 and 0.76 mg kg^{-1} of Cu and Zn, respectively. These results were lower than those reported by Sun and Xing,[33] which was 0.52 mg kg^{-1} for Cu and 7.06 mg kg^{-1} for Zn, but were close to the ones in the present study for Zn: 7.72 mg kg^{-1}. In the same study, the concentration values found for Mg, Al, Na and K were 253.77; 3.27; 474.858 and 3,471.52 mg kg^{-1}, respectively. These values are also close to the present study, which were 292.62; 2.77; 312.03 and 3,236.0 mg kg^{-1} for Mg, Al, Na and K, respectively.

For Hg and Cd, the found concentrations values were below the reference limit in muscle that is 30 µg kg^{-1} and 0.05 mg kg^{-1}, respectively.[34,35] The Brazilian legislation does not establish maximum levels for Cr.

Table 5 shows the recommended daily intake values[36] for the analytes Ca, Cu, Fe, K, Mg, Na, and Zn and the calculated values for conventional chicken, country

Table 4. Concentrations obtained for Al, Ca, Cd, Cr, Cu, Fe, Hg, K, Mg, Na and Zn by MIP-OES in chicken breast sample using the conventional nebulization (CN) and multimode system (MS) (n = 3)

Analyte		Sample			
		Conventional / (mg kg^{-1})	Country / (mg kg^{-1})	Turkey / (mg kg^{-1})	Christmas / (mg kg^{-1})
Al	CN	2.77 ± 0.02 (0.4)^{Aa}	0.92 ± 0.02 (1.3)^{Ac}	2.13 ± 0.29 (10.6)^{Ab}	1.79 ± 0.19 (7.8)^{Ab}
	MS	2.77 ± 0.05 (1.8)^{Aa}	1.26 ± 0.15 (11.7)^{Ac}	1.87 ± 0.01 (0.5)^{Ab}	1.72 ± 0.09 (5.2)^{Ab}
Ca	CN	88.30 ± 0.07 (0.1)^{Aa}	39.08 ± 0.25 (0.5)^{Ac}	50.61 ± 1.12 (1.8)^{Ab}	49.01 ± 1.28 (2.1)^{Abc}
	MS	84.16 ± 9.93 (11.8)^{Aa}	34.18 ± 2.51 (7.3)^{Ac}	58.71 ± 1.04 (1.8)^{Ab}	42.15 ± 0.75 (1.8)^{Ac}
Cu	CN	1.99 ± 0.20 (9.9)^{Aa}	0.61 ± 0.03 (4.3)^{Ac}	0.76 ± 0.05 (6.2)^{Ab}	0.65 ± 0.02 (2.4)^{Bc}
	MS	1.86 ± 0.11 (5.9)^{Aa}	0.64 ± 0.03 (3.1)^{Ac}	0.76 ± 0.04 (4.1)^{Ab}	0.75 ± 0.02 (2.1)^{Ab}
Fe	CN	3.95 ± 0.20 (4.9)^{Aa}	2.20 ± 0.21 (9.6)^{Ac}	2.97 ± 0.18 (6.2)^{Ab}	4.52 ± 0.16 (3.5)^{Aa}
	MS	3.15 ± 0.30 (9.4)^{Bb}	2.10 ± 0.08 (3.8)^{Ac}	2.78 ± 0.30 (10.8)^{Ab}	4.22 ± 0.19 (4.5)^{Aa}
K	CN	3236 ± 40 (1.2)^{Aa}	2915 ± 26 (0.9)^{Aab}	2581 ± 48 (1.9)^{Abc}	2425 ± 119 (4.9)^{Ac}
	MS	3182 ± 309 (10.9)^{Aa}	2643 ± 189 (7.8)^{Ab}	2077 ± 139 (7.2)^{Bc}	1792 ± 75.9 (4.5)^{Bc}
Mg	CN	292.62 ± 6.35 (2.2)^{Aa}	273.25 ± 7.64 (2.8)^{Ab}	251.87 ± 2.49 (1.0)^{Ac}	220.75 ± 0.90 (0.4)^{Ad}
	MS	286.14 ± 5.53 (1.9)^{Aa}	280.60 ± 7.78 (2.8)^{Aa}	232.03 ± 2.16 (0.9)^{Bb}	210.88 ± 5.77 (2.7)^{Ac}
Na	CN	312.03 ± 0.59 (0.2)^{c}	325.12 ± 21.95 (6.7)^{c}	1639 ± 26 (1.6)^{b}	4036 ± 174 (4.3)^{a}
Zn	CN	7.72 ± 0.79 (10.3)^{Ab}	5.38 ± 0.43 (8.1)^{Ac}	10.60 ± 0.27 (2.5)^{Ba}	9.07 ± 0.20 (2.2)^{Bab}
	MS	8.21 ± 0.85 (10.0)^{Ac}	6.88 ± 0.68 (9.4)^{Ac}	16.78 ± 0.46 (2.6)^{Aa}	12.15 ± 1.28 (10.3)^{Ab}

Results followed by equal capital letters in the same column, for each analyte, do not indicate significant difference at $p < 0.05$; results followed by lower case letters in the same column, for each analyte, do not indicate significant difference at $p < 0.05$; CN: conventional nebulization; MS: multimode system.

Table 5. Comparison between results of intake with recommended daily intake

Analyte	Conventional / (mg *per* 100 g)	Country / (mg *per* 100 g)	Turkey / (mg *per* 100 g)	Christmas / (mg *per* 100 g)	RDI[36] / (mg *per* day)
Ca	8.83	3.91	5.06	4.90	1000
Cu	0.20	0.06	0.08	0.06	0.9
Fe	0.40	0.22	0.30	0.45	14
K	323.6	291.5	258.1	242.5	4700
Mg	29.26	27.32	25.19	22.07	260
Na	31.20	32.51	163.9	403.6	2000
Zn	0.77	0.54	1.06	0.91	7

RDI: recommended daily intake.

chicken, turkey and Christmas chicken considering the recommended daily requirement of meat for an adult individual of 100 g *per* day.[36-39] The calculated values for all samples are below the recommended daily intake limit for the investigated metals, which shows that chicken's meat are a complementary part of a healthy diet and that there is a need for other sources providing the nutrients of these analytes, considered essential for the functioning of cellular metabolism. For Christmas chicken (spiced), Na presented a high intake value (403.60 mg *per* 100 g). For Al, the maximum limit allowed for all ages is 2 mg kg^{-1} of body weight.[36] The value obtained in the conventional chicken was 0.28 mg *per* 100 g, which is below the tolerable limit, demonstrating that there is no risk of intoxication by this element through the ingestion of this kind of food.

Conclusions

From the results was possible to conclude that the sample preparation method employing the reflux system allows a suitable decomposition. We used only HNO_3 for sample decomposition, simplifying the method and the results presented accuracy and precision. It was possible to determine the concentrations of Al, Ca, Cd, Cr, Cu, Fe, Hg, K, Mg, Na and Zn in the breast of conventional and country chicken, turkey and Christmas chicken

samples by MIP-OES. Limits of detection obtained are suitable for the determination of metals in chicken breast samples. The highest analyte concentrations were obtained in the conventional chicken, the most exposed matrix to anthropogenic actions. The analytes presented concentrations lower than the recommended daily intake, showing that chicken breast should be a complementary part of a healthy diet.

Supplementary Information

Supplementary data are available free of charge at http://jbcs.sbq.org.br as PDF file.

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