Determination of aluminum in highly concentrated iron samples: Study of interferences using high-resolution continuum source atomic absorption spectrometry ☆

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Abstract

High-resolution continuum source atomic absorption spectrometry (HR-CS AAS) has been used to investigate spectral and non-spectral interferences found with a conventional line source atomic absorption spectrometer in the determination of aluminum in pharmaceutical products containing elevated iron and sugar concentrations. A transversely heated graphite furnace was used as the atomizer in both spectrometers. The two most sensitive aluminum lines at 309.3 nm and 396.2 nm were investigated and it was found that an iron absorption line at 309.278 nm, in the vicinity of the aluminum line at 309.271 nm, could be responsible for some spectral interference. The simultaneous presence of iron and the organic components of the matrix were responsible for radiation scattering, causing high continuous and also structured background absorption at both wavelengths. The aluminum and iron absorption could not be separated in time, i.e., the iron interference could not be eliminated by optimizing the graphite furnace temperature program. However, an interference-free determination of aluminum was possible carrying out the measurements with HR-CS AAS at 396.152 nm after applying least squares background correction for the elimination of the structured background. Analytical working range and other figures of merit were determined and are presented for both wavelengths using peak volume registration (center pixel±1) and the center pixel only. Limits of detection and characteristic masses ranged from 1.1 to 2.5 pg and 13 to 43 pg, respectively. The method was used for the determination of the aluminum contamination in pharmaceutical formulations for iron deficiency treatment, which present iron concentrations from 10 to 50 g l^{-1}. Spike recoveries from 89% to 105% show that the proposed method can be satisfactorily used for the quality control of these formulations.
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1. Introduction

Parenteral supplementation of iron is required in some patients with iron deficiency, including those with oral iron intolerance and dialysis dependence. Anemia associated with chronic renal insufficiency has clinical and public health importance. Although oral iron application is effective in some patients, especially those receiving hemodialysis require intravenous iron to replenish their iron stores. Approximately 85% of hemodialysis patients are administered intravenous iron. Iron gluconate and iron sucrose have become the predominant forms of therapy [1].

The toxicity of Al is well known in the pathogenesis of some disorders observed in patients with chronic renal failure undertaking hemodialysis. The US Food and Drug Administration and other regulatory agencies [2,3] have recommended minimizing patient exposure to Al by restricting its level in dialysis fluids. The limit for Al in water used to prepare such fluids is 10 μg l^{-1},

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and for the fluid itself 30 μg l^{-1} [3]. Hemodialysis fluids, however, are not the only Al source for chronic renal patients. The medication administrated to the patients can also contribute to elevate their Al serum level, mainly if it is parenterally administrated, since in this case there are no barriers for its absorption.

In spite of being an important issue, only a few studies deal with the determination of Al traces in the presence of Fe [4,5] and no one is dedicated to Fe in pharmaceutical products. Although there are no rules limiting the Al contamination in iron formulations, the frequency and the intravenous way of administration make this control as important as that of hemodialysis fluids.

The Fe concentration in these solutions reaches values up to 50 g l^{-1}; therefore it is necessary to count on a technique that allows the measurement of Al traces in the presence of elevated Fe concentrations. Since these formulations contain from 5 to 300 g l^{-1} of carbohydrates, the measurement technique must also be able to deal with high organic matter. Graphite furnace atomic absorption spectrometry (GF AAS) is one of the most suitable techniques for the determination of Al traces, mainly considering that it can tolerate the presence of organics, which are difficult to handle in other techniques such as voltammetry and chromatography, although GF AAS is not free of interferences.

Spectral interferences in conventional GF AAS might be corrected using deuterium lamp or the Zeeman-effect background correction. However, the determination of Al in an Fe matrix with conventional equipment using deuterium background correction turned out to be particularly difficult and no consistent results could be obtained. The present study was therefore carried out using a conventional line source atomic absorption spectrometer with the Zeeman-effect background correction and also with a prototype high-resolution continuum source atomic absorption spectrometer.

Although the probability of direct overlap of atomic lines is small in AAS, the Zeeman splitting of absorption lines increases the number of lines that could cause spectral interferences. In the 1980s several studies were carried out showing spectral interferences from concomitant atomic lines adjacent to analyte absorption lines [6–9]. Using high-resolution continuum source atomic absorption spectrometry (HR-CS AAS), Welz and co-workers have shown that the interferences associated with the determination of thallium in coal [10] and in marine sediments [11] could be eliminated using adequate furnace conditions and by altering instrumental parameters such as start and end of signal integration, the pixels used for signal evaluation, and least-squares background correction (LSBC) [12] after the measured data have been stored. LSBC is a mathematical procedure making a linear fit of one or more pre-recorded reference spectra to every single sample spectrum. The reference spectrum is increased or decreased by multiplication with a magnification factor. The differences between the reference spectrum and the sample spectrum, as well as their squares, are calculated on the pixel basis, and the sum of the square values over all pixels is added up. After that, the mentioned magnification factor is varied in order to minimize the sum of the squares or — in other words, to find the 'least squares'. Finally the optimal reference spectrum is subtracted from the sample spectrum in order to eliminate the structured background [13].

Becker-Ross et al. [14] used HR-CS AAS to avoid and correct the well-known interferences associated with the determination of selenium and arsenic in biological samples. Salomon et al. [15] also used this technique to carry out a thorough study to characterize the interferences in the determination of Al in seawater.

The goal of this work was to study the interferences caused by Fe and carbohydrates on the measurement of Al. The use of HR-CS AAS as a diagnostic tool enabled to identify the problem associated with the determination of small amounts of Al in the presence of high Fe and sugar matrices and to establish a reliable method for the analysis of pharmaceutical formulations for iron deficiency treatment.

2. Experimental

2.1. Instrumentation

The initial measurements were carried out using a Model 4100ZL atomic absorption spectrometer (Perkin Elmer, Überlingen, Germany) equipped with longitudinal the Zeeman-effect background correction, an electrothermal atomizer with a transversely heated graphite tube (pyrolytic coated), and an AS-70 autosampler. An Al hollow cathode lamp (Narva, Berlin, Germany) was used; the lamp current was set to 10 mA, and the resonance lines at 309.3 and 396.2 nm were used with a spectral bandwidth of 0.7 nm. Argon was used as the purge gas. The graphite furnace temperature program is given in Table 1. The sample volume used in all measurements was 10 μl.

The majority of measurements were carried out using a prototype high-resolution continuum source atomic absorption spectrometer, built at ISAS, Department for Interface Spectroscopy, Berlin. The prototype is based on an AAS 6 Vario atomic absorption spectrometer (Analytik Jena AG, Jena, Germany), from which the entire optical compartment including detector and associated controls had been removed and replaced by a double monochromator (DEMON) similar to the system described by Heitmann et al. [16]. The instrument features have been described in detail in previous publications [12,14].

Table 1
Graphite furnace temperature programs for the determination of Al using conventional line source GF AAS with the Zeeman-effect background correction and HR-CS GF AAS

Step	Temperature/°C		Ramp		Hold time/s		Gas flow rate/ l min^{-1}	
	A	B	A/s	B/°C s^{-1}	A	B	A	B
1	90	90	5	10	15	5	2.5	3
2	120	120	30	10	10	5	2.5	3
3	700	700	5	10	5	5	2.5	3
3	1600	1600	5	100	20	10	2.5	3
5	2350	2600	0	3000	3	3	0	0
6	2600	2600	1	100	3	3	2.5	3

A: Zeeman-effect GF AAS, B: HR-CS GF AAS.
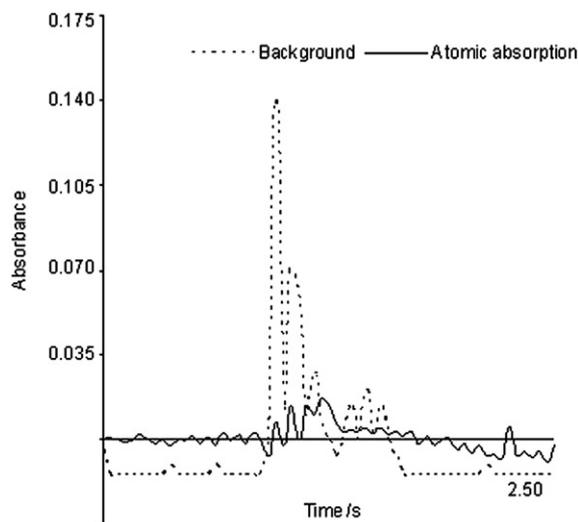
Fig. 1. Absorbance signal of 0.2 ng Al in the presence of Fe (5 g l^{-1}), gluconate (75 g l^{-1}) and sucrose (75 g l^{-1}), measured with the commercial line source atomic absorption spectrometer with the Zeeman-effect background correction at 309.3 nm. Pyrolysis temperature: 1600 °C; atomization temperature: 2350 °C.

The system was controlled by a Pentium III, 1000 MHz personal computer, running a data acquisition program developed at ISAS, Berlin. At 309.271 nm and 396.152 nm, the main Al absorption lines, the spectral resolution per pixel is 2.5 and 3.0 pm, respectively. The Al absorption was measured using the center pixel (CP) only and CP±1 (peak volume), i.e., over a spectral interval of approximately 8–9 pm.

2.2. Reagents

All chemicals used in this study were of analytical reagent grade. An aqueous stock solution containing 1000 mg l^{-1} Al (Merck, Darmstadt, Germany) was used to prepare the working standard solutions. All solutions were prepared with water purified in a Milli-Q system (Millipore, Bedford, USA). A 1000 mg l^{-1} Fe standard solution (Merck) was used for preliminary experiments. Iron nitrate (Fe(NO$_3$)$_3$·9 H$_2$O), iron sulfate (FeSO$_4$·7 H$_2$O), iron chloride (FeCl$_3$.6H$_2$O), sucrose (all Merck) and sodium gluconate (Fluka, Buchs, Switzerland) were used to prepare artificial matrix solutions. Concentrated ammonium hydroxide solution (Merck) was used for pH adjustment and chrome azurol S (Merck) as complexing agent for Al.

2.3. Samples

Four different pharmaceutical formulations containing iron were analyzed by the proposed method, one intravenous and three for oral administration. The formulations were: Nor-ipurum (Altana Pharma, Germany), containing 20 mg Fe (III) per ml as hydroxide plus sucrose, Lomavital (Lomapharm, Germany) containing 7 mg Fe per 10 ml as gluconate, Iron tablet (Krüger GmbH, Germany) containing 5 mg Fe per tablet (4.5 g) as gluconate, and Combiron (Aché Laboratórios Farmacêuticos S.A., Brazil), containing 125 mg ferrous sulfate per ml.

3. Results and discussion

3.1. Preliminary experiments

Preliminary experiments were carried out with artificial samples containing the main constituents of iron formulations: Fe (5 g l^{-1}), gluconate (75 g l^{-1}) and sucrose (75 g l^{-1}), individually and mixed, using the conventional line source spectrometer (PE 4100ZL). The measurements were carried out at both wavelengths using the graphite furnace temperature program presented in Table 1. Fig. 1 shows the absorbance signals obtained at 309.3 nm. The system could obviously not accurately correct for the background absorption due to the residual sample matrix, and an oscillation on both background
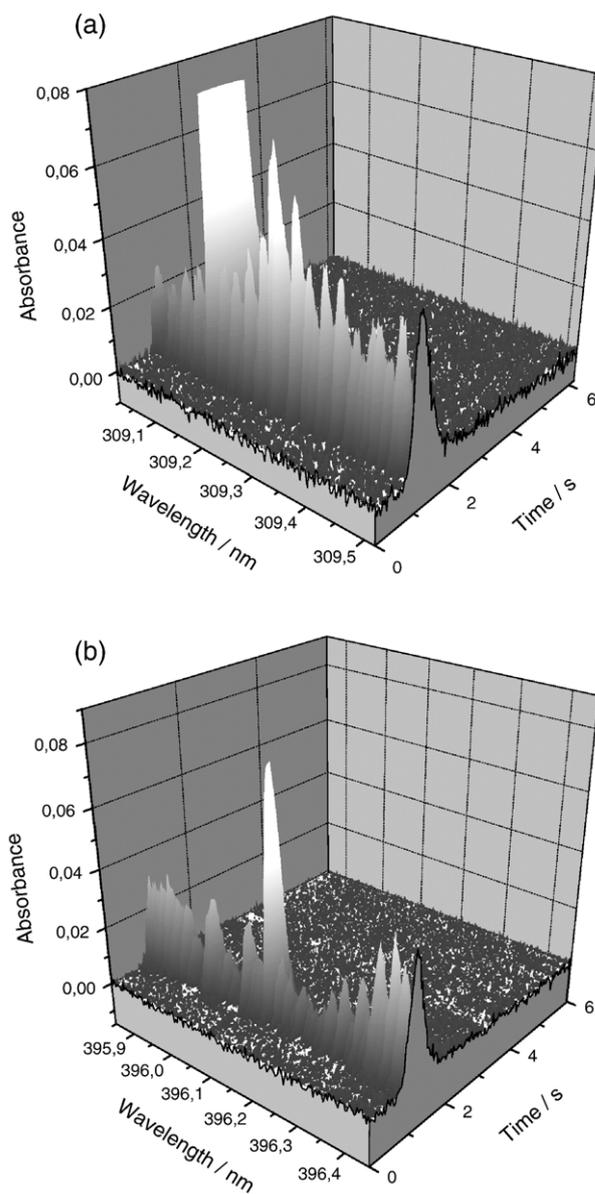
Fig. 2. Time- and wavelength-resolved absorbance spectrum of 0.2 ng Al in the presence of Fe (5 g l^{-1}), gluconate (75 g l^{-1}) and sucrose (75 g l^{-1}), measured with HR-CS AAS. Pyrolysis temperature: 1600 °C; atomization temperature: 2600 °C. (a) at 309.271 nm (b) at 396.152 nm.
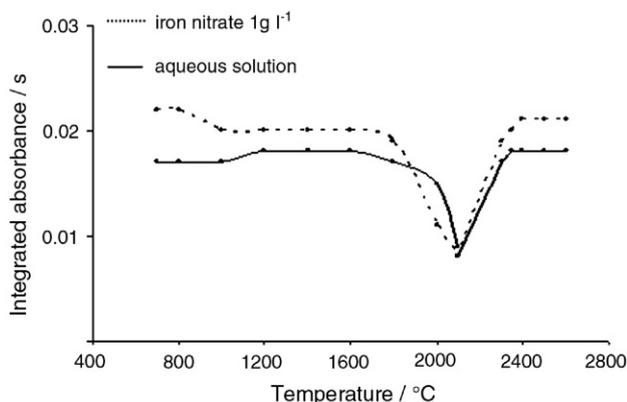
Fig. 3. Pyrolysis and atomization curves for Al (0.2 ng) in aqueous solution and in the presence of Fe (0.01 mg). Atomization temperature for pyrolysis curves: 2600 °C. Pyrolysis temperature for atomization curves: 1600 °C. Wavelength: 309.271 nm.

and analyte signal was observed. The absence or the presence of gluconate and sucrose individually or together with Fe did not make any difference in analyte and background signals. The same behavior was observed at 393.2 nm.

Attempts to improve the signals by altering pyrolysis and atomization temperatures failed, as neither the signal oscillation nor the background could be eliminated. In order to define which kind of interference was responsible for these artifacts, the same samples were analyzed with the HR-CS AAS equipment. The results showed that the interference was most likely caused by the simultaneous presence of all components of the sample. The organic components of the matrix caused both, continuous and structured background at both wavelengths. The latter background can be seen in Fig. 2a and b, whereas the former one is automatically corrected by the software of the instrument. Iron may be responsible for some spectral interference due to its absorption line at 309.278 nm [17], exactly between the Al duplet at 309.271/309.284 nm, whereas no Fe lines were observed in the vicinity of the Al line at 396.152 nm.

3.2. Optimization of pyrolysis and atomization temperatures

The interference was first studied investigating the Al absorption in the presence of Fe. A 1000 mg l^{-1} Fe standard (as the nitrate) was used to establish pyrolysis and atomization curves for Al (20 μg l^{-1}) in the presence and in the absence of Fe using HR-CS AAS. The curves, which are shown in Fig. 3, are similar and the presence of Fe does not cause any significant change; the slightly higher absorbance in the presence of Fe is due to an Al contamination in the Fe standard solution. Since no significant changes in the Al response were observed between 1200 °C and 1700 °C, 1600 °C was chosen as the pyrolysis temperature to promote maximum elimination of matrix components.

As could already be seen in the time- and wavelength-resolved absorbance spectra in Fig. 2a and b, and even better in the individual absorbance signals recorded around the CP shown in Fig. 4, the structured background was not separated in

time from the analyte signal under these conditions. This means that it is not possible for any atomization temperature to separate the Al and Fe signals temporally.

3.3. Background correction

3.3.1. Continuous background absorption

Since the software of the instrument is designed to eliminate automatically all events that are broad band, i.e. that affect all pixels of the array in a similar way, the continuous background observed by the simultaneous presence of Fe and the organic constituents of the sample (gluconate and sucrose) was eliminated by the software and is not displayed in the spectra. Nevertheless, the background absorption observed for these samples could not be satisfactorily managed by any of the background correction systems available for line source AAS, particularly not by deuterium background correction; this is probably the reason for the above-mentioned unsatisfactory results obtained in the analysis of Fe-containing pharmaceutical formulations. Even the Zeeman-effect background correction had problems in coping with this interference, probably because the molecular absorption spectrum with pronounced fine structure that appears at both wavelengths (Fig. 2a and b) is influenced by the magnetic field. In this case the background without and with magnetic field is different, which results in erroneous correction.

3.3.2. Correction for discontinuous spectral events

Once the continuous background is eliminated, HR-CS AAS makes possible the observation of the spectral environment around the analyte line. As already mentioned, there is a Fe absorption line at 309.278 nm, only 0.007 nm away from the Al line. This line is not very strong compared to the Al line, but depending on the Fe concentration, the signals can partially overlap. Fig. 5 shows the absorbance signals for Al at 309.271 nm in the presence of different concentrations of Fe. It can be seen that
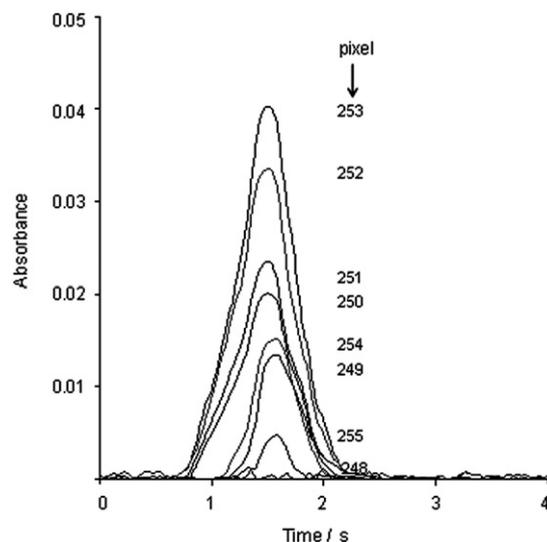
Fig. 4. Absorbance over time recorded for individual pixels, from pixel 248 to pixel 255 (wavelength range 309.266 nm to 309.284 nm) for an atomization temperature of 2600 °C and a sample containing 0.2 ng Al and 0.1 mg Fe.
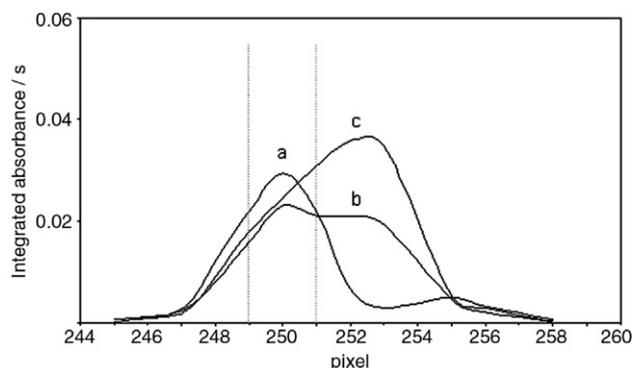
Fig. 5. Integrated absorbance over wavelength recorded over the spectral range from pixel 245 to 258 (309.261 nm to 309.292 nm), for samples containing different Al and Fe concentrations. (a) 50 µg l^{-1} Al; (b) 20 µg l^{-1} Al and 5 g l^{-1} Fe; (c) 20 µg l^{-1} Al and 10 g l^{-1} Fe.

in the presence of a high mass of iron, the Fe line, the maximum of which is at pixel 253, caused a distortion at the wing of the Al line.

Since the Fe absorption signal could not be separated in time from the analyte signal by optimizing the graphite furnace temperature program, an attempt was made to eliminate this spectral interference using the high spectral resolution of the spectrometer and LSBC. In order to get a pure Fe reference spectrum, different iron salts were tested and the spectra collected within the spectral window used for Al determination. Unfortunately, all salts were more or less contaminated with Al. We therefore tried to purify them through the complexation of Al and retention of the complex in an adsorbent material [18]. Since the Fe solutions (nitrate, sulfate and chloride) had an acidic pH, it was not possible to form the aluminum complex in these solutions without pH adjustment. However, by adjusting the pH, Fe precipitated as the hydroxide. Moreover, the complexing agent chrome azurol S and practically all other complexing agents for Al that would be retained by the sorbent are also able to complex Fe(III). Substituting Fe(III) by Fe(II) was also not a solution because Fe(II) cannot be maintained in solution without further acidification. Although complete elimination of Al was not possible, we succeeded to reduce its concentration. By complexing Fe with citrate and adjusting the pH to 6 with ammonium hydroxide, Fe did not precipitate and did not react with chrome azurol S. The limitation in this case was the ability of citrate to complex Al as well. However, after the cleaning procedure the Al concentration in a 1 g l^{-1} Fe solution (as the chloride) was reduced from approximately 15 µg l^{-1} to 2 µg l^{-1}. The Al absorption signals were measured using the CP only and CP±1 at both wavelengths. In spite of the better signal-to-noise ratio obtained using CP±1, recording only the CP made possible an almost interference-free determination of Al in the presence of Fe at 309.271 nm, as is shown in Table 2. The results demonstrate that the difference between the two evaluation modes (CP and CP±1) is practically zero when the samples do not contain any Fe. In the presence of Fe, this difference always showed a positive bias and the higher the Fe concentration, the bigger the difference. However, if the calculation is done with the data collected at 396.152 nm, no significant difference between the results computing the CP or CP±1 was found. Considering that

Table 2
Comparison of the results obtained measuring Al absorbance at the center pixel (CP) and the peak volume (CP±1) in the presence and in the absence of Fe, at 309.271 nm and at 396.152 nm

Wavelength	Iron conc.	Al added	Al measured/µg l^{-1}		Difference
nm	g l^{-1}	µg l^{-1}	CP	CP±1	%
309.271					
	–	10	11.2	11.2	0
	–	40	41.1	41.3	+0.5
	1.0	–	14.7	20.0	+36
	1.0	10	24.9	29.9	+20
	1.0	20	35.1	39.5	+13
	1.0	40	44.9	50.2	+12
396.152					
	–	10	10.5	10.7	+1.9
	–	40	40.9	40.8	−0.2
	1.0	–	15.0	14.9	−0.7
	1.0	10	25.2	25.9	+2.8
	1.0	20	34.9	35.3	+1.2
	1.0	40	45.1	45.0	−0.005

no Fe line was observed in the vicinity of this wavelength, this result was according to expectation.

These results show that in the presence of only Fe as the matrix, the Al measurement can be carried out without interference either at 309.271 nm or at 396.152 nm. For the former wavelength however, the signal evaluation has to be made using the CP only. Since no Fe interference was observed at 396.152 nm, the measurement could be carried out using CP±1 as well. On the other hand, in the case of the simultaneous presence of Fe and sugars, a structured BG was observed at both wavelengths. Fig. 2 shows that the structured BG caused by the
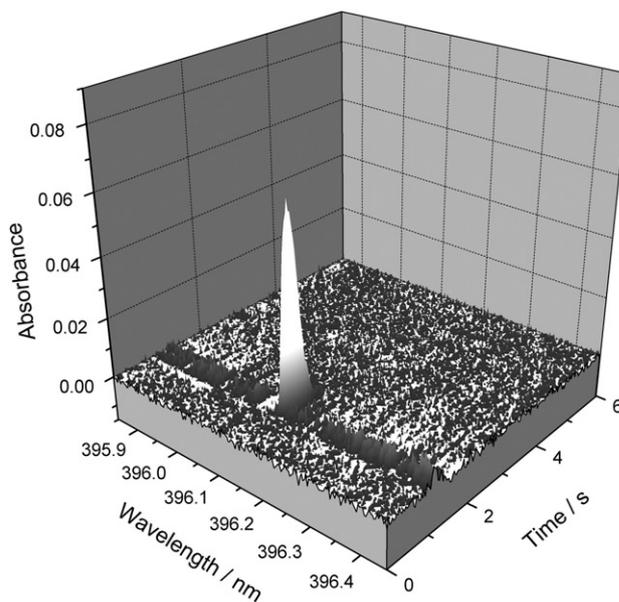
Fig. 6. Time- and wavelength-resolved absorbance spectrum of 0.2 ng Al in the presence of Fe (5 g l^{-1}), gluconate (75 g l^{-1}) and sucrose (75 g l^{-1}), measured with HR-CS AAS at 396.152 nm after application of least squares background correction to the spectrum shown in Fig. 2b. Pyrolysis temperature: 1600 °C; atomization temperature: 2600 °C.

Table 3
Figures of merit for the measurement of Al by HR-CS AAS at 309.271 nm and 396.152 nm, using the temperature program in Table 1

Parameter	Calculation	Wavelength	
		309.271 nm	396.152 nm
Analytical curve	CP±1	$y=0.0028x\pm0.0008$	$y=0.0021x\pm0.0011$
	CP	$y=0.0011x\pm0.0004$	$y=0.0009x\pm0.0005$
Regression (r^2)	CP±1	0.9996	0.9986
	CP	0.9997	0.9984
m_o/pg [a]	CP±1	13	16
	CP	36	43
LOD [b]/pg	CP±1	1.1	1.4
	CP	2.1	2.5

Sample volume=10 µl; analytical range 5–300 µg l^{-1}.

[a] m_0=characteristic mass.

[b] LOD=limit of detection (3σ, n=10).

sugar matrix overlaps directly with the Al signal at 309.271 nm, but it does not exactly coincide with the Al signal at 396.152 nm. In the latter case it can be eliminated by applying the LSBC, as shown in Fig. 6, displaying the same spectrum as in Fig. 2b, but after correction. Due to the difficulty of obtaining a sugar sample without any Al contamination it was not possible to apply the LSBC for the 309.271-nm wavelength.

3.4. Figures of merit

Since both wavelengths are useful for the determination of Al in the presence of Fe, the measurements using HR-CS AAS were optimized at 309.271 nm and at 396.152 nm. With conventional equipment the choice of the wavelength depends on the background correction system used. For biological samples, using the Zeeman-effect background correction, the 396.2-nm line is to be preferred due to the wider linear range, in spite of the slightly poorer sensitivity. Some authors consider that the about 10% lower sensitivity at this wavelength is more than compensated by a linear response up to about 1 A against approximately 0.4 A at 309.3 nm [19]. With deuterium background correction this wavelength cannot be used due to the low intensity of the D_2 lamp at 396.2 nm. Measuring with HR-CS AAS, the sensitivity ratio between the two lines is essentially the same as with line source equipment, and there are no limitations due to background correction.

The figures of merit determined at both wavelengths with HR-CS AAS using CP and CP±1 are presented in Table 3. As

could be expected, the 396.152-nm line is less sensitive than the 309.271-nm line. However, linear calibration curves were obtained for aqueous solutions with an Al concentration range between 5 and 300 µg l^{-1} for a 10-µl sample volume (0.05–3.0 ng Al) at both wavelengths. It is interesting to note that the linearity was actually slightly better for the more sensitive line at 309.271 nm; this means that the secondary line at 309.284 nm, which causes the non-linearity in line source AAS, has no influence on the measurement in HR-CS AAS. The relative standard deviation obtained for five measurements of aqueous solutions ranged from 1% to 5%. For samples containing 5 g l^{-1} Fe, 75 g l^{-1} gluconate, and 75 g l^{-1} sucrose, the relative standard deviation ranged from 3% to 8%. The results show that the precision of the proposed method is satisfactory considering the complexity of the matrix.

The purified Fe solution was used to obtain the limit of detection (LOD) in the presence of matrix constituents. The LOD, which is defined as three times the standard deviation of 10 measurements of a blank solution containing 1 g l^{-1} Fe, divided by the slope of the calibration curve, was 18 pg and 22 pg Al at 309.271 nm and 396.152 nm, respectively.

3.5. Samples

Two kinds of samples were considered for analysis: samples containing only Fe and those containing Fe and sugar. For samples containing no sugar, the measurement could be carried out at 309.271 nm using CP only or at 396.152 nm using CP±1. For samples containing sugars, LSBC had to be applied in addition in order to eliminate the structured background.

Artificial samples were prepared containing Fe, sucrose and gluconate, individually and mixed, in the concentration range normally used in commercial formulations. The pH was adjusted to 7 by adding concentrated ammonium hydroxide, which was used instead of sodium hydroxide because it presented practically no Al contamination. Since there is no certified reference material available for this kind of samples, recovery experiments were carried out spiking the samples with 20 µg l^{-1} Al to check the accuracy of the method.

The results showed that, although it is possible to measure Al in these solutions directly, dilution of the sample at least 1+1 with water is worthwhile, as it helps to reduce Fe memory effects as well as the formation of carbonaceous residues in the graphite tube. Residues were observed after 20–30 firings of undiluted samples due to the elevated concentration of carbohydrates.

Table 4
Aluminum present as contaminant in iron salts measured at CP (309.271 nm) and at CP±1 (396.152 nm) using HR-CS AAS

Sample [a]	309.271 nm		396.152 nm	
	Al/µg g^{-1}	Recovery [b]	Al/µg g^{-1}	Recovery [b]
	Mean±SD	%	Mean±SD	%
Fe(NO$_3$)$_3$·9 H$_2$O	11.6±0.1	98	12.1±0.1	97
FeSO$_4$·7 H$_2$O	2.1±0.02	92	2.0±0.1	97
FeCl$_3$·6 H$_2$O	3.1±0.02	92	3.0±0.02	95

[a] All samples from Merck.

[b] Recovery from samples spiked with 20 µg l^{-1} Al after sample dissolution.

Table 5
Aluminum present as contaminant in pharmaceutical products for iron deficiency treatment using HR-CS AAS; wavelength=396.152 nm

Sample [a]	Al content (mean±standard deviation)	Recovery/% [b]
Noripurum	2870±420 µg l^{-1}	89
Loma vital	128±18 µg l^{-1}	105
Combiron	582±65 µg l^{-1}	98
Iron tablet	4.1±0.4 µg g^{-1}	95

[a] Results from the analysis of three samples of the same lot.

[b] Recovery from samples spiked with 20 µg l^{-1} Al after dilution.

Since all artificial samples contained Al due to the contamination of the chemicals, recovery experiments with spiked samples were carried out and showed that the method is suitable for the determination of Al in such matrices. Spike recoveries for samples containing different amounts of Fe, sucrose and gluconate, obtained using HR-CS AAS, evaluating CP for 309.271 nm and CP$\pm$1 for 396.152 nm with LSBC, varied between 96% and 108%.

Table 4 shows the level of Al contamination found in the chemicals used in this study; the Fe(III) salts are more contaminated than the Fe(II) salt, what is probably due to the similarity between the trivalent cations Fe(III) and Al(III).

The results of the analysis of commercial samples carried out with HR-CS AAS at 396.152 nm and applying LSBC (as in Fig. 6) are presented in Table 5. These samples were also spiked with 20 µg l^{-1} Al, and the results confirm that the proposed method is adequate for the determination of Al in an Fe matrix and for the quality control of pharmaceutical formulations.

4. Conclusion

The purpose of the present study was to define the conditions for the Al determination in the presence of Fe aiming to control the quality of formulations used for iron deficiency treatment of uremic patients. It was possible to identify the problems associated with the determination by GF AAS and to establish a reliable method using HR-CS AAS. The latter technique allowed the detection and elimination of interferences due to continuous and fine-structured background, caused by matrix components, which were observed in the measurement with line source AAS using the Zeeman-effect background correction.

The spectral interference caused by a Fe line that is situated just between the Al duplet at 309.271/309.284 nm is significant for samples containing more than 0.5 g Fe l^{-1}. Considering the difficulty in obtaining Fe compounds completely free of any Al contamination, the application of LSBC is not feasible to eliminate this interference. However, it could be avoided by measuring the Al absorption using the center pixel only, or at 396.152 nm, where no Fe lines were observed in the vicinity of the Al line. The fine-structured background caused by carbohydrates, such as sucrose and gluconate, could be eliminated by measuring at 396.152 nm using LSBC.

The analysis of commercial samples for Fe supplementation revealed that they are highly contaminated by Al. These results help to show that dialysis fluids are not the unique source of Al for patients on hemodialysis treatment. Therefore, care must be taken with formulations administrated in elevated amounts to chronic renal patients as the medication for anemia treatment.

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