

## Application Note

# Determination of trace and major elements in olive oil by ICP-MS and ICP-OES using two-channel nebulizer MultiNeb®

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## 1. Introduction

Olive oil is a natural product obtained from olives. Large amounts of olive oil are annually produced around the Mediterranean basin and consumed worldwide. It is a prime component of the Mediterranean diet. Sometimes called “liquid gold”, olive oil is mainly appreciated for its flavor and high nutritional value, along with its recognized potential in the prevention of certain diseases. It is a rich source of antioxidants and monounsaturated fats, both of which are thought to protect cardiovascular health. However, olive oil can contain pollutants of various origins, including toxic elements.

The presence of trace elements in olive oils may be due to soil composition and environmental pollution as well as to contaminations during the oil production and conservation process. Elements that might be found at trace level in olive oil, such as Ca, Co, Cu, Fe, Mg, Mn and Ni, are known to have adverse effects on the flavor and oxidative stability of olive oil, while other elements, such as As, Cr, Cd and Pb, are deleterious for their metabolic role and toxicity. As quality criteria, the International Olive Council (IOC) has established a maximum residue level (MRL) for the content of As, Cu, Pb ( $0.1 \text{ mg kg}^{-1}$ ) and Fe ( $3 \text{ mg kg}^{-1}$ ) in olive oils and olive-pomace oils (International Olive Council, 2019).

The olive oil industry is subject to significant fraudulent practices that can lead to serious economic implications and even affect consumer health. Therefore, many analytical strategies have been developed for olive oil's geographic authentication, including multi-elemental and isotopic analyses. False declaration of geographical origin is among the most prevalent forms of olive oil fraud and is the most challenging to detect. The choice of appropriate analytical strategies for olive oil characterization is complex. Olive oil is a particularly challenging matrix due to its high fatty composition and viscosity. Its lipid nature frequently hampers the traditional direct sample introduction strategies common for various analytical instruments. Furthermore, during the olive oil production process, which starts with olive growing and concludes with storing the extracted oil, many factors affect its overall chemical composition.

However, olive oil analysis is still challenging as the oil is a fatty matrix with a rich and varied organic content, where chemical elements, other than C, H and O, mainly occur at trace levels ranging from few  $\mu\text{g}\cdot\text{kg}^{-1}$  to few  $\text{mg}\cdot\text{kg}^{-1}$ . Therefore, reliable, accurate and precise measurement of trace elements in olive oil is a key issue that requires adequate and efficient sample pretreatment and preparation methods. A wide range of olive oil preparation techniques has been proposed in the scientific literature. Some preparation methods aim to destroy the organic matter using strong acids (e.g., microwave-assisted digestion, calcination), while others are non-destructive, aiming to extract the elements without significantly altering the matrix (e.g., liquid-liquid extraction, extraction using a chelating agent, sample dilution, emulsification). Trace elements are then quantified by means of several atomic spectrometric techniques (flame atomic absorption spectroscopy: FAAS, graphite furnace atomic absorption spectroscopy: GF-AAS, inductively coupled plasma atomic emission spectroscopy: ICP-OES, inductively coupled plasma mass spectrometry: ICP-MS). The official methods are based on a colorimetric procedure for determining As (AOAC International, 2000), while AAS is used for the quantification of Cu, Fe and Pb (Firestone, 2005; ISO, 1994). These procedures are not suitable for process control purposes due to their time-consuming and mono-element analysis characteristics. For this reason, ICP-MS is an interesting tool, not only due to its high sensitivity, but also because it allows easy multi-element analysis.

Due to the critically low concentrations of some elements in olive oil, the latest studies tended to promote the use of ICP-MS and ICP-OES known for its high sensitivity and multielemental capability. When using plasma-based ionization techniques, the possible incomplete mineralization of the samples could affect the instrumental performance by forming deposits and clogging parts such as injectors, cones and lenses. In addition, the presence of traces of unoxidized organic matter could also extinguish plasma sources and thus generates spectral interferences from carbon-based polyatomic ions contributing to the spectral background. Methods involving dilution with organic solvents for olive oil studies [53,70] have the main advantage of being based on the direct analysis of diluted oily matrices (with an adjusted sample introduction system). Recently, a high-temperature torch integrated sample introduction system (hTISIS) was applied for the analysis of oils and fats after dilution with xylene by ICP-OES. The addition of oxygen as an auxiliary gas in ICP-OES was also investigated for that purpose. It is, however, crucial to avoid matrix effects when performing analyses with direct introduction techniques. The timesaving benefit offered by this technique is attractive, but the rigorousness necessary for its implementation and to achieve satisfactory results explain its limited use with respect to olive oil elemental analysis.

Here we describe a simple, quick and robust method for elements in olive oil using the multiple inlet nebulizer MultiNeb<sup>®</sup> (Ingeniatrics Tecnologías S.L.) by ICP-OES in combination with ICP-MS analysis. Conventionally, the internal standard is mixed with the calibration standards and samples using a Y connection, when conventional nebulizer is employed. However, the novel MultiNeb<sup>®</sup> (Ingeniatrics Tecnologías S.L.) has been developed which allows a high mixing efficiency between two liquids, miscible or immiscible, since the mixing takes place under turbulent conditions of high pressure at the tip of the nebulizer.

## 2. Experimental Samples

The olive oils used for the experiments were obtained from Spanish local supermarkets. Spiked stock standards were gravimetrically prepared for each oil by using a multi-element standard solution.

## Reagents and solutions

All reagents used were of the highest available purity. Helium was used as collision gas, respectively, in an ICP-MS system, were of high-purity grade (>99.999%). Water was purified with a Milli-Q Gradient system (Millipore, Watford, UK). The aqueous levels of calibration standards were prepared by appropriate dilution of a Multi-element calibration standard-2A, contains 10 mg.L<sup>-1</sup> of Ag, Al, As, Ba, Be, Ca, Cd, Co, Cr, Cs, Cu, Fe, Ga, K, Li, Mg, Mn, Na, Ni, Pb, Sb, Se, Sr, Tl, U, V, Zn (and Hg) in a matrix of 5% HNO<sub>3</sub> (Agilent Technologies, Part Number: 8500-6940). In addition, for quality controls solutions (spiked samples and monitoring solutions), monoelemental calibration standards to 1000 mg.L<sup>-1</sup> for all analytes were purchased by ICP CetriPUR, Merck, Darmstadt, Germany.

Glycerol >99.9 %, ACS reagent (Thermo Scientific Chemicals) was employed in calibration levels solution with order to increase the viscosity of the solutions and as a contribution of C, H, and O, major components of the olive oil matrix. For total element determination in olive oil, nitric acid (65 mass %) and hydrogen peroxide were of the highest available purity (Merck, Darmstadt, Germany). All standard solutions were prepared daily.

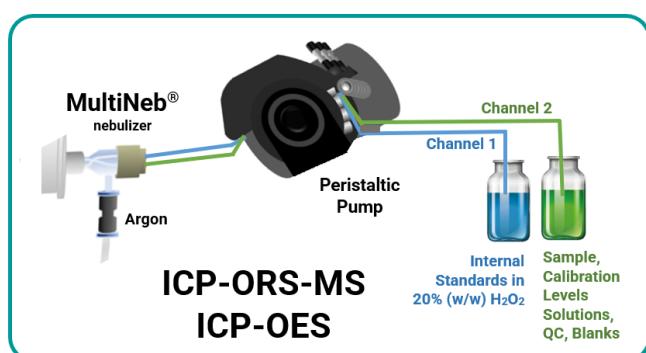
In addition, Sc, Rh, and Ir at a concentration of 2 µg.L<sup>-1</sup> for ICP-MS and 0,5 mg.L<sup>-1</sup> for ICP-OES analysis were used as internal standards for the low, medium, and heavy masses, respectively, in order to correct instrumental drifts, since they are unlikely to be present in olive oil samples. A solution containing internal standard is prepared by appropriate dilution of a 1000 mg L<sup>-1</sup> of mono-elemental stock solutions of each internal standard element investigated in this work (ICP CetriPUR, Merck, Darmstadt, Germany).

## Instrumentation

A microwave oven (CEM Matthews, NC, USA, model MARS 6) was employed for sample mineralization. All measurements were carried out using an Agilent 7900 ICP-MS (Agilent Technologies) and Agilent 5110 ICP-OES (Agilent Technologies) equipped with a SPS4 autosampler (Agilent Technologies) with 0.5 mm ID sampling probe (Agilent Technologies, Part No.: G8410-80101). The instruments operating conditions are shown in Table I.

ICP-MS Operational Conditions		
7900 ICP-MS Parameters (Agilent Technologies)		
RF Power (W)	1550	
Plasma gas flow (L min <sup>-1</sup> )	15.0	
Nebulization gas flow (L min <sup>-1</sup> )	MultiNeb <sup>®</sup>	0.7
Sampling Depth (mm)	8.0	
Cell gas flow (mL min <sup>-1</sup> )	5.0 (He)	
KED (V)	3.5	
Cones	Nickel	
Integration time (s)	0.7 per isotope	
Extract 2 (V)	-230	
Omega Bias (V)	-80	
Omega Lens (V)	7.2	
OctP RF (V)	200	
Sample introduction rate (rps)	0.1	
Isotopes monitored	<sup>75</sup> As, <sup>27</sup> Al, <sup>111</sup> Cd, <sup>59</sup> Co, <sup>52</sup> Cr, <sup>63</sup> Cu, <sup>57</sup> Fe, <sup>201</sup> Hg, <sup>55</sup> Mn, <sup>60</sup> Ni, <sup>208</sup> Pb, <sup>121</sup> Sb, <sup>78</sup> Se, <sup>88</sup> Sr, <sup>51</sup> V, <sup>205</sup> Tl, and <sup>66</sup> Zn <sup>35</sup> Sc, <sup>103</sup> Rh and <sup>185</sup> Re (as Internal Standards)	
ICP-OES 5110 (Agilent Technologies)		
RF Power (kW)	1.5	
Plasma gas flow (L min <sup>-1</sup> )	15	
Auxiliary gas flow (L min <sup>-1</sup> )	1.0	
Spray chamber type	Single-pass glass cyclonic chamber	
Nebulization gas flow (L min <sup>-1</sup> )	MultiNeb <sup>®</sup>	0.65
Pump speed (rpm)	10	
Replicates	3	
Stabilization time (s)	15	
Rinse time (s)	40	
Fast pump	On	
Uptake time (s)	30	
Wavelengths monitored (nm)	<b>Axial mode:</b> As 193.759, Cd 226.502, Co 230.786, Cr 267.716, Hg 194.164, Ni 231.604, Pb 220.353, Sb 217.582, Se 196.090, Sr 460.733, V 292.402 and Tl 351.924. <b>Radial mode:</b> Al 396.152, Ca 315.887, Cu 324.754, Fe 259.940, K 769.896, Mg 280.270, Mn 257.610, Na 588.995 and Zn 213.856. <b>Y Axial mode:</b> 224.306 and 324.306 (as Internal Standard). <b>Y Radial mode:</b> 324.306 and 371.030 (as Internal standard).	

The MultiNeb<sup>®</sup>-based configuration is composed by the MultiNeb<sup>®</sup> nebulizer associated with a spray chamber without any additional modification required, as the MultiNeb<sup>®</sup> is built on the right dimensions to allow easy connection to any commercial spray chamber conventionally used in ICP analytical methodologies (Figure 1). This implies an important advantage over conventional systems since it does not require the continuous cleaning of ICP components or the use of expensive additional components such as cooled spray chambers, torch and cones, principally, or an auxiliary oxygen supply. This simple and powerful alternative to remove spectral interference caused by organic matrix enables to analyze organic samples with confidence.



**Figure 1.** Schematic representation of MultiNeb<sup>®</sup>-based configuration employed in this Application Note.

## Matrix-matched calibration

Interferences due to carbon matrix components in ICP techniques can be divided in two groups: spectral and non-spectral. The former are related to the limited resolution capability of the spectrometer. In this sense, the analysis of Se in carbon-rich matrices using ICP-OES is interfered by the CO molecular band. In ICP-MS, the analysis of Cr and Mg using the most abundant isotopes (because of <sup>52</sup>Cr and <sup>24</sup>Mg, respectively) in matrices with high levels of carbon could be hindered due to the <sup>52</sup>ArC<sup>+</sup> and <sup>24</sup>C<sup>+</sup> polyatomic interferences. Non-spectral interferences are defined as any signal variation induced by the physic-chemicals properties of the matrix sample, such as density, viscosity and others.

In this sense, because of the higher density in the final solution after microwave acid digestion and C as a matrix matched component, in this study was employed glycerol in calibration levels, analytical blanks and quality control solutions with order to evaluate both effects, principally. For this purpose, different concentrations of glycerol were tested (0,5-5 % (w/w) contents of glycerol).

In addition, the signal in both ICP-OES and ICP-MS could be enhanced or depressed when carbon or easily ionisable elements are present in the matrix. These interferences are usually generated in the sample introduction system and/or in the processes of excitation of the atoms in ICP-OES and the transport of the ions in ICP-MS.

On the other hand, a total of three internal standards have been used depending on the mass of the isotope in ICP-MS and yttrium as internal standard in ICP-OES. The Table II summarizes the internal standard employed for each analyte throughout this work.

The best results were obtained using 2 % (w/w) for ICP-OES analysis and 0,75 % (w/w) for ICP-MS analysis of glycerol in calibrations levels, analytical blanks and quality controls solutions, in terms of sensitivity, reproducibility and precision in recoveries results for each analyte in spiked samples quantified and the best response of the internal standard employed using ICP-MS and ICP-OES analytical techniques.

**Internal Standard Calibration ICP-MS and ICP-OES**

Isotopes monitored (m/z)	IS
<sup>27</sup> Al, <sup>52</sup> Cr, <sup>57</sup> Fe, <sup>55</sup> Mn, <sup>51</sup> V	<sup>45</sup> Sc
<sup>75</sup> As, <sup>111</sup> Cd, <sup>59</sup> Co, <sup>63</sup> Cu, <sup>60</sup> Ni, <sup>121</sup> Sb, <sup>78</sup> Se, <sup>88</sup> Sr, <sup>66</sup> Zn	<sup>103</sup> Rh
<sup>201</sup> Hg, <sup>208</sup> Pb, <sup>205</sup> Tl	<sup>185</sup> Re
Wavelengths monitored (nm)	IS
As 193.759, Cd 226.502, Co 230.786, Cr 267.716, Hg 194.164, Ni 231.604, Pb 220.353, Sb 217.582, Se 196.090, V 292.402	Y 224.306
Axial mode: Tl 351.924 Sr 460.733 Radial mode: Ca 315.887, Cu 324.754, Fe 259.940, Mg 280.270, Mn 257.610, and Zn 213.856.	Y 324.306
Al 396.152, K 769.896 and Na 588.995	Y 371.030

**Table II.** Internal standard used for each analyte throughout this work using ICP-MS and ICP-OES.

## Sample preparation

For olive oil sample preparation, different sample procedures and extraction techniques have been developed in order to remove the organic content of the edible oil samples before their analysis, including liquid-liquid extraction, dry ashing, microwave dry ashing, microwave-assisted digestion (MAD), microwave-induced combustion, simple dilution with a suitable solvent, acid extraction in vortexed samples, ultrasonic acid extraction (USE) and emulsification. Among these, MAD is the most commonly used sample preparation technique for ICP-MS or ICP-OES detection.

For the sample digestion protocol, 1 mL of 30% hydrogen peroxide was added to 0.5 g of the olive oil to be mineralized. The mixture was left overnight for pre-mineralization at room temperature. The next day, 3 mL of concentrated nitric acid was gradually added since olive oil is a highly reactive matrix. The final mixture was then digested in a microwave system following an optimized gradually increasing heating program up to 250 °C where the temperature was maintained for 20 min (P max = 110 bar). The resulting clear solutions were then transferred to clean PFA vials (Savillex Corporation, Eden Prairie, MN, USA) and diluted with ultrapure water to a final volume of 10 g or 25 g for ICP-OES or ICP-MS analysis, respectively. All samples were prepared by triplicated.

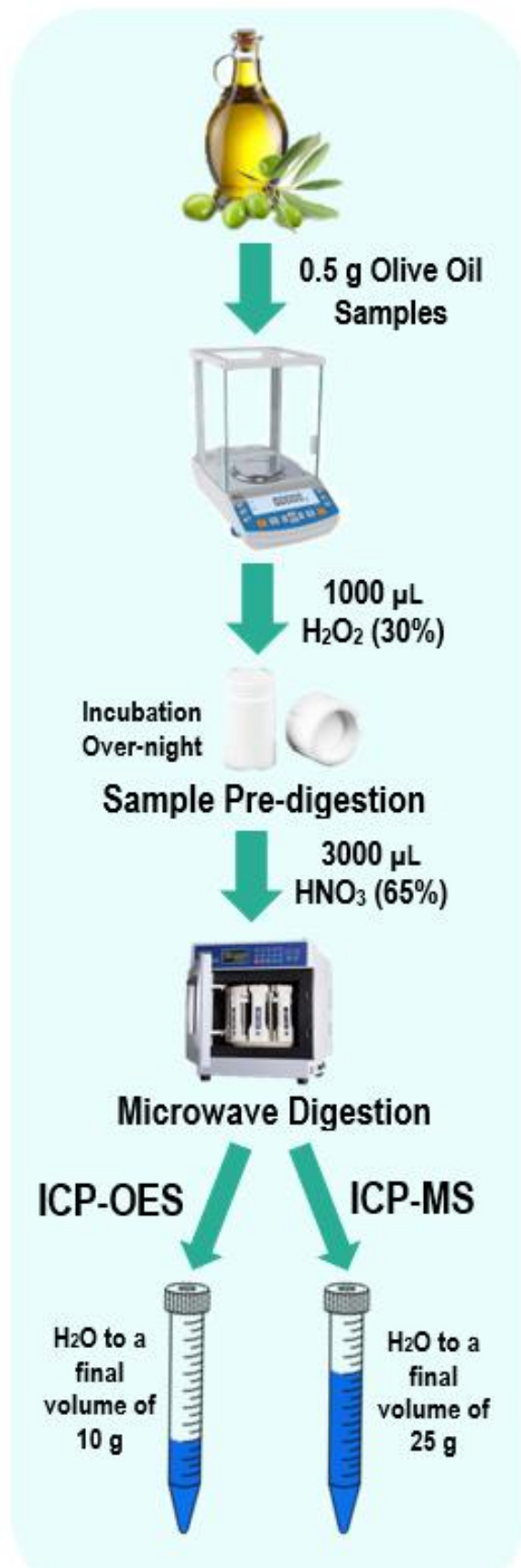
For ICP-OES analysis, the calibration solutions at ten different concentrations ranging from 0.01 mg.L<sup>-1</sup> to 5 mg.L<sup>-1</sup>, analytical blanks and quality control solutions were prepared by appropriate dilution of multi-elemental standard solutions with a matrix-matched solution of 2 % (w/w) of glycerol and 5 % (w/w) of nitric acid in ultrapure water. On the other hand, for ICP-MS analysis, the calibration solutions at ten different concentrations ranging from 0.005 µg.L<sup>-1</sup> to 500 µg.L<sup>-1</sup>, analytical blanks and quality control solutions were prepared by appropriate dilution of multi-elemental standard solutions with a matrix-matched solution of 0.75 % (w/w) of glycerol and 2 % (w/w) of nitric acid in ultrapure water.

Samples concentrations were calculated after applying the corrections with the blank, the internal standard, and the analytical blank. First, the calibration blank signal was subtracted in order to ensure that the ICP-OES or ICP-MS measurement provides a zero signal when no analyte is present. Then, the instrumental sensitivity drifts were corrected by the internal standard signal. Finally, an “analytical blank” prepared using the whole set of reagents was mineralized and underwent the same preparation procedure as the samples under the same conditions (microwave conditions as summarized in Table III). This blank reflects the potential contamination that occurred during the whole samples preparation workflow, and it was subtracted from the samples’ elemental concentrations in order to calculate the “true” concentration of each element. All labware was washed in 20% (v/v) HNO<sub>3</sub> and rinsed with ultra-pure water before use.

Step	Procedure	Time (min)	T (°C)	Power (W)
1	Ramp	20	120	800
2	Hold	10	120	800
3	Ramp	15	200	800
4	Hold	10	200	800

**Table III.** Operational parameters used during microwave acid digestion.

An overview of the total sample preparation procedure is presented in Figure 2.



**Figure 2.** Workflow used for sample preparation.

When high matrix samples are measured using ICP source, the matrix elements can affect analyte signals in several distinct ways. Probably the most widely recognized is the gradual downward drift that typically occurs due to the build-up of matrix deposits on the ICP-OES and ICP-MS sample introduction accessories and interface components (sampling cone, skimmer cone and torch injector) when high matrix samples are measured over an extended period. In this study, following the workflow for sample preparation previously described, standard calibration levels, QC samples, analytical blanks and samples were only diluted 1:20 for ICP-OES analysis and 1:50 for ICP-MS analysis. After this treatment, resulting digested solutions are directly aspirated for one channel of MultiNeb<sup>®</sup> nebulizer, using peristaltic pump tubings with 0.50 mm i.d., the solution aspirated through the second channel of the nebulizer containing internal standards solutions in 20 % H<sub>2</sub>O<sub>2</sub> (w/w) to correct instrument drift and CO<sub>2</sub> formation.

On the other hand, major elements such as Ca, K, Fe, Na and Mg, could be better measured by ICP-OES since this technique was less affected by matrix effect while the rest of elements should be determined by ICP-MS.

### 3. Results and Discussion

#### Sensitivity and signal stability

Nebulizers designed by Ingeniatrics Tecnologías SL, such as MultiNeb<sup>®</sup>, use *Flow Blurring* nebulization technology instead of the traditional Venturi effect, as conventional concentric nebulizer. This allows the generation of a very fine droplet aerosol with a narrow size distribution (most droplets are smaller than 10 µm), which improves efficiency over a wide range of nebulization gas flow rates, especially 0.60-0.75 L min<sup>-1</sup> (100-200 kPa nebulization pressure).

The method detection limits (MDLs) were established by analyzing five of the calibration blank and multiplying the obtained standard deviation by three. The results obtained are show in Table V.

For the study of signal stability and plasma drift, a monitoring standard solution as quality control (QC) was analyzed once every 5 samples, in order to evaluate the stability of the signal.

The recoveries must fall within the limits of 91-107 % and 87-111 % for ICP-OES and ICP-MS, respectively (Table IV). The concentration of the different elements in QC sample using as a monitoring control solution is shown in Table IV.

Element	QC sample Composition (ng.g <sup>-1</sup> )	Recoveries ICP-OES (%)	Recoveries ICP-MS (%)
As	0.5	<LOD	97-103
Al	150	91-108	95-106
Ca	150	95-102	87-111
Cd	5	<LOD	98-102
Co	10	<LOD	97-102
Cr	10	<LOD	92-109
Cu	25	96-104	97-102
Fe	1000	97-104	92-107
Hg	20	91-108	97-104
K	500	98-103	89-110
Mg	250	97-102	91-107
Mn	20	93-107	97-102
Na	2500	97-105	90-109
Ni	10	<LOD	97-104
Pb	20	98-102	99-102
Sb	1	<LOD	96-104
Se	1	<LOD	95-104
Sr	5	<LOD	99-102
V	5	<LOD	98-99
Tl	5	<LOD	97-105
Zn	100	96-102	99-102

**Table IV.** Experimental values for recoveries results each analyte in QC sample analyzed for 5 replicates of the different samples using MultiNeb<sup>®</sup> nebulizer employed in this work by ICP-OES and ICP-MS detection in a sequence of 50 samples in the same analytical batch.

Based on the results shown in Table IV, the use of the multiple inlet nebulizer, MultiNeb<sup>®</sup>, which allows the simultaneously nebulization of two liquid flows, it demonstrates the long signal stability along the sequence in the same analytical batch. Because of a supplementary addition of oxygen in plasma, as a hydrogen peroxide solution, a resulting aerosol is diluted two times prior to plasma, reducing the carbon content and benefiting the formation of carbon dioxide.

### Experimental Values in Olive Oil Samples

Analyte	Detection Limit (LOD)		Values	ICP-OES		ICP-MS	
	ICP-MS (ng.g <sup>-1</sup> )	ICP-OES (ng.g <sup>-1</sup> )		Concentration (ng.g <sup>-1</sup> )	Recovery (%)	Concentration (ng.g <sup>-1</sup> )	Recovery (%)
As	0.009	4.75	Mean	<LOD	<LOD	0.65	94
			RSD (%)			106	
Al	0.18	4.41	Mean	165	89	177	106
			RSD (%)	2.24		2.91	
Ca	0.98	6.07	Mean	236	94	210	112
			RSD (%)	2.62		4.21	
Cd	0.002	3.21	Mean	<LOD	<LOD	1.16	106
			RSD (%)			2.36	
Co	0.004	2.36	Mean	<LOD	<LOD	18	102
			RSD (%)			2.54	
Cr	0.011	2.48	Mean	<LOD	<LOD	2.28	97
			RSD (%)			2.66	
Cu	0.018	1.21	Mean	36.4	107	31.6	98
			RSD (%)	4.98		2.87	
Fe	0.016	4.21	Mean	984	98	965	107
			RSD (%)	1.35		3.66	
Hg	0.006	5.82	Mean	<LOD	<LOD	11.3	93
			RSD (%)			108	
K	0.26	4.33	Mean	765	102	734	113
			RSD (%)	2.16		4.97	
Mg	0.35	4.26	Mean	238	96	214	108
			RSD (%)	2.66		3.67	
Mn	0.008	2.66	Mean	<LOD	<LOD	18.4	102
			RSD (%)			2.88	
Na	0.265	3.11	Mean	3242	103	2960	111
			RSD (%)	2.08		4.92	
Ni	0.008	5.26	Mean	<LOD	<LOD	10.8	99
			RSD (%)			2.12	
Pb	0.003	1.78	Mean	44.2	92	42.6	97
			RSD (%)	4.21		2.11	
Sb	0.006	5.14	Mean	<LOD	<LOD	0.32	106
			RSD (%)			4.62	
Se	0.011	6.48	Mean	<LOD	<LOD	0.48	97
			RSD (%)			3.05	
Sr	0.006	3.21	Mean	<LOD	<LOD	2.26	105
			RSD (%)			3.54	
V	0.001	4.61	Mean	<LOD	<LOD	4.73	95
			RSD (%)			2.14	
Tl	0.002	2.06	Mean	<LOD	<LOD	2.87	108
			RSD (%)			3.65	
Zn	0.013	2.59	Mean	116	105	126	102
			RSD (%)	3.11		2.38	

**Table V.** Experimental values for each analyte monitored, LOD as well as the RSD (%) and recoveries results os spiked samples obtained for 3 replicates of the different samples analyzed using MultiNeb® nebulizer employed in this work by ICP-OES and ICP-MS detection.

## Precision and reproducibility

As certified reference materials were not available, precision was evaluated based on recovery assays, spiked twice time the concentration of each analyte in each sample matrices employed in this study. The results are shown in Table V. Additionally, each sample was analyzed using 3 replicates, and the results obtained, expressed as relative standard deviation (RSD, %) in the same table, demonstrates the notable reproducibility obtained using the proposed methodology in this technical application note for multielemental quantification of 21 elements in olive oil samples.

Additionally, we can see that major elements such as Ca, K, Fe, Na and Mg, could be better measured by ICP-OES since this technique was less affected by matrix effect while the rest of elements should be determined by ICP-MS. Related to this, the combination of both techniques in a complementary way for profiling trace and sub-trace elements was the option of choice for further quantitative analysis and validation of the results obtained using both analytical techniques.

## 4. Conclusions

The results obtained in this study using MultiNeb<sup>®</sup> nebulizer provides higher precision, sensitivity and reproducibility for multielement determination in olive oil samples by ICP-MS and ICP-OES simultaneously determination after microwave acid digestion procedure. In addition, because of the higher density in the final solution after microwave acid digestion and C as a matrix matched component, in this study was employed glycerol in calibration levels, analytical blanks and quality control solutions with order to evaluate both effects, as a matrix-matched calibration.

On the other hand, the enhanced precision results obtained with the MultiNeb<sup>®</sup> nebulizer are related to the higher sensitivity and reproducibility obtained in comparison with the Y connection normally employed for this purpose, what demonstrates that the mixing of the internal standard dissolved in hydrogen peroxide solution, as a supplementary oxygen supply when carbon matrices are analyzed using plasma source, minimizes the effects on the nebulization process and therefore improves the analytical operation and results, favorizing the complete combustion of carbon, avoiding its byproducts and the subsequent clogging of the torch's injector, cones and will, therefore prevent the spectral interferences, providing a better sensitivity, reproducibility and precision.

Additionally, the proposed analytical methodology prolongs the lifetime of torches compared to the direct supply of oxygen to the plasma.

The results obtained demonstrate the remarkable reproducibility obtained using the proposed methodology in this technical application note for multielemental quantification of 21 elements in olive oil samples.





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