

Assessment Of Trace Elements In Traditional Moroccan Cosmetics By Inductively Coupled Plasma Atomic Emission Spectroscopy.

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Abstract— A methodology based on inductively coupled plasma atomic emission spectroscopy (ICP-AES) after microwave assisted acid digestion has been developed and validated to determine the trace element content of traditional Moroccan cosmetic products like henna and takaout purchased in local markets of Morocco. Limit of detection values equal or lower than few $\mu\text{g g}^{-1}$ were obtained for all elements under study. To assure the accuracy of the whole procedure, recovery studies were carried out on traditional cosmetic samples spiked at different concentration levels from 40 to 1600 $\mu\text{g L}^{-1}$. Quantitative average recovery values were obtained for all elements evaluated, demonstrating the suitability of this methodology for the determination of trace elements in these samples. Accurate results were found also for a certified reference material NIST 1573a. Results obtained for henna samples were compared with those found by the Danish Environmental Protection Agency for products available in the Danish market.

Index Terms— traditional Moroccan cosmetic products, trace elements, ICP-AES, henna, takaout

1 INTRODUCTION

Morocco is fortunate to have a large medicinal and cosmetic knowledge inherited from the Arabic medicine and, based on it there are many products available in the open markets. Recently, ignorance, poverty and illiteracy have increased the factor of risk of bad practicing these customs due to a lack of control of the aforementioned products [1]. The Moroccan population is particularly exposed to the dangers of these products which are commonly used without a deep analytical control [2]. Use of traditional cosmetics and remedies, such khôl, henna, teething powder, etc., is very common, especially among women, children and babies. In this context, takaout and henna product were chosen in this study to establish the trace element content of available products. Takaout galls (*Tamarix Articulata*) is a traditional cosmetic product used by Moroccan women as hair care and hair strengthening [3] and also used for hypertension and cardiac diseases treatment for man and women [4, 5]. Takaout is available as a plant from Moroccan herbalists, rich in p-phenylenediamine [6], which is used in oxidatively based hair dyeing preparations being established by the Scientific Committee on Cosmetics that p-phenylenediamine is a strong contact allergen. Henna is a cosmetic product extracted from dried powdered leaves of the henna plant (*Lawsonia inermis*) used traditionally in the skin decoration of women. Henna has been widely used over centuries for cosmetic and medical purposes. Many people believe it gives healthy, beautiful hair and that it lowers body temperature in cases of high fever. It is also applied on the hands and feet for cosmetic purposes. Henna product is a finely ground brown or green powder made from plants that are either grown locally or imported from Yemen, Saudi Arabia, Sudan, Algeria or India. Many people add various herbs or other substances like p-phenylenediamine in order to give it a stronger colour. According to certain authors, traditional plants

play an important role in the general state of health of a population. Many medical remedies and mixtures used in this medicine can present a health risk due to the presence of toxic products such as trace elements lead, cadmium, mercury, etc. [7]. In this context, levels of essential and toxic elements must be determined routinely in cosmetic traditional products. For this purpose, different atomic spectrometry techniques such as Atomic Absorption Spectrometry (AAS) [8, 9], Electrothermal Atomic Absorption Spectrometry (ET-AAS) [7], Energy dispersive X-ray Microanalysis [10], Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES) [11], and Inductively Coupled Plasma Mass Spectrometry (ICP-MS) [12] have been used for the determination of elements like Pb and others in henna samples (see table 1). Levels of trace elements in takaout sample were never evaluated in the literature. Regarding the precedents of trace element determination in henna samples published in the literature, table 1 resumes the studies found, classified as a function of matrix, analytical method, elements determined and digestion method employed to do the determination of trace element profile. Six references were found in the bibliography including, different sample pre-treatments; such as dry ashing, ultrasound assisted treatment and microwave assisted digestion. On the other hand, in spite of the scientific interest of all those publications except that of the Danish Environment Protection Agency (Danish EPA) [12], there is a lack of information about the content of many element which can be present in henna at mg Kg⁻¹ levels and, because of that the aim of the present work has been to develop and validate a simple and fast analytical procedure, based on ICP-AES after microwave assisted digestion to verify the trace element profile of traditional cosmetics like henna and takaout obtained in the Moroccan market and produced in Morocco or imported from India

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TABLE 1: Recommended methods available for the determination of trace elements in henna samples.

MATRIX	METHOD	ELEMENTS	PROCEDURE	REF
KOHL	AAS	Pb	Microwave assisted digestion with nitric, sulfuric and perchloric acids.	[8]
HENNA			Dry ashing and hot plate nitric acid digestion	
MEDICINAL PLANT (HENNA)	Energy dispersive X-ray	C, O, Mg, P, S, Cl, K, Al, Ca, Si, Fe.	-	[10]
KOHL, HENNA	ICP-AES, ICP-MS	65 element	Microwave assisted digestion with HNO ₃	[12]
HENNA	ICP-OES	Pb	Dry ashing and hot plate nitric acid digestion	[11]
HENNA	ETAAS	Pb	Microwave assisted digestion	[7]
HENNA	AAS	Co, Ni	Dissolution with water at 80-90 °C and sonication	[9]

2. EXPERIMENTAL

2.1. APPARATUS AND REAGENTS

Determinations were carried out using a Perkin Elmer Model Optima 5300 DV spectrometer (Norwalk, CT, USA) ICP-AES equipped with a Cross Flow nebulizer and an auto sampler AS 93-plus. Argon C-45 (purity higher than 99.995%) supplied by Carbuos Metálicos (Barcelona, Spain) was employed as plasmogen and carrier gas. A multi-elemental standard solution of 100 µg mL⁻¹ containing 30 elements (Al, As, Ba, Be, Bi, B, Cd, Ca, Cr, Co, Cu, Fe, Pb, Li, Mg, Mn, Mo, Ni, K, Se, Na, Sr, Tl, Ti, V, Zn, Ce, La, Nd, Pr) and of 20 µg mL⁻¹ containing of 12 lanthanide elements (Dy, Er, Eu, Gd, Ho, Lu, Sm, Sc, Tb, Tm, Yb, Y) were dissolved in 5% HNO₃ from Scharlau Chemie (Barcelona, Spain) and used as stock solution for calibration. A microwave oven laboratory system Ethos SEL from Millestone (Sorisole, Italy) equipped with an optical fiber sensor for automatic temperature control, an automatic gas detector and 10 high pressure vessels of 100 mL inner volume, operating at a maximum exit power of 1000 W was employed for microwave-assisted digestion of samples. HCl 37% (w/v), HNO₃ 69% (w/v) and H₂O₂ 35% reagent grade from Scharlau and nanopure water, with a maximum resistivity of 18.2 MΩ cm, obtained from a Milli-Q Millipore system (Bedford, MA, USA) were employed for sample digestion and sample dilution. An ultrasound water bath of 350 mL volume from Selecta (Barcelona, Spain) with 50 W power and 50 Hz frequency was employed for sample sonication after digestion in order to avoid the presence of nitrous oxide vapours.

2.2 SAMPLES

Five samples of takaout roumia and four samples of henna, two originally from Morocco and two imported from India, were purchased from different Moroccan herbalists. Samples were stored in plastics flasks. The certified reference materials NIST 1573a Tomato Leaves (Gaithersburg, MD, USA) was analyzed in the same experimental conditions used for samples in order to evaluate the accuracy of the method. The blanks for the elements determined by ICP-AES were prepared by following all the analytical steps of the method in

the absence of any sample or standard. As recommended in the respective certificate, the trace elemental concentration of the reference material was evaluated on a dry weight basis.

2.3. SAMPLE PRE-TREATMENT

All teflon digestion vessels were previously cleaned in a bath of 10% (v/v) nitric acid solution for 48 hours to avoid cross-contamination. Samples were grounded with a mixer grinder and the obtained powdered samples were sieved through a 250 µm mesh before their digestion. For microwave digestion, 0.1 g of each powder sample was weighed inside the digestion reactor. After that 2 mL of concentrated nitric acid, 2 mL concentrated hydrochloric acid, 2 mL concentrated hydrogen peroxide and 4 mL of ultra-pure water were added to the samples, waiting for the elimination of foam for 5 min and the reactors were closed and installed inside the oven. All samples were digested according to the following program: step 1, 5 min to reach 180°C; step 2, 15 min at 180°C; step 3, cooling down. After cooling to ambient temperature, the reactors were opened and sonicated to eliminate the nitrous oxide vapours, nine samples and one blank were treated simultaneously. The resultant solutions were transferred to a plastic flask and made up to 25 mL with ultra-pure water. Finally, the solutions were centrifuged to eliminate silica and the supernatant was directly feed to the ICP-AES.

2.4. ICP-AES DETERMINATION

The operating conditions of the ICP-AES equipment are summarized in Table 2. The analytical emission lines were selected as the most sensitive and selective ones. The calibration standards were prepared by diluting the stock multi-elemental standard solutions in 0.5% nitric acid. The calibration range for all the 42 evaluated elements was made from 0.005 to 5 mg L⁻¹ and it was modified according to the expected concentration range in the samples of the different studied elements.

TABLE 2: Operating parameters for ICP-AES determination of trace elements in digested takaout and henna samples

PARAMETER		VALUE	
RF Power (W)		1300	
Plasma Flow (L min ⁻¹)		15	
Auxiliary Flow (L min ⁻¹)		2.0	
Nebulizer Flow (L min ⁻¹)		0.8	
Sample Uptake rate (mL min ⁻¹)		1.1	
View		Axial	
Background correction		2-Point	
Number of replicates		3	
Nebulizer		Cross Flow	

ELEMENT	SPECTRAL LINE (NM)	ELEMENT	SPECTRAL LINE (NM)	ELEMENT	SPECTRAL LINE (NM)
AL	396.153	Eu	381.967	PB	220.353
AS	188.979	Fe	238.204	PR	390.844
B	249.677	Gd	342.247	SC	361.383
BA	233.527	Ho	345.600	SE	196.026
BE	313.107	K	766.490	SM	359.260
BI	223.061	La	398.852	SR	407.771
CA	317.933	Li	670.784	TB	350.917
CD	226.502	Lu	261.542	TI	334.940
CE	413.764	Mg	285.213	TL	190.801
CO	228.616	Mn	257.610	TM	384.802
CR	267.716	Mo	202.031	V	290.880
CU	327.393	Na	589.592	Y	371.029
DY	353.170	Nd	406.109	YB	328.937
ER	337.271	Ni	231.604	ZN	206.200

3. RESULTS AND DISCUSSION

3.1. ANALYTICAL CHARACTERISTICS

The main analytical characteristics of the developed ICP-AES procedure are indicated in Table 3. The limit of detection (LOD) was calculated as the concentration corresponding to three-times the standard deviation of ten replicates of a blank solution. Additionally, LODs were calculated in the original samples ($\mu\text{g g}^{-1}$) taken into consideration the amount of sample digested and the final dilution employed in the

recommended procedure. The limit of detection of the 42 elements studied varied between $0.006 \mu\text{g g}^{-1}$ for Be and Tm, and $84 \mu\text{g g}^{-1}$ for Na. As it can be seen from data in this table, the limit of detection values are adequate for the determination of trace elements in takaout and henna samples. On the other hand, recovery percentage values found for the analysis of a takaout sample spiked with final concentrations from 40 to $1600 \mu\text{g L}^{-1}$ varied between 87% for Cr to 130% for Pb, and from 92% for Ce to 112% for Ni, K and Eu in the case of henna samples.

TABLE 3: Analytical figures of merit of ICP-AES determination of trace elements in takaout and henna samples previously digested in a microwave oven.

Element	Sensitivity (signal L mg ⁻¹)	LOD		Recovery (%)		RSD (%)	
		In solution (µg L ⁻¹) ^a	In sample (µg g ⁻¹) ^b	takaout	henna	takaout	henna
Al	12.67	63.7	15.9	95 ± 2	104 ± 11	5 (627-4622)	8 (610-3290)
As	0.683	3.2	0.8	111 ± 9	106 ± 3	26 (1.0)	17 (1.52)
B	10.8	8.7	2.2	-	-	-	-
Ba	3.69	1.1	0.3	101 ± 3	107 ± 1	8 (1.3-31)	4 (27-167786)
Be	700	0.025	0.006	105 ± 6	104 ± 2	-	-
Bi	0.386	7.5	1.9	120 ± 10	99 ± 5	-	-
Ca	12.20	40.0	10.0	110 ± 3	101 ± 3	3 (978-8966)	5 (8218-17818)
Cd	4.47	0.5	0.1	104 ± 6	105 ± 1	-	5 (2.8-3.5)
Ce	2.40	11.8	3.0	90 ± 8	92 ± 9	21 (21-38)	7 (20-58)
Co	1.71	1.0	0.2	106 ± 7	107 ± 2	7 (5.1-9)	-
Cr	5.14	1.3	0.3	87 ± 10	108 ± 1	6 (1.12-63)	3 (32.9-86.1)
Cu	14.92	1.1	0.3	106 ± 7	109 ± 1	7 (5.5-12)	13 (6.7-21)
Dy	9.15	2.1	0.5	99 ± 5	102 ± 6	-	-
Er	25.87	2.7	0.7	104 ± 7	103 ± 4	5 (7.2-130)	6 (21-89)
Eu	21.80	0.3	0.1	99 ± 6	112 ± 10	-	-
Fe	3.95	8.7	2.2	106 ± 2	102 ± 12	5 (478-4919)	4 (749.3-2399)
Gd	3.27	2.5	0.6	98 ± 5	99 ± 5	-	-
Ho	7.7	3.5	0.9	97 ± 4	102 ± 3	6 (3-7.1)	-
K	1.37	74.9	18.7	104 ± 3	112 ± 4	3 (6125-13395)	3 (5173-16294)
La	20.7	1.1	0.3	97 ± 6	102 ± 2	7 (4.4-8.1)	11 (6.3-9)
Li	107.1	41.8	10.5	106 ± 5	106 ± 1	7 (2.1-7.02)	8 (0.87-10.3)
Lu	23.11	0.3	0.1	97 ± 6	100 ± 2	-	-
Mg	44	45.7	11.4	93 ± 2	95 ± 12	2 (801-4576)	4 (1950-5125)
Mn	33.52	0.2	0.04	99 ± 6	106 ± 4	7 (14.3-70)	3 (65-120)
Mo	1.43	2.3	0.6	100 ± 5	105 ± 1	22 (3.5-8.3)	-
Na	9.0	336.4	84.1	97 ± 3	101 ± 14	3 (1623-6098)	3 (1922-13803)
Nd	5.2	5.1	1.3	93 ± 10	109 ± 3	-	-
Ni	1.8	5.5	1.4	97 ± 6	112 ± 1	6 (13.5-20)	15 (7.8)
Pb	0.342	12.1	3.0	130 ± 10	105 ± 3	10 (9-14)	-
Pr	2.6	6.3	1.6	103 ± 2	96 ± 6	6 (9-21)	-
Sc	41.0	0.5	0.1	99 ± 5	101 ± 1	-	-
Se	0.32	4.1	1.0	114 ± 7	108 ± 1	-	-
Sm	1.69	8.8	2.2	95 ± 6	101 ± 7	-	0.2 (12.72)
Sr	802	1.3	0.3	102 ± 5	107 ± 8	6 (10-36)	3 (147-353)
Tb	2.33	5.9	1.5	98 ± 4	102 ± 10	10 (4.3-13)	-
Ti	20.24	3.1	0.8	108 ± 9	99 ± 6	12 (4.4-210)	7 (21-85)
Tl	0.030	21.0	5.2	89 ± 8	105 ± 18	12 (12-21.4)	-
Tm	460	0.04	0.01	105 ± 6	111 ± 9	-	-
V	4.25	1.5	0.4	102 ± 5	104 ± 1	-	-
Y	41.92	0.8	0.2	98 ± 6	101 ± 1	-	10 (1.8-8.4)
Yb	59.41	0.4	0.1	99 ± 6	103 ± 2	-	-
Zn	6.31	0.5	0.1	114 ± 7	109 ± 3	7 (22.1-31.5)	9 (6.58-15.3)

3.2. EVALUATION OF THE ACCURACY OF THE METHOD

The accuracy of the proposed method was evaluated by analyzing a Certified Reference Material from the National Institute of Standards and Technology NIST 1573a Tomato Leaves. Obtained values agree well with those certified with relative accuracy errors ranging from -2 to +10%, except for As, Cd, Mo, Se, and V for which the LOD of the method were higher or of the same order than the certified value.

3.3. EVALUATION OF THE MATRIX EFFECT

Standard addition curves obtained from a takaout and a henna powdered sample spiked at different concentration levels from 400 to 1600 $\mu\text{g L}^{-1}$, except for Al, Ca, Fe, Pb, Mg and Na, for which spiked levels were from 40 to 160 $\mu\text{g L}^{-1}$ were compared with external calibration lines established from multi-elemental standards. The slopes of both kinds of calibration lines were statistically comparable thus evidencing the lack of matrix effects in the analysis of these two types of samples.

3.4. TRACE ELEMENT CONTENT IN TAKAOUT SAMPLES

From the 42 studied elements, 21 elements (Al, B, Ba, Ca, Co, Cr, Cu, Er, Fe, K, La, Mg, Mn, Na, Ni, Sc, Sr, Ti, Y, Yb, Zn) were found in at least one of the Moroccan takaout samples (see table 4). For the rest of the considered elements results found were, in all the samples, lower than the LOD values reported in table 3. From data in table 4 it can be seen that K (at concentration levels from 6337 till 14504 $\mu\text{g g}^{-1}$), followed by Na (1626 to 6119 $\mu\text{g g}^{-1}$), Ca (956 to 9533 $\mu\text{g g}^{-1}$), Mg (799 to 4925 $\mu\text{g g}^{-1}$), Fe (472 to 5184 $\mu\text{g g}^{-1}$) and Al (629 to 4627 $\mu\text{g g}^{-1}$) are the main elements presented in takaout samples. For Mn, Sr, Zn, levels of the order of 10 $\mu\text{g g}^{-1}$ were found in all the samples and for Cr, Ba, Er and Ti data show a high variability between samples with minimum and maximum values of 1.4 and 53 $\mu\text{g g}^{-1}$ for Cr, from 3 to 32 $\mu\text{g g}^{-1}$ for Ba, between 1.3 and 29 $\mu\text{g g}^{-1}$ for Er and between 6 and 236 $\mu\text{g g}^{-1}$ for Ti. The rest of the elements detected were at concentration levels of few $\mu\text{g g}^{-1}$.

3.5. TRACE ELEMENT CONTENT IN HENNA SAMPLES

From the 42 studied elements, 22 elements (Al, As, Ba, Ca, Cd, Ce, Cr, Cu, Er, Fe, K, La, Li, Mg, Mn, Na, Ni, Sm, Sr, Ti, Y, Zn) were found in the Henna samples (see table 5). For the rest of the considered elements results found were, in all the cases, lower than the LOD values of the method (see table 3). From data in table 5 it can be seen that the trace element profile of Moroccan samples (MS1 and MS2) includes K and Ca at concentration levels higher than 10000 $\mu\text{g g}^{-1}$, Al, Fe, Mg and Na at a level of 1000-5000 $\mu\text{g g}^{-1}$, Sr at a level of 100-500 $\mu\text{g g}^{-1}$, Ba, Ce, Mn, Ti and Zn at a level of 10-100 $\mu\text{g g}^{-1}$, followed by the rest of elements at concentrations lower than 10 $\mu\text{g g}^{-1}$. For Indian samples (IS1 and IS2) the trace element profile includes a high level of Ba (more than 100000 $\mu\text{g g}^{-1}$), Na around 10000 $\mu\text{g g}^{-1}$, Al, Ca, Fe, K and Mg between 1000 and 10000 $\mu\text{g g}^{-1}$, Sr at the same level of the Moroccan samples (100-500 $\mu\text{g g}^{-1}$), Ce, Cr, Cu, Er, Mn and Ti between 10 and 100 $\mu\text{g g}^{-1}$, and the rest of elements at concentrations lower than 10 $\mu\text{g g}^{-1}$. So, on considering the different type of samples analysed it can be seen in table 5 that Moroccan samples are richer in Al, Ca, K, Li, Mg, and Zn than Indian ones, while, the Indian samples are richer in Ba, Cd, Cr, Cu and Na than Moroccan samples. For the rest of elements, there is no significant variability between both types.

4. COMPARISON BETWEEN RESULTS OF THIS STUDY AND RESULTS PUBLISHED BY DANISH EPA

The comparison between results found in this study and the concentration ranges (Min-Max) of trace elements in henna samples reported by the Danish Environment Protection Agency [12] concerning products imported by Denmark (see Figure 1) shows that the levels of Cd, Ce, Cr, Cu, Er, K and La in our study are higher than those obtained by the Danish EPA. For the rest of elements evaluated, data found are of the same order in all the samples studied than those indicated in the Danish EPA study.

TABLE 4: Results obtained for the determination of trace elements in Moroccan takaout samples by ICP–AES in ($\mu\text{g g}^{-1}$)

Element	^a LOD	^b LOQ	^c RSD	S ₁	S ₂	S ₃	S ₄	S ₅
Al	15.9	47.7	5	629 ± 34	4627 ± 102	940 ± 75	774 ± 28	2675 ± 169
B	2.2	6.6	32	8.0 ± 0.5	7.7 ± 4.5	-	-	-
Ba	0.3	0.9	23	3 ± 1	32 ± 3	31 ± 2	6 ± 3	26 ± 4
Ca	10	30	5	3594 ± 89	6774 ± 43	956 ± 93	3538 ± 7	9533 ± 1016
Co	0.2	0.6	62	5 ± 1	4 ± 3	0.9 ± 0.4	0.92 ± 0.99	-
Cr	0.3	0.9	46	1.4 ± 1.3	53 ± 1	-	-	47 ± 21
Cu	0.3	0.9	20	5 ± 2	11.1 ± 0.2	10 ± 3	8 ± 1	13 ± 2
Er	0.7	2.1	14	1.3 ± 0.2	8.1 ± 0.5	3.4 ± 0.3	1.9 ± 0.4	29 ± 5
Fe	2.2	6.6	6	472 ± 27	3317 ± 123	2048 ± 237	582 ± 23	5184 ± 369
K	18.7	56.1	3	12477 ± 84	12605 ± 118	6337 ± 367	11109 ± 18	14504 ± 1253
La	0.3	0.9	34	1.38 ± 0.06	2.2 ± 1.8	-	-	6.1 ± 0.9
Mg	11.4	34.2	4	2107 ± 30	3974 ± 30	799 ± 56	1906 ± 5	4925 ± 492
Mn	0.04	0.12	6	13.0 ± 0.4	65 ± 3	65 ± 7	16.6 ± 0.7	74 ± 5
Na	84.1	252.3	3	5452 ± 52	6119 ± 35	1626 ± 102	5581 ± 9	5718 ± 343
Ni	1.4	4.2	29	6 ± 1	23.0 ± 0.2	3 ± 2	6 ± 1	22 ± 10
Sc	0.1	0.3	13	-	-	-	-	0.16 ± 0.02
Sr	0.3	0.9	4	16.7 ± 0.6	33.3 ± 0.8	9 ± 1	19.3 ± 0.5	35.8 ± 0.3
Ti	0.8	2.4	14	6 ± 2	59 ± 5	24 ± 3	13.0 ± 0.1	236 ± 34
Y	0.2	0.6	13	-	-	-	-	0.31 ± 0.04
Yb	0.1	0.3	2	-	-	-	-	0.113 ± 0.002
Zn	0.1	0.3	5	25 ± 1	29.8 ± 0.5	29 ± 4	20.7 ± 0.5	29 ± 1

^aLODs were calculated as the concentrations corresponding to signals equal to three-times the standard deviation of a blank solution and taken into consideration the amount of takaout digested and the dilution of samples made after digestion ($\mu\text{g g}^{-1}$).

^bLOQs were calculated as the concentrations corresponding to signals equal to ten-times the standard deviation of a blank solution and taken into consideration the amount of takaout digested and the dilution of samples made after digestion ($\mu\text{g g}^{-1}$).

^cRSD were calculated in % from the average of the repeatability of three independent analysis made in actual samples.

^d(-) elements were not determined because concentrations found were under the LOD values.

TABLE 5: Results obtained for the determination of trace elements in henna sample by ICP–AES in ($\mu\text{g g}^{-1}$)

Element	LOD	LOQ	RSD	MS ₁	MS ₂	IS ₁	IS ₂
Al	15.9	47.7	13	1505 ± 62	3293 ± 248	1695 ± 602	610 ± 32
As	0.8	2.4	30	-	1.5 ± 0.7	1.5 ± 0.2	-
Ba	0.3	0.9	5	26.6 ± 2.3	35.4 ± 2.6	164311 ± 1755	167786 ± 5732
Ca	10	30	3	17826 ± 1168	12466 ± 58	9541 ± 930	8222 ± 159
Cd	0.1	0.3	7	-	-	2.7 ± 0.3	2.86 ± 0.08
Ce	3	9	10	43.3 ± 4.5	20 ± 3	24.4 ± 0.1	58 ± 8
Cr	0.3	0.9	4	-	-	86 ± 1	33 ± 2
Cu	0.3	0.9	15	8.29 ± 0.06	7 ± 1	21 ± 6	11 ± 2
Er	0.7	2.1	7	4.1 ± 0.6	14 ± 1	17.7 ± 0.6	4.7 ± 0.2
Fe	2.2	6.6	4	1097 ± 50	2404 ± 145	1733 ± 123	750.9 ± 0.5
K	18.7	56.1	3	16310 ± 1069	14816 ± 202	6087 ± 165	5179 ± 149
La	0.3	0.9	16	6.3 ± 0.3	8 ± 2	9 ± 1	8 ± 2
Li	10.5	31.5	9	11 ± 1	-	-	-
Mg	11.4	34.2	4	5125 ± 321	4468 ± 30	2235 ± 126	1950 ± 38
Mn	0.04	0.12	5	78 ± 6	75 ± 3	120 ± 5	65 ± 2
Na	84.1	252.3	3	1930 ± 83	1990 ± 49	8437 ± 423	13861 ± 266
Ni	1.4	4.2	13	-	-	8 ± 1	-
Sm	2.2	6.6	0.1	-	-	-	3.820 ± 0.005
Sr	0.3	0.9	4	218 ± 16	147 ± 3	295 ± 7	353 ± 8
Ti	0.8	2.4	9	21 ± 3	70 ± 8	85 ± 2	22 ± 2
Y	0.2	0.6	10	1.0 ± 0.2	-	1.30 ± 0.01	-
Zn	0.1	0.3	8	11.35 ± 0.06	15 ± 2	6.6 ± 0.8	7.7 ± 0.5

^aLODs were calculated as the concentrations corresponding to signals equal to three-times the standard deviation of a blank solution and taken into consideration the amount of henna digested and the dilution of samples made after digestion ($\mu\text{g g}^{-1}$).

^bLOQs were calculated as the concentrations corresponding to signals equal to ten-times the standard deviation of a blank solution and taken into consideration the amount of henna digested and the dilution of samples made after digestion ($\mu\text{g g}^{-1}$).

^cRSD were calculated in % from the average of the repeatability of three independent analysis made in actual samples.

^d(-) elements were not determined because concentrations found were under the LOD values.

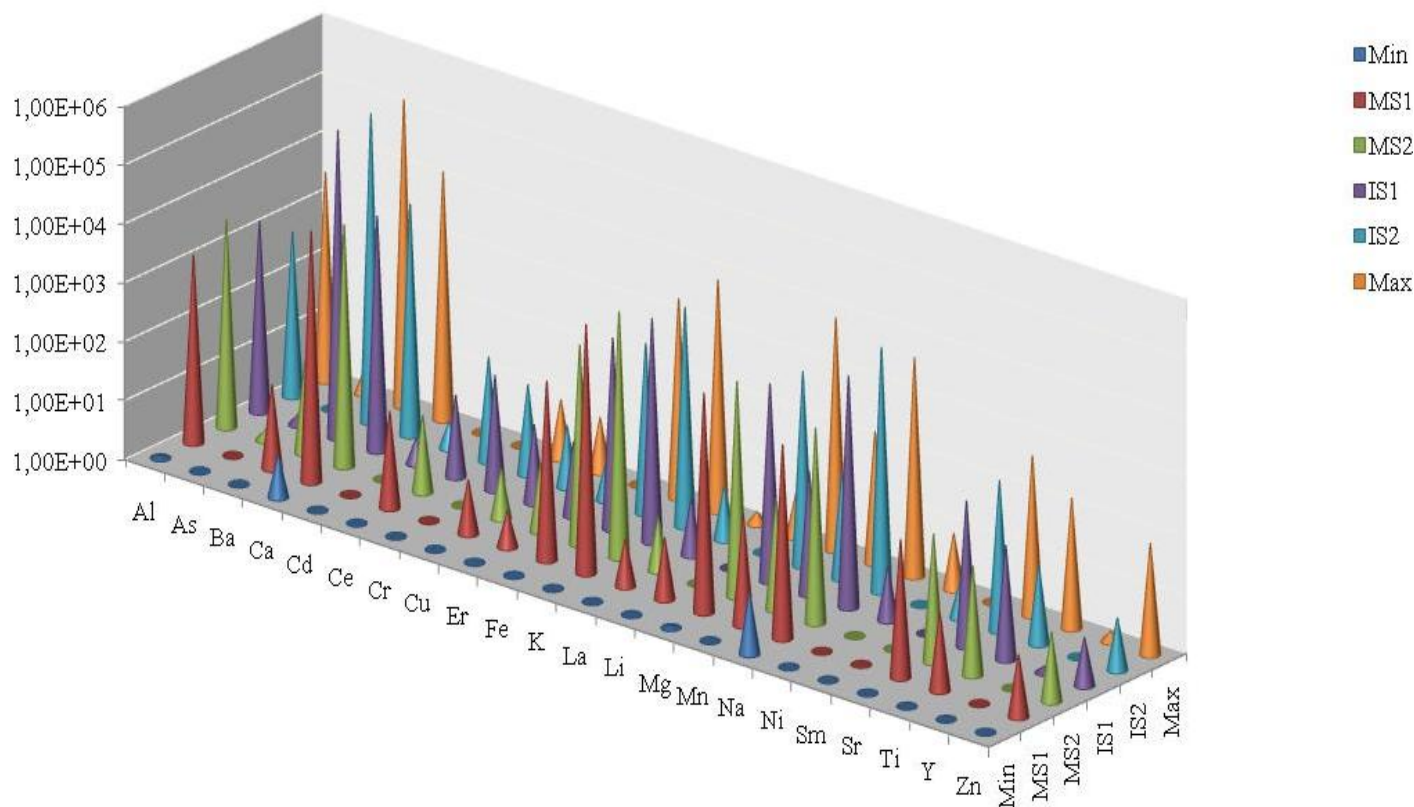


FIGURE 1: Average of trace element contents obtained in the henna samples in the present study compared with concentration ranges (Min to Max value) obtained in Danish market samples by Danish EPA [12].

5. CONCLUSIONS

The methodology developed to determine the trace element composition of Moroccan traditional cosmetic products by ICP-AES after microwave assisted acid digestion has been validated in terms of accuracy and precision providing a fast way to determine potential toxic elements additionally than to provide the trace element profile of takaout and henna Moroccan and Indian products to assess the quality and singular properties of those products.

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