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Determination of Gum Arabic (*Acacia nilotica*) Constituents Using Laser Induced Breakdown Spectroscopy

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ABSTRACT

In this work, Laser Induced Breakdown Spectroscopy (LIBS) was used to determine the constituent of Gum Arabic (*Acacia nilotica*) collected from five different locations in Sudan. Gum samples were irradiated with 80 mJ pulse energy of Nd-YAG laser (1064 nm) and Atomic spectra Database was used for the spectral analysis of the plasma emitted from these samples. It was found that the samples contain the elements C, O, H, S, N, P, Na, Mg, Ca, Fe, Cr, Mn, Co with different amounts. Some elements like (Ti, Br, Ar, Th, Kr, Sc and Pr) are recorded here for the first time.

1. INTRODUCTION

Laser-induced breakdown spectroscopy (LIBS) is a method of atomic emission spectroscopy (AES) that uses laser-generated plasma as the hot vaporization, atomization, and excitation source [1-4]. Foremost of these is the ability to interrogate samples *in situ* and remotely without any preparation. In its basic form, a LIBS measurement is carried out by forming laser plasma on or in the sample and then collecting and spectrally analyzing the plasma light. Qualitative and quantitative analyses are carried out by monitoring emission lines positions and intensities [5-7]. LIBS can be used to investigate different materials especially those composed of large molecules such as Gum Arabic. *Acacia nilotica* Sunt has been found the most valuable timber-producing species [8-10]. An ability to regenerate successfully on flooded sites along the Nile and its tributaries, coupled with timber properties that satisfy most of the utilization standards make the species the most important in the economy of the Sudan. This work aimed to use LIBS for Identification of Gum Arabic (*Acacia nilotica*).

2. METHODS AND MATERIAL

2.1. Experimental Setup

Figure 1 illustrates the LIBS setup which was used in this work. The LIBS system composed of Q-switched Nd-YAG Laser (Laser wavelength is 1064 nm, pulse duration 10 ns, Pulse Energy 80 mj, Spot size 2 - 8 mm, and repetition rate 2 Hz), Ocean Optics 4000+ spectrometer, connected with PC.

2.2. The Materials

Four samples of GumArabic (*Acacia nilotica*) (sunt) obtained from different locations in Sudan. Were used in this work, they are illustrated in Table 1.

2.3. Experimental Procedure

Each sample was put in a quartz cell and irradiated by the Nd-YAG laser where the spark of the sample plasma was collected by a fiber optic to the spectrometer which was interfaces to a computer. The emission spectra were collected in the range from 200 - 900 nm. In order to test the homogeneity of Gum Arabic samples, several LIBS measurements were performed at its surface. The recorded spectra of the samples were analyzed using Atomic Spectral Database (NIST) data.

Irradiation with pulse energy of 80 mJ resulted in generating exited elemental species and cations in higher oxidation states. This was evident from the emission spectral lines corresponding to species such as Cr^{3+}, Ti^{2+} and Ar^{3+}.

Although the samples of GA in this study were collected from different locations in Sudan having different soil characteristics, their LIBS emission spectra reflect presence of the same elements in all samples. This may indicate that there is no influence of the soil type on the elemental composition of exudates gums like GA.

3. RESULTS AND DISCUSSION

LIBS emission spectra of *Acacia nilotica* (sunt)gum samples irradiated with laser of 80 mJ pulse energy are shown in Figures 2-5 while Table 2 shows the results of analysis and elemental composition of the mentioned gum samples, which were obtained with the help of Atomic spectra database and the Handbook of basic Atomic spectroscopy.

The elements constituting the samples observed in the emission spectra were C, O, H, S, N, P, Na, Mg, Ca, Fe, Cr, Mn, Co. This is in agreement with findings of other researches published previously. [11-13]. In addition to these, other elements had been detected for the first time in natural gums, namely

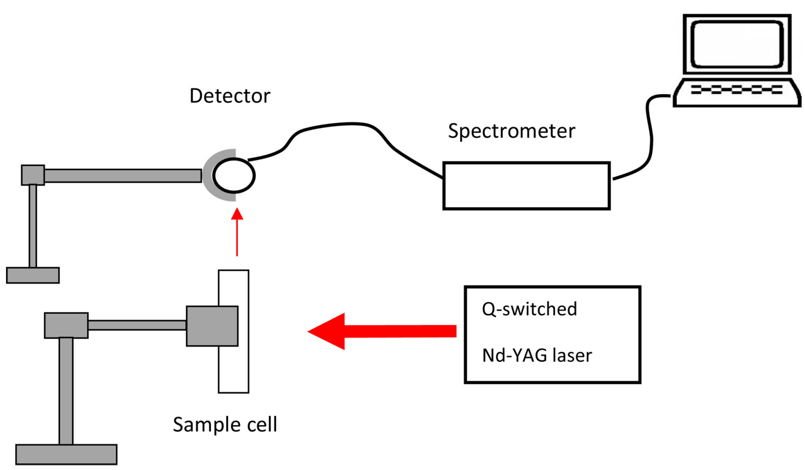

Figure 1. Schematic diagram of the setup.

Table 1. Samples grouping.

Classification	Location of samples collection
Sample (1)	South Kordofan
Sample (2)	Blue Nile state
Sample (3)	White Nile state
Sample (4)	Khartoum state

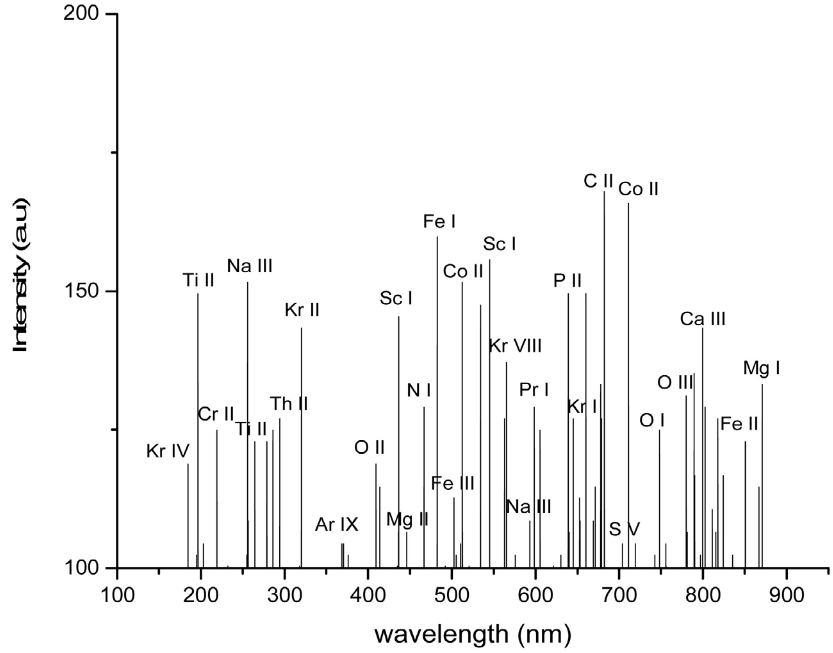

Figure 2. LIBS emission spectrum of sample (1).

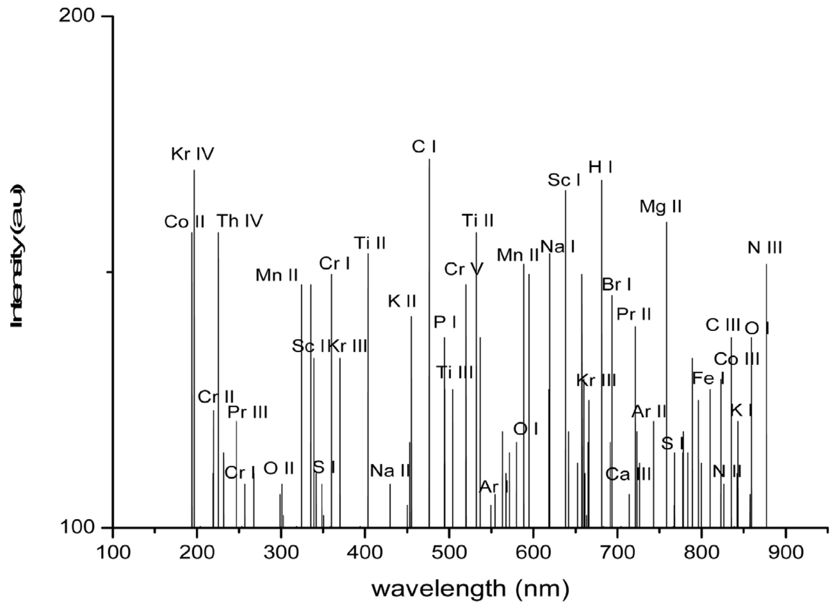

Figure 3. LIBS emission spectrum of sample (2).

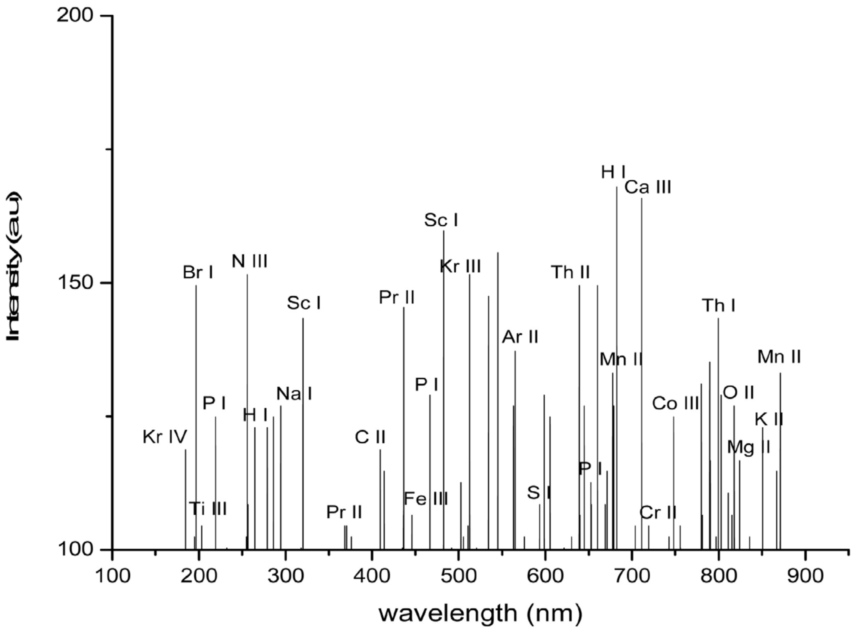

Figure 4. LIBS emission spectrum of sample (3).

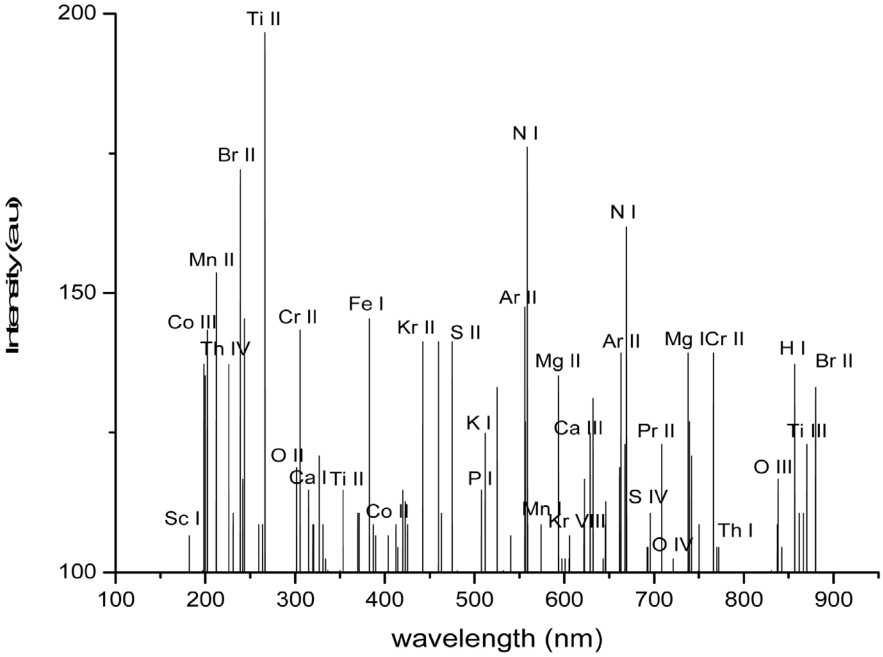

Figure 5. LIBS emission spectrum of sample (4).

(Ti, Br, Ar, Th, Kr, Sc and Pr).

Interestingly the elements Th, Pr, Kr, and Sc have not been observed in any of the previous studies undertaken on *Acacia nilotica* using the conventional (AAS or ICP) techniques. These elements and their ions are reported here for the first time in the elemental analysis of *Acacia nilotica* using LIBS, this adds to the many advantages of this technique, compared to other conventional techniques mentioned above. Sample of *Acacia nilotica* showed the presence of heavy metals like Fe, Cr, Pr and Th which may hinder its application in food and pharmaceutical formulation.

Table 2. The analyzed data of *Acacia nilotica* (sunt) collected from different locations after irradiation by laser energy of 80 mJ.

Element	λ(nm)	Emission intensity (a.u)			
		(S_{11})	(S_{12})	(S_{13})	(S_{14})
Fe I	217.0590			121.0267	110.7591
	228.7649		106.2807	159.9672	
	314.4824			137.4112	135.4997
	345.0688		128.9459	133.2605	
	401.3327	119.3883	135.4997		
	498.3784	115.2375	137.4112	112.7252	151.8842
	516.5037		125.1774	104.2053	127.4713
Fe II	185.7174	111.0868		108.7930	
	215.7110		104.9699	121.0267	110.7591
	258.5961		110.7591	141.6166	
	510.0844		125.1774	112.9437	
	633.5628	116.8760	121.3544		110.7591
	684.1625	103.0038		149.6450	
	797.4455	149.6450		125.5051	158.0010
Fe III	364.3269	118.7329	114.9098	135.4997	110.7591
	512.7276		125.1774	127.4713	
	538.7827		129.0005	116.8760	
	596.5570		114.5821		
	618.4584		129.0005		
	731.7414		123.3205	122.6990	110.7591
	823.1230	165.4833			112.9437
Na I	249.1559			131.2943	114.9098
	261.2394	103.0038	110.7591	165.4287	
	355.2643		126.8159	137.4112	
	589.4944		104.6422		119.0606
	691.7147	148.0611	104.3691	104.3145	141.9442
Na II	242.7364			131.2943	
	254.8200	135.4997	116.8760	152.2119	149.6450
	308.0630	104.6422		122.9929	
	316.3705		126.8159	158.2195	135.4997
	519.1470			104.2053	127.4713

Continued

Na III	203.0875	106.6084	104.9699	141.6166	139.0497
	323.9227	137.7389		125.1774	113.2168
	395.6685	125.1774	118.7329	135.1720	
	590.8929		114.9098		119.0606
	652.4433	129.3282	127.1436		113.5991
	713.6161	162.2610			138.0666
Ca I	272.1901		103.0038	108.7930	122.9929
	616.9480	143.8558	129.0005	127.7990	
	720.0355			163.7902	111.0868
	734.7623	119.7160	123.3205	112.9437	119.0606
Ca II	423.2341	119.0606	103.0038	108.7930	119.0606
	608.6406		126.8159	119.0606	
	757.0413	164.1179	115.2375		
Ca III	199.3114		129.9836	114.9098	
	281.6303	120.8083		136.7558	139.3773
	508.1963		137.4112	112.9437	
	535.0066		129.0005	116.8760	133.2605
Mg I	265.7707	120.8083	114.9098	118.8421	
	548.6006			192.7362	121.0267
	631.6748	116.8760	121.3544		110.7591
	748.7338	135.4997			113.2714
	781.2083	114.9098	111.0868		
	805.3753	141.2889	153.8503	129.3282	112.9437
	847.2900	129.3282		125.1774	125.1774
Mg II	355.2643		126.8159	108.5745	
	427.0102		103.0038	108.7930	
	545.2021	141.6166		192.7362	121.0267
	787.6277		111.0868	112.9437	
	811.4171	137.0835	153.8503	126.7613	
Mg III	183.0741	111.0868		165.4287	135.4997
	425.1221	119.0606	103.0038	108.7930	119.0606
	562.5721	133.2605	139.0479	112.9437	125.5051
	692.4700	148.0611	104.3691		141.9442
	704.5535	143.5281		123.3205	133.2605

Continued

K I	297.1123	137.7389	165.7564	116.8760	113.2168
	690.9595	141.9442	104.3691	104.3145	106.3353
	710.9729	162.2610	114.9098	106.9361	138.0666
	785.7396	137.7389		112.9437	
K II	368.8582	125.1774	121.0267	141.6166	
	380.9418	115.2375		118.8421	
	579.1870	103.0038	108.7930		112.6160
K III	334.1181		111.0868		
	348.0897			133.2605	116.5483
	388.4940			139.0497	
	457.5966	120.8083		112.7252	112.6160
	767.2367	104.6422	106.9361	114.5821	145.7673
S I	540.2932	119.0606		192.7362	121.0267
	558.0408		125.1774	125.8328	125.5051
	595.8018		114.5821	119.0606	
	673.9671	123.3205	112.9437	112.9437	
	724.1892		110.8137	163.7902	111.0868
	792.9142		126.7613	108.7930	
	866.5482	108.7930	139.3773		127.1436
S II	361.6836		110.7591		
	405.8640	119.3883	135.4997		
	500.6441	106.9361			164.1179
	522.9231	131.2943	109.1206	188.2577	135.4997
	536.8947	114.9098	129.0005	116.8760	
	687.9386	141.9442		155.8164	119.0606
	740.4264	112.9437	137.4112		
S III	252.1768	135.4997	116.8760		114.9098
	337.5166	161.9333	104.9699		
	632.4300	143.5281		106.2807	110.7591
C I	473.4562	103.0038	133.2605	165.4287	147.7334
	529.3425	114.9098	116.5483		
	568.9915	139.3773	112.6160	129.3282	121.0267
	579.9422			112.6160	103.0038
	763.4606	136.1551	110.8137	163.7902	111.0868

Continued

C II	359.0404		125.1774	112.9437	
	625.2554	110.7591	129.0005	106.6084	133.2605
	663.7716	122.9929			119.0606
	803.1097	141.2889	153.8503	129.3282	
C III	218.1919	131.2943	109.1206	151.6056	135.4997
	794.8023	149.6450		108.7930	
	853.709	114.9098	116.8760	104.6422	
	880.5197	137.7389	139.3773		112.9437
N I	493.4695	110.7591	103.0038	106.6084	135.4997
	672.0790	106.6084	117.2037	112.9437	
	765.3487	104.6422		114.5821	
	789.8933		111.0868	112.9437	
	870.3243	108.7930		121.0267	
N II	384.7179	120.8083		118.8421	
	502.5322	106.9361		176.0240	164.1179
	531.9857	114.9098	116.5483	116.8760	133.2605
	593.1585		126.8159	119.0606	119.0606
	683.4073	103.0038		149.6450	
	700.0222		151.8842	155.8164	119.0606
N III	184.5846	111.0868	104.9699	108.7930	104.9699
	471.1905	103.0038		136.8651	145.7673
	489.6934			171.8732	
	644.5135	110.7591	129.0005	106.6084	133.2605
O I	613.9271	143.8558	127.1436	141.6166	106.6084
	777.4322			122.6990	110.7591
	840.8707	121.0267	108.7930	141.6166	
O II	296.469			116.8760	
	394.9133	125.1774	118.7329	135.1720	110.7591
	444.7578			145.7673	110.7591
	638.094	111.4145		106.2807	
	736.6503	119.7160	103.0038	106.9361	122.6652
	762.7054	104.6422		114.5821	

Continued

	319.3913		105.2976	158.2195	135.4997
	351.4882		128.9459		116.5483
	394.5257	125.1774	118.7329	135.1720	
	650.9329	129.3282	127.1436		113.5991
O III	673.5895	123.3205	117.2037	112.9437	
	729.4757	119.3883	110.8137	112.9437	
	749.8667	135.4997	149.6450		113.2714
	809. 5290	137.0835		125.5051	158.0010
	817.0812	161.9333	110.4314	110.7591	127.1436
	194.0248			114.9098	135.4997
	212.1501	106.6084	104.9699		
Cr I	234.4291	114.9098	120.6990	153.8503	147.7334
	346.9569			133.2605	116.5483
	456.3637	119.3883		112.7252	104.6422
	253.6872	135.4997	116.8760	152.2119	149.6450
	275.9662	104.6422		165.4287	147.7334
Cr II	386.6059	120.8083		139.0497	
	554.2647	119.0606	125.1774	120.6990	108.7930
	572.7676			111.0868	
Cr V	637.7165	123.3205		106.2807	
	731.3638	119.3883	123.3205	112.9437	149.6450
	259.3513		110.7591		
Ti I	370.7463	104.6422	121.0267	114.9098	156.0349
	478.3651		133.2605	104.6422	
	562.1945	139.3773	139.0479	112.9437	125.5051
	229.1426	114.9098	106.2807	159.9672	
Ti II	299.0004		103.0038	136.7558	139.3773
	430.7863	103.1130		163.7902	111.0868
	521.0350	131.2943		188.2577	135.4997
	350.7330			133.2605	116.5483
Ti III	755.1532	143.5281	111.0868	119.0606	104.6422
	829.9200	112.9437	114.9098	110.7591	119.0606
	238.582	119.0606	103.0038	103.0038	147.4047
Br I	518.769			104.2053	127.4713
	668.302	122.9929		125.1774	106.3353
	813.305	161.9333	110.4314	126.7613	127.1436

Continued

Br II	417.9475		103.0038	106.9361	122.6652
	797.8231	149.6450		108.7930	
Ar I	375.2776			121.0267	156.0349
	437.9609	104.9699		135.4997	
	526.6992		109.1206	151.6056	
	556.1528		125.1774	125.8328	108.7930
	565.2154	139.3773	110.7591	112.9437	
	654.7090	129.3282	127.1436	127.7990	113.5991
Ar II	380.9418	120.8083		118.8421	104.6422
	523.6783	131.2943	109.1206	151.6056	135.4997
	538.4051		129.0005	135.4997	106.6084
	684.5402	143.5281		149.6450	103.3315
	783.8516	114.9098		131.2943	
	879.0093	121.0267			112.9437
Ar IV	244.6246	111.0868		131.2943	104.9699
	464.7712		103.1130	176.0240	110.7591
	803.4873	141.2889	153.8503	129.3282	
Th I	373.0119	120.8083		118.8421	156.0349
	585.6069		104.6422	104.6422	147.7334
	721.1683		103.1130	163.7902	111.0868
	764.2159	104.6422		114.5821	145.7673
	778.5650	108.7930	111.0868	122.6990	110.7591
Th II	376.7880			121.0267	
	478.3651		133.2605	104.6422	
	537.2723		129.0005	116.8760	
	594.6690		114.5821		119.0606
	621.1017	110.7591		106.6084	133.2605
	858.6183	114.9098		104.6422	
Kr III	213.6605	106.6084	104.9699		110.7591
	251.0493	135.4997	116.8760	152.2119	114.9098
	285.0288			136.7558	139.3773
	371.1239		105.2976	114.9098	156.0349
	452.3100			112.7252	104.6422

Continued

Mn II	255.4424	135.4997	116.8760	152.2119	149.6450
	313.7272			137.4112	
	320.5242	137.7389	105.2976	125.1774	135.4997
	635.4509	116.8760	121.3544	106.2807	110.7591
Sc I	460.9951			112.7252	110.7591
	474.5890	103.0038	133.2605	104.6422	145.7673
	544.0693	141.6166		192.7362	
	632.0524	116.8760	121.3544		110.7591
Pr II	513.4828		125.1774	127.4713	
	550.8662			192.7362	121.0267
	587.8720		104.6422		
	594.6690	129.3282	114.5821		119.0606
Co III	667.5477	122.9929		125.1774	106.3353
	743.8249	112.9437	111.0868	163.7902	104.6422
	794.4247	149.6450	111.0868	108.7930	
P I	274.8334	104.6422			
	342.4255		128.9459	104.6968	
	474.9666	103.0038	133.2605	104.6422	145.7673
	551.6215	136.1551	125.1774	120.6990	108.7930
H I	373.7672		121.0267	114.9098	156.0349
	393.0253		118.7329		
	410.395	119.3883	113.5991		111.0868
	434.184	103.1130		135.4997	117.2037
	486.0502	103.0038	133.2605	171.8732	
	656.5970	202.2938	202.6215	131.6220	110.7591
	832.5633			110.7591	135.4997

4. CONCLUSIONS

Sample of *Acacia nilotica* showed the presence of heavy metals like Fe, Cr, Pr and Th which may hinder its application in food and pharmaceutical formulation and the elemental composition of Gum Arabic by LIBS technique enabled observing elements, such as Br, Ti and Ar, to be reported for the first time.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest regarding the publication of this paper.

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