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Characteristics of Gum Arabic (Acacia Senegal) 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 Senegal*) collected from five different locations in Sudan. Gum samples were irradiated with 80 mJ pulse energy of Nd -YAG laser (1064nm) and Atomic spectra Database was used for the spectral analysis of the plasma emitted from these samples. The results showed that all the five samples contain Fe, Na, Ca, Mg, K, S, C, N, O, Cr, Br, Ti, Ar, and H with different amounts. Some elements like Br, Ti and Ar are recorded here for the first time.

Keywords : Gum Arabic, LIBS, Laser Spectroscopy, Gum Investigation.

I. INTRODUCTION

Laser-induced breakdown spectroscopy (LIBS) is a plasma-based method of atomic emission spectroscopy (AES) that uses instrumentation similar to that used by other AES methods [1]. The unique characteristics of LIBS originate from the use of a powerful laser pulse to both prepare the target sample and then excite the constituent atoms to emit light. Sample preparation results from the ablation action of the focused laser pulse on the target that removes a small mass of the target in the form of atoms and small particles. Coincident with ablation is the formation of micro plasma in the focal volume of the laser pulse which excites the ablated atoms [2]. The plasma continues this excitation after the laser pulse. In addition, small ablated particles are vaporized in the hot plasma and the resulting atoms excited and the emitted light .This emission is the finger print of the material .Most of the materials can be characterized using this technique. [3]. Unlike many other common techniques, that are laboratory based and often require complex and time consuming procedures, LIBS requires little to no sample preparation[4, 5].One of the advantages of LIBS is its ability to characterize large molecules such as Gum Arabic.

Gum Arabic Acacia Senegal is a unique product in Sudan and over the worlds that have a wide applications and uses. It is natural exudates of two species of the acacia tree; *Acacia Senegal (*Hashab*)* and *Acacia Seyal* (Talha). Gum Arabic being a mixture of polysaccharides and glycoprotein has the properties of a glue and binder that is water soluble taste mild acid, colorless, does not dissolves in alcohol and edible by humans [6,7].Gum Arabic contains many elements that make it useful in many fields such as an important ingredient in soft drink, syrups, "hard" gummy candies such as gumdrops, marshmallows, chocolate candies and edible glitter, a popular modern cake-decorating staple[8,9]. Different methods are used to identify the components of Gum Arabic, but the limitation of these methods writes from within the components of gum materials again these methods had not sufficiently studied the optical properties of the gum Arabic. This work aimed to use LIBS for characterization of Gum Arabic (*Acacia Senegal*).

II. METHODS AND MATERIAL

2.1 The Equipments:

Figure (1) illustrates a diagram of the experimental setup which was used in this work

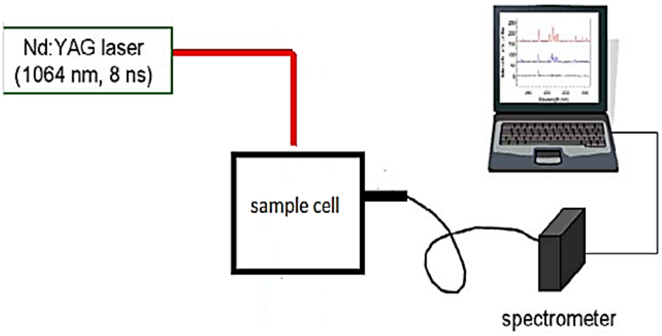

Figure 1. Schematic diagram of the setup

It was consisted of Nd: YAG laser with wavelength 1064 nm, pulse duration 10ns, Pulse Energy 80 mj, Spot size (2-8) mm, and repetition rate 2 Hz); a quartz cell with 5.64cm x 3.84cm x 2.42cm dimension used as a sample cell; mirrors and concave lenses used as optical systems; Ocean Optics LIBS 4000+ spectrometer model USB4-UV/VIS, connected with PC.

2.2 The Materials

Five samples of Gum Arabic (*Acacia Senegal*) were collected from different locations in Sudan as illustrated in table (1).

Table (1). Samples Grouping

Classification	Location
Sample (1)	South Kordofan
Sample (2)	North Kordofan
Sample (3)	Blue Nile state
Sample (4)	White Nile state
Sample (5)	Gadaref

2.3 The Experimental Procedure

A laser pulse with 80mj energy was focused on the cell without the sample and the spectrum was recorded and saved as dark spectrum .The sample was then irradiated with the same energy and the spectrum of the emitted plasma was recorded. The net spectrum was obtained by subtracting the dark spectrum. The resulted emission spectrum was analyzed using Atomic Spectral Database where the elements in the sample were identified. This step was repeated for all the five samples.

III. RESULT AND DISCUSSION

Figures (2) to (6) show the LIBS emission spectra for the samples after irradiation with 80 mJ pulse energy. Table (2) lists the analysis of the wavelengths corresponding to different elements and their intensities in the five samples.

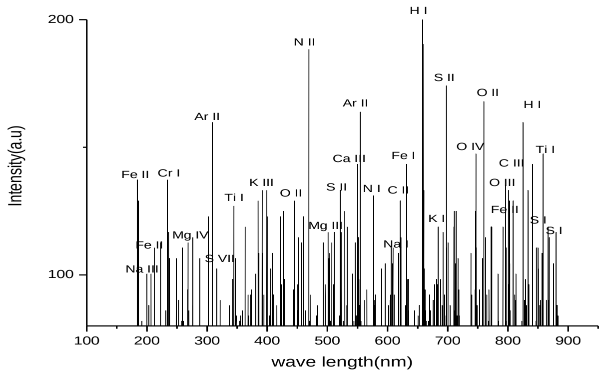

Figure 2. LIBS emission spectrum of sample (1)

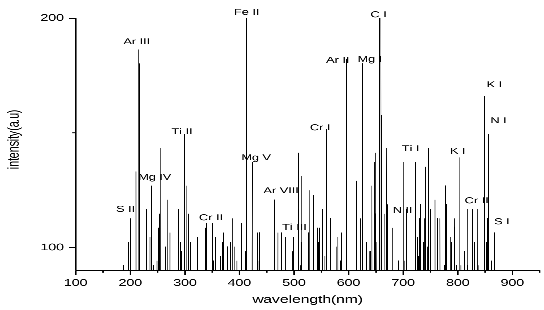

Figure 3. LIBS emission spectrum of sample (2)

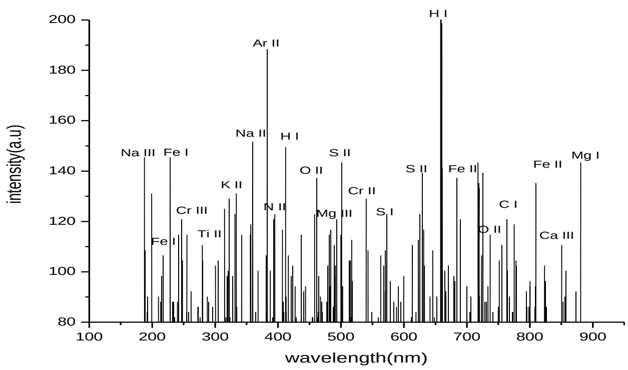

Figure 4. LIBS emission spectrum of sample (3)

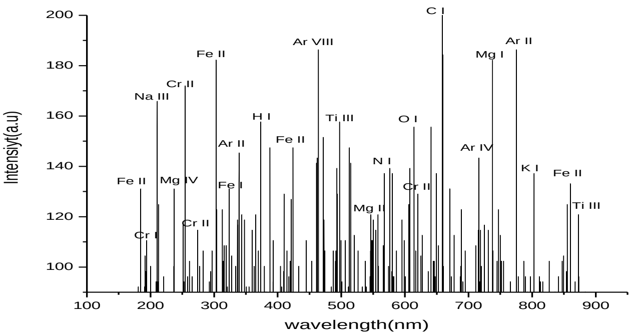

Figure 5. LIBS emission spectrum of sample (4)

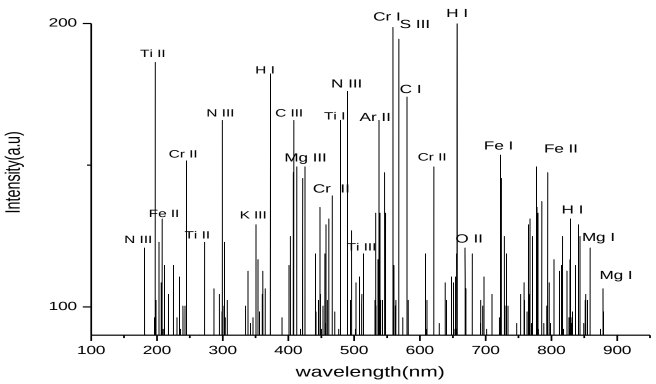

Figure 6. LIBS emission spectrum of sample (5)

Table 2 illustrate that the most wavelengths for identification of the elements, were found between 180-900 nm region .The main basic elements found in Gum Arabic samples were Mg, Ca, K and Na. In addition to these elements heavy metals, usually found at trace levels, such as Fe and Cr, were also observed. Interestingly the spectra showed lines corresponding to elements that have not been observed by other techniques, usually employed in elemental analysis of gum Arabic such as Atomic Absorption Spectroscopy (AAS) and Inductively Coupled Plasma (ICP) spectroscopy. These elements are Br, Ti and Ar. As the irradiated samples were in a liquid state, the presence of Ar could be justified by assuming presence of some sort of a complex containing the Ar atom within the Gum macromolecules.

As gum Arabic is a natural polysaccharide, it was expected to observe spectral emission lines for elements likes (H, O, C, S and N) with high intensities. Other elements like (Fe, Na, Ca, Mg and K) appeared in all samples with considerable amounts. These are in agreement with the results of previous studies published in scientific literature. [10, 11].

Irradiation with pulse energy of 80mj 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.

IV. CONCLUSION

The study of 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.

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Authors' Contributions

Author A' designed the study, wrote the protocol, and wrote the first draft of the manuscript. 'Author B' and 'Author C' managed the analyses of the study. 'Author C' managed the literature searches. All authors read and approved the final manuscript."

Table 2. The analyzed data of the samples (Hashab) after irradiation with pulse energy of 80 m J.

Element	λ(nm)	Intensity of emission (a.u)				
		S_1	S_2	S_3	S_4	S_5
Fe I	217.0590	87.5368				
	224.2336	181.3162	107.9027	114 .2763		116.4336
	228.7649	117.8154	146.3517			
	314.4824	93.5445			110.1256	
	345.0688	73.9049	77.3211	128.7766		
	458.3518		124.3036			
	516.5037	114.2053	113.6701	82.1627	112.0480	111.7476

Fe II	185.7174		130.4915	130.5297	132.3539	
	221.5904	176.5729	99.6723	114.4511	97.6897	
	258.5961	89.4593	85.3085			
	406.6192	118.2086		77.4549	93.5445	
	510.0844	102.7744	106.1496			
	633.5628	103.4571	118.1758			100.0327
	684.1625		138.1813	120.2348		
	746.8458	144.6695		148.9377	103.8776	
Fe III	364.3269	97.6297	85.4396			
	393.0253	101.7149	122.2610			
	512.7276	103.4571	105.4497			
	596.5570	184.0797			120.5789	
	775.5442	93.6646	120.2184			
Na I	249.1559	95.2266	122.2610	107.9628		
	261.2394	101.7149	93.5445			
	289.5601	117.8154		108.6837		107.7225
	432.6743	107.9027	81.9661		103.7575	93.9049
	589.4944	107.9628	95.5871	103.3397		
	691.7147	95.5871	122.2610	93.6045		101.7749
Na II	242.7364	144.3091	116.7941			101.7749
	254.8200		83.2768		172.9655	
	274.0781	115.7127	110.3768			
	316.3705	105.4997	120.2184	103.6974	161.1305	103.7575
	359.7956			87.4494	116.0731	114.1507
	519.1470		97.5641			
Na III	203.0875		81.5729	112.2884	126.5865	116.0731
	323.9227	105.8601	130.4915	91.9716	132.5341	
	590.8929		95.5871			
	713.6161			126.0131		
Ca I	272.1901	107.7225	87.5368	100.0737		124.7241
	616.9480	130.4915	111.9879		107.9027	
	734.7623	95.5324	136.8869	103.3970	115.8929	
Ca II	420.5908		99.6723			
	423.2341	138.1813	103.7575	97.7498	148.3342	150.8574
	608.6406			111.5674	140.6444	120.8793
	757.0413	121.9006	111.9879	107.8618		
Ca III	199.3114	113.3697	132.1736	103.9978	101.8350	103.9978
	281.6303		106.2807			
	483.2741	105.9202	117.8809		90.3386	
	508.1963	142.2665	91.4418			118.5363
	823.5006	91.8022	103.7575	185.1010	97.6297	185.1010
Mg I	265.7707	122.0207		120.2348	101.6548	108.1430
	382.0746	102.6761	189.1261			
	548.6006	118.5363	85.7018	144.7924		
	751.3771	118.1758	105.8601		105.8601	134.6368
	847.2900		118.1758	111.9442	104.1780	134.5767

Mg II	355.2643	105.4997	120.2184		93.7247	117.8154
	545.2021	109.9453		114.1425	122.2009	149.1753
	811.4171			93.6673	97.6297	114.4511
Mg III	286.1617	106.3407	91.9297	137.8809		
	450.0444	105.8601	118.1758	97.7498		93.5445
	704.5535	118.1758	85.4396	118.0993	107.9027	103.6974
	875.9884		93.8285	105.8519		93.5445
K I	297.1123	150.8574	103.7575		108.0830	
	311.8391	103.3970	100.2512		124.5439	
	690.9595			89.4593	95.5871	
	710.9729	118.3560	82.0316	126.7667	109.9453	
	785.7396	118.3560	114.3910		103.8175	138.6018
	868.4362	108.2632	94.5494	111.5674	106.5210	95.6471
K II	368.8582	103.7575	100.9939	93.9814	108.3833	124.3036
	380.9418	105.4997		101.7067		
	681.5193		98.1540	99.6968		
K III	334.1181	115.7728			120.2184	
	388.4940	117.8154			148.5745	
S I	467.7920		91.7312	189.3855		141.2452
	558.0408	152.5395	124.3036	122.2610	199.0988	
	816.3260	113.601		120.2976	95.8274	
S II	328.4540			97.6297		97.6297
	500.6441		144.6695	126.5264	118.1622	126.5264
	522.9231	123.9432		166.9579	118.6646	166.9579
	679.6312	109.9453	99.6723	100.0737	123.3424	
	698.1341				175.0655	
	740.4264	136.6193			93.6045	
S III	252.1768			91.9716	117.9355	
	337.5166	109.9453		88.8940	120.3986	114.0906
	436.4504	107.9027	115.7127			
	632.4300	103.4571	118.1758	104.3145		
C I	292.5810	103.3970		120.2184		
	529.3425	125.8656		126.3899		
	568.9915	113.6701	103.7575		138.5417	195.6144
	601.4660		100.4478	89.3336	97.3894	
	763.4606		122.2610			
C II	511.9724			118.1622	93.5445	106.2206
	621.4793	179.8743	123.9432	130.5352	130.3713	150.8574
	663.7716		101.7149	97.7498	115.0518	
	803.1097	140.5843		130.5980	138.5417	
C III	524.4335	109.9453	93.5445		107.9628	106.2206
	851.8214	103.8175	111.6275			
	880.5197	114.0305	144.8498			
N I	493.4695	109.9453		114.2053	140.9448	101.8776
	639.2270	99.6723	92.2555	114.7515	157.2255	104.4183
	672.0790		103.7575			

	765.3487	122.2610	114.0305	93.6673	95.5871	130.4915
	789.8933				97.6297	95.6471
	856.7303		93.5445	109.9972	126.1660	122.3211
N II	384.7179			130.5352		
	462.1279		138.5417	87.4494	145.0300	132.7143
	683.4073		138.1813	111.9442	126.2261	120.2785
	700.0222	138.1813		114.1425		93.5445
N III	181.9413		82.0316		132.6542	122.2610
	210.6397				166.8978	93.7247
	471.1905	107.1818		93.6673	152.9000	100.0327
	489.6934		111.9879			
O I	513.8605	114.5712	132.8891	103.4571	105.4497	97.7498
	646.4015	138.9022	110.3440		156.8050	
	777.4322	128.2687	105.8601			
	840.8707		94.0251	145.2949		130.4915
O II	296.469	142.9273	88.2577			
	394.9133		109.9972	93.6045	111.6275	167.4986
	444.7578				111.9879	104.1179
	460.2398			124.2545	142.3866	104.1179
	638.094	99.9126				
	736.6503	103.3970	115.8929			
	762.7054			116.1523		99.7323
O III	304.6645	128.2687	105.8601		109.9453	
	351.4882	95.2266	112.2883			
	394.5257	123.9432				
	610.5286	85.8984		93.6045		103.6373
	650.9329	142.6870			138.6018	109.9453
	667.5477	144.6695	93.5445		97.6297	
	749.8667	97.2692		89.2080	114.2108	148.8148
Cr I	194.0248				111.9879	187.8044
	212.1501	131.6930	83.6701			
	234.4291	105.4997		138.6018		112.3484
	346.9569	111.9879		107.8618		98.0502
	412.2834			126.4664	108.0830	151.0376
	456.3637			114.1425		120.5789
	502.5322			107.9246	95.7673	109.9453
Cr II	245.7574	144.3091	116.7941		172.9655	153.0202
	275.9662			116.1332	115.5925	
	290.6930	103.3970	90.0273	109.9972		
	539.5379		130.1310			
	554.2647		123.7793	165.3304	116.1332	
Cr V	731.3638			116.1332	157.2255	120.3986
	798.9560				97.3894	95.6471
Ti I	259.3513			112.0480	97.3894	
	370.7463	107.5423				
	478.3651		103.7575			167.2583

	562.1945		107.7225	91.6575	140.8246	117.2146
Ti II	229.1426		106.2151		107.7225	167.2583
	514.6157	132.1736	105.6801	134.4920		
	586.7392				107.7826	
	721.9235	92.1245	144.6695			97.6897
Ti III	350.7330			115.0895	93.9049	130.4915
	755.1532				103.8175	
	829.9200			99.6968	122.3211	132.9546
Br I	238.582		128.2687	108.2386	132.7143	102.1354
	422.478	116.876	138.1813	124.2545	128.4489	146.7121
	518.769	145.658			114.1507	
	668.302	175.532	144.6695	93.6045		122.3211
	813.305	134.571	100.0327		95.4669	130.8028
Ar I	375.2776		101.6548	93.1840	107.9027	
	526.6992	111.6876	125.8656		116.1332	97.8099
	565.2154		114.2709	95.4259		103.7575
	598.4451	127.9683			111.8678	
	654.7090	140.6444	107.9027			93.5445
Ar II	453.8205			101.7067	103.7575	101.7149
	538.4051		104.4784	111.9279	103.8175	167.2583
	835.9617					116.1332
Ar IV	464.7712			130.4314		187.8044
	717. 3922			156.9251	107.8618	144.6095
H I	366.2150				122.0207	
	393.0253	122.6652	122.2610	95.7400	159.0278	183.7192
	410.395	99.3118	151.0376	93.7302	130.3713	
	434.184	107.5423	91.8022			
	486.0502		88.1267		108.0830	
	656.5970	200.7209	200.3604	201.6957	201.2015	201.4418
	825.3887	104.5985		161.1851		