Spectroscopic studies on *Satavari* root and *Amla*

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Abstract

Powdered plant materials of satavari root and amla are analyzed by ICP-MS, EPR, IR and NIR studies. The results indicate that copper is present in higher concentration when compared to other elements. An EPR study of satavari root and amla confirm the presence of Fe (III), Cu(II) and Cr(III). NIR results are due to carbonate and water fundamentals.

Key words: EPR, Optical absorption, ICP-MS analysis, copper, manganese, iron, Satavari root and Amla.

1. Introduction

The fresh juice of the root of satavari (*asparagus racemosus*) when mixed with honey as a demulcent in bilious dyspepsia or diar-rhoea. It is a constituent in the preparation of medicated oils for external application in nervous and rheumatic affections and urinary problems. The plant material contains alkaloids, proteins, starch, tannin, mucilage and disogenin apart from saponins. Both aerial and root parts have amylase and lipase activities [1]. Aerial parts have anti cancer activity in human epidermal carcinoma of the nasopharynx [2]. It is proved that it increases milk production in lactating women.

Amla (locally called osciri) (*Emblica officinalis*) is highly nutritious and is an important dietary source of Vitamin C, minerals and amino acids. Glutamic acid, proline, aspartic acid, alanine, and lysine are 29.6, 14.6, 8.1, 5.4 and 5.3% respectively of the total amino acids. The pulpy portion of fruit, dried at 100°C and freed from the nuts contains: gallic acid 1.32%, tannin, sugar 36.10%, gum 13.75%, albumin 13.08%, crude cellulose 17.08%, mineral matter 4.12% and moisture 3.83%. Amla fruit ash contains chromium, 2.5; zinc, 4; and copper, 3 ppm. Presence of chromium is of therapeutic value in diabetes. Fruit also contains phyllembelin

and curcuminoides. The fruit contained 482.14 units of superoxide dismutase/g fresh weight, and exhibited antisenescence activity. The seed oil contains 64.8% linolenic acid [3-6].

Many analytical techniques such as volumetric analysis, column chromatography, liquid chromatography and spectrophotometric methods are frequently employed for quality control and standardization [7]. In order to elucidate the composition, structural properties of trace metal ions present in medicinal plants, several techniques such as carbon-hydrogen-nitrogen-sulphur (CHNS), inductively coupled plasma mass spectrometer (ICP-MS), electron paramagnetic resonance (EPR), near infrared (NIR) and infrared studies (IR) are employed in the present investigation.

In the present study, the authors determined the content of carbon, nitrogen and hydrogen by CHNS scan, the transition metal ions present and their valence state and site symmetries by ICP-MS analysis, EPR and infrared spectroscopic techniques.

2. Experimental

Powdered and dried medicinal plant material samples of amla and satavari root of Kadapa district of Andhra Pradesh, India are used in the

present work. To know the organic composition of the compound CHNS scan has been carried.

Coupled Plasma Mass Spectrometer (ICP-MS) (Perkin Elmer Élan DRCII ICP-MS Toronto, Ontario, Canada) was used for the determination of trace elements present in the sample. The methodology of preparation of the sample, internal standards and optimization procedure described in earlier literature are employed [8] in the present investigations.

EPR spectra of the samples in powder form are recorded at room temperature (RT) on a JEOL JES-TE100 ESR spectrometer operating at X-band frequencies ($\nu = 9.40107$ GHz for satavari root, $\nu = 9.40128$ GHz for amla and $\nu = 9.40118$ GHz for flax seed respectively), having a 100 kHz field modulation to obtain a first derivative EPR spectrum. NIR spectrum of the sample was recorded on a Nicolet Nexus FT-IR spectrometer with a Nicolet near IR fib report accessory. A white light source was employed with a quartz beam splitter and TECNIR.

Infrared spectra were obtained using a Nicolet Nexus 870 FTIR spectrometer with a smart endurance single bounce diamond ATR cell. Spectra over the $4000\text{--}525\text{ cm}^{-1}$ range were obtained by the co-addition of 64 scans with a resolution of 4 cm^{-1} and a mirror velocity of 0.6329 cm/s . Spectral manipulation such as baseline adjustment, smoothing and normalisation was performed using the GRAMS® software package (Galactic Industries Corporation, Salem, NH, USA). The spectra were transformed according to the Kubelka-Munk algorithm.

Band component analysis was undertaken using the Jandel "PEAKFIT" software package which enabled the type of fitting function to be selected and specific parameters to be fixed or varied accordingly. Band fitting was carried out using a Gauss-Lorentz cross product function with the minimum number of component bands used for the fitting process. The Gauss-Lorentz ratio was maintained at values greater than 0.7 and fitting was undertaken until reproducible results were obtained with squared correlations of r^2 greater than 0.995.

Results and analysis

3.1 CHNS analysis

The results of the carbon, hydrogen, nitrogen and sulphur analysis are presented in Table I. The CHNS results indicate that satavari root and amla does not contain sulphur atom. satavari root

contains nitrogen which is less than hydrogen and amla does not contain any nitrogen. In both the samples carbon and hydrogen is present in the ratio of 7:1 respectively.

Table I
Carbon, nitrogen, sulphur and hydrogen analysis of satavari root and amla

Sample Name	Carbon (%)	Nitrogen (%)	Sulphur (%)	Hydrogen (%)
Satavari root	39.7	0.74	not found	5.64
Amla	43.15	--	not found	5.15

3.2. ICP-MS Analysis

SO-1, an herbal type reference material was dissolved in the way as the sample in ICP-MS analysis as a calibration standard. This standard sample is well characterized and is a certified sample for most of the trace elements including rare earth elements. A full mass scan {mass to atomic number ratio (m/z) $45 - 239$ } is carried out for quantification. A responsive curve (signal intensity vs mass to charge ratio) is obtained using a multi element standard solution for calibration of the ICP-MS. The data presented on a reference samples along with the samples are given in Table II. The common transition metal ion that occurs in many herbs is iron. The elemental analyses of the compounds indicate that small amounts of transition metals are present in them. In all the compounds vanadium and chromium is present in the equal ratio. Amla contains chromium (13.882/2.5 ppm), copper (15.5/3.00 ppm) and zinc (17.469/4.00 ppm) are present in higher concentrations than those reported in literature [3-6]. Satavari root contains chromium (17.168/2.5 ppm), copper (12.436 /3.00 ppm) and zinc (39.650/4.00 ppm) nearly double the quantity of chromium than amala. The content of copper in all the compounds nearly same but higher than chromium present in them. Nearly zinc is in the ratio of 1:2 in amla and satavari root respectively. Nickel is in the ratio of 2:3 in amla and satavari root respectively. In both satavari root and amla, barium is the most abundant element. The lead is present in both the samples but below the permissible value. The transition elements include V, Cr, Ni, Cu and Zn present in satavari root and amla samples above 5 ppm. The non-transition elements include Rb, Sr and Ba present in both satavari root and amla samples. It is worth noticing that Zr is present in both satavari root and amla.

Table-II
Trace element concentrations (ppm) in
satavari root and amla obtained by ICP-MS

Element/ Analyte	Mass	Standard :SO-1 Conc. Mean (ppm)	Standard - 1 Conc. Mean (ppm)	Satavari root Conc. Mean (ppm)	Amla Conc. Mean (ppm)
Sc	45	17.782	17.700	1.479	1.585
V	51	135.242	133.000	15.649	13.578
Cr	52	170.059	170.000	17.168	13.882
Co	59	29.116	29.000	0.861	0.364
Ni	60	93.105	92.000	12.271	8.651
Cu	63	61.396	61.000	12.436	15.584
Zn	66	145.932	144.000	39.650	17.469
Ga	71	24.054	24.100	0.269	0.206
Rb	85	141.221	141.000	8.229	10.557
Sr	88	327.588	331.000	24.682	19.838
Y	89	24.544	24.500	0.495	0.408
Zr	90	84.178	84.000	2.755	5.142
Nb	93	11.616	11.700	0.235	0.251
Cs	133	5.128	5.070	0.109	0.031
Ba	137	887.403	870.000	45.270	37.402
La	139	54.312	54.000	0.859	0.277
Ce	140	103.640	102.000	1.606	0.592
Pr	141	11.844	11.800	0.180	0.062
Nd	146	44.817	44.000	0.700	0.229
Sm	147	8.126	7.900	0.133	0.044
Eu	151	1.589	1.570	0.035	0.033
Gd	157	6.069	6.100	0.120	0.055
Tb	159	0.853	0.880	0.017	0.010
Dy	163	5.623	4.500	0.082	0.059
Ho	165	1.119	1.100	0.020	0.017
Er	166	2.010	2.000	0.037	0.024
Tm	169	0.415	0.420	0.007	0.007
Yb	172	2.224	2.240	0.045	0.040
Lu	175	0.308	0.310	0.006	0.005
Hf	178	2.549	2.500	0.078	0.123
Ta	181	0.681	0.700	0.021	0.036
Pb	208	20.152	20.000	5.368	5.599

3.3. EPR Results

(a) Satavari root

The fine powder EPR spectrum of the satavari root is recorded at room temperature is given in Fig. 1 (a). It is well known that iron is the most common impurity in herbs and exhibit a wide variety of resonances. It is well known that Fe (III) samples exhibit a series of g values ranging from 0 to 8. This is due to the fact that the three Kramer's doublets $|S=5/2\rangle$ split into $|S\pm 5/2\rangle$, $|S\pm 3/2\rangle$ and $|S\pm 1/2\rangle$ separated by 4D and 2D respectively where D is the zero field splitting parameter. Depending on the relative populations of these doublets, one observes g values ranging from 0 to 8.0. Accordingly the resonances with g = 6.00, 4.25 can be considered to be arising from Fe(III) impurity [9]. The resonance at g = 2.28 can be assigned to Cu(II). The hyperfine line from either ^{63}Cu or ^{65}Cu could not be resolved. The sharp peak having a g value of 2.00 can be ascribed to Cr(III). Hence the EPR analysis of the satavari root indicates that the paramagnetic impurities present in the herb are Fe (III), Cu(II) and Cr(III).

Fig.1(a). EPR spectrum of Satavari at RT ($\nu=9.40107$ GHz)

(b) Amla (osciri)

The powder EPR spectrum of amla obtained at room temperature is given in Fig.1(b). It contains a series of lines of various intensities and widths. The g values obtained for the four peaks are 6.6, 4.3, 2.38 and 2.03. The resonance at g = 6.6 can be considered to be arising from isolated Fe(III) ions incorporated as an impurity in the compound. The zero field splitting parameter D is very large compared to microwave frequency shows a single line occurs around g = 4.0 [10]. Accordingly the resonance with g = 4.3 may be due to Cr (III). The sextet has a g value of 2.03. The spin Hamiltonian parameters suggest that ion responsible for this resonance is Mn(II). The resonance at g = 2.38 can be considered to be arising from Cu(II) impurity. The hyperfine line from either ^{63}Cu or ^{65}Cu could not be resolved. Hence the EPR analysis of the sample indicates that the paramagnetic impurities present in the amla are Fe(III), Mn(II), Cu(II) and Cr(III).

Fig. 1(b). EPR spectrum of Amla at RT ($\nu=9.40128$ GHz)

3.4 IR results

Infrared Spectroscopy

CHNS analysis indicating that more content of carbon and hydrogen present in both the samples. So they readily combine with oxygen and gives hydroxides, carbonates, etc., accordingly the IR and NIR spectra are analysed.

Infrared spectroscopy provide sensitive test for structural distortion of CO_3^{2-} [11]. The carbonate ion has six normal modes of vibrations. A molecular ion CO_3^{2-} with D_{3h} point group in a lattice exhibits generally four normal modes of vibration. [12,13]. They are symmetric stretch (ν_1), an out-of-plane bend (ν_2), a doubly degenerate asymmetric stretch (ν_3) and another doubly degenerate bending mode (ν_4). The symmetries of these modes are

$$A_1'(R) + A_2''(IR) + E'(R,IR) + E''(R,IR)$$

and occur at 1063, 879, 1415 and 687 cm^{-1} as the symmetric vibration $\nu_1(A_1')$ is reported to be infrared inactive. Generally intense IR and weak Raman peaks at 1400 cm^{-1} are due to $\nu_3(E')$. IR modes near 880 cm^{-1} are due to the out-of- plane bend (ν_2). IR modes around 700 cm^{-1} region are due to the in-plane bending mode (ν_4). This mode is doubly degenerate for undistorted CO_3^{2-} groups. The fundamental frequencies of CO_3^{2-} ion are $\nu_1 = 1063$, $\nu_2 = 879$, $\nu_3 = 1415$ and $\nu_4 = 680$ cm^{-1} [14, 15].

IR spectra of satavari root and amla recorded from 4000 to 500 cm^{-1} is shown in Fig.2. From the figure it is clear that no bands are noticed in between 4000 to 3600 cm^{-1} and 2800 to 1800 cm^{-1} . From the figure it is also evident that two groups of sharp absorptions are observed in both the samples. These are divided as 3600 to 3000 cm^{-1} (shown in Fig.3), 3000 to 2700 cm^{-1} (shown in Fig.4) and 1800 to 500 cm^{-1} (shown in Fig.5). The results of the band component analysis of the IR spectra recorded at room temperature reported in Table III.

Fig. 2 IR spectrum of satavari root and amla at room temperature in the range 4000 - 500 cm^{-1} .

Fig. 3 IR spectrum of satavari root and amla at room temperature in the range 3700 - 2700 cm^{-1} .

Fig. 4 IR spectrum of satavari root and amla at room temperature in the range 3000 – 2700 cm^{-1} .

Fig. 5 IR spectrum of satavari root and amla at room temperature in the range 1700- 500 cm^{-1} .

The 1700 to 500 cm^{-1} spectral region

The very sharp and intense bands observed at 1026, 1022, 1066, 1113, 986 cm^{-1} in satavari root and 1061, 1034, 1119 cm^{-1} in amla are identified as ν_1 of carbonate ion. The bands observed at 1375, 1321, 1271 in satavari root and 1331, 1240 cm^{-1} in amla are identified as overtone of ν_4 vibrational mode of carbonate ion. The band observed at 1427 in satavari root and 1454 in amla are due to ν_3 of CO_3^{2-} . A weak overlapped band at 1724, 1741 cm^{-1} in satavari root is identified as due to $2\nu_2$ of CO_3^{2-} . In amla no similar band is noticed. A group of broad intense bands at 1649, 1637, 1603 cm^{-1} in satavari root and very sharp intense dual band at 1697, 1618 cm^{-1} in amla are identified as H-O-H bend of water molecule present in them. Where as triple independent small intensity bands observed at 922, 864 and 802 cm^{-1} in amla is due to out of plane bend ν_2 of CO_3^{2-} . The bands at 667, 633 cm^{-1} in amla may be due to lattice vibrations of the metal ion and surround ligands.

The 3000 to 2700 cm^{-1} spectral region

The absorption bands at 2857, 2839 in satavari root and 2825, 2850, 2881 in amla is due to $\nu_1 + 2\nu_2$ of CO_3^{2-} . The band observed at 2939 in satavari root and 2966, 2926 cm^{-1} in amla is due to combination of $2\nu_1 + \nu_2$ of CO_3^{2-} .

The 3700 to 2700 cm^{-1} spectral region

Water has three fundamental modes. They are symmetric OH stretch (ν_1), H-O-H bending mode (ν_2) and asymmetric OH stretch (ν_3). In solid phase these appear at 3220 (ν_3), 1620 (ν_2) and 3400 (ν_1) cm^{-1} [16]. The shifting of ν_1 and ν_3 towards lower frequency and ν_2 towards higher frequency is due to hydrogen bonding [17]. The band observed at 3215 in satavari root and 3228 cm^{-1} in amla is assigned to symmetric OH stretch (ν_3). The band observed at 1637 in satavari root and 1618 cm^{-1} (Amla) is due to HOH bending mode (ν_2) of water sample. Further the broad and intense bands at 3373, 3506 in satavari root and 3302, 3496 cm^{-1} in amla is due to symmetric OH stretch (ν_1).

Table - III
Results of the infrared spectroscopic analysis of satavari root and amla.

Satavari root			Amla		
Infrared 298K					
Centre	FWHM	% area	Centre	FWHM	% area
--	--	--	544	0.0	1.31
--	--	--	631	9.8	0.35
--	--	--	666	12.4	0.47
--	--	--	700	18.4	0.29
--	--	--	717	18.9	0.20
--	--	--	758	7.6	0.09
--	--	--	800	8.6	0.19
--	--	--	860	11.2	0.33
890	45.6	0.48			
925	35.1	1.07	917	22.4	0.99
950	48.7	0.99			
983	33.6	3.14	982	42.8	0.93
1019	55.4	8.32	1035	69.4	9.19
1063	52.8	5.17	1059	14.3	1.44
1107	31.6	1.47	1101	31.2	2.03
			1110	0.0	0.84
			1118	19.9	1.64
1135	34.0	1.23			
1161	15.3	0.26			
			1208	28.0	1.47
1230	30.5	0.27	1237	27.3	1.91
1261	49.4	0.78	1264	22.1	0.56
			1296	15.7	0.46
1316	39.6	1.03	1315	12.0	0.23
			1318	92.6	6.19
1338	31.3	0.35			
1367	41.0	1.24	1373	24.2	0.46
			1398	27.1	1.16
1418	55.6		1420	21.5	0.80
1457	31.0	0.50	1449	28.7	1.83
			1508	17.2	0.18
1598	56.4	1.20			
1637	64.0	2.75	1613	57.0	4.06
1674	26.3	0.31	1660	35.7	1.09
			1693	39.8	3.01
1734	39.4	0.47	1723	34.6	6.96
2748	97.3	0.26			
			2822	43.4	1.13
2842	96.2	0.95	2850	15.3	0.17
2884	69.7	2.45	2880	63.8	1.68
2934	49.4	1.79	2925	43.4	1.13
			2964	15.3	0.10
3100	108.8	2.70	3099	94.9	1.35
3208	176.7	19.6			
			3280	56.8	5.62
			3292	226.3	37.27
3359	213.8	36.6			
			3486	132.4	3.86

3500	146.3	2.62			
			4000	0.0	-0.83

3.5 NIR results

NIR spectra of satavari root and amla recorded from 10000 to 4000 cm^{-1} are shown in Fig.6. All the spectra are nearly the same. From the figures it is clear that no bands are noticed in between 10000 to 8200 cm^{-1} , 7100 to 6700 cm^{-1} and 5300 to 5100 cm^{-1} . From the figures it is also evident that three groups of sharp absorptions are observed in all the samples. These are divided as 8200 to 6800 cm^{-1} (shown in Fig.7), 6700 to 5200 cm^{-1} (shown in Fig.8) and 5200 to 4000 cm^{-1} (shown in Fig.9). The results of the band component analysis of the NIR spectra recorded at room temperature are reported in Table IV.

Fig. 6 NIR spectrum of satavari root and amla at room temperature in the range 10000 – 4000 cm^{-1} .

Fig. 7 NIR spectrum of satavari root and amla at room temperature in the range 8300 – 6800 cm^{-1} .

Fig.8 NIR spectrum of satavari root and amla at room temperature in the range of 6700 – 5200 cm^{-1} .

Fig. 9 NIR spectrum of satavari root and amla at room temperature in the range of 5200 – 4000 cm^{-1} .

The 8300 to 6800 cm^{-1} spectral region

The Near-IR spectral regions may be conveniently divided into three regions (a) the high wave number region $> 7500 \text{ cm}^{-1}$. In this region electronic bands due to characteristic of Cu^{2+} and Fe^{3+} ions are observed. Suppose if $\text{Fe}(\text{II})$ bands are observed in this region they appear as split components but not individual peaks. Based on ICP-MS analysis the bands observed at

7575 cm^{-1} , 7884 cm^{-1} , 8169 cm^{-1} in satavari root and at 7783 cm^{-1} , 8192 cm^{-1} in amla in the (Fig.7) high wave number region (between 9000 and 7600 cm^{-1}) may be due to $\text{Cu}(\text{II})$ in all these materials. Further these bands have almost the same intensity.

The very sharp band at 7201 cm^{-1} with split components on either side at 7382 cm^{-1} 7097 cm^{-1} with higher intensity in satavari root and less intense band at 7256 cm^{-1} with component at 7143 cm^{-1} in amla are due to $2\nu_3$, the asymmetric OH.

The 6700 to 5200 cm^{-1} spectral region

Fig.8 shows two sets of profile of bands around 5375 cm^{-1} with components and with highest intensity in the entire region of the spectrum and another group of bands about 6000 cm^{-1} with components on either side.

Tetrahedrally bonded $\text{Cu}(\text{II})$ would be expected to have a stronger d-d band at $\approx 6000 \text{ cm}^{-1}$ [18]. The $\text{Cu}(\text{I})$ is probably located in a tetrahedral site. Tetrahedral is the preferred coordination of $\text{Cu}(\text{I})$ [19] and no authenticated octahedrally coordinated $\text{Cu}(\text{I})$ complexes are known. In view of the highly covalent character of the bonds and also the stabilities of $\text{Cu}(\text{I})$ oxides and sulphides [19] it is probable that copper is present as $\text{Cu}(\text{I})$ in the compounds. Almost similar band observed at 6167 cm^{-1} in satavari root and 6090 cm^{-1} with a component at 5920 cm^{-1} in amla is attributed to $\text{Cu}(\text{I})$. Almost similar band observed at 6167 cm^{-1} in satavari root and 6187 cm^{-1} in amla is assigned to $7\nu_4 + \nu_3$ of CO_3^{2-} . Only in satavari root a band is noticed at 6426 cm^{-1} which may be due to $3\nu_3 + 2\nu_1$ of CO_3^{2-} .

The 5200 to 4000 cm^{-1} spectral region

Fig.9 shows three groups of sharp bands. The maximum intense sharp band at 4964 cm^{-1} in satavari root, a profile of band at 4995 cm^{-1} with split component almost equal in width on either side at 4875 and 5087 cm^{-1} in amla and group of bands at 4995 cm^{-1} with components at 4929 , 5076 cm^{-1} is identified as due to water OH overtones. Another sharp band at 4490 cm^{-1} in satavari root and a band at 4493 cm^{-1} in amla is attributed to combination tones of $\nu_1 + 2\nu_3 + \nu_4$ of CO_3^{2-} . The bands at 4343 , 4243 cm^{-1} in satavari root and 4200 , 4266 cm^{-1} in amla is due to overtone of $3\nu_3$ of carbonate ion present in the

compounds. A moderate sharp band at 4162 cm^{-1} in satavari root and a band at 4131 cm^{-1} in amla is assigned to combination tones of $2(\nu_3 + \nu_4)$ of CO_3^{2-} .

Satavari root			Amla		
Near Infrared 298K					
Centre	FWHM	% area	Centre	FWHM	% area
--	--	--	4050	56.5	0.23
4121	38.9	0.09	4124	118.0	2.15
4158	54.0	0.28	--	--	--
4197	49.8	0.16	4199	102.4	1.05
4236	81.6	0.40	--	--	--
4290	74.9	0.43	4363	57.2	0.29
4336	51.8	0.41	--	--	--
4367	35.4	0.13	--	--	--
4486	127.1	3.30	4495	104.8	1.61
4601	144.4	2.21	--	--	--
--	--	--	4869	149.3	2.84
4973	178.4	4.85	4985	153.2	6.54
--	--	--	5089	94.0	1.20
5290	95.8	2.63	5291	79.4	2.47
5362	136.0	5.05	5357	121.7	5.01
5469	204.1	7.59	5466	189.2	8.12
--	--	--	--	--	--
5620	274.1	7.45	5632	163.3	2.95
5838	359.0	10.44	--	--	--
--	--	--	5912	95.2	0.69
5997	266.7	6.44	5975	60.7	0.50
--	--	--	6084	172.3	2.39
6160	282.2	6.20	6186	96.6	0.49
6423	296.3	4.51	--	--	--
6602	212.1	1.17	--	--	--
7081	164.2	2.13	7123	190.1	4.64
7194	212.8	5.89	7237	250.7	7.44
7371	274.6	6.38	7450	401.3	18.13
7575	367.3	11.01	--	--	--
7880	425.2	9.27	7784	578.5	26.29
8155	283.6	1.58	8202	450.6	5.82

Conclusions

- CHNS analysis indicates that no sulphur atom is present in satavari root and amla samples. Also carbon and nitrogen is almost equal in quantity in all the samples. They are in the ratio of 8:1
- ICP-MS analysis indicates that in all the compounds vanadium and chromium is present in the equal ratio. But in amla chromium (13.882/2.5 ppm), copper (15.5/3.00 ppm) and zinc (17.469/4.00 ppm) are present in higher levels than

the reported value. The content of copper in all the compounds is nearly same but higher than chromium present in them. Zinc is in the ratio of 1:2 in amla and satavari root respectively. Nickel is in the ratio of 2:3 in amla and satavari root. In all the compounds barium is higher in quantity than of its constituents. Lead is also present in all the samples but is less than the toxic lead

- EPR analysis of all the compounds indicate that the common paramagnetic impurity present in them is Fe (III), where as in satavari root and in amla in addition to iron, Cu(II) and Cr(III) are also present. Very small amount of Mn(II) is also present in amla. These results are already further supported by ICPMS analysis.
- IR spectra are nearly the same for all the compounds no bands are noticed in between 4000 to 3600 cm^{-1} and 2800 to 1800 cm^{-1} . Also only two groups of sharp absorptions are observed in all the samples. These are identified as fundamentals and combination and overtones of vibrational modes of carbonate, water molecules in the compounds.
- The NIR results are evident that three groups of sharp absorptions are observed in all the samples. The high wave number region (between 9000 and 7600 cm^{-1}) bands have the same intensity and are attributed to Cu (II) in all the compounds. A band observed around 6000 cm^{-1} in satavari root and in amla is attributed to Cu(I) in tetrahedrally coordinated site. The other bands are assigned to combination and overtones of carbonate and water molecules in the compounds.

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