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Research Article

THE FT-IR SPECTROMETRIC STUDIES OF VIBRATIONAL BANDS OF *SEMECARPUS ANACARDIUM* LINN.F. LEAF, STEM POWDER AND EXTRACTS

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ABSTRACT

The present study was aimed to identify the functional groups present in the crude powder and extracts of *Semecarpus anacardium* Linn.f. leaves and stem through FT-IR spectrometry. 14 different polar and nonpolar organic solvents were used in the soxhlet extraction of the plant material. All the vibrational bands originated from different groups like C-H, C=C, C≡C, C-O, C=O, C-I, C-Cl, C-Br, C-F, >CH_2, C-N, C=C-C, S-S, N-H, NO_2, H-X, O-H, P-O-C etc., and may be termed as key bands and can be studied for their absorption characteristics to differentiate individual plant parts like leaves, stem etc. The FT-IR analysis of leaf powder of *Semecarpus anacardium* proved the presence of alcohols, phenols, alkanes, alkenes, carboxylic acids, ethers, esters, aliphatic iodo compounds and polysulfides. The FT-IR analysis results of stem powder of *Semecarpus anacardium* revealed the presence of alcohols, phenols, alkanes, alkenes, amines, amides, aldehydes, ketones, esters, ethers carboxylic acids, nitro compounds, aliphatic iodo compounds. The FT-IR studies revealed the different characteristic peak values with various functional groups. The results of the present study generated the FT-IR spectrum profile for the medicinally important plant *Semecarpus anacardium* and can be used to identify the plant in the pharmaceutical industry.

Keywords:*Semecarpus anacardium* Linn.f., FT-IR spectrometry, functional groups.

INTRODUCTION

Fourier transform infrared spectrometry (FT-IR) is one of the most widely used methods to identify the chemical constituents and elucidate the structures of compounds and has been used as a requisite method to identify medicines in Pharmacopoeia of many countries. FT-IR has played a vital role in pharmaceutical analysis in recent years[1]. FT-IR spectrometry is a physico-chemical analytical technique that does not determine concentrations of individual metabolites but provides a snapshot of the metabolic composition of a tissue at a given time[2]. The FT-IR method measures predominantly the vibrations of bonds within chemical functional groups and generates a spectrum that can be regarded as a biochemical or metabolic "fingerprint" of the sample[3]. Infrared spectroscopy provides a useful method for herbal analysis as well as for quantitative analysis of drugs and with the help of FT-IR continuous monitoring of the spectral baseline and simultaneous analysis of different components of the same sample is possible[4-6]. Applying metabolomic techniques to pharmacognosy as a marker is a new approach, generally used to identify the functional groups[7].

Semecarpus anacardium Linn.f. (Family- Anacardiaceae) commonly known as Bhallataka or marking nut is used in indigenous systems of medicine for the treatment of various diseases[8,9]. It is a deciduous tree distributed in the sub-Himalayan tract and in tropical parts of India. Many compounds mainly biflavonoids, phenolics, bhilawanols, sterols, anacardic acid and glycosides have been identified as constituents of *Semecarpus anacardium* nut extract. On the basis of chemical and spectral data, several biflavonoids such as jeediflavanone, galluflavanone, nallaflavanone, semecarpetin and anacarduflavanone have been characterized[10]. Several monophenolic compounds known as semecarpol and bhilawanol were also isolated[11]. Further analysis revealed the presence of iron, copper, sodium, calcium and aluminium in traces[12] and also the plant is good source of minerals like sulphur, magnesium, phosphorus[13].

The present study was intended to resolve the functional constituents present in the leaves and stem of *Semecarpus anacardium* which will be useful for the proper identification of the active compounds and the chemical profiles will be used as a pharmacognostic marker to differentiate the adulterant from the commercial samples.

MATERIALS AND METHODS

Plant collection and authentification

The leaves and stem of *Semecarpus anacardium* were collected from an open field around Mumbai, Maharashtra. The identification of the plant was done at the Blatter Herbarium, St. Xavier's College, Mumbai. The plant specimen matches with the Blatter Herbarium specimen no.T-472 of S. C. Tavakari. Leaves were shade dried and made into coarse powder with mechanical grinder and then passed through sieve, B.S.S Mesh No.60.

Apparatus

Bruker Alpha-T FTIR equipped with universal sampling module, equipped with a room temperature DTGS detector. The scan range was taken from 400 to 4000 cm^{-1} with a resolution of 4 cm^{-1}.

Chemicals

Chloroform, Toluene, Carbon tetrachloride, Ethyl acetate, Hexane, Ethyl alcohol, Methanol, Acetone, 2-propanol, Petroleum ether (60-80°C), 2-butanone, Dichloromethane, Ethyl ether were all A.R. grade (Merck, India), Distilled water.

Preparation of the plant extract

The leaf powder of *Semecarpus anacardium* (20 gms) was extracted with 250 ml each of polar and nonpolar solvents by soxhlet extraction for 8 hrs. The extracts obtained were later kept for evaporation to remove the excess solvents. These extracts were then stored in plastic bottles in refrigerator for FT-IR analysis. Powdered leaf material was extracted using water, chloroform, toluene, carbon tetrachloride, ethyl acetate, hexane, ethyl alcohol, methanol, acetone, 2-propanol, petroleum ether (60-80°C), 2-butanone, dichloromethane, ethyl ether. The crude powder and dried extracts were mixed with KBr salt using mortar and pestle and compressed into a thin pellet.

RESULTS AND DISCUSSION

The FT-IR spectrum was used to identify the functional groups of the active components based on the peak value in the region of infrared radiation. The leaf and stem powder and extracts of *Semecarpus anacardium* were analysed by the FT-IR spectrometers and the functional groups of the components were separated based on its peak ratio. The FT-IR analysis of leaf powder and different leaf extracts of *Semecarpus anacardium* proved the presence of alcohols, phenols, alkanes, alkenes, carboxylic acids, ethers, esters, polysulfides and aliphatic iodo compounds etc., [Table 1-15, Fig 1-15]. The FT-IR analysis results of stem powder and stem extracts of *Semecarpus anacardium* revealed the presence of alcohols, phenols,

alkanes, alkenes, amines, amides, aldehydes, ketones, esters, ethers carboxylic acids, nitro compounds, aliphatic iodo compounds etc., [Table 16-18, Fig 16-18].

Table 1: FT-IR Peak Values of *Semecarpus anacardium* Leaf Powder

Wave number cm^{-1}	Bond	Functional Group Assignment	Group Frequency, cm^{-1}
3310.05	O-H	Hydrogen bonded Alcohols, Phenols	3200-3600
2919.69	C-H	Alkanes	2850-2970
1616.85	C=C	Alkenes	1610-1680
1449.51	C-H	Alkanes	1340-1470
1102.52	C-O	Alcohols, Ethers, Carboxlic acids, Esters	1050-1300
534.25	C-I stretch	Aliphatic iodo compounds	500-600
472.39	S-S stretch	Polysulfides	470-500

Table 2: FT-IR Peak Values of *Semecarpus anacardium* Water Leaf Extract

Wave number cm^{-1}	Bond	Functional Group Assignment	Group Frequency, cm^{-1}
3432.66	O-H	Hydrogen bonded Alcohols, Phenols	3200-3600
2090.52	Carbonyl stretch	Transition metal carbonyl compounds	1800-2100
1645.21	C=C	Alkenes	1610-1680

Table 3: FT-IR Peak Values of *Semecarpus anacardium* Chloroform Leaf Extract

Wave number cm^{-1}	Bond	Functional Group Assignment	Group Frequency, cm^{-1}	Wave number cm^{-1}	Bond	Functional Group Assignment	Group Frequency, cm^{-1}
3817.83	-	Unknown	-	**1718.36**	C=O	Aldehydes, Ketones, Carboxylic acids, Esters	1690-1760
3733.70	-	Unknown	-	**1421.28**	C-H	Alkanes	1340-1470
3584.20	O-H	Hydrogen bonded Alcohols, Phenols	3200-3600	**1363.89**	NO_2	Nitro compounds	1300-1370
3524.53	O-H	Monomeric Carboxylic acids	3500-3650	**1222.85**	C-N	Amines, Amides	1180-1360
3413.62	N-H	Amines, Amides	3300-3500	**1092.80**	C-O	Alcohols, Ethers, Carboxlic acids, Esters	1050-1300
3004.74	H-C	Aromatic H-X group	3000- 3050	**953.73**	C-H	Alkenes	675-995
2969.80	C-H	Alkanes	2850-2970	**903.19**	C-H	Alkenes	675-995
2925.15	C-H	Alkanes	2850-2970	**773.00**	C-Cl stretch	Aliphatic chloro compounds	700-800
2145.11	C≡C	Alkynes	2100-2260	**529.91**	C-I	Aliphatic iodo compounds	500-600

Table 4: FT-IR Peak Values of *Semecarpus anacardium* Toluene Leaf Extract

Wave number cm^{-1}	Bond	Functional Group Assignment	Group Frequency, cm^{-1}
3839.61	-	Unknown	-
3649.93	O-H	Monomeric Carboxylic acids	3500-3650
2918.66	C-H	Alkanes	2850-2970
2364.60	-	Unknown	-
1726.17	C=O	Aldehydes, Ketones, Carboxylic acids, Esters	1690-1760
1315.02	NO_2	Nitro compounds	1300-1370
1188.34	C-N stretch	Secondary amine	1130-1190
970.09	C-H	Alkenes	675-995
472.00	S-S stretch	Polysulfides	470-500

Table 5: FT-IR Peak Values of *Semecarpus anacardium* CCl_4 Leaf Extract

Wave number cm^{-1}	Bond	Functional Group Assignment	Group Frequency, cm^{-1}	Wave number cm^{-1}	Bond	Functional Group Assignment	Group Frequency, cm^{-1}
3439.44	O-H	Hydrogen bonded Alcohols, Phenols	3200-3600	**970.81**	C-H	Alkenes	675-995
2954.89	C-H	Alkanes	2850-2970	**894.07**	C-H	Alkenes	675-995
2917.37	C-H	Alkanes	2850-2970	**829.73**	C-H	Alkenes	675-995
2849.26	C-H	Alkanes	2850-2970	**729.82**	C-H	Aromatic rings	690-900
2329.08	-	Unknown	-	**719.51**	C-H	Aromatic rings	690-900
1736.08	C=O	Aldehydes, Ketones, Carboxylic acids, Esters	1690-1760	**646.63**	C-Br	Aliphatic bromo compounds	600-700
1541.19	NO_2	Nitro compounds	1500-1570	**605.98**	C-Br	Aliphatic bromo compounds	600-700
1494.30	C=C-C	Aromatic ring Aryl Stretch	1510-1450	**578.55**	C-I stretch	Aliphatic iodo compounds	500-600
1462.86	C-H	Alkanes	1340-1470	**515.61**	C-I stretch	Aliphatic iodo compounds	500-600
1377.66	C-H	Alkanes	1340-1470	**493.23**	S-S stretch	Polysulfides	470-500
1363.92	NO_2	Nitro compounds	1300-1370	**483.02**	S-S stretch	Polysulfides	470-500
1275.76	C-O	Alcohols, Ethers, Carboxylic acids, Esters	1050- 1300	**473.97**	S-S stretch	Polysulfides	470-500

1247.76	C-O	Alcohols, Ethers, Carboxylic acids, Esters	1050- 1300	**464.05**	S-S stretch	Aryl disulfides	430-500
1187.96	C-N	Amines, Amides	1180-1360	**454.10**	S-S stretch	Aryl disulfides	430-500
1081.51	C-O stretch	Alcohols, Ethers, Carboxylic acids, Esters	1050- 1300	-	-	-	-

Table 6: FT-IR Peak Values of *Semecarpus anacardium* Ethyl acetate Leaf Extract

Wave number cm^{-1}	Bond	Functional Group Assignment	Group Frequency, cm^{-1}	Wave number cm^{-1}	Bond	Functional Group Assignment	Group Frequency, cm^{-1}
3630.55	O-H	Monomeric Alcohols, Phenols	3590-3650	**1555.18**	C=C	Aromatic rings	1500-1600
3548.02	O-H	Monomeric Carboxylic acids	3500-3650	**1465.86**	C-H	Alkanes	1340-1470
3464.77	N-H	Amines, Amides	3300-3500	**1447.87**	C-H	Alkanes	1340-1470
2985.53	H-O	H-bonded H-X group	2500-3500	**1373.22**	C-H	Alkanes	1340-1470
2942.10	C-H	Alkanes	2850-2970	**1300.66**	NO_2	Nitro compounds	1300-1370
2909.19	C-H	Alkanes	2850-2970	**1240.00**	C-O	Alcohols, Ethers, Carboxlic acids, Esters	1050-1300
2878.16	C-H	Alkanes	2850-2970	**1160.39**	C-O	Alcohols, Ethers, Carboxlic acids, Esters	1050-1300
2674.36	O-H	Hydrogen bonded Carboxylic acids	2500-2700	**1098.11**	C-O	Alcohols, Ethers, Carboxlic acids, Esters	1050-1300
2473.39	-	Unknown	-	**1047.65**	C-N stretch	Primary amines	1020-1090
2307.39	-	Unknown	-	**1004.65**	C-F stretch	Aliphatic fluoro compounds	1000-1150
2155.10	C≡C	Alkynes	2100-2260	**938.53**	C-H	Alkenes	675-995
2086.45	Carbonyl stretch	Transition metal carbonyl compounds	1800-2100	**917.93**	C-H	Alkenes	675-995
2009.89	Carbonyl stretch	Transition metal carbonyl compounds	1800-2100	**847.54**	C-H	Aromatic rings	690-900
1889.93	Carbonyl stretch	Transition metal carbonyl compounds	1800-2100	**786.62**	C-H	Aromatic rings	690-900
1743.93	C=O	Aldehydes, Ketones, Carboxylic acids, Esters	1690-1760	**634.55**	C-Br stretch	Aliphatic bromo compounds	600-700
1655.17	C=C	Alkenes	1610-1680	**608.11**	C-Br stretch	Aliphatic bromo compounds	600-700

Table 7: FT-IR Peak Values of *Semecarpus anacardium* Hexane Leaf Extract

Wave number cm^{-1}	Bond	Functional Group Assignment	Group Frequency, cm^{-1}	Wave number cm^{-1}	Bond	Functional Group Assignment	Group Frequency, cm^{-1}
3411.66	N-H	Amines, Amides	3300-3500	**1187.53**	C-N	Amines, Amides	1180-1360
2954.63	C-H	Alkanes	2850-2970	**1158.43**	C-O stretch	Alcohols, Ethers, Carboxylic acids, Esters	1050- 1300
2924.63	C-H	Alkanes	2850-2970	**1080.94**	C-O stretch	Alcohols, Ethers, Carboxylic acids, Esters	1050- 1300
2869.31	C-H	Alkanes	2850-2970	**1026.43**	C-F stretch	Aliphatic fluoro compounds	1000-1150
1742.55	C=O	Aldehydes, Ketones, Carboxylic acids, Esters	1690-1760	**967.76**	C-H	Alkenes	675-995
1626.28	C=C	Alkenes	1610-1680	**893.83**	C-H	Alkenes	675-995
1492.33	NO_2	Aromatic nitro compounds in simple Hetero-oxy compounds	1485-1555	**818.51**	C-H	Alkenes	675-995
1459.07	C-H	Alkanes	1340-1470	**700.15**	C-H	Aromatic rings	690-900
1377.02	C-H	Alkanes	1340-1470	**646.17**	C-Br	Aliphatic bromo compounds	600-700
1363.17	C-H	Alkanes	1340-1470	**607.60**	C-Br	Aliphatic bromo compounds	600-700
1313.23	NO_2	Nitro Compounds	1300-1370	**497.39**	S-S stretch	Polysulfides	470-500
1248.70	C-O stretch	Alcohols, Ethers, Carboxylic acids, Esters	1050- 1300	**-**	-	-	-

Table 8: FT-IR Peak Values of *Semecarpus anacardium* Ethyl alcohol Leaf extract

Wave number cm^{-1}	Bond	Functional Group Assignment	Group Frequency, cm^{-1}	Wave number cm^{-1}	Bond	Functional Group Assignment	Group Frequency, cm^{-1}
3338.16	O-H	Hydrogen bonded Alcohols, Phenols	3200-3600	**1380.57**	C-H	Alkanes	1340-1470
2974.40	H-O	H- bonded H-X group	2500-3500	**1330.73**	NO_2	Nitro compounds	1300-1370
2927.67	C-H	Alkanes	2850-2970	**1274.67**	C-O	Alcohols, Ethers, Carboxlic acids, Esters	1050-1300
2885.41	C-H	Alkanes	2850-2970	**1090.48**	C-O	Alcohols, Ethers, Carboxlic acids, Esters	1050-1300
2541.90	O-H	Hydrogen bonded Carboxylic acids	2500-2700	**1050.43**	C-O	Alcohols, Ethers, Carboxlic acids, Esters	1050-1300
2256.37	C≡C	Alkynes	2100-2260	**881.27**	C-H	Aromatic rings	690-900
1925.32	Carbonyl stretch	Transition metal carbonyl compounds	1800-2100	**803.71**	C-H	Alkenes	675-995
1654.85	C=C	Alkenes	1610-1680	**771.19**	C-H	Alkenes	675-995
1455.62	C-H	Alkanes	1340-1470	-	-	-	-
1422.86	C-H	Alkanes	1340-1470	-	-	-	-

Table 9: FT-IR Peak Values of *Semecarpus anacardium* Methanol Leaf Extract

Wave number cm^{-1}	Bond	Functional Group Assignment	Group Frequency, cm^{-1}
3855.39	-	Unknown	-
3366.30	N-H	Amines, Amides	3300-3500
2946.08	C-H	Alkanes	2850-2970
2833.75	C-H stretch	Methoxy, Methyl ether O-CH_3	2850-2815
2522.92	O-H	Hydrogen bonded Carboxylic acids	2500-2700
2223.33	C≡C	Alkynes	2100-2260
2044.45	Carbonyl stretch	Transition metal carbonyl compounds	1800-2100
1651.62	C=C	Alkenes	1610-1680
1449.68	C-H	Alkanes	1340-1470
1219.47	C-O	Alcohols, Ethers, Carboxlic acids, Esters	1050-1300
1114.64	C-O	Alcohols, Ethers, Carboxlic acids, Esters	1050-1300
1031.99	Methylene >CH_2 stretch	Cyclohexane ring vibrations	1000-1055

Table 10: FT-IR Peak Values of *Semecarpus anacardium* Acetone Leaf Extract

Wave number cm^{-1}	Bond	Functional Group Assignment	Group Frequency, cm^{-1}
3421.46	O-H	Hydrogen bonded Alcohols, Phenols	3200-3600
2978.67	H-O	H- bonded H-X group	2500-3500
2103.29	C≡C	Alkynes	2100-2260
1701.17	C=O	Aldehydes, Ketones, Carboxylic acids, Esters	1690-1760
1645.75	C=C	Alkenes	1610-1680
1421.11	C-H	Alkanes	1340-1470
1368.65	NO_2	Nitro compounds	1300-1370
1232.40	C-N	Amines, Amides	1180-1360
1163.09	C-O	Alcohols, Ethers, Carboxlic acids, Esters	1050-1300
1093.66	C-O	Alcohols, Ethers, Carboxlic acids, Esters	1050-1300
1022.61	Methylene >CH_2 stretch	Cyclohexane ring vibrations	1000-1055
950.41	C-H	Alkenes	675-995

Table 11: FT-IR Peak Values of *Semecarpus anacardium* 2-propanol Leaf Extract

Wave number cm^{-1}	Bond	Functional Group Assignment	Group Frequency, cm^{-1}	Wave number cm^{-1}	Bond	Functional Group Assignment	Group Frequency, cm^{-1}
3818.10	-	Unknown	-	**1768.93**	C=O stretch	Open chain Acid anhydrides	1740-1790
3798.55	-	Unknown	-	**1646.13**	C=C	Alkenes	1610-1680
3734.19	-	Unknown	-	**1467.73**	C-H	Alkanes	1340-1470
3365.96	N-H	Amines, Amides	3300-3500	**1409.17**	C-H	Alkanes	1340-1470
2971.53	H-O	H- bonded H-X group	2500-3500	**1379.58**	C-H	Alkanes	1340-1470
2932.69	C-H	Alkanes	2850-2970	**1341.03**	C-H	Alkanes	1340-1470
2884.32	C-H	Alkanes	2850-2970	**1309.51**	NO_2	Nitro compounds	1300-1370
2721.64	C-H stretch	Aldehyde	2700-2800	**1161.90**	C-O	Alcohols, Ethers, Carboxlic acids, Esters	1050-1300
2659.32	O-H	Hydrogen bonded Carboxylic acids	2500-2700	**1129.90**	C-O	Alcohols, Ethers, Carboxlic acids, Esters	1050-1300
2409.24	-	Unknown	-	**1110.44**	C-O	Alcohols, Ethers, Carboxlic acids, Esters	1050-1300
2195.69	C≡C	Alkynes	2100-2260	**953.02**	C-H	Alkenes	675-995
1903.12	Carbonyl stretch	Transition metal carbonyls	1800-2100	**817.31**	C-H	Alkenes	675-995

Table 12: FT-IR Peak Values of *Semecarpus anacardium* Petroleum ether Leaf Extract

Wave number cm^{-1}	Bond	Functional Group Assignment	Group Frequency, cm^{-1}
3438.97	O-H	Hydrogen bonded Alcohols, Phenols	3200-3600
2917.95	C-H	Alkanes	2850-2970
2849.53	C-H	Alkanes	2850-2970
1737.22	C=O	Aldehydes, Ketones, Carboxylic acids, Esters	1690-1760
1463.08	C-H	Alkanes	1340-1470
1384.31	NO_2	Nitro compounds	1300-1370
1275.17	C-N	Amines, Amides	1180-1360
1187.83	C-N	Amines, Amides	1180-1360
1081.91	C-O	Alcohols, Ethers, Carboxlic acids, Esters	1050-1300
971.02	C-H	Alkenes	675-995
894.90	C-H	Alkenes	675-995
473.41	S-S stretch	Polysulfides	500-470

Table 13: FT-IR Peak Values of *Semecarpus anacardium* 2- butanone Leaf Extract

Wave number cm^{-1}	Bond	Functional Group Assignment	Group Frequency, cm^{-1}	Wave number cm^{-1}	Bond	Functional Group Assignment	Group Frequency, cm^{-1}
3584.29	O-H	Monomeric Carboxylic acids	3500-3650	**1417.12**	C-H	Alkanes	1340-1470
3524.31	O-H	Hydrogen bonded Alcohols, Phenols	3200-3600	**1366.25**	C-H	Alkanes	1340-1470
3416.21	N-H	Amines, Amides	3300-3500	**1257.24**	C-O	Alcohols, Ethers, Carboxlic acids, Esters	1050-1300
2980.19	H-O	H-bonded H-X group	2500-3500	**1206.41**	C-O	Alcohols, Ethers, Carboxlic acids, Esters	1050-1300
2940.34	C-H	Alkanes	2850-2970	**1172.93**	C-O	Alcohols, Ethers, Carboxlic acids, Esters	1050-1300
2910.06	C-H	Alkanes	2850-2970	**1086.89**	C-O	Alcohols, Ethers, Carboxlic acids, Esters	1050-1300
2883.10	C-H	Alkanes	2850-2970	**996.12**	P-O-C stretch	Aliphatic Phosphates	990-1050
2122.95	C≡C	Alkynes	2100-2260	**945.67**	C-H	Alkenes	675-995
1718.83	C=O	Aldehydes, Ketones, Carboxylic acids, Esters	1690-1760	**760.62**	C-H	Aromatic rings	690-900
1459.54	C-H	Alkanes	1340-1470	**588.57**	C-I stretch	Aliphatic iodo compounds	500-600

Table 14: FT-IR Peak Values of *Semecarpus anacardium* Dichloromethane Leaf Extract

Wave number cm^{-1}	Bond	Functional Group Assignment	Group Frequency, cm^{-1}
3438.08	O-H	Hydrogen bonded Alcohols, Phenols	3200-3600
2923.26	C-H	Alkanes	2850-2970
2852.31	C-H	Alkanes	2850-2970
1736.00	C=O	Aldehydes, Ketones, Carboxylic acids, Esters	1690-1760
1455.92	C-H	Alkanes	1340-1470
1379.03	C-H	Alkanes	1340-1470
1162.94	C-O	Alcohols, Ethers, Carboxlic acids, Esters	1050-1300
971.96	C-H	Alkenes	675-995
731.50	C-H	Alkenes	675-995

Table 15: FT-IR Peak Values of *Semecarpus anacardium* Ethyl ether Leaf extract

Wave number cm^{-1}	Bond	Functional Group Assignment	Group Frequency, cm^{-1}
3332.53	O-H	Hydrogen bonded Alcohols, Phenols	3200-3600
2924.66	C-H	Alkanes	2850-2970
2853.66	C-H	Alkanes	2850-2970
1706.21	C=O	Aldehydes, Ketones, Carboxylic acids, Esters	1690-1760
1616.46	C=C	Alkenes	1610-1680
1511.38	NO_2	Nitro compounds	1500-1570
1458.58	C-H	Alkanes	1340-1470
1377.60	C-H	Alkanes	1340-1470
1216.68	C-N	Amines, Amides	1180-1360
971.69	C-H	Alkenes	675-995
829.59	C-H	Alkenes	675-995
758.78	C-H	Alkenes	675-995

Table 16: FT-IR Peak Values of *Semecarpus anacardium* Stem Powder

Wave number cm^{-1}	Bond	Functional Group Assignment	Group Frequency, cm^{-1}
3330.15	O-H	Hydrogen bonded Alcohols, Phenols	3200-3600
2918.66	C-H	Alkanes	2850-2970
1734.07	C=O	Aldehydes, Ketones, Carboxylic acids, Esters	1690-1760

1617.17	C=C	Alkenes	1610-1680
1459.06	C-H	Alkanes	1340-1470
1319.17	NO_2	Nitro Compounds	1300-1370
1240.91	C-N	Amines, Amides	1180-1360
1063.94	C-O	Alcohols, Ethers, Carboxlic acids, Esters	1050-1300
533.90	C-I stretch	Aliphatic iodo compounds	500-600

Table 17: FT-IR Peak Values of *Semecarpus anacardium* Methanol Stem Bark Extract

Wave number cm^{-1}	Bond	Functional Group Assignment	Group Frequency, cm^{-1}
3857.06	-	Unknown	-
3366.50	O-H	Hydrogen bonded Alcohols, Phenols	3200-3600
2945.34	C-H	Alkanes	2850-2970
2833.57	C-H stretch	Methoxy, Methyl ether O-CH_3	2850-2815
2522.84	O-H	Hydrogen bonded Carboxylic acids	2500-2700
2226.61	C≡C	Alkynes	2100-2260
2044.45	Carbonyl stretch	Transition metal carbonyl compounds	1800-2100
1654.75	C=C	Alkenes	1610-1680
1450.06	C-H	Alkanes	1340-1470
1114.90	C-O	Alcohols, Ethers, Carboxlic acids, Esters	1050-1300
1032.44	Methylene >CH_2 stretch	Cyclohexane ring vibrations	1000-1055

Table 18: FT-IR Peak Values of *Semecarpus anacardium* 2- butanone Stem Bark Extract

Wave number cm^{-1}	Bond	Functional Group Assignment	Group Frequency, cm^{-1}	Wave number cm^{-1}	Bond	Functional Group Assignment	Group Frequency, cm^{-1}
3529.95	O-H	Hydrogen bonded Alcohols, Phenols	3200-3600	**1459.53**	C-H	Alkanes	1340-1470
3416.79	O-H	Hydrogen bonded Alcohols, Phenols	3200-3600	**1416.78**	C-H	Alkanes	1340-1470
2980.23	H-O	H-bonded H-X group	2500-3500	**1365.37**	NO_2	Nitro compounds	1300-1370
2940.51	C-H	Alkanes	2850-2970	**1257.53**	C-N	Amines, Amides	1180-1360
2910.07	C-H	Alkanes	2850-2970	**1206.43**	C-O	Alcohols, Ethers, Carboxlic acids, Esters	1050-1300
2883.27	C-H	Alkanes	2850-2970	**1172.63**	C-O	Alcohols, Ethers, Carboxlic acids, Esters	1050-1300
2830.86	C-H stretch	Methoxy, Methyl ether O-CH_3	2815-2850	**1086.89**	C-O	Alcohols, Ethers, Carboxlic acids, Esters	1050-1300
2516.77	O-H	Hydrogen bonded Carboxylic acids	2500-2700	**1033.84**	C-N stretch	Primary amine	1020-1090
2302.49	-	Unknown	-	**996.44**	P-O-C stretch	Aliphatic Phosphates	990-1050
2122.90	C≡C	Alkynes	2100-2260	**945.37**	C-H	Alkenes	675-995
1887.21	Carbonyl stretch	Transition metal carbonyl compounds	1800-2100	**760.89**	C-H	Aromatic rings	690-900
1718.77	C=O	Aldehydes, Ketones, Carboxylic acids, Esters	1690-1760	**589.32**	C-I stretch	Aliphatic iodo compounds	500-600

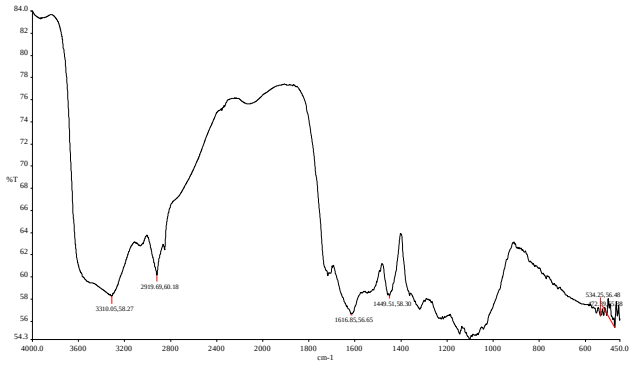

Fig 1:FT-IR Spectrum of *Semecarpus anacardium* Leaf Powder

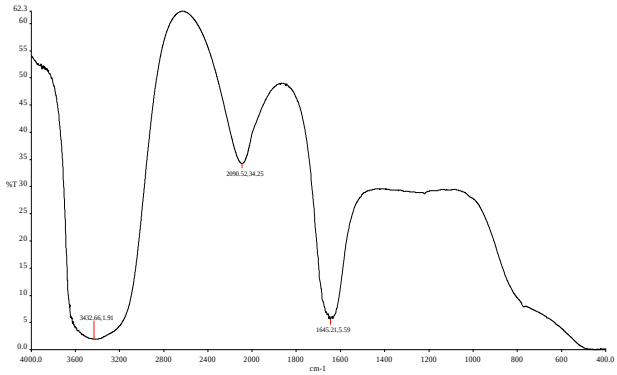

Fig 2:FT-IR Spectrum of Water *Semecarpus anacardium* Leaf Extract

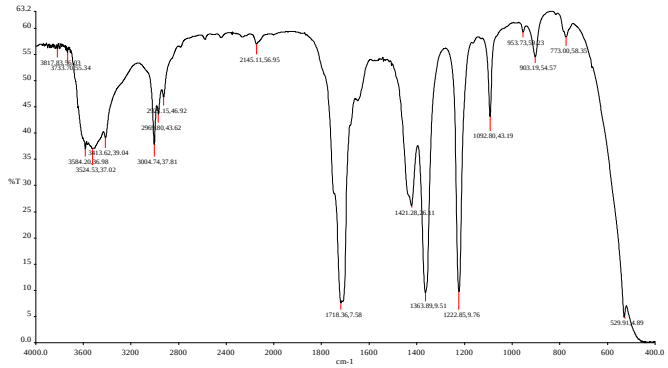

Fig 3:FT-IR Spectrum of Chloroform *Semecarpus anacardium* Leaf Extract

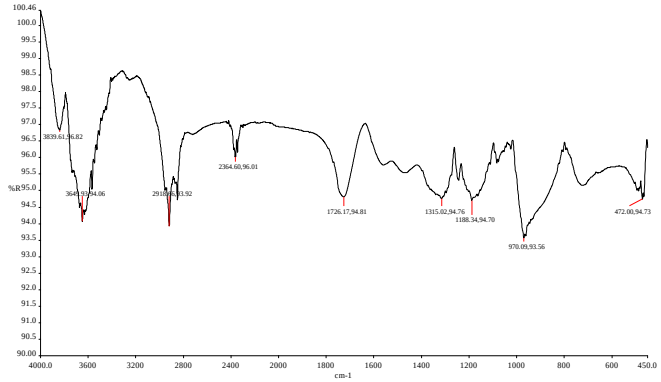

Fig 4:FT-IR Spectrum of Toluene *Semecarpus anacardium* Leaf Extract

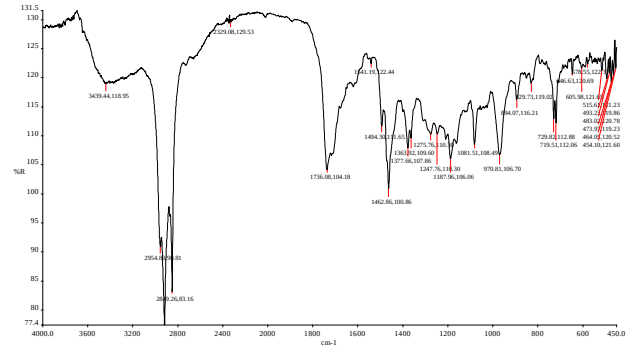

Fig 5:FT-IR Spectrum of CCl_4 *Semecarpus anacardium* Leaf Extract

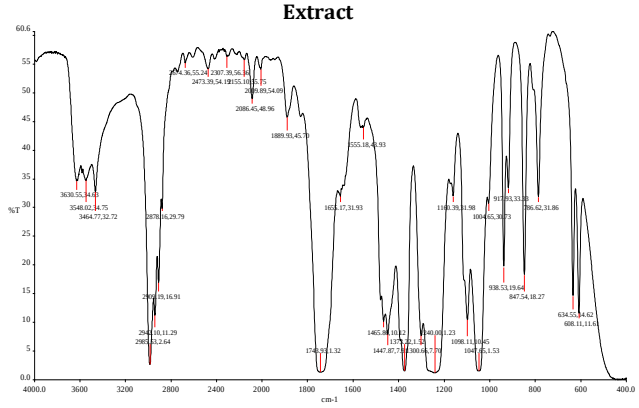

Fig 6:FT-IR Spectrum of Ethyl acetate *Semecarpus anacardium* Leaf Extract

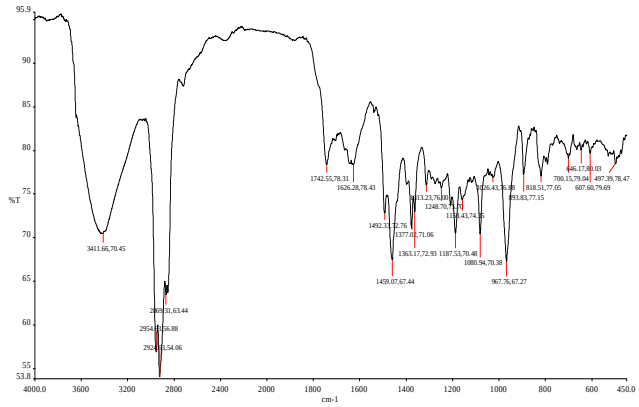

Fig 7:FT-IR Spectrum of Hexane *Semecarpus anacardium* Leaf Extract

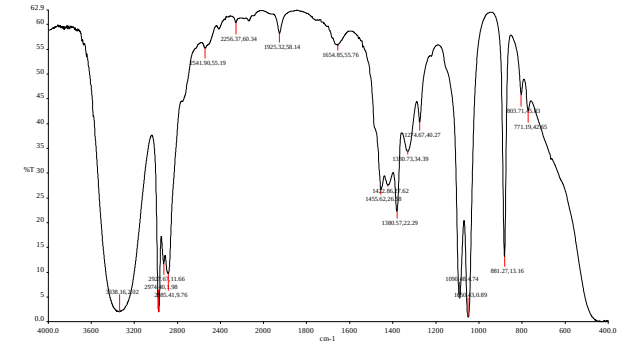

Fig 8:FT-IR Spectrum of Ethyl alcohol *Semecarpus anacardium* Leaf Extract

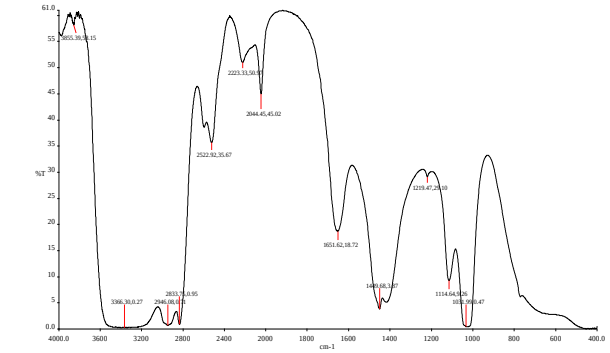

Fig 9:FT-IR Spectrum of Methanol *Semecarpus anacardium* Leaf Extract

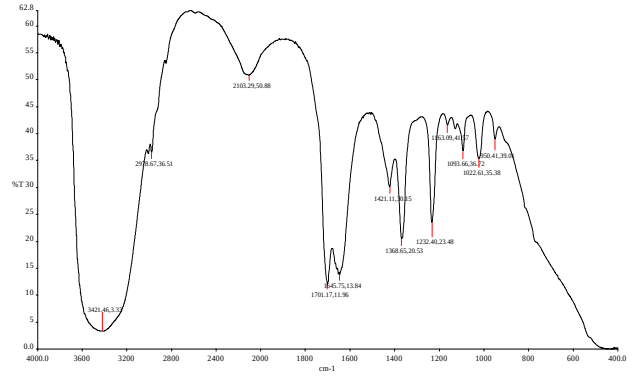

Fig 10: FT-IR Spectrum of Acetone *Semecarpus anacardium* Leaf Extract

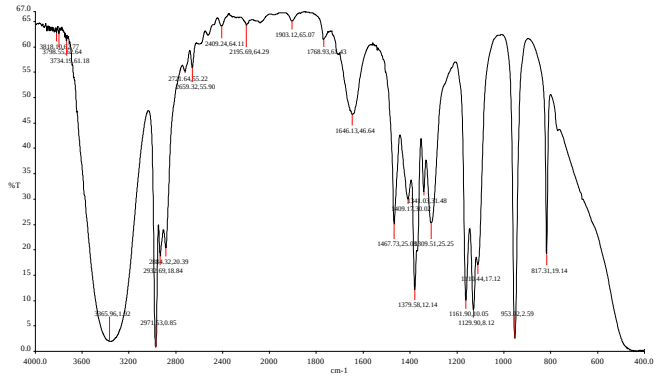

Fig 11:FT-IR Spectrum of 2-propanol *Semecarpus anacardium* Leaf Extract

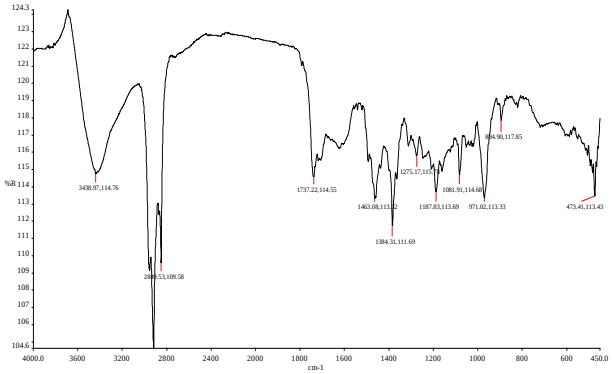

Fig 12:FT-IR Spectrum of Petroleum ether *Semecarpus anacardium* leaf Extract

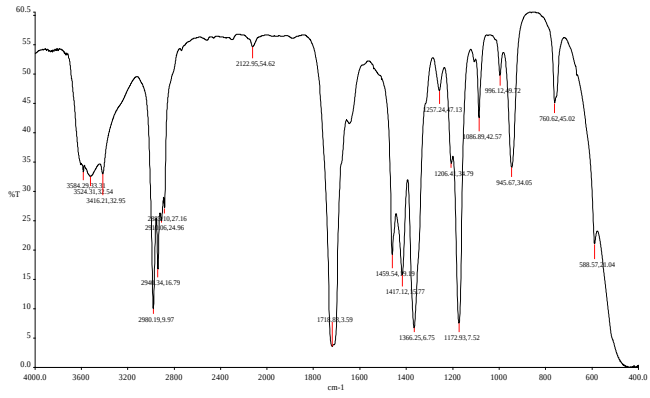

Fig 13:FT-IR Spectrum of 2- butanone *Semecarpus anacardium* leaf Extract

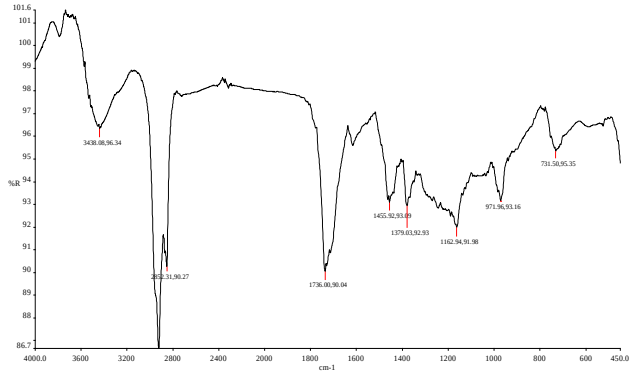

Fig 14:FT-IR Spectrum of Dichloromethane *Semecarpus anacardium* Leaf Extract

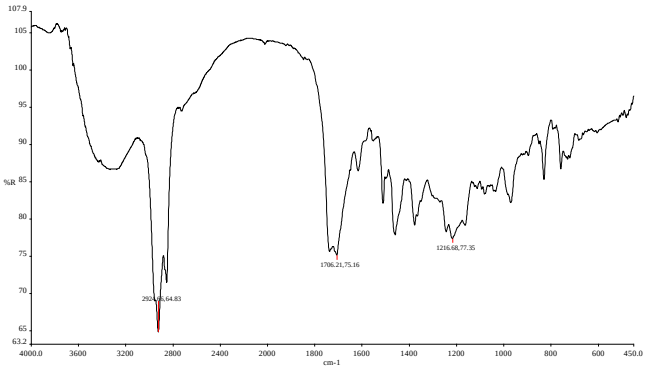

Fig 15:FT-IR Spectrum of Ethyl ether *Semecarpus anacardium* Leaf Extract

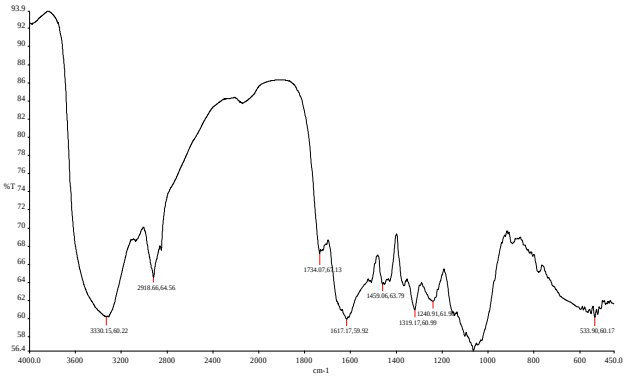

Fig 16:FT-IR Spectrum of *Semecarpus anacardium* Stem Powder

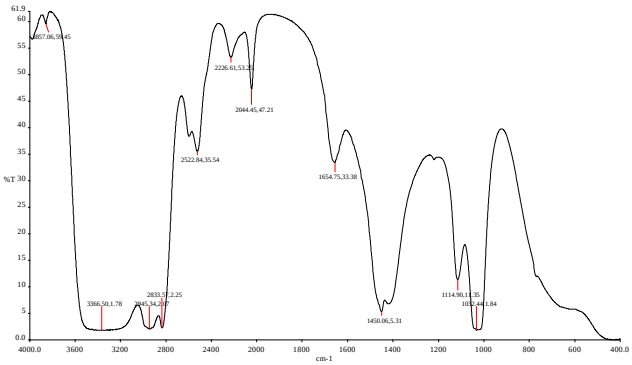

Fig 17:FT-IR Spectrum of Methanol *Semecarpus anacardium* Stem Bark Extract

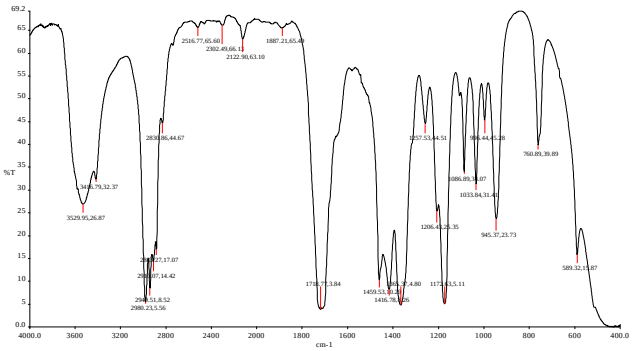

Fig 18:FT-IR Spectrum of 2- butanone *Semecarpus anacardium* Stem Bark Extract

The functional groups which are present in the samples are further described in details. C-H bond of Alkane (2850-2970 cm^{-1}) group frequency are only present only in crude leaf powder of *Semecarpus anacardium* and in chloroform, toluene, carbon tetrachloride and

hexane leaf extracts. C-H bond of Alkane (1340-1470 cm^{-1}) group frequency were found to be present only in *Semecarpus anacardium* acetone leaf extract. Both the group frequencies of the C-H bond of Alkane (2850-2970 cm^{-1}) and (1340-1470 cm^{-1}) were present in ethyl acetate, ethyl alcohol, methanol, 2-propanol, petroleum ether, 2-butanone, dichloromethane, ethyl ether leaf extracts, stem powder and methanol, 2- butanone stem bark extracts.

C=C bond of Alkene (1610-1680 cm^{-1}) group frequency were present in the crude *Semecarpus anacardium* leaf powder and water, ethyl acetate, ethyl alcohol, methanol, acetone, 2-propanol, ethyl ether leaf extracts, stem powder and methanol extract of stem bark. C-H bond of Alkene (675-995 cm^{-1}) group frequency occured in chloroform, toluene, carbon tetrachloride, ethyl acetate, hexane, ethyl alcohol, acetone, 2-propanol, petroleum ether, 2-butanone, dichloromethane, ethyl ether leaf extracts and 2- butanone stem bark extract. C≡C bond of Alkyne (2100-2260 cm^{-1}) group frequency was present in chloroform, ethyl acetate, ethyl alcohol, methanol, acetone, 2-propanol, 2-butanone leaf extracts and methanol and 2- butanone stem bark extracts.

C-H bond of Aromatic ring (690-900 cm^{-1}) group frequency were present in carbon tetrachloride, ethyl acetate, hexane, ethyl alcohol, 2- butanone leaf extracts and 2- butanone stem bark extract.

C=C bond of Aromatic ring (1500-1600 cm^{-1}) group frequency were present only in ethyl acetate leaf extract.

O-H bond of Monomeric Alcohols, Phenols (3590-3650 cm^{-1}) group frequency were present only in ethyl acetate leaf extract. O-H bond of Hydrogen bonded Alcohols, Phenols (3200-3600 cm^{-1}) group frequency were present in leaf powder and water, chloroform, carbon tetrachloride, ethyl alcohol, acetone, petroleum ether, 2-butanone, dichloromethane, ethyl ether leaf extracts, stem powder and methanol, 2- butanone stem bark extracts. O-H bond of Monomeric Carboxylic acid (3500-3650 cm^{-1}) group frequency was present in chloroform, toluene and 2- butanone leaf extracts. O-H bond of Hydrogen bonded Carboxylic acid (2500-2700 cm^{-1}) group frequency were present in ethyl acetate, ethyl alcohol, methanol, 2-propanol leaf extracts and methanol, 2- butanone stem bark extracts.

N-H bond of Amines, Amides (3300-3500 cm^{-1}) group frequency were present in chloroform, ethyl acetate, hexane, methanol, 2-propanol and 2- butanone leaf extracts. C-N bond of Amines, Amides (1180-1360 cm^{-1}) group frequency were present in chloroform, carbon tetrachloride, acetone, petroleum ether and ethyl ether leaf extracts, stem powder and 2- butanone stem bark extract.

C-O bond of Alcohols, Ethers, Carboxlic acids, Esters (1050-1300 cm^{-1}) group frequency were present in leaf powder and chloroform, carbon tetrachloride, ethyl acetate, hexane, ethyl alcohol, methanol, acetone, 2-propanol, petroleum ether, 2- butanone and dichloromethane leaf extracts, stem powder and methanol, 2-butanone stem bark extracts. C=O bond of Aldehydes, Ketones, Carboxylic acids, Esters (1690-1760 cm^{-1}) group frequency were present in chloroform, toluene, carbon tetrachloride, ethyl acetate, hexane, acetone, petroleum ether, 2-butanone, dichloromethane and ethyl ether leaf extracts, stem powder and 2- butanone stem bark extract.

NO_2 bond of Nitro compounds (1500-1570 cm^{-1}) group frequency were present only in carbon tetrachloride and ethyl ether leaf extracts. NO_2 bond of Nitro compounds (1300-1370 cm^{-1}) group frequency were present in chloroform, toluene, carbon tetrachloride, ethyl acetate, hexane, ethyl alcohol, acetone, 2-propanol and petroleum ether leaf extracts, stem powder and 2- butanone stem bark extract.

The C-H stretch vibrations for methyl and methylene are the most characteristic in terms of recognizing the compound as an organic compound containing at least one aliphatic fragment. In this functional groups from Saturated Aliphatic and Alicyclic compounds like Cyclohexane ring vibrations (1000-1055 cm^{-1}) were present in methanol and acetone leaf extracts and methanol stem bark extract. Special methyl ($-CH_3$) frequencies like Methoxy, methyl ether O-CH_3, C-H stretch (2815-2850 cm^{-1}) were present only in 2- butanone stem bark extract.The existence of one or more aromatic rings in a structure is normally readily determined from the C-H and C=C-C ring-related vibrations. The other most important set of bands are the aromatic ring vibrations centered around 1600 and 1500 cm^{-1}, which usually appear as a pair of band structures, often with some splitting. The appearance and ratio of these band structures is strongly dependent on the position and nature of substituents on the ring. Aromatic ring (aryl) group C=C-C (1450-1510 cm^{-1}) was present only in carbon tetrachloride leaf extract.

In Halogenated aliphatic compounds, the C-X bond typically possesses a unique group frequency, which may be assigned to the halogen–carbon stretching. Aliphatic fluoro compounds (1000-1150 cm^{-1}) C-F stretch were present in ethyl acetate and hexane leaf extracts. Aliphatic chloro compounds (700-800 cm^{-1}) C-Cl stretch were present only in chloroform leaf extract. Aliphatic bromo compounds (600-700 cm^{-1}) C-Br stretch were present in carbon tetrachloride, ethyl acetate and hexane leaf extracts. Aliphatic iodo compounds (500-600 cm^{-1}) C-I stretch were present in leaf powder and chloroform, carbon tetrachloride, 2-butanone leaf extracts, stem powder and 2- butanone stem bark extract.

In Amino Compounds with some respects, the infrared spectra and the characteristic group frequencies of amines tend to parallel those of alcohols and ethers. The terms primary, secondary, and tertiary are used to describe amines, but the substitution relates to the nitrogen, not the adjoining carbon (as with alcohols). Only the primary and secondary amines exhibit the most characteristic group frequencies, which are associated with the N-H bond. Primary amine (1020-1090 cm^{-1}) CN stretch were present in ethyl acetate leaf extract and 2- butanone stem bark extract. Secondary amine (1130-1190 cm^{-1}) CN stretch were present only in toluene leaf extract.

The Carbonyl group compounds are not only chemically important, but are also important in the interpretation of infrared spectra. The C=O absorption is almost always one of the most characteristic in the entire spectrum, and it is also most likely to be the most intense spectral feature. Aldehyde (2700-2800 cm^{-1}) group frequencies were present only in 2-propanol leaf extract. Open-chain acid anhydride (1740-1790 cm^{-1}) group frequencies were present in only in 2-propanol leaf extract. Transition metal carbonyls (1800-2100 cm^{-1}) group frequencies were present water, ethyl acetate, ethyl alcohol, 2-propanol leaf extracts and methanol, 2-butanone stem bark extracts.

The group of Hetero-oxy compounds features X-O (where X= nitrogen, sulfur, phosphorus, and silicon) and X=O vibrations. In general, the stretching frequencies is observed within the main fingerprint spectral region (1500–400 cm^{-1}). Many of the compounds can be considered to be analogs of ethers, especially when an alkoxy group is present, featuring the X-O-C linkage. Aromatic nitro compounds (1485-1555 cm^{-1}) group frequencies were present only in hexane leaf extract. Aliphatic phosphates (990-1050 cm^{-1}) P-O-C stretch were present in 2- butanone leaf extract and 2- butanone stem bark extract.

Thiols and Thio-substituted compounds by definition, can be considered to be the direct analogs of the equivalent oxygenated compounds such as alcohols and ethers. Catenation is a unique chemical characteristic of sulfur, where the formation of S-S bonds in extended chains is common, hence the inclusion here of the S-S stretching frequencies. Aryl disulfides (430-500 cm^{-1}) S-S stretch was present only in CCl_4 leaf extract. Polysulfides (470-500 cm^{-1}) S-S stretch was present in leaf powder and toluene, carbon tetrachloride, hexane, petroleum ether leaf extracts.

In H-X group, the stretching of bonds between heavier atom and hydrogen (H-X-) occurs in the region between 2000 and 4000cm^{-1}. The X-atoms and the structure to which they are attached determines the exact frequency. H-C (aromatic) (3000-3050 cm^{-1}) group frequency was present only in chloroform leaf extract. H-bonded (H-O): (2500-3500 cm^{-1}) group frequencies were present in ethyl acetate, ethyl alcohol, acetone, 2-propanol, 2-butanone soxhlet leaf extracts and 2- butanone stem bark extract.

The above listed infrared functional group absorptions characteristic were cited from the literature[14-16]. The FT-IR analysis

revealed the similarity and variation between the leaf and stem parts of *Semecarpus anacardium*. From the spectra we can clearly see that although they show substantial overlap of each absorption spectrum of various components, each band represents an overall overlap of some characteristic absorption peaks of functional groups in the samples. By using the macroscope fingerprint characters of FT-IR spectrum, we can judge the origin of different extracts accurately and effectively, trace the constituents in the extracts, identify the medicinal materials and even evaluate the qualities of medicinal materials[7].

CONCLUSION

The FT-IR analysis of *Semecarpus anacardium* clearly reveals the differences of categories of chemical constituents in crude powder and 14 different polar and nonpolar organic solvent extracts of leaf and stem bark. The crude plant material when extracted by organic solvents, shows more characteristic features in the FT-IR spectrum as the chemical compositions become more concentrated. Due to the similarity of the extraction method i.e. soxhlet extraction, the chemical constituents in the concentrated extracts are relatively consistent and therefore they show higher repeatability and comparability in FT-IR spectra. So, FT-IR spectrum reflecting objectively the panorama of chemical composition in complex plant material is a most appropriate method to validate and identify the mixed substance products such as traditional herbal medicine as well as their corresponding extracts. The results of the present study confirms that leaf and stem bark of *Semecarpus anacardium* is rich in the resources of phytoconstituents.

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