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Isolation, characterization and identification of bioactive compounds from Herbal Medicines and Medicinal Plant Extracts by Fourier Transform Infrared Spectroscopy: A brief review

Review Article

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Abstract

Herbal medicines are mostly used from thousands of years in primary health care of society and community of both developed and developing countries. It mainly includes whole plant, herbs, extracts, isolated compounds, polyherbal preparations, phytoformulations etc. Identification of bioactive compounds from phytomedicines plays a very important role in drug development and drug design process. The characterization of phytomedicines is very much essential in the identification of compounds. For the purpose of identification two methods, Spectroscopy and Chromatography play important role. Fourier Transform Infrared Spectroscopy (FTIR) is the widely used technique which is mainly used to identify functional groups in herbal medicines. Various scientific research articles published on extraction, isolation, characterization and identification of phytoconstituents from medicinal plants and other forms of herbal medicines is being reviewed in this article. We have mainly focused on the FTIR characterization and identification of phytochemicals from herbal medicines and are briefly presented in this review work. Our present review article concludes that the FTIR spectroscopy plays very much essential role in the identification and characterization of bioactive compounds from herbal medicines.

Keywords: Bioactive Compounds, Characterization, Fourier Transform Infrared Spectroscopy, Functional Groups, Herbal Medicines.

Introduction

From time immemorial the major source of phytopharmaceuticals and dietary supplements are the Medicinal plants. Phytochemicals and provitamins are the natural products derived from Medicinal Plants that are now known as Food Supplements which help to maintain health and fight disease. The cosmetic industry also has accepted and is using these derived products from the plants. The importance of scientific research on herbal supplements was stated in the World Health Organization (WHO) in the year 1987, and also there is sufficient evidence that such products may have beneficial effects. Herbal drug use is one of the oldest forms of health care without any doubt and thus WHO has estimated that major portion i.e. 80% of the world population thus still relies on this type of Product i.e. Botanical medication. Diversity and richness is one of the notable and remarkable features of the Natural flora with Therapeutic and Cosmetic role. Still however, there is research needed to explore their proper application in Modern therapy.(1) Since early 1950's, Infrared (IR) Spectroscopy is the analytical tool which has been used routinely for Chemists but before this, the Spectra was recorded using Grating or Prism-type instruments which are the so-called Dispersive techniques. In the last decade, FTIR spectrometers have become available in a great number for routine laboratory work which is basically used to determine the type of Functional groups present in the sample.(2)

FTIR is a preferred method of Infrared (IR) spectroscopy analytical method. In IR spectroscopy mainly, when the IR radiations are passed through a sample and some of it will be absorbed by the sample itself and some of it will be passed through i.e. nothing but transmitted. The result from this process is spectrum which represents the molecular transmission and absorption which creates a molecular fingerprint of the sample which generally is as shown in Figure 1 (Spectrum of Sulphanilamide obtained by FTIR). Spectrum obtained by IR process represents the fingerprint of a sample, which has absorption peaks that correspond to the frequencies of vibrations between the bonds of the atoms that make up the sample. No two molecular structures produce the same IR spectrum similarly as no two fingerprints never match to each other which makes IR spectroscopy useful for several types of analysis of functional groups. The IR region is commonly divided into three peaks; near-IR (400-10

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cm^{-1}), mid-IR (4000-400 cm^{-1}), and far-IR (14,000-4000 cm^{-1}).

FTIR spectroscopy is preferred over filter or dispersive methods of IR spectral analysis for the following reasons:

- This analytical technique is Non-destructive.
- Its mechanical working is simple, with only one moving part in it.
- Its speed can be increased, for every second number of scans collected.
- Its sensitivity can be increased as it can scan for every second and these can be added together to ratio out random noise.
- This method provides a measurement which is precise and thus requires no external calibrations.(3)

General Working Principle of FTIR Spectroscopy

Limitations encountered with dispersive instruments lead to development of FTIR in order to overcome the limitations. The main difficulty was the slow scanning process. This method measures all of the infrared frequencies simultaneously, instead of measuring them individually. The solution which was developed made use of a very simple optical device i.e. interferometer, it produces some unique Type of Signals which have all of the infrared frequencies encoded into it. These signals can be scanned and measured very fast. Most of the interferometers employ a Beam splitter which will divide the infrared beam which is coming into two optical beams in which one beam will reflect off towards a flat mirror which is fixed at a place and the other beam will reflect off towards another flat mirror which works on a mechanism which will allow this mirror to move a very short distance away from the beam splitter. The two beams will reflect off from their respective mirrors and are then recombined at beam splitter where they meet. Among the two beam's the path of one beam in which it travels is a fixed length and the path of the other is constantly changing since its mirror moves and the signal which exits at the interferometer is the result of these two beams which are "interfering" with each other. The resulting signal of the process is called an interferogram, whose unique property is that at every data point (a function of the moving mirror position) will make up the signal and will have information about every infrared frequency which will come from the source.

Which means that when the interferogram obtained is measured, all frequencies are measured simultaneously and is the reason which makes interferometer result in extremely fast measurements.

Analyst requires a frequency spectrum (a plot of intensity at each individual frequency) in order to make identification, since the measured Interferogram signal obtained cannot be interpreted directly. Individual frequencies are required to be decoded by "Decoding" process, which can be achieved through fourier transformation which involves transformation process performed by the computer which then presents the user with the spectral information which is required for analysis, this process is a well-known mathematical technique and its general working is mentioned in Figure 2.(4)

Instrumentation of FTIR Spectroscopy

The instrumental process is as follows and diagrammatic representation is as shown in **Figure 4**.

Source

Infrared energy is emitted in the form of radiation emerging from a glowing blackbody source, which then passes through an aperture, it is used since it controls the amount of energy that will reach the sample. Different types of light sources are mentioned in Table 1.

Sample

The beam next enters the sample compartment where the sample is placed where in the beam is either transmitted through the sample or reflected off of the surface of the sample, it will depend on the type of analysis being carried out. This is the region where the specific frequencies of energy are absorbed and are the unique characteristic of the sample.

Interferometer

The beam will enter the interferometer where in encoding of the spectra will take place. The result obtained is the interferogram which is the signal that exists the interferometer.

Detector

For the final measurement the beam will pass through the detector. The detectors that are used are specially designed to measure the Special Interferogram signal. Different types of detectors used are mentioned in Table 2.

Computer

The signal measured is digitized and is sent to the computer system where the Fourier transformation takes place. The Infrared spectrum obtained finally is then presented for interpretation of results.(4)

Table 1: Sources used in Infrared Spectrometer

Source	Base Material used in Source	IR Wavelength (mm)
Nernst glower	Heated rare earth oxide rod	$1e^{50}$ (mid- to far-IR)
Globar	Heated SiC rod (w1500K)	$1e^{50}$(mid- to far-IR)
W filament lamp	1100K	$0.78e^{2.5}$ (near-IR)
Hg arc lamp	Plasma	$50e^{300}$ (far-IR)
CO_2 laser	Stimulated emission lines	$9e^{11}$

Table 2: Detectors used in Infrared Spectrometer

Detector	Base Material of Detector	Test Range
Thermocouple	Thermo electric effected dissimilar metal junction	Cheap, slow, insensitive
Bolometer	Ni, Pt resistance thermometer (thermistor)	Highly sensitive, <400cm
Pyroelectric	Triglycine sulfatepiezo electric material	Fast and sensitive(mid-IR)
Photo conducting	Light sensitive cells	Fast and sensitive(near-IR)

Interpretation and Analysis of FTIR Spectra

Absorption of electromagnetic radiation at different frequencies which correlate to the vibration of specific sets of chemical bonds which are present within the molecule will result in IR spectrum. It is important to note various types of energy a molecule will possess at any given moment of time. The different types of energy a molecule will possess are electronic energy, vibrational energy, rotational energy, and translational energy.

FTIR analysis is used for

- Identification and characterization of unknown materials (e.g., solids, films, liquids or powders)
- Identification of contaminant present in a material or its presence on it (e.g., powders, particles, liquids or fibre)
- Identification of additives obtained after extraction from a Polymer matrix.
- In failure analysis investigations identification of decomposition, oxidation or uncured monomers.

Methodology

We have reviewed various scientific research articles that were published on extraction, isolation, characterization and identification of phytoconstituents from medicinal plants and other forms of herbal medicines. We have mainly focused on the FTIR characterization and identification of phytochemicals from herbal medicines and was briefly presented in the present review work. The detailed methodology and interpretation of results were presented below as follows:

Isolation, Characterization and Identification of Bioactive Compounds from Phytomedicines by FTIR

Various research articles, data and reports are published by scientist on FTIR interpretation of herbal drugs from medicinal plants were presented and reported as follows:

T. Anand *et al.*, have worked on *Hybanthus ennearpermus* plant for its phytochemical analysis using FTIR (Fourier Transform Infrared Spectroscopy) analytical method, where in ethanolic extract of herbal drug (*Hybanthus ennearpermus*)was evaluated for the presence of bioactive constituents, which was carried out using Perkin Elmer Spectrophotometer and characteristic peaks were detected at wavelength range 300-1100nm and reported that the ethanolic extract spectrum confirmed the presence of phenols, alkenes, alcohols, alkyl halides, amines, carboxylic acids, aromatics and nitro compounds (3).

K. Vikas *et al.,* worked on traditional medicinal plant like *Cassia tora* L population authentication phytochemically by FTIR analysis. 6 different populations of *C. tora* was studied and the peaks obtained in FTIR spectra at 1623 cm^{-1} (carbonyl group) and 1034 cm^{-1}(>CO- group) wavenumber were powerful in separating the populations, these peaks are assigned to flavonoids and carbohydrates respectively. By FTIR fingerprinting *C. tora* population obtained from Ranchi site was suitable for harvesting dur to potential therapeutic bioactive compounds (4).

S. Chandran *et al.*, have evaluated some selected Indian medicinal plants on its antagonistic potential activity against *Malassezia spp* and also Embelin was evaluated in combination with Ketoconazole for its synergistic effect, among selected 16 Indian medicinal plants, maximum degree of antimicrobial activity was found in Embelia ribes. They found that Embelin was the bioactive principle has potential antagonistic activity and it was characterized by FTIR analysis (5).

S. S. Sahaya *et al.*, worked on phytochemical screening and antimicrobial activity of *Tragia involucrata* L. by performing FTIR analysis along with UV-Vis Spectroscopy and the peaks in FTIR spectrum confirmed presence of different functional groups like, alcohol O-H stretch, amides N-H stretch, phosphines (P-H stretch), anhydrides (C=O stretch), carboxylic acid (C=O stretch), alkenes (C=C stretch conjugated), alkenes (C-H plane bend), sulfoxides (S=O stretch), alkyl halides (C-Cl stretch (6).

S. Mandal *et al.*, worked simultaneously on UV-Vis and FTIR analysis to compare the concentration of pigments-chlorophylls and carotenoids and to detect presence of different functional groups five Indian medicinal plants- namely *Ocimum sanctum* L. (Tulsi), *Calotropis gigantea* L. (Akanda), *Paederia scandens* (Gadali), *Azadirachta indica* L. (Neem) and *Murraya koenigii* L. (Curry). FTIR analysis showed the presence of keto, alcohol, amino groups in aromatic and aliphatic components in fingerprint-like spectra (7).

F. Nawaz*et al*., have worked on phytochemical screening of leaf extracts of *Monothe cabuxifolia* by FTIR spectroscopic analysis. Extracts n-hexane, toluene, chloroform, carbon tetra chloride, butanol, methanol were analysed and FTIR spectroscopic studies reported the presence of several functional groups of important bioactive compounds in the extracts and the peaks values of functional groups confirmed that amides, alcohols, ketones, phenols, carboxylic acids, alkanes, aldehydes and aromatic compounds were present (8).

K. A. Jahangir *et al.*, have worked on the FTIR analysis of extracts and fractions of whole plant of *Heliotropium europaeum* along with I*n Vitro* anti-inflammatory, anticancer (MCF-7, 3T3, and HeLa Cell

Lines) and Brine Shrimp Lethality assay and it was reported that FTIR analysis interpreted the presence of functional groups such as saturated compounds i.e. Alkanes, unsaturated compounds i.e. Alkenes Aromatic compounds, Carboxylic acids, Esters and Sulfate esters, Alcohols, Phenols, Alkyl halides, Phosphines, Silanes, Nitriles, Thiols, Amines, Phosphoric acids and Nitro compounds.(9)

N. Geetha *et al*., have done Comparison work of Microwave Assisted Medicinal Plant Extracts to detect the presence of Phytocompounds through FTIR and Qualitative Phytochemical Analysis. The samples obtained from Microwave assisted extraction were subjected for Fourier transform infrared spectroscopy (FTIR) analyses and it was reported that FTIR analysis confirmed the presence of Alkyl halides like Chloroalkanes Bromo alkanes, Aromatic group, Alkenes and Alkynes, Polysaccharides, Alcohols, Amine, Carboxylic acids, Sulfonyl group, Nitro compounds, Amino acids, Dienes, Amine, Secondary amines which are the Functional groups of secondary metabolites were available in *Centella asiatica* (L.) Urban, *Solanum trilobatum* (L.), *Ocimum sanctum* (L.), *Eclipta alba* (L.) Hassk., *Cynodon dactylon* (L.) Pers. and *Justicia adhatoda* (L.) Nees in important Medicinal plants.(10)

R. D. Dharmasoth *et al.,* have analysed Leaf extracts of *Grewia tilifolia* (Vahl) plant through FTIR Spectroscopy and Qualitative Phytochemical screening and reported that FTIR spectroscopy revealed presence of different functional groups in compounds of respective extracts with characteristic peak values. Analysis showed the presence of groups which are majorly present, they are Alkanes and Alkenes, Alcohols, Phenols, Aldehydes, Ketones, Carboxylic acids, Esters, Ethers, Aromatics, Primary amines and Aliphatic amine compounds.(11)

M.S. Subashini*et al.,* have done analysis of leaves of *Gymnema sylvestre* R.Brfrom Kolli Hills by Thin layer chromatography, Fourier transform infrared spectroscopy and Gas chromatography- Mass spectroscopy to detect the presence of Potential Bioactive constituents and it was reported that FTIR spectroscopy revealed the presence of Functional compounds such as Alkanes, Alkynes, Alcohols, Phenols, Aldehydes, Aromatic compounds and Carboxylic acids, Alkyl halides with characteristic peak values.(12)

K. S. Tarang *et al.,* have worked on Identification of Functional groups present in Ethanol leaf extract in *Thymus linearis* through Fourier transform infrared spectroscopy (FTIR) analysis. Eleven Functional groups were identified in extract by analysis and it showed the presence of Alkyne, Aldehyde, Aliphatic ether, Aromatic amine, Anhydride, Alkene, 1,2,4 trisubstituted, 1,4-disubstitutedhalo compound, which showed major peak. FTIR results interpreted the presence thymol, carvacrol and phytol. (13)

K Kalaichelvi *et al.,* worked on Screening of Phytoconstituents of *Micrococca mercurialis (L)* Benth by using FTIR (Fourier Transform Infrared Spectroscopy) and UV-Vis spectrum analysis. Whole plant was evaluated and extraction was carried outusing 2 solvents i.e. Aqueous and Organic and the extracts obtained were of Petroleum ether, ethanol, acetone, chloroform and aqueous. The spectrum after analysis revealed that Alkanes, Alkynes, Alkyl halides, Alcohols, Aromatics, Phenols, Nitro compounds, Aldehydes and Amines were present.(14)

M.B. Patil *et al.,* studied *Catunaregam spinosa* (Thunb.) Tirven and worked on its Ethnobotanical, Phytochemical and FTIR analysis. The study was performed by taking different solvent systems i.e. Methanol, Chloroform and Ethyl acetate, the functional groups were detected in leaf extracts of different solvents by observing FTIR spectral peak values.(15)

K. Somendra *et al.,* worked on Pharmacological Validation of *Bridelia retusa* based on FTIR analysis and reported that FTIR spectrophotometric analysis exhibited the presence of Primary and Secondary alcohols, Alkenes, Aldehyde, Primary & Secondary Amines, Aliphatic Bromo compounds, Aliphatic ether, Aromatic amines, Acid halides, Ester, Halo compounds, Vinyl ether, and Aromatic compounds. The presence of these Phytocompounds suggested better possibilities for the plant as a source of Phytomedicines in Pharmaceutical industries and research for the discovery of lead compounds for Drug discovery.(16)

A.V. Sunila *et al.,* have worked on Comparing FTIR Fingerprints obtained in Fruits of *Pouteria campechiana* (Kunth) at its 6 different developmental stages. The study, resulted in Spectra was analysed for Spectral peaks for the presence of Characteristic Functional groups which may represent the Chemistry of compounds present in the Pulp of Fruit. More or less Similar peaks were obtained by fruits of all 6 stages but the difference observed was in peak heights. Some of the peaks were shared and others were unique to the particular stage. The spectrum obtained by the fruit in Fourth stage showed peaks at 2300 and 2330 cm^{-1} which specifically corresponds to C=O stretch of CO_2 absorption and it is at this Stage the Ripening process of the fruit begins. The maturity stage of the Fruit can be correlated with presence and absence of specific spectral peaks obtained at different development stages. (17)

R. A. Bashir *et al.,* worked on reported Preliminary Phytochemical screening and FTIR (Fourier Transform Infrared Spectroscopy) spectroscopy analysis of leaf and stem bark of methanolic extracts of *Khaya senegalensis*, FTIR analysis resulted the presence of Alcohol (OH) stretching for alcohol group, Alkanes (CH), Carbonyl (C=O) and Amines (N-H) as functional groups and reported the plant as a Source of Antimicrobials that could be used in the Health care delivery process.(18)

Okereke Stanley C. *et al.,* have analysed Spectral data obtained from methanolic extracts of *Tithonia diversifolia* (Hemsl.) A. Gray leaves by Gas chromatography mass spectrometry/FTIR and analysis revealed the presence of Aldehydes, Phenols, Alcohols, Ketones, Alkanes and Primary amines and based on this analysis, it was reported that the plant had the ability to

manage certain infections and diseases and thus it can be relied upon as Traditional medicine for the same.(19)

T. Antony Sandosh *et al.,* have worked to characterise bioactive constituents present in *Stylosanthes fruticose* by performing Phytochemical Analysis using UV-VIS, GC-MS and FTIR method. The instrument used to scan the crude extracts was Perkin Elmer spectrophotometer and it was reported that characteristic peaks were detected in the wavelength range200-1100nm and it was reported that after performing FTIR analysis the spectrum obtained, confirmed the presence of secondary alcohols, Alkanes, Phenols, Alkenes, Aromatics, Carboxylic acids, Nitro compounds and Amines in different crude extracts that were studied.(20)

Yanli *et al.,* have worked on Geographic origin, identification and rapid determination of four constituents of *Gentiana rigescens* species by performing FTIR analysis combined with Chemometrics, the FTIR spectra that were characteristic were selected and an identification model of the different geographic origins of the plant was built by PLS-DA i.e. Partial least squares discriminant analysis,93 common peaks were selected by interpretation of characteristic spectra and by performing this it was reported that FTIR analysis when combined with chemometric methods can accurately identify the different geographic origins of plant along with rapid prediction of the contents present in it i.e. swertiamarin, gentiopicroside, swerosideand loganic acid.(21)

H. Subrahmanian *et al.,* worked on Analysis of *Erythrina variegata* L. species by Fourier Transform InfraRed Spectroscopy. The study was performed to determine the functional groups present and process was performed by using the instrument Shimadzu FTIR spectrometer 4000 series and the scan range used for analysis was between 4,000–400 cm^{-1}. The analysis showed the presence of characteristic peak values in the spectra with different useful mixtures of Functional groups such as Hydroxy group, Metal carbonyl, Aliphatic, Alcohols, Nitrile, Alkynes, Phenols, Ketones, Amide, Carboxylic acids and Aromatics. It was reported that the plant leaves, flowers and barks had 17, 31 and 15 functional groups present respectively and also an intense peak of 3348.42 cm-1 was observed in leaves, 1049.28 cm-1 was observed in flowers and 1583.56 cm-1 was observed in barks and these peaks corresponded to the hydroxyl groups, phosphate ion and amide respectively.(22)

K. Saravanakumar *et al.,* have worked on GC-MS and FT-IR Profiling of *Pleiospermium alatum* species leaves methanolic extract and the spectrum was recorded in Thermo Scientific NICOLET-iS5 spectrophotometer, the peak values was obtained with various Functional compounds such as Amizone, Alcohol, Alkanes, Phenol, Protein, Enzyme, Isopropyl. (23)

P. Made *et al.,* have worked on phytochemical screening and FTIR spectroscopy on *Enhalus acoroides* leaves extract to determine the functional groups present and to evaluate the profile of Pigments present in plant leaf extract and it was reported that the major Functional groups found in the leaf extract were Hydroxyl groups, Lipids, Alkanes, Secondary amines, Fatty acids, Benzenoid compounds and Phenols also the presence of chlorophyll and carotenoids in the extract was identified.(24)

M. K. Oladunmoye *et al.,* worked on Antibacterial activity and FTIR Spectral Analysis of *Gliricidia sepium* species Leaves, analysis was performed on methanolic extracts of the plant and the spectrum obtained confirmed the presence of Alcohols, Alkanes, Aldehydes, Amide, Alkenes, Carboxylic acids, Aromatics, Ketones, Ethers, Esters, Primary amines, Phenols Aliphatic bromo compound, Aliphatic amines compounds and Aryl disulphide at different peaks.(25)

H. H.Rafid *et al.,* have worked on Characterization of Antimicrobial Metabolites Produced by the species *Salvadora persica* and Analysing Chemical Compounds present in it using GC-MS and FTIR methods and it was reported that the FTIR analysis spectrum provided the presence of Alkyl halides, Alkanes, and alkenes which shows major peaks at 960.55, 1029.99, 1097.50, 1141.86, 1321.24, 1373.32, 1616.35, 1723.65, 2852.72 and 2922.16. In the Plant Methanolic extract, 21 Bioactive compounds were identified.(26)

A. Kumari*et al.* ,have worked on Phytochemical Screening of *Glycyrrhiza Glabra* root extracts by UV-VIS Spectrophotometer, FTIR & HPLC Spectroscopic methods and it was reported that FTIR spectrum of 62% pure glabridin was compared to the spectra shown by the three extracts i.e. Ethanol, Methanol and Ethyl acetate.(27)

V Anusuba *et al.,* have worked on *Cucumis dipsaceous* Ex. Spach. Ehreb leaves spectral analysis using FTIR and GC-MS methods, FTIR was performed by using the instrument Perkin Elmer Spectrophotometer and it was reported that Spectroscopic analysis showed the presence of Alcohols, Alkanes, Phenols, Alkynes, Alkyl halides, Aromatics, Carboxylic acids, Aldehydes, Nitro compounds and Amines.(28)

AR Florence *et al.,* have worked on *Gmelina asiatica* L. Leaves spectral analysis by FTIR and GC-MS. FTIR analysis was performed by using the instrument Perkin Elmer Spectrophotometer and reported that the Spectroscopic analysis revealed the presence of Alcohols, Alkynes, Alkanes, Phenols, Alkyl halides, Carboxylic acids, Aldehydes Aromatics, Nitro compounds and Amines.(29)

K Showmiya *et al.,* worked on plant *Citrus maxima* Linn species. The study was performed onEthanolic leaf extract and its FTIR analysis and Phytochemical screening was performed. After analysis extract reported the presence of Amide, Alkenes, Alkyne, Alkane, Ether, Alcohol, Ketone, Alkyl halides and Aromatics groups in the extract.(30)

R. Selva Raju *et al.,* have worked on FT-IR Spectroscopic Analysis of *Ocimum gratissmium* Leaf powder and its analysis showed the presence of some Functional groups with the corresponding intensity peaks of O-H stretching or hydrogen bonding for

Alcohols or Phenols groups of active compounds. C-H stretching corresponded to Alkanes and Alkynes, C=O stretching was denoted for Amides and Esters, C-H (CH_2X) was assumed to be Alkyl halide groups of the Bioactive compounds, C-H bending was denoted for Alkynes. Also Functional groups of Bioactive components like Eugenol, Esters, Alkanes, Alkyl halides, Carbohydrates, Amides, Hydroxyl and others were detected.(31)

The summary of research work conducted using FTIR characterizations of phytomedicines were presented in Table 3.

Table 3: FTIR Characterization of Bioactives from Phytomedicines

Sl. No.	Authors name	Work performed	Functional groups identified
1	T. Anand *et al*	Phytochemical analysis of *Hybanthus ennearpermus*	Phenols, Alcohols, Alkenes, Alkyl halides, Carboxylic acids, Aromatics, Nitro compounds and Amines.
2	K. Vikas *et al*	Phytochemical authentication on *Cassia tora* L. Traditional Medicinal plant	Carbonyl group
3	S Chandran *et al*	Evaluation on selected Indian Medicinal plants for Antagonistic potential activity against Malassezia spp	Maximum antimicrobial activity was found in *Embelia ribes*species
4	S. S. Sahaya*et al*	Phytochemical screening and antimicrobial activity of *Tragia involucrata*	Alcohol, amides, phosphines, anhydrides, carboxylic acid, alkenes, sulfoxides, alkyl halides
5	S. Mandal*et al*	Detect presence of Functional groups in *Ocimum sanctum* L., *Calotropis giganteam* L., *Paederia scandens, Azadirachta indica* L. and *Murraya koenigii* L.	Keto, alcohol, amino groups in aromatic and aliphatic components.
6	F. Nawaz*et al*	Phytochemical screening of leaf extracts of *Monotheca buxifolia*	Amides, alcohols, phenols, alkanes, ketones, aldehydes, aromatic compounds and carboxylic acids
7	K. A. Jahangir*et al*	Analysis of *Heliotropium europaeum*	Aromatic compounds, phenols, carboxylic acids, esters, alkanes, alkenes, alcohols, alkyl halides, sulfate esters, phosphines, silanes, nitriles, thiols, amines, phosphoric acids and nitro compounds
8	N. Geetha *et al*	Detection of Phytocompounds and Qualitative Phytochemical analysis of samples obtained from microwave assisted extraction	Chloroalkanes, Vinyl group, Bromo alkanes, aromatic group, alkyl halides, alkyne, polysaccharides, alcohols, amine, alkyl group and secondary amines they are functional groups available in *Cenrella asiatica* L., *Solanum trilobatum* L., *Ocimum sanctum* L., *Eclipta alba* L., *Cynodon dactylon* L. and *Justicia adhatoda* L.
9	R. D. Dharmasoth *et al*	Phytochemical screening of leaf extracts of *Grewia tilifolia*	Alcohols, phenols, alkanes, carboxylic acids, aldehydes, ketones, alkenes, primary amines, aromatics, esters, ethers, alkyl halides and aliphatic amine compounds
10	M. S. Subashini *et al*	Analysis of *Gymnema sylvestre* leaves	Alcohols, phenols, alkanes, alkynes, alkyl halides, aldehydes, carboxylic acids and aromatics
11	K. S. Tarang *et al*	Identification of functional groups present in Ethanolic leaf extract of *Thymus linearis*	Alkyne, aldehyde, aromatic amine, aliphatic ether, anhydride, alkene, 1,2,4 trisubstituted, 1,4- disubstituted halo compound
12	K. Kalaichelvi *et al*	Screening of Phytoconstituents of *Micrococca mercurialis*	Alcohols, Phenols, Alkanes, Alkynes, Alkyl halides, Aldehydes, Aromatics, Nitro compounds and Amines.
13	M.B. Patil *et al*	Ethnobotanical, Phytochemical and FTIR study of *Catunaregam spinosa* species	FTIR spectral peak values for different functional groups were obtained for Leaf extract from Methanol, chloroform and ethyl acetate
14	K. Somendra *et al*	Pharmacological Validation of *Bridelia retusa*	Primary and secondary alcohols, alkenes, aldehyde, Primary and secondary amines, aliphatic bromo compounds, aliphatic ether, aromatic amines, acid halides, ester, halo compounds, vinyl ether and aromatic compounds
15	A.V. Sunila *et al*	Comparing FTIR fingerprint of fruits of *Pouteria campechiana*at different development stages	The fourth stage showed peak for C=O stretch of CO2 absorption

16	R. A. Bashir *et al*	Phytochemical screening and FTIR analysis of leaf and stem bark of methanolic extracts of *Khaya senegalensis*	Alcohol, alkanes, carbonyl and amines
17	S. C. Okereke *et al*	GC-MS/ FTIR analysis of methanolic extracts of *Tithonia diversifolia* leaves	Alcohols, phenols, aldehydes, ketones, alkanes and primary amines
18	T. Antony Sandosh *et al*	Phytochemical analysis of *Stylosanthes fruticosa*	Secondary alcohols, phenols, alkanes, alkenes, carboxylic acids, aromatics, nitro compounds and amines
19	Z. Yanli *et al*	Determination of Constituents of *Gentiana rigescens*	FTIR analysis combined with chemometric methods can accurately identify different origins of plant and rapidly predict content present in it
20	H. Subrahmaniam *et al*	Analysis of *Erythrina variegate* L.	Hydroxy group, aliphatic, metal carbonyl, alcohols, nitrile, phenols, alkynes, ketones, carboxylic acids, amide and aromatics
21	K. Saravanakumar *et al*	Analysis of *Pleiospermium alatum* leaves of methanolic extract	Amizone, alcohol, phenol, alkanes, protein, enzyme, isopropyl
22	P. Made *et al*	Phytochemical screening of *Enhalus acorodies* leaf extract	Hydroxy groups, lipids, alkanes, secondary amines, fatty acids, benzenoid compounds and phenols
23	M.K. Oladunmoye *et al*	Antibacterial activity and FTIR analysis of *Gliricidia sepium* leaves	Alcohols, Aldehydes, alkanes, amide, alenes, aromatics, carboxylic acids, ketones, esters, ethers, phenols, primary amines, aliphatic bromo compound, aryl disulphide and aliphatic amine compounds
24	H. H. Rafid *et al*	Antimicrobial metabolites analysis of *Salvadora persica*	21 Bioactive compounds were identified in the plants methanolic extract
25	A. Kumari *et al*	Phytochemical screening of *Glycyrrhiza glabra* root extracts	62% pure glabridin was compared to the spectra shown by ethanol, methanol and ethyl acetate extracts
26	V. Anusuba *et al*	Analysis was done on *Cucumis dispaceous* species	Alcohols, phenols, alkanes, alkynes, alkyl halides, aldehydes, carboxylic acids, aromatics, nitro compounds and amines
27	AR Florence *et al*	Worked on *Gmelina asiatica* L. leaves	Alcohols, phenols, alkanes, alkynes, alkyl halides, aldehydes, carboxylic acids, aromatics, nitro compounds and amines
28	K. Showmiya *et al*	Phytochemical screening and FTIR analysis of *Citrus maxima* L.	Amide, alkenes, alkyne, alkane, ether, alcohol, ketone, alkyl halides and aromatic gropus
29	Dr. R. Selva Raju *et al*	Worked on spectroscopic analysis of *Ocimum gratissmium* leaf powder	Alcohols, phenols, alkanes, alkynes, amides and esters, alkyl halide

Conclusion

Herbal medicines or phytomedicines are mostly used since ages from thousands of years in the primary health care of society and community of both Developed and Developing countries. Phytomedicines or herbal medicines mainly include whole plant, herbs, extracts, isolated compounds, polyherbal preparations, phytoformulation etc. Identification of bioactive compounds from phytomedicines plays a very important role in drug development and drug design process. The characterization of phytomedicines is very much essential in the identification of compounds. Spectroscopy and Chromatography methods are important in the process of identification. FTIR is widely used technique mainly used to identify functional groups in herbal medicines. The present review concludes that the FTIR spectroscopy plays very much essential role in the identification and characterization of bioactive compounds from herbal medicines.

List of Abbreviations

- FTIR: Fourier Transform Infrared Spectroscopy
- WHO: World Health Organization
- Infrared: IR

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Figure 1: Molecular FTIR Fingerprinting of Sulphanilamide

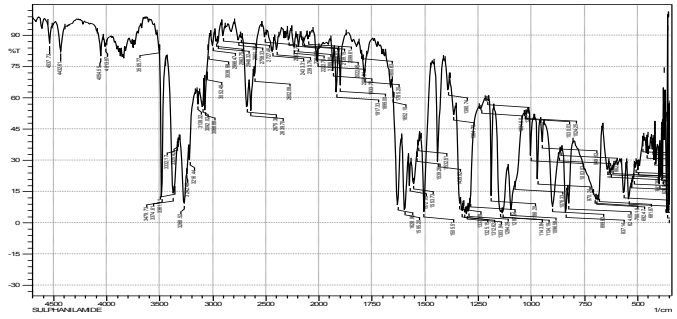


Figure 2: Instrumentation of FTIR Spectroscopy

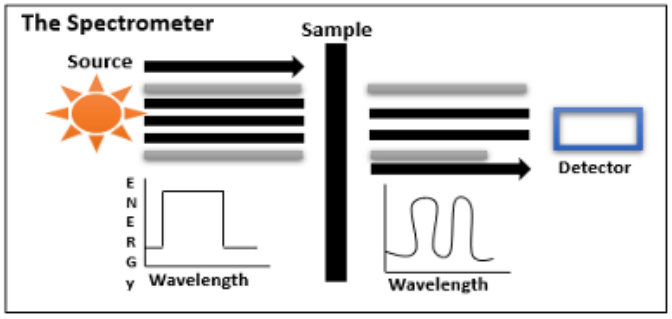


Figure 3: General Principle of FTIR Spectroscopy

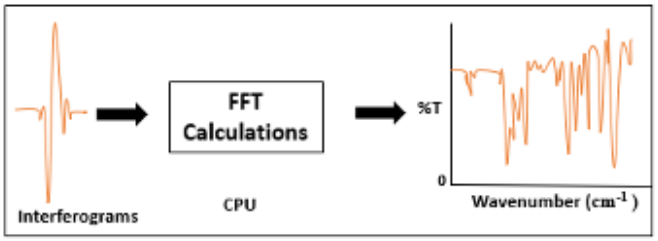
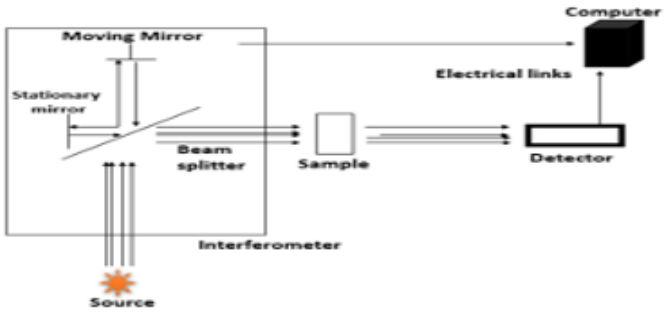


Figure 4: General representation of Instrument of FTIR



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