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3. Emerging Trends in Microwave Chemistry Assisted Extraction of Phytochemicals

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Learning Outcomes:

At the end of this chapter the reader will be able to understand:

- Introduction
- Microwave Chemistry: Principle, Benefits and Applications
- Microwave Assisted Extraction: Principle, Methodology, Advantages and Applications
- Microwave Aided Extraction Technology in Herbal Drug Research
- Microwave Assisted Extraction of Phytochemicals
- Studies using Microwave Assisted Extraction of Phytochemicals
- Conclusion

Abstract:

Plants are considered as natural factories for construction of wide range of phytochemicals. A large number of secondary metabolites like alkaloids, glycosides, tannins, phenolic compounds, resins and flavonoids are manufactured by plants. Developments in natural chemistry research led investigators to documentation and separation of diverse bioactive chemicals. These phytochemicals are widely used as therapeutic agents in treatment and management of various acute and chronic disorders and diseases. The superiority of active herbal preparation is considerably contributed by extraction techniques. Extraction is crucial and first most important step in the development of phytochemicals. Conventional extraction techniques reported to possess few limitations and disadvantages. The principles of microwave chemistry are useful in order to overcome few of the limitations of conventional extraction techniques. Hence in the Microwave assisted extraction has been introduced. This is an effective and new tool with numerous benefits as compared to the old-style approaches of extraction. The important benefits of microwave assisted extraction

are in terms of reduction in cost, time of extraction, amount of solvent used, and energy consumptions. This chapter give brief overview on basic approach, principle and applications of microwave chemistry. This chapters also emphasizes on the microwave assisted extraction techniques and its applications towards the development of phytochemicals.

3.1 Introduction:

The Microwave region is lie in the electromagnetic range between the radio waves and infrared waves. They have wavelengths between 0.01 and 1 meter, and functions in a frequency array between 0.3 and 30 Ghz. Usually a frequency of 2.45 Ghz is utilized for laboratory activities like to conduct the chemical reactions as this waves proper penetration depth which are suitable for the laboratory reactions. Beyond 30 Ghz wavelength frequency, the microwave frequency overlaps with the radio frequency.

Generally, the microwave electromagnetic range is distributed into two categories namely sub-bands including the lower microwave frequency called as L band and the higher frequency known as W band. L band microwave frequency is mainly used for the purpose of communication and W band frequencies are used for the analytical techniques such as spectroscopic characterization. Microwave chemistry is the branch of chemical science which involves the study and utilization microwave radiation to chemical synthesis.

Microwaves action as high frequency electric fields and mainly causes the heating of any material. It generates the mobile electric charges, such as polar molecules in a solvent or accompanying ions in a solid. Thus the microwaves are widely used in various industries including pharmaceutical, biotechnology, chemicals, petroleum and polymer industries.

The Microwave-assisted reactions are fast, clean, and economic and eco-friendly. The principles and approaches of microwave chemistry have been widely used in the natural products chemistry research as well to extract and isolate diverse chemical entities from natural sources like plants and minerals.

3.2 Microwave Chemistry:

In the year 1946, the technology of Microwave technology was originated and discovered. It was started with research performed by Dr. Percy Le Baron Spencer. He was performing laboratory examinations for a new vacuum tube known as magnetron. Magnetron is a device that produces an electromagnetic radiation.

During this experiment, accidentally he discovered that a candy bar in his pocket liquefied on exposure to radiations of microwave. In the year 1947, Dr. Spencer established the idea and recognized that microwaves might be used as a technique of heating.

Then, he intended the first microwave oven for domestic practice. Subsequently, in future years the expansion of microwave radiation and its applications were studied. Table 3.1 provides the information about development and evolution of Microwave chemistry.

Table 3.1: Development and Evolution of Microwave Chemistry

Sr. No.	EVOLUTION	YEAR
1	Discovery of Microwave radiation as heating method	1946
2	Introduction of first commercial domestic micro oven	1947
3	Development of first laboratory useful micro oven instrument	1978
4	Generation of microwave radiations to dry organic materials	1980-1982
5	Utilization of microwave radiation for analysis of chemicals	1983-1985
6	Publication of research papers related to applications of microwave radiation in synthesis of chemicals	1986
7	Emergence and development of Microwave Chemistry as a field of study due to its useful applications in chemical synthesis	1990
8	Development of first high pressure vessel for conducting full digestion of oxides, oils and pharmaceutical samples.	1990
9	Synthesis of chemicals based on microwave radiations using batch system reactor and single mode cavity system	1992-1996
10	Publication of book titled Microwave Enhanced Chemistry-Fundamentals, Sample Preparations, and Applications	1997
11	Introduction of first commercial microwave synthesizer to carry out the chemical preparation.	2000
12	Conduct of various research using microwave chemistry and its applications, commercialization, industrial utility, publication of research papers.	2022

3.2.1 Principle of Microwave Chemistry:

Microwave chemistry is the branch of chemistry that deals with study and applications of microwave radiations to conduct chemical reactions or chemical synthesis and chemical analysis. The approach of Microwave-assisted synthesis works on the basis of aligning dipoles of the substance in an external field via the excitation fashioned by electromagnetic radiations of microwave and is generally performed in mixture with an identified synthesis scheme.

This technique is moderately beneficial as the synthesis development can be modified to produce product with many advantages. The procedure of alignment or orientation of substance by the external electrical field may result in the creation of internal heat which is accountable for a decrease in processing time and energy requisite. It is particularly due to the heating consistency of microwaves. The reaction time can be fairly condensed by accepting microwave-assisted preparations.

A. Benefits of Microwave Chemistry:

Microwave chemistry has many benefits as mentioned below:

- Microwave radiation are extremely effective and used as heating source in chemical synthesis.
- Microwave chemistry is helpful in emerging the cleaner synthetic routes and procedures.
- Microwave chemistry helps to enhance the rate of chemical reactions and improve the percentage yield of product.
- Microwave chemistry helps to achieve the better reproducibility of reactions.
- It helps to deliver efficient and uniform heating to the chemical reactions.
- It also helps to provide the selective heating in a chemical synthesis schemes.

B. Applications of Microwave Chemistry:

The concept and approaches of microwave chemistry is widely used and applicable in various industries. The wide range of applications of microwave chemistry and related techniques are useful in various fields. Figure 3.1: Shows The Applications of Microwave Chemistry in Various Areas.

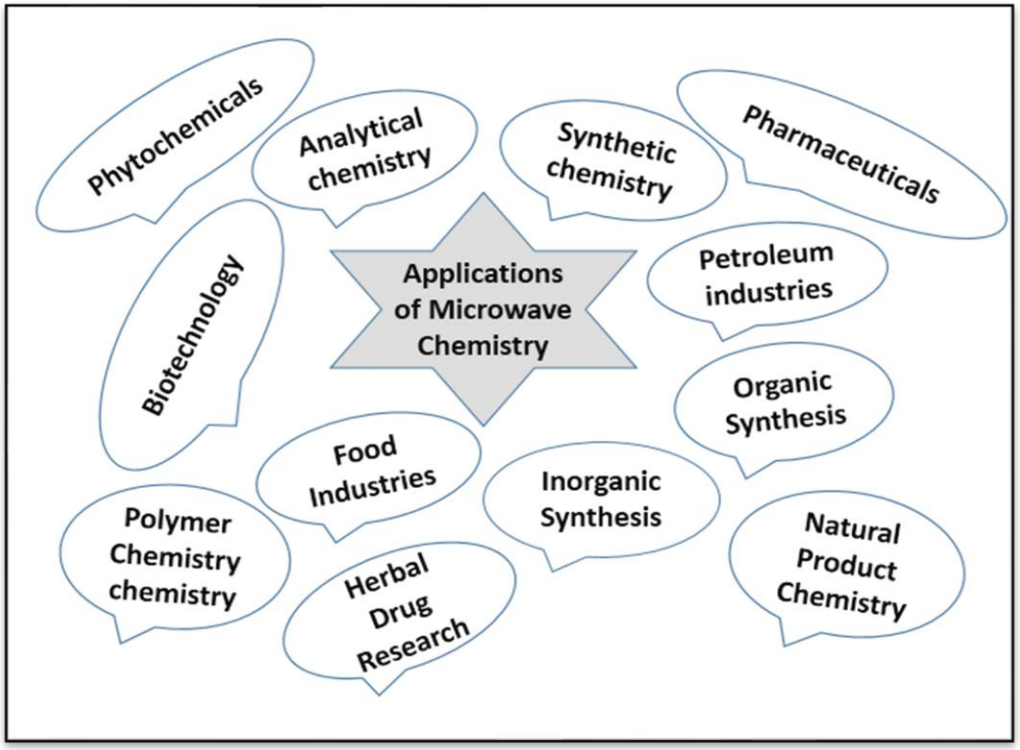


Figure 3.1: Applications of Microwave Chemistry in Various Fields

a. General Applications: The concept of microwave chemistry is widely used in various industries like biotechnology, pharmaceuticals, petroleum, plastics, chemicals and food industries. Various general applications of microwave chemistry are listed as below:

- The microwave chemistry is useful in the field of analytical and synthetic chemistry
- It has wide range of applications in natural products chemistry research.
- Microwave heating is extensively used for ashing in the petroleum and fuels, plastics, pharmaceuticals and food industries.
- Microwave digestion systems are used in analytical laboratories for sample decomposition and preparation.
- Microwave radiation used in trace and ultra-trace metals analysis.
- Microwave extraction is widely used in herbal drug research.
- Microwave assisted extraction systems are used to conduct routine solvent extractions of soils, sediments, sludge, polymers and plastics, pulp and paper, biological tissues, textiles and food samples.
- Microwave assisted moisture analysis has been widely used in the food and beverage, chemical, environmental, organic and pharmaceutical industries.
- Microwave moisture analysis is specifically applied at product development stages such as process and quality control, testing of raw materials, intermediate and finished products.

b. Applications in Chemical Synthesis: The application of microwave radiation are widely useful in the synthesis of large number of chemical moieties. It is widely used in the organic and inorganic synthesis in laboratories. The Microwave-enhanced preparations help the scientist to perform his work faster, get higher yields, and enhance the purity of product. Apart from this due to the advanced instrumentation and innovative research in Microwave chemistry, it has been observed that the yield of product is been scaled up from mg to kg. The techniques of microwave chemistry play valuable role in the organic and inorganic synthesis and few of the important applications are listed as below:

- **Applications in Organic Synthesis:** Organic synthesis can be defined as the synthesis of a preferred organic molecule by using precursors. The Microwave assisted organic preparation is one of the novel research area in the organic preparations as it gives better results with many advantages over the conventional routes and hence Microwave organic preparations are found to exert great role in the synthetic laboratories. The important applications of microwave synthesis in organic synthesis are highlighted as below:

- The Microwave assisted organic preparations are widely used in the pharmaceuticals companies, mainly in order to develop the molecules in the optimization of lead stage in the drug development.
- Literature reported that the scientist has been successfully used the approach of microwave synthesis in conduct of large number of named chemical reactions. Few of these reactions conducted using microwave techniques are listed below:

    - Condensation reactions
    - Cyclisation reactions

- Cycloaddition reaction
- Dehydration
- Diels Alder reaction
- Epoxidation
- Esterification

- Heck reaction
- Hydrogenation of [beta]-lactams
- Hydrolysis
- Mannich reaction
- Protection and deprotection of functional groups
- Reduction reactions
- Suzuki reaction

- **Applications in Inorganic synthesis:** Inorganic preparations can be defined as the preparation of a preferred inorganic compound from suitable precursors. The Microwave assisted inorganic compound synthesis is one of the innovative research region in the inorganic preparations as it gives better results with many advantages over the conventional routes and hence Microwave inorganic preparations are found to exert great role in the synthetic laboratories. The important applications of microwave synthesis in the field of inorganic synthesis are highlighted as below:

- The Microwave assisted inorganic preparations are extensively used in the pharmaceuticals companies, mainly in order to develop the inorganic molecules.
- Microwave chemistry is widely used in the preparation of organometallic derivatives.
- Microwave chemistry is also used in the synthesis of coordination compounds.
- It is used in the synthesis of intercalation molecules.
- It is also used in the preparation of ceramic products.

c. Applications in Polymer Chemistry: Polymer chemistry is one of the important field in the chemistry and it is mainly used in the preparation of Polymer products.

- The concept and approaches of microwave chemistry is widely used in the development of polymers and related products.
- The approaches of microwave techniques are also widely used in order to conduct the polymerization reaction.

3.3 Microwave Assisted Extraction:

The microwave assisted extraction is a model and newest green approach to an analytical method in which microwave radiation frequency is used for the extraction of chemical compounds or isolates particularly from plant materials. This technique utilized to extract the samples or chemical compounds from biological matrices for the purpose of its further analysis. Microwave assisted extraction is a procedure of utilizing the microwave energy to heat liquids in connection with a sample in order to distinct the chemical from the matrix into the liquid. Earlier microwave ovens are utilized for the digestion of samples for metal

analysis. All microwave ovens (Home or the laboratory used) are usually operate at 2.45 GHz frequency. The microwave region found to exists at frequencies of wavelengths from 0.3mm to 1m or 100 GHz to 300 MHz.

Principle of Microwave Assisted Extraction: The basic principles of the microwave assisted extraction method are different from traditional methods of extraction like solid-liquid or simple extraction techniques. As we know the electromagnetic radiations are known to cause the cell structure and this leads to the extraction. When the microwave radiation is passed through the matrix or plant materials, it causes the molecular communication with the wave. Thus the microwave radiation is converted into heat energy that supports the mass transfer from plant cell or material into the solvents. By using this principles, the phytochemicals can be extracted from plant materials by using microwave radiation. The traditional solvent extraction techniques from plant materials trust on the appropriate assortment of solvents and the use of thermal energy and agitation to recover the mass transfer and increase the solubility of the anticipated agent. Hence new system of microwave assisted extraction helps to condense the extraction time, less solvent ingesting, decrease the contamination and superior attention for thermolabile chemicals have added consideration.

Methodology: In order to perform the microwave assisted extraction two methods are utilized using different devices mainly:

- Open Microwave Assisted Extraction System/Atmospheric Microwave Assisted Extraction System
- Closed Microwave Assisted Extraction System/Pressurized Microwave Assisted Extraction System

a. **Open Microwave Assisted Extraction System/Atmospheric Microwave Assisted Extraction System:** In case this method the sample is situated in an open vessel to which a suitable organic liquid is placed. The microwave radiation produced from the magnetron is focused by the waveguide onto the sample/liquid, thus producing the liquid to boil. The hot liquid is then arising into interaction with a water cooled reflux condenser. This effects the liquid to condense and reappearance to the vessel. This procedure is recurrent for a little period of time so allowing compounds of interest to be come out from the sample material into the liquid.
b. **Closed Microwave Assisted Extraction System/Pressurized Microwave Assisted Extraction System:** In this case, the microwave radiations enter into the oven, and are detached by a mode stirrer. The mode stirrer permits an even delivery of microwaves within the oven. In this approach the sample and liquid are situated within the closed container which is typically prepared of microwave transparent resources such as polymers and their derivatives.

3.3.1 Advantages of Microwave Aided Extraction:

A prospective substitute to old-style solid liquid extraction method is the microwave assisted method. Microwave assisted techniques has good number of compensations over the traditional extraction and few of them are listed as below:

- Microwave assisted extraction technique helps to extract multiple samples for at a time.
- Microwave supported extraction method requires small quantity of liquid for extraction.
- Microwave aided extraction technique carries the extraction in very short period of time.
- Microwave assisted extraction gives the Improved yield.
- This technique gives improved accuracy in the results.
- This approach is suitable for the thermolabile chemical extraction.
- It requires remarkably less extraction period and the time of extraction usually extending from few seconds to few minutes.
- It requires very less amount of liquid in extraction and amount is a few milliliters.
- It shows also the better precision due to the automation of the apparatus.
- It is useful to extract heavy metals and pesticide deposit present in very minute units.
- It shows the improved mass transfer mechanism due to the agitation of sample vessels.

3.3.2 Applications of Microwave Supported Extraction Techniques:

The wide range applications of microwave aided extraction technology are listed as below:

- The microwave assisted technique is useful in order to extract large number of phytochemicals from the plant materials.
- It is widely used technique in the extraction of sample in herbal drug industries.
- It has showed the utilization in extraction of sample or analyte from the biological matrix in the bioanaytical laboratories in the clinical research.
- In the analytical research and development department of pharmaceutical industries this approach is extensively used.
- This approach is used in order to extract the secondary bioactive chemicals from the plant materials including alkaloids, glycosides, tannins, polyphenols, flavonoids, terpenes, lignans and phenolic derivatives.
- The closed vessel microwave method is used for the extraction of terpenes from plant material.
- The extraction of imidazolinone herbicides and sulphonylurea herbicides has been carried out and reported in the literatures.
- It has been also used in the extraction of fungicides like hexaconzole from weathered soil.
- The extraction of additives polypropylene and polyethylene has been achieved in the polymer chemistry and related research.
- It has been widely used in the food industries in the preparation of vitamins in foodstuffs.
- It can be used for determination of various metals and metallic compounds like Zn, Pb, and Cu from soils.
- Microwave aided extraction is a consistent source of extraction of phytoconstituents.
- It also can be used for the extraction of essential oils from plant sources.
- This technique also used in the analysis of heavy metals and other pollutants present in the different type soils.
- Microwave supported extraction is used in the synthesis and preparation of pharmaceuticals samples in the pharmaceutical industries.

3.4 Microwave Aided Extraction Technology in Herbal Drug Research:

Herbal medicines are also known as phytomedicines and they have been widely used by human culture. The plants are considered as natural factories for manufacture of numerous phytochemicals or plant compounds. A large quantity of secondary metabolites like alkaloids, glycosides, tannins, phenolic derivatives and flavonoids are manufactured by plants.

They act as a great source in the development of modern medicines. The advancements in natural chemistry sciences directed researchers to documentation and isolation of diverse bioactive phytocompounds. The one of the most important step in the development of herbal medicines include the extraction of plant samples. Based on the basis of physical nature and chemical properties of phytochemicals, several approaches are in procedure to gain the crude extract. Few of the conventionally used extraction techniques in herbal drug industries are listed as below:

- Infusion
- Digestion
- Decoction
- Percolation
- Maceration
- Soxhlet Extraction etc.

The above mentioned extraction techniques are used for the extraction of plant chemicals from plant material but at the same time they are also associated with some limitations and disadvantages like:

- Extraction time is more
- Solvent consumption is more
- Soxhlet extraction method is not suitable because in the method the targeted compound may undergoes the decomposition due to usage of high temperature.
- The traditional extraction technique carries the extraction in more time.
- The traditional extraction technique may give the less yield.
- This technique gives less accuracy in the results.
- This approach is not suitable for the thermolabile chemical extraction.
- It requires remarkably more extraction period and the time of extraction usually extending more than hours.
- It requires more amount of liquid in extraction.
- It shows also the less precision due to the non-automation in the extraction apparatus.
- Many time it is not useful to extract heavy metals and pesticide deposit present in very minute units.
- It shows the less mass transfer mechanism due to the poor agitation of sample vessels.

In order to overcome one or other limitations of the conventional methods the approach of microwave assisted tool has emerged due to its wide range of advantages as discussed earlier in this chapter.

A. Emerging Trends in Microwave Aided Extraction: A Competent and Modern Approach for Pharmaceuticals and Botanicals:

The microwave aided extraction is attentive and targeted technique of extraction of plant chemicals and can be effortlessly joined with other analytical devices like chromatographic techniques. Its treatment is additional made easier due to the automation of the apparatus. This approach is new and widely used in order to develop the modern medicines and pharmaceuticals from the various botanicals. There are many recent advancements and emerging trends in the development of microwave assisted solid extraction techniques from natural matrices. Some recent trends and applications are discussed in this chapter under below headings:

- Development of marker compounds
- Assessment of plant productivity
- Extraction of plant chemicals for drug development and its commercial applications.

a. Development of Markers: The microwave driven extraction tool is also reported for the development of marker compounds from the plant materials. Literature reported various methods and compound which are extracted and isolated using this approach and successfully used for marker based standardization of phytomedicines and related products**.** Few of the marker compounds extracted using microwave techniques are listed as below:

- Vitexin
- Isovitexin

b. Assessment of Plant Productivity: The microwave driven extraction offers the opportunity for performing the multiple extractions which is suitable for the fast screening of an abundant set of samples to assess the efficiency of organisms. For example, in order to compare amount of coumarin and related compounds like melilotic acid, and o-coumaric acid, the microwave assisted technique can be used also it can be used to analyze the productivity of *Melilotus officinalis* plant.

c. Extraction of plant chemicals for drug development and its commercial applications: The plant compounds isolated from the medicinal plants are widely used in the management and treatment of various diseases and disorders. The plant secondary metabolites include alkaloids, flavonoids, tannins, terpenes, polyphenols and many other functional derivatives. The microwave assisted extraction tool has been reported in the literatures in order to extract these plant secondary chemicals with better extraction and activity reports. Few of the examples of such microwave assisted extracted chemicals are discussed as below:

- **Extraction of Alkaloids:** The alkaloids are a famous class of secondary metabolites characterized by the presence of basic nitrogen. These class of compounds are widely used as therapeutic agent in very small amount. Over the years, many active alkaloids have been extracted microwave irradiation tools. Few important examples of execrated alkaloids by this tool are listed as below:

- Extraction and isolation of ephedrine, cocaine, and ergot alkaloids has been reported by using microwave extraction tool.
- An efficient microwave supported extraction protocol as a drug discovery process has been reported for the extraction and isolation of bioactive alkaloids like neferine, dauricine, liensinine, isoliensinine, nuciferine from *Lotus plumule* plant.
- The simultaneous microwave assisted extraction protocol have been developed for the collection of cocaine, cocaethylene, benzoylecgonine, morphine, 6-monoacethylmorphine, and codeine from human urine, hair, and vitreous humor samples.
- The microwave aided aqueous two phase extraction protocol has been reported for the rapid and simultaneous extraction and separation of alkaloids like oxymatrine, Matrine, 5α-hydroxysophocarpine, sophocarpine, oxysophocarpine, cytisine, N-methylcytisine, sophoranol, and sophoridine etc. from the plant *Radix Sophorae tonkinensis*.
- Recently literatures have reported the microwave supported extraction protocol for multicomponent analysis and the extraction of Berberine and polyphenol chemicals from various plant species of *Berberis*.
- Microwave extraction tool also has been used for the extraction of cocaine and benzoylecgonine from the leaves of *Erythroxylum coca.*

- **Extraction of Stilbene-based Polyphenolic Chemicals:** The Stilbene-based polyphenolic chemicals have been widely used as antibacterial, anti-inflammatory, hypolipidemic, cardiovascular, anti-diabetic, anti-ulcer, hepatoprotective, and anticancer agents. The few examples of useful Stilbene-based Polyphenolic Chemicals extracted by using microwave radiations includes: *trans*-resveratrol (3, 5, 4′-trihydroxystilbene), pterostilbene, viniferin, and other polyphenolic-stilbene derivatives etc.
- **Extraction of Terpenoids:** The Terpenes and isoprenoids, in general, expanded much consideration for their many biological functions like hormones, aliphatic tissue anchors, upholding tissue structure, biotic roles like defense compounds, insect or animal attractants, and wide medicinal uses such as flavors, fragrances, and drugs etc. Few examples of terpenes and related derivatives which are extracted using microwave techniques are listed as below:
    - Artemisinin from *Artemisia annua*
    - Paclitaxel from *Taxus baccata L.*

3.5 Microwave Assisted Extraction of Phytochemicals:

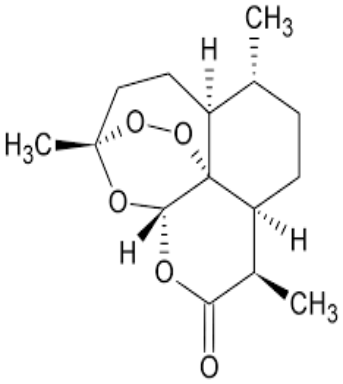
The extraction includes separating dissolvable chemical from non-dissolvable material using suitable liquids. There are two groups of extraction techniques reported for phytochemicals collection namely the traditional and modern extraction techniques. The list of traditional extraction methods includes the Soxhlet, soaking, maceration, digestion, decoction etc. These traditional extraction tools are associated with some limitations. In order to overcome the limitations of older extraction techniques few modern extraction techniques are evolved which includes turbo-fast blending, sonication, ultrasonic aided, subcritical, supercritical, enzyme assisted, pressure assisted, and microwave assisted techniques. Out of all these listed modern methods of extraction, the microwave supported

extraction has established the highest responsiveness due to its condensed consumption of liquid, less operation time, good reproducibility, improved recovery, upright selectivity, and condensed sample manipulation. In recent years, the microwave assisted extraction is usually used in gaining the chemicals of bio origin from plant materials. This has significantly improved the total attention in expansion and growth of research areas in plant chemistry research. It is a green expertise that is operational for taking out the plant compounds from plant sources. The microwave supported extraction has been employed in several ways to extract bioactive compounds from different plant samples. The isolates from these plant materials are being used in nutraceuticals and pharmaceutical uses. The microwave irradiation is mostly used to resolve some of the drawbacks associated with traditional methods. Table 3.2 presents some of the previous studies and the list of phytochemicals extracted from plants using microwave aided technology. The chemical structure of selected phytochemicals extracted using approach of microwave chemistry are given in Karnataka, India.

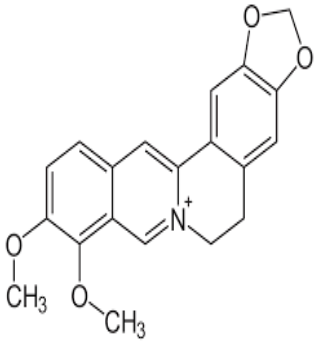
Table 3.2: List of Phytochemicals Extracted by Microwave Chemistry Approach

Sr. No.	Phytochemicals	Source of Plant
1	Artemisinin	*Artemisia annua* L.
2	Berberine	*Berberis aristata*
3	Coumarin	*Melilotus officinalis*
4	Caffeine	Green tea leaves
5	Carvone	*Carum carvi* L.
6	Carvone	*Mentha crispa* L.
7	Curcumin	Turmeric plant
8	Eugenol	*Ocimum basilicum* L.
9	Glycyrrhizic acid	Licorice roots
10	Isorhamnetin-3-O-rutinoside	Sea buckthorn
11	Limonene	*Carum carvi* L.
12	Limonene	*Mentha crispa* L.
13	Linalool	*Ocimum basilicum* L.
14	Monoterpenes	*Lavandula angustifolia* Mill.
15	Oxygenated monoterpenes	*Lavandula angustifolia* Mill.
16	Pectin	Grape fruis

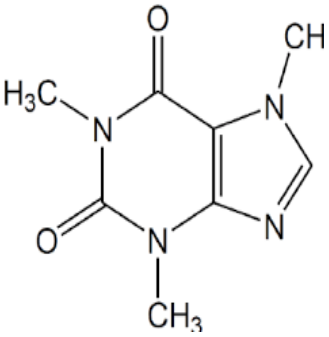
Sr. No.	Phytochemicals	Source of Plant
17	Phenolics chemicals	*Cinnamomum zeylanicum*
18	Polyphenols	Green tea leaves
19	Quercetin	Cranberry
20	Quercetin 3-O-Glucoside	Sea buckthorn
21	Sesquiterpenes	*Lavandula angustifolia* Mill.
22	Silybinin	*Silybum marianum* (L.)
23	Triterpene saponins	*Xanthoceras sorbifolia* Bunge.
24	5,8-Dihydroxycoumarin	Sweet grass leaves
25	5-Hydroxy-8-O-β-D-glucopyranosyl-benzopyranone	Sweet grass leaves



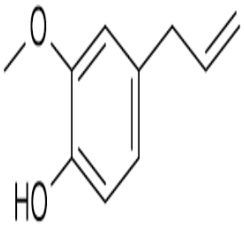
Artemisinin



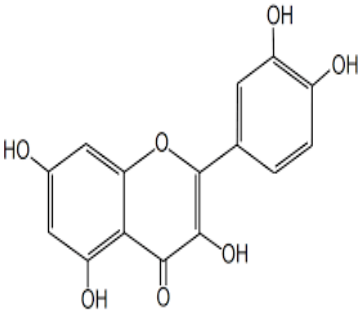
Berberine



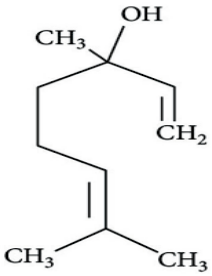
Caffeine



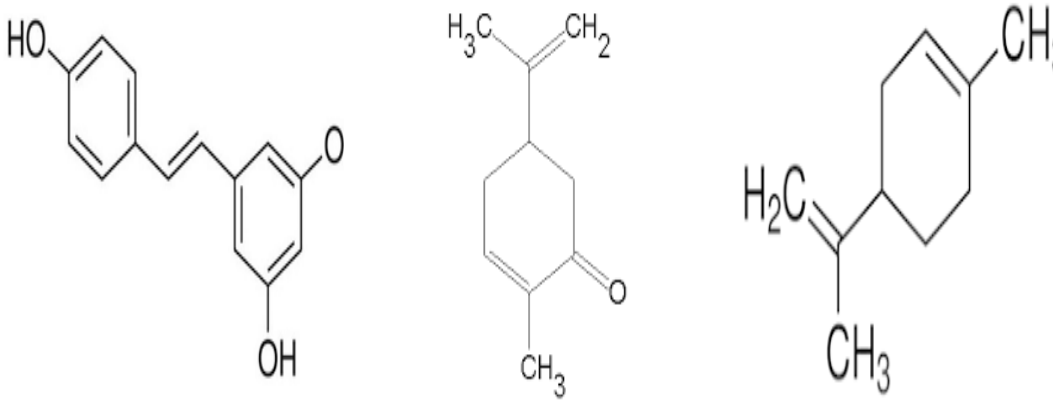
Eugenol



Quercetin



Linalool



Resveratrol **Carvone** **Limonene**

Figure 3.2: Structures of Phytochemicals Extracted by Microwave Chemistry Approach

3.6 Studies Using Microwave Assisted Extraction of Phytochemicals:

a. **Microwave Aided Extraction of Plant Chemicals from Ficus racemosa:** This research was conducted and published in the literature to optimize the microwave aided extraction procedure for the pulling out of plant chemicals from fruits of Ficus racemosa, which is measured as an underutilized and extreme basis of numerous polyphenols. The extreme phytochemical characteristics were found in the optimized conditions using 30 second of time 3.5 of pH, and 360.55 W microwave power using microwave oven. The research work further identified and quantified the presence of ascorbic acid, catechin, gallic acid, tannic acid, and quercetin. The research showed that F. racemosa can be positively applied for the extraction of phytochemicals by microwave supported extraction technique, which can be further used in food and pharmaceutical productions.
b. **Microwave Aided Extraction of Plant Chemicals from *Nonea pulmonarioides:*** In this research investigation the microwave supported extraction tool was selected to isolate the secondary plant chemicals from *Nonea pulmonarioides*. They suggested that the microwave chemistry approach in extraction is an efficient method. In this study of *N. pulmonarioides*, extracted using microwave extraction technique they found that the faster extraction was obtained in 5 minutes of time with an more yield than the maceration extraction technique. The phytochemical screening specified the existence of several classes of plant secondary compounds.

3.7 Conclusion:

The microwave assisted extraction technique has quickly grown during the latest periods as a technique for the extraction of secondary plant compounds which are of pharmaceutical and nutraceuticals attention. This is a model and innovative approach utilized for the extraction of phytochemicals due to several advantages like less extraction time, decrease in the solvent consumption, more precision and accuracy in results, better yield, and

multiple sample extraction etc. This technique has proven to be operative in all features, including inexpensive and practical, compared to old-style extraction practices. Microwave supported technology showed the effective role in the extraction of plant secondary chemicals including alkaloids, flavonoids, terpenes, polyphenols, Coumarin derivatives, and saponins etc. The advanced instrumentation leads to better extraction and it has helped to develop the modern medicines for management of various diseases and disorders. Hence microwave assisted extraction technique is considered to be an emerging trend and one of the model approach in the field of natural products chemistry research especially it has gained more attention and scope in the phyto chemistry and drug development research.

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