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A SYSTEMATIC REVIEW ON CONVENTIONAL AND MODERN EXTRACTION METHODS FOR MEDICINAL HERBS

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Extraction Methods, Herbal extraction, Comparative study, Phytochemical extraction, Extraction efficiency

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ABSTRACT: Herbal medicine has been used for thousands of years, with early records from the Sumerians and continued global use, especially in developing countries. Despite the rise of synthetic drugs like aspirin, interest in plant-based treatments remains strong due to the limitations of conventional medicine and the belief in the safety of natural products. About 25% of modern drugs originate from plants. Traditional extraction methods like maceration, percolation, infusion, and decoction have long been used, but they are time-consuming and less efficient. To improve yield and efficiency, advanced extraction techniques like Soxhlet extraction, steam distillation, microwave-assisted extraction (MAE), ultrasound-assisted extraction (UAE), and supercritical fluid extraction (SFE) have been developed. Each method varies in effectiveness, required expertise, cost, and environmental impact. The efficiency of extraction depends on factors such as solvent choice, particle size, and temperature. Despite advances, traditional methods are still valuable for their simplicity and accessibility.

INTRODUCTION: For centuries people have used plants for healing. Plant products ñ as parts of foods or botanical potions and powders ñ have been used with varying success to cure and prevent diseases throughout history. Written records about medicinal plants date back at least 5000 years to the Sumerians, and archeological records suggest even earlier use of medicinal plants. The strong historic bond between plants and human health began to unwind in 1897, when Friedrich Bayer and Co. introduced synthetic acetyl salicylic acid (aspirin) to the world.

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Aspirin is a safer synthetic analogue of salicylic acid, an active ingredient of willow bark, and was discovered independently by residents of both the New and Old worlds as a remedy for aches and fevers.

Herbal medicine is the use of plants, plant parts, their water or solvent extracts, essential oil, gums, resins, exudates or other form of advanced products made from plant parts used therapeutically to provide proactive support of various physiological systems; or, in a more conventional medical sense, to treat, cure, or prevent a disease in animals or humans about 70-80% of the world populations, particularly in the developing countries, rely on. On-conventional medicine in their primary healthcare as reported by the World Health Organization. In recent years, there has been growing interest in alternative therapies and the therapeutic use of natural products, especially those derived from plants. This interest in drugs of plant origin is due to several reasons, namely, conventional medicine can be inefficient (e.g. side effects and ineffective therapy), abusive and/or incorrect use of synthetic drugs results in side effects and other problems, a large percentage of the world's population does not have access to conventional pharmacological treatment, and folk medicine and ecological awareness suggest that natural products are harmless. However, the use of these substances is not always authorized by legal authorities dealing with efficacy and safety procedures, and many published papers point to the lack of quality in the production, trade and prescription of phytomedicinal products.

About 25% of the drugs prescribed worldwide come from plants, 121 such active compounds being in current use. Of the 252 drugs considered as basic and essential by the World Health Organization (WHO), 11% are exclusively of plant origin and a significant number are synthetic drugs obtained from natural precursors. Examples of important drugs obtained from plants are digoxin from Digitalis spp., quinine and quinidine from Cinchona spp., vincristine and vinblastine from. *Catharanthus roseus*, atropine from *Atropa belladonna* and morphine and codeine from *Papaver somniferum*. Herbs and spices are recognized source of bioactive compounds of many different chemical classes and with many real and potential applications in foods and medicines.

This fact has been recognized for millennia and thus there is a long history of the use of techniques to concentrate the substances responsible for the beneficial effects. The first record of the use of herbs for medicine can be found in Sumerian clay tablets from 4000 years ago, which included descriptions of the use of thyme (Thymus spp.) and licorice (*Glycyrrhiza glabra*) for medical applications. This practice then evolved toward the use of concentrates derived from medicinal herbs and some of the earliest techniques used were infusion and decoction; other techniques have evolved from these practices as practitioners recognized that extraction techniques could be designed to target particular groups of medicinal compounds. As outlined in other chapters in this book, extraction techniques have now evolved to the point where recovery of the compound is not only targeted at a particular group of compounds, but also designed to be as efficient as possible through recovering the highest yield while minimizing energy and the use of toxic solvents. Notwithstanding this, the basic principles of a targeted extraction remain the same. First, the source material is usually pretreated to physically facilitate release of the target compound from its intracellular location. This step can range from simple maceration to the use of high-voltage electric fields to puncture cell walls Medicinal and aromatic plant (MAPs) extracts are currently attracting much attention because of their interesting phytochemical composition that has led to the development of new pharmacological and cosmetic drugs.

Extraction represents a critical step in the itinerary of phytochemical discovery from MAPs. The final extract recovered can be substantially influenced by the type of extraction procedure used. For a long time, extract preparation has been carried out using numerous ethnic groups, using maceration, percolation, infusion, and decoction methods. These extraction techniques have been reported to be conventional. Continuing to improve the extraction process, during the 18th century a progressive form of the decoction methods was reported, named Soxhlet. However, these conventional methods, such as Soxhlet, have the disadvantage of requiring large solvent volumes and taking a long time to extract chemicals with poorer yields. To face these challenges, research was oriented toward advanced, non-conventional extraction techniques. These include microwave-assisted, ultrasonic-assisted, and supercritical fluid extractions. Moreover, these advanced techniques were reported to possibly have a lower extract quality.

Principles of Extraction: Extraction from herbs and spices for their medicinal and flavor-adding value has long been practiced, where the aim is to selectively separate bioactive compounds while maintaining optimum quality and quantity. Selection of the extraction process should be carried out in a manner that allows the extraction of bioactive compounds with maximum efficiency but also with specificity and selectivity to simplify the subsequent separation steps.

The principle of extraction lies in the distribution of a component into two immiscible phases, which further enable the separation and recovery of these compounds. The analyte will be distributed between the two phases according to the distribution constant, temperature, and the relative volumes of the phases. However, the extraction rates are based on the migration kinetics and hence are governed by the temperature and diffusion rate in the two phases (Smith 2003). This book details novel methods for the extraction of bioactives from herbs and spices.

These methods have some advantages over conventional techniques in terms of energy efficiency and yields; however, in many cases there are issues with up scaling, capital investment costs, and the technical expertise required to carry them out. Therefore, this chapter examines the use of conventional extraction techniques which benefit from relatively low capital costs, the availability of off-the-shelf systems, and are simple to carry out. Based on the physical state of herbs and spices, conventional extraction processes can be divided into liquid–liquid and solid–liquid extraction (SLE).

The Process of Drug Extraction can summarily be divided into Four Essential Steps:

1. Penetration of the solvent into the drug.
2. Dissolution of constituents.
   Outward diffusion of the solution from the cells.
3. Separation of dissolved portion and the exhausted drug.

The Efficiency of Drug Extraction Depends, Therefore, upon the following:

1. Nature and properties of the drug and its extractable constituents.
2. The particle size of the powdered drug.
3. The nature of the solvent.
4. The state of contact between the solvent and the drug particles.

A History of the Uses of Herbs: Herbs have been used for many purposes, including as ingredients for medicinal products, beauty enhancers, fragrances, and food. In the case of beauty enhancers, the natural components in herb products are easily absorbed by the human skin, and are both safe and compatible with human body, as natural ingredients that have demonstrated no known toxicity. Natural products in skincare formulations have been shown to exhibit significant antioxidant, emollient, and UV–B protection properties.

In the early nineteenth century, the first chemical analyses performed by scientists were utilized to determine the active ingredients from plant extracts, which subsequently led to the development of natural (traditional) medicines that had been passed historically through generations by words of mouth. Many of the herbs and spices used for food seasoning also yield useful medicinal compounds. Simple preparation methods for processing the plant herbs by boiling either the entire plant or selected parts of the plant have been employed by herbal medical practitioners for over 5,000 years.

Traditional Extraction Methods:

Maceration: Maceration was carried out on the shaker (Unimax 1010, Heidolph, Germany) at room temperature using three particle sizes (0.3, 0.7 and 1.5 mm), three solid-to-solvent ratios (1:10, 1:20and 1:30), five types of solvent (30%, 50%, 70% and 96% ethanol and water) and five extraction times (5, 15, 30, 60 and 90 min).

In our preliminary screening, slight decline in TP yield at 90 min, particularly after 120 and 150 min (data not shown) could be noticed as a result of maceration. This is in accordance with the previous findings that prolonged extraction time causes decrease of TPC in ethanol extracts of wild sage already at 60 and 90 min, as well as in extracts of henna after 90 min. Extracts were obtained by maceration of 2.50 g, 1.25 g and 0.83 g of plant material in an Erlenmeyer flask (100 mL), according to the solid-to solvent ratios, with 25 mL of every type of extraction solvent.

The flasks were covered with aluminum foil to avoid light exposure and ethanol evaporation. Obtained extracts were filtered through a cellulose filter (fine pore, 0.45 µm) and reconstituted filtrates were properly diluted with the solvent to the required concentrations.

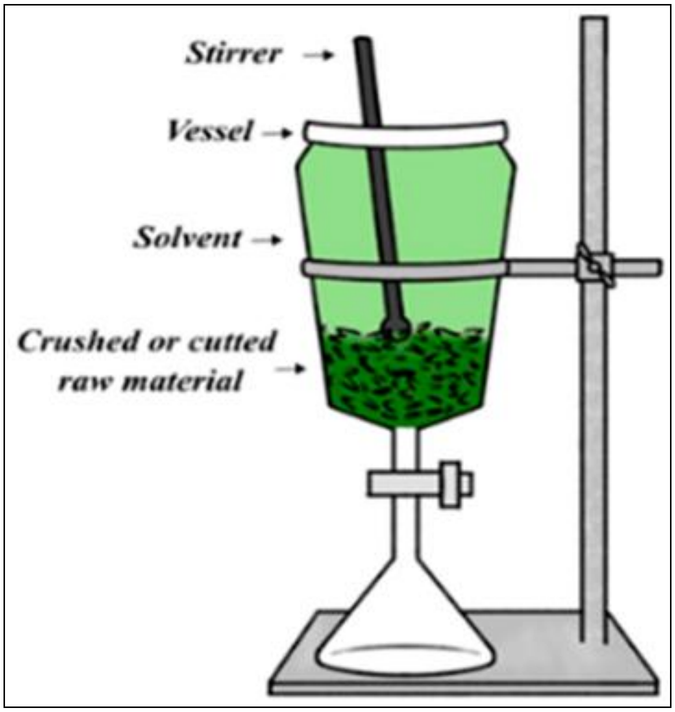


FIG. 1: MACERATION EXTRACTION METHOD

Advantages:

1. Maceration is a simple method using non-complicated utensil and equipment.
2. Skilled operator not required.
3. Energy saving process.
4. For certain substances which are very less soluble in solvent and requires only prolonged contact with solvent is ideal.
5. Suitable method for less potent and cheap drugs.

Disadvantage:

1. Unfortunately, the duration of extraction time is long and sometimes takes up to weeks.
2. Not exhaustively extract the drug.
3. It is very slow process and time consuming.
4. Solvent required is more.

Percolation: The present invention comprises an apparatus and methods for making herbal extracts. The apparatus employs a percolation vessel having a filter and discharge valve. A heater is provided to heat the contents of the vessel to up to about 60 °C. During the cold percolation process. A control is provided to monitor the contents of the vessel and regulate the heater output to obtain and maintain the proper temperature. A pump draws the output of the vessel and recirculates it to the vessel top so that the vessel effluent passes through the vessel charge. The method entails continuously percolating a solvent through a bed of herbaceous material in the vessel at a temperature between room temperature and about 60 °C. To produce an extract comprising active principles contained in the herbaceous material. The thus produced extract is highly concentrated and contains a large proportion of the active principles in the raw material. The thus-produced extract can be used in lower unit doses to provide enhanced medicinal treatment.

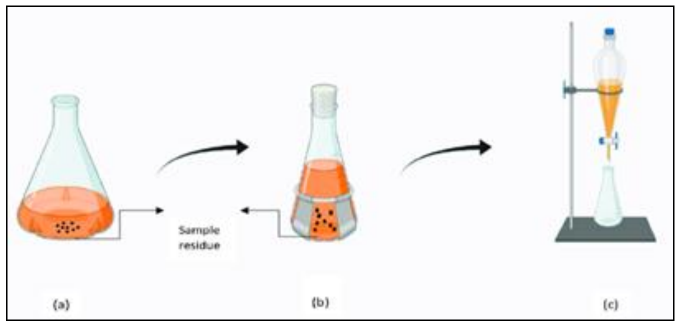


FIG. 2: PERCOLATION EXTRACTION METHOD

Advantages:

1. Requires less time than maceration.
2. Extraction of thermolabile constituents can be possible.
3. Suitable method for potent and costly drugs.
4. Short time and more complete extraction.

Disadvantages:

1. Requires more time than soxhalation.
2. More solvent is required.
3. Skilled person is required.
4. Special attention should be paid on particle size of material and throughout process.

Cold Pressing: Cold pressing is used to extract the essential oils from citrus rinds such as orange, lemon, grapefruit, and bergamot. The rinds are separated from the fruit, are ground or chopped, and are then pressed. The result is a watery mixture of essential oil and liquid, which will separate given time. It is important to note that oils extracted using this method have a relatively short shelf life, so make or purchase only what you will be using within the next six months.

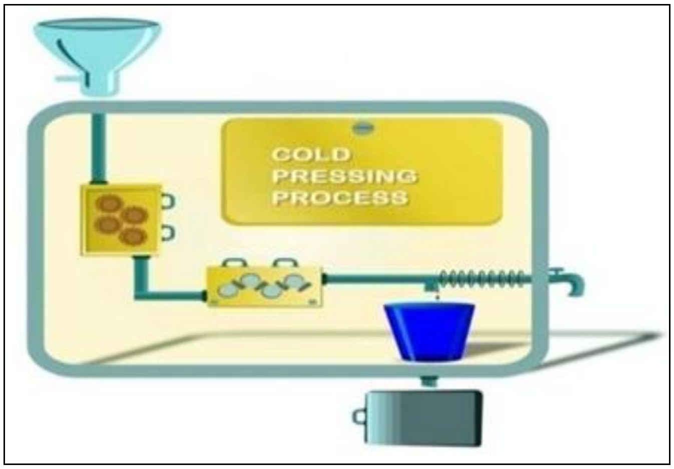


FIG. 3: COLD PRESSING EXTRACTION METHOD

Digestion: This is a form of maceration in which gentle heat is used during the process of extraction. It is used when the moderately elevated temperature is not objectionable, and the solvent efficiency of the menstruum is increased thereby.

Infusion: An infusion is a dilute solution of the readily soluble constituents of crude drugs. Fresh infusions are prepared by macerating the solids for a short period of time with either cold or boiling water. The USP has not included infusions for some time.

Decoction: This once-popular process extracts water-soluble and heat-stable constituents from crude drugs by boiling in water for15 min. cooling, and passing sufficient cold water through the drug to produce the required volume.

Advantages:

1. Suitable for extracting heat-stable compounds.
2. This method does not required more and expensive equipment.
3. It is easy to perform.
4. No need trained operator.

Disadvantage: Unfortunately, it is not advised for the extraction of heat sensitive constituents.

Strength and Limitation: This technique is the easiest and simple method. However, organic waste come into an issue as large volume of solvents is used and proper management of the waste is needed. Alteration in temperature and choice of solvents enhance the extraction process, reduce the volume needed for extraction and can be introduced in the maceration technique, when such alteration is not objectionable. Boiling *Centella asiatica* at 90°C showed to increase phenolics content and antioxidant activities, but jeopardized the pH of the extracts with increase extraction time in this method, solvents used in the soaking process play a critical role.

Different Methods of New Advances Extraction Techniques:

Steam Distillation Extraction: To extract the essential oil, the plant material is placed into a still (very similar to a pressure cooker) where pressurized steam passes through the plant material. The heat from the steam causes globules of oil in the plant to burst and the oil then evaporates. The essential oil vapour and the steam then pass out the top of the still into a water-cooled pipe where the vapours are condensed back to liquids. At this point, the essential oil separates from the water and floats to the top. Now, this doesn't sound like a particularly complicated process, but did you know that it takes more than 8 million Jasmine flowers to produce just 2 pounds of jasmine oil? No wonder pure essential oils are expensive.

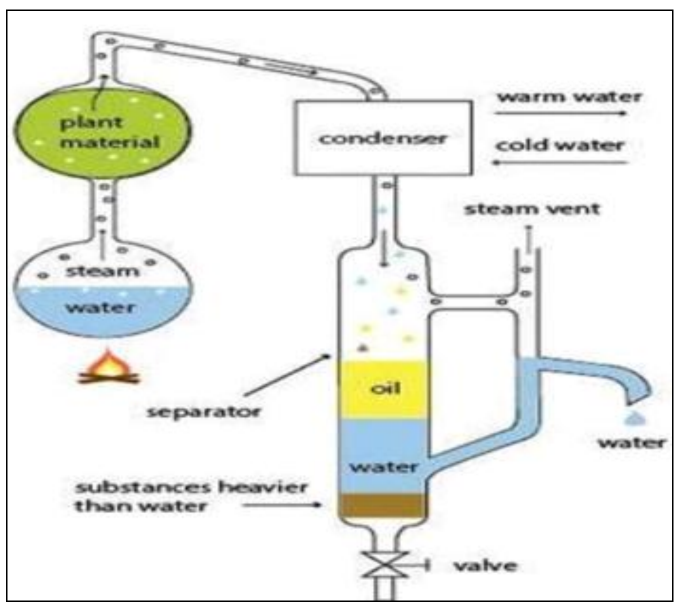


FIG. 4: STEAM DISTILLATION EXTRACTION

Soxhlet Extraction or Hot Continuous Extraction: In this method, finely ground sample is placed in a porous bag or "thimble" made from a strong filter paper or cellulose, which is place, is in thimble chamber of the Soxhlet apparatus. Extraction solvents is heated in the bottom flask, vaporizes into the sample thimble, condenses in the condenser and drip back. When the liquid content reaches the siphon arm, the liquid contents emptied into the bottom flask again and the process is continued.

Strength and Limitation: This method requires a smaller quantity of solvent compared to maceration. However, the Soxhlet extraction comes with disadvantage such as exposure to hazardous and flammable liquid organic solvents, with potential toxic emissions during extraction. Solvents used in the extraction system need to be of high-purity that might add to cost.

This procedure is considered not environmental friendly and may contribute to pollution problem compared to advance extraction method such as supercritical fluid extraction (SFE). The ideal sample for Soxhlet extraction is also limited to a dry and finely divided solid and many factors such as temperature, solvent-sample ratio and agitation speed need to be considered for this method.

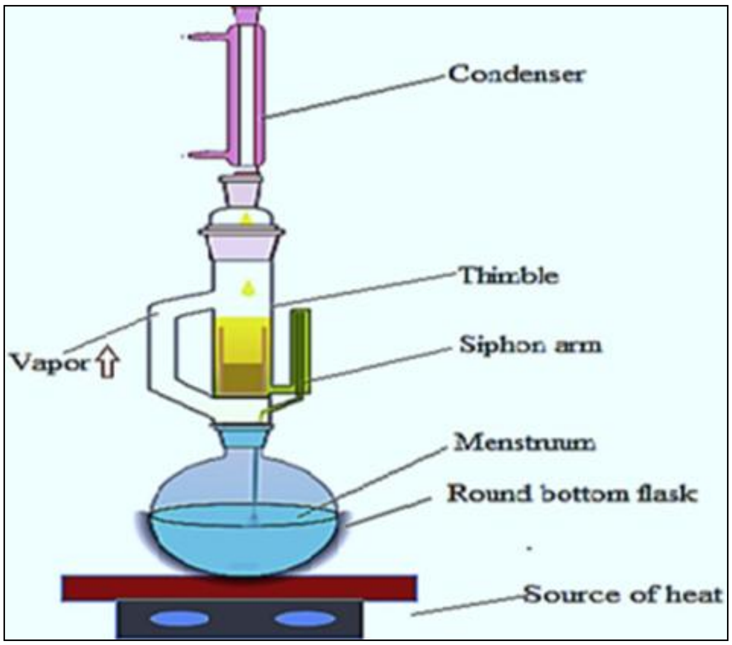


FIG. 5: SOXHLET EXTRACTION METHOD

Different Methods of a New Recent Advance in Extraction Techniques:

Microwave-Assisted Extraction Method (MAE): Microwave assisted extraction (MAE) is also an extraction technique based on heating an organic solvent. The principle is roughly that a sample and an appropriate solvent (or solvent mixture) are put in a vessel, which is then pressurized and heated by microwaves. After typically 5 to 20 min the extraction is complete, and the vessels are allowed to cool down before removing the sample/solvent mixture. The solvent must be filtered to remove sample particles prior to analysis of the extracted components. See figure 5 for a schematic of a MAE equipment. MAE is a more manual technique than PLE as it is performed in batch mode. However, many samples can be processed at the same time. Another feature of MAE is that the heating of the solvent is fast, it goes from inside the sample and outwards, and the heating capability depends on the microwave absorbing properties of the solvent. Polar solvents such as acetone will absorb microwave energy efficiently, as they have molecules with permanent dipole moment that can interact with microwaves. Non-polar solvents such as hexane will not be heated when exposed to microwaves, but can instead be used in mixtures with polar solvents in order to obtain the desired heating properties. Some common solvent mixtures that have been used in MAE are acetonitrile/methanol, hexane/acetone, ethyl acetate/cyclohexane, and isooctane/acetone.

Instrumentation of Microwave Assisted Extraction Techniques: There are two types of MAE vessels like closed type and open type. Both the system includes four common parts as given below:

Microwave Generator: Magnetron which produces microwave energy.

Waveguide: Spread microwave to the microwave cavity.

Circulator: Grant the microwave to change ahead.

Applicator: To set the test.

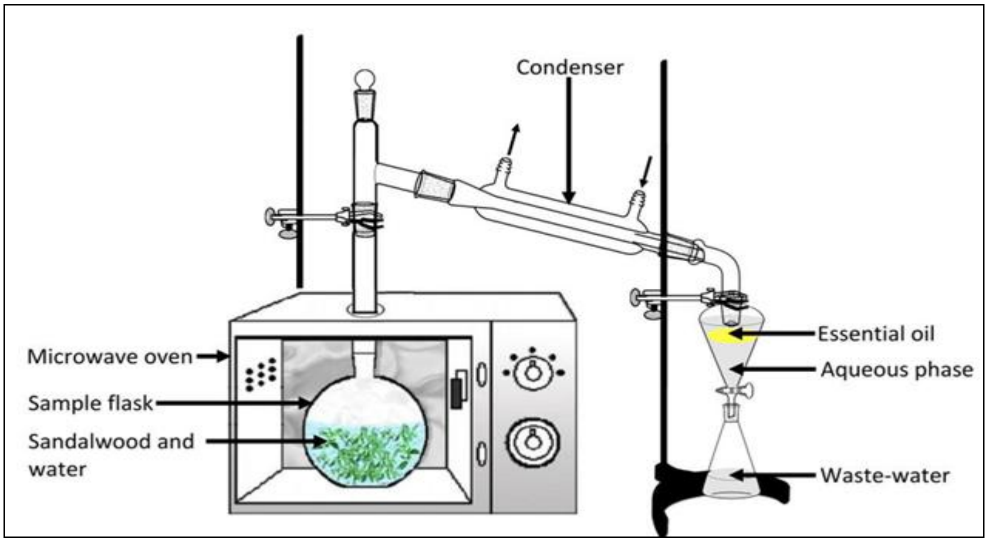


FIG. 6: MICROWAVE ASSISTED EXTRACTION METHOD

Supercritical Fluid Extraction Method: Extracting one or more components from the sample may be a prerequisite for analyzing complicated materials. The optimal technique for isolating and extracting these materials should be quick, simple, inexpensive, and ensure full recovery of the intended materials with no harm. It should also yield a concentrated solution that is acceptable for measurement, generate the least amount of trash, and avoid needless delays. In the past, challenging materials from the environment, medicines, food, and petroleum were frequently extracted using the Soxhlet extraction process using hydrocarbon or chlorinated organic solvent. Nevertheless, liquid extraction frequently falls short of several of the optimal requirements. A material that has been heated and compressed to the point that it behaves like a combination of a gas and a liquid is known as a supercritical fluid.

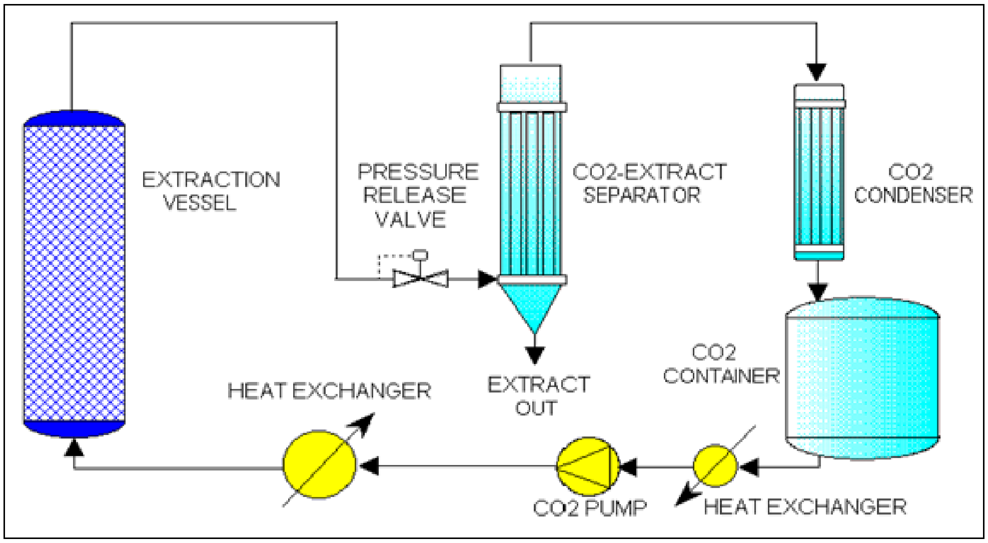


FIG. 7: SUPERCRITICAL FLUID EXTRACTION METHOD

Its unique characteristics may be altered by varying the pressure or temperature in the vicinity of this spot. Because of this, it may be utilized in scientific and industrial procedures in place of dangerous compounds. Two fluids that may become supercritical and are frequently employed in this state are carbon dioxide and water. Plants may be extracted using carbon dioxide without producing hazardous by products. Minor changes in pressure and temperature can accurately control its extraction characteristics.

Ultrasound-assisted Extraction (UAE) or Sonication Extraction: UAE involves application of high-intensity, high-frequency sound waves and their interaction with materials. UAE is a potentially useful technology as it does not require complex instruments and is relatively low-cost. It can be used both on small and large scale. UAE involves ultrasonic effects of acoustic cavitations. Under ultrasonic action solid and liquid particles are vibrated and accelerated and, because of that solute quickly diffuses out from solid phase to solvent. Several probable mechanisms for ultrasonic enhancement of extraction, such as cell disruption, improved penetration, and enhanced swelling, capillary effect, and hydration process have been proposed.

If the intensity of ultrasound is increased in a liquid, then it reaches at a point at which the intramolecular forces are not able to hold the molecular structure intact, so it breaks down and bubbles are created, this process is called cavitation. Collapse of bubbles can produce physical, chemical and mechanical effects which result in the disruption of biological membranes to facilitate the release of extractable compounds and enhance penetration of solvent into cellular materials and improve mass transfer. The beneficial effects of sound waves on extraction are attributed to the formation and asymmetrical collapse of microcavities in the vicinity of cell walls leading to the generation of microjets rupturing the cells. The pulsation of bubbles is thought to cause acoustic streaming which improves mass transfer rate by preventing the solvent layer surrounding the plant tissue from getting saturated and hence enhancement of convection Skin of external glands of plant cell wall is very thin and can be easily destroyed by sonication, and this facilitates release of essential oil contents into the extraction solvent, thus resulting in reduced extraction time and increased extraction efficiency.

Ultrasound has the main advantage of shorter reaction/preparation time, usage of small amounts of material, efficient and minimum expenditure on solvents, and the increase in sample throughput. It is very useful for the isolation and purification of bioactive principles.

One disadvantage of the procedure is the occasional but known deleterious effect of ultrasound energy (> 20 kHz) on the active constituents of medicinal plants through formation of free radicals and consequently undesirable changes in the drug molecules.

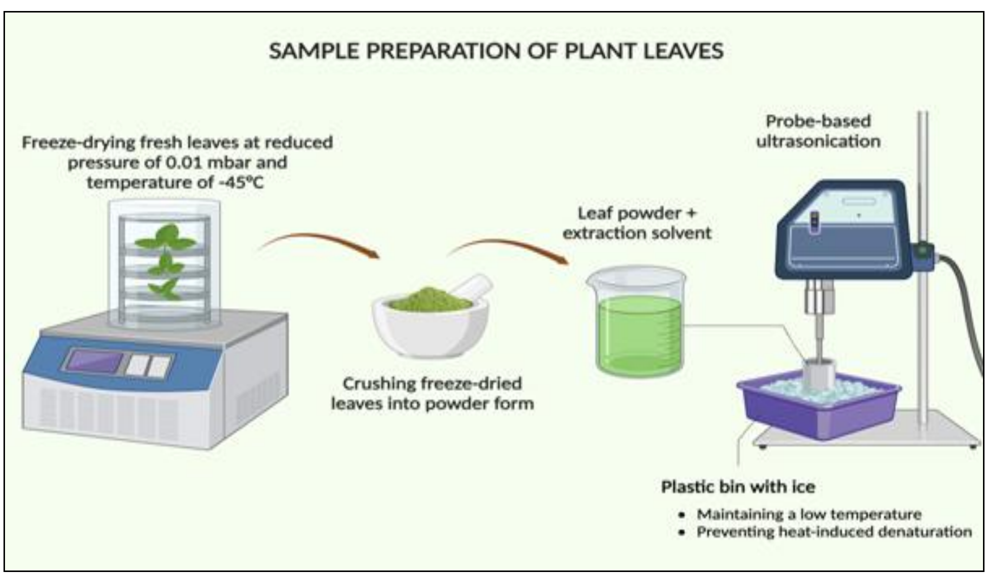


FIG. 8: ULTRASOUND-ASSISTED EXTRACTION METHOD

Stir-Bar Sportive Extraction (SBSE): SBSE has many similarities to SPME, as it is also a solventless sample preparation technique and it uses similar sorbents (based on PDMS). SBSE was first described by Baltussen and co-workers in 1999.In SBSE, an aqueous sample is extracted by stirring for a certain time with a PDMS-coated stir-bar. The stir-bar is thereafter removed from the sample and the absorbed compounds are then either thermally desorbed and analyzed by GC-MS, or desorbed by means of a liquid for interfacing to a LC system. Heat-desorption gives higher sensitivity while liquid desorption provides higher selectivity. Headspace sorptive extraction (HSSE) is a similar technique developed by Bicchi *et al.* in 2000. In HSSE, a PDMS stir-bar is used for head-space sampling of volatile organic molecules. This technique also has similarities to HS-SPME. There are several review articles discussing and comparing HSSPME, DI-SPME, SBSE and HSSE. A stir-bar in SBSE is coated with up to 125 pL PDMS, which enables quantitative extraction of many organic compounds from aqueous samples of 10-100 mL in volume. This should be compared to the situation in SPME, where the maximum volume of PDMS that can be coated onto the fiber is around 0.5 |iL (100 \xm thick coating). Hence, compared to SPME, SBSE offers a favorable alternative for quantitative analysis with much higher sensitivity and repeatability. Another advantage is that just as with SPME, no organic solvent is required for the extraction. However, SBSE is not as easily coupled on-line to other separation techniques such as GC and HPLC. Common applications for SBSE (and HSSE) are the analysis of PAHs in drinking water flavors and off-flavors in food samples, and benzoic acid and other preservatives in beverages. The technique has also widely been used for pesticide analysis in sample matrices like wine, grapes, honey, and other food matrices. The parameters to optimize in SBSE are similar to those in SPME.

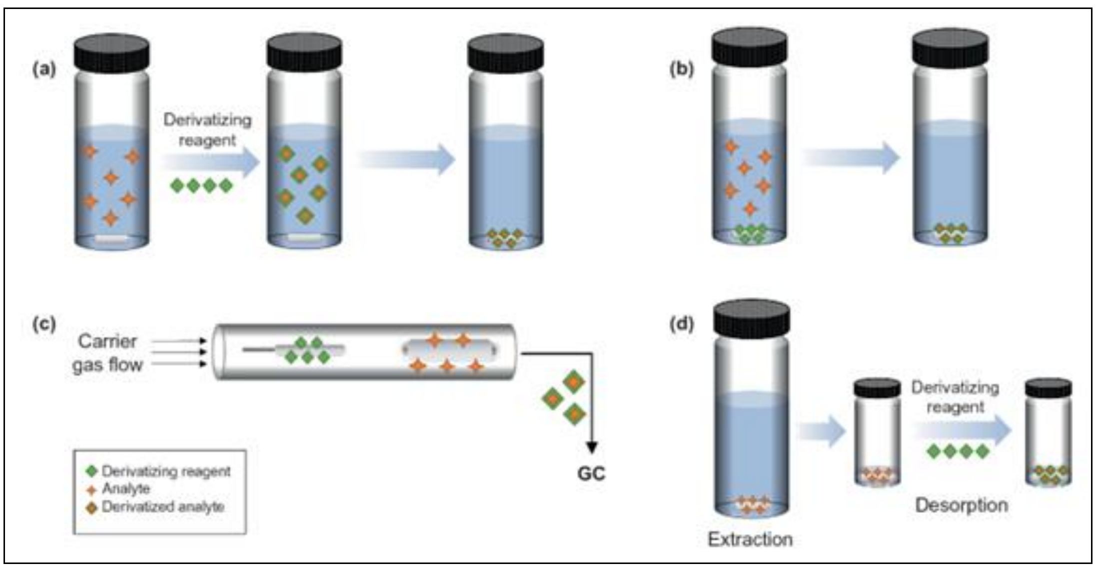


FIG. 9: STIR-BAR SPORTIVE EXTRACTION METHOD

Accelerated Solvent Extraction (ASE): Accelerated solvent extraction (ASE) is performed at elevated temperatures (50 to 200°C) and at pressures between 10 and 15 MPa maintaining the solvent in liquid form. These conditions tend to enhance the solvent diffusivity and accelerate the extraction process. Giergielewicz-Możajska shows the ASE equipment used in experimental work. There is a pressurization system that creates and applies pressure to the pressure vessel. The temperature and pressure in this system are set to be constant. The sample, together with the solvent are placed in the closed container inside the pressure vessel. The container is connected to a thermocouple to detect temperature change in the sample container. If temperature change occurs, the heating and cooling jacket (surrounding the sample container) will operate to keep constant the temperature inside the sample container. The pressure, on the other hand, is controlled by the pressure relief valve. When the pressure increases, the pressure relief valve will be opened to prevent pressure from building up. When the pressure decreases, the pressurization system will apply pressure to the vessel. Note that, pressure is only created when the pressure inside the vessel drops below the set pressure, thereby saving the pressurization energy during the extraction process. Note that the ASE method is normally applied for thermally-stable organic pollutants from environmental matrices. The ASE is not suitable for thermally labile compounds because the high temperature needed in the ASE method may lead to degradation of heat-sensitive compounds. This is perhaps the reason why very few applications of ASE have been published in the field of nutraceuticals.

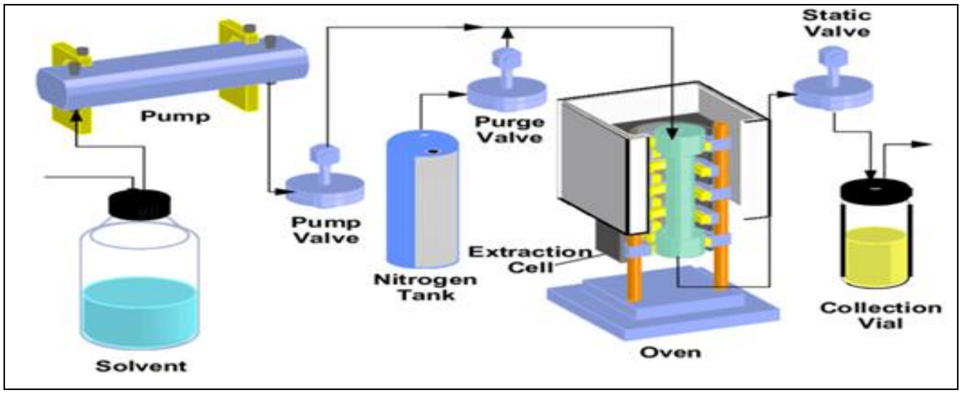
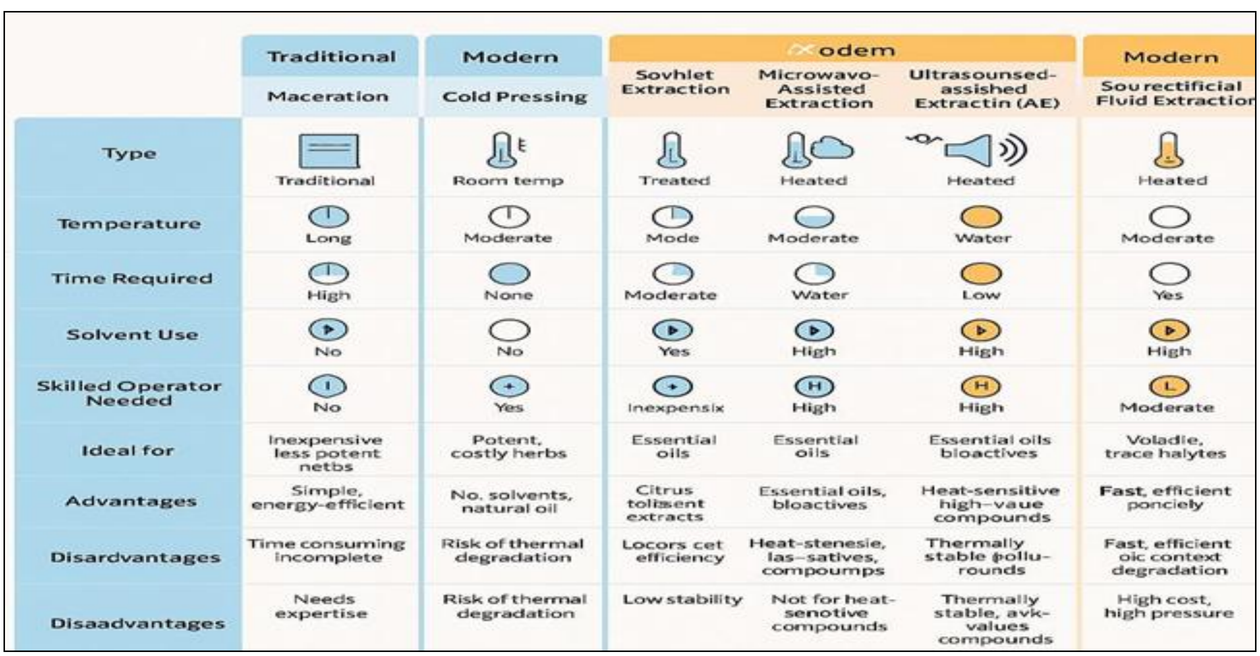


FIG. 10: ACCELERATED SOLVENT EXTRACTION METHOD

TABLE 1: COMPARATIVE STUDY OF TRADITIONAL AND MODERN XTRACTION METHOD

Traditional Extraction Methods	Modern Extraction Methods
Traditional methods like maceration, percolation, infusion, decoction, digestion, and cold pressing are easy to do and don't need expensive tools.	Modern methods, such as steam distillation, Soxhlet extraction, microwave-assisted extraction, supercritical fluid extraction, ultrasound-assisted extraction, stir-bar sportive extraction, and accelerated solvent extraction, use advanced machines and technology.
They are commonly used in local or small-scale herbal preparations.	These methods are faster, give better results, and use less solvent.
These methods are good for beginners and don't need much energy or training, but they take a long time and may not remove all the important parts of the plant.	They are especially useful when working with expensive or rare plants.
For example, maceration needs a long soaking time, and decoction, which involves boiling, is not good for delicate compounds that break down with heat.	However, they require trained people and more costly equipment, so they are mostly used in laboratories or industries.



	Traditional Maceration	Modern Cold Pressing	odem Sovhlet Extraction	Microwavo-Assisted Extraction	Ultrasounsed-assished Extractin (AE)	Modern Sou rectificial Fluid Extraction
Type	Traditional	Room temp	Treated	Heated	Heated	Heated
Temperature	Long	Moderate	Mode	Moderate	Water	Moderate
Time Required	High	None	Moderate	Water	Low	Yes
Solvent Use	No	No	Yes	High	High	High
Skilled Operator Needed	No	Yes	Inexpensix	High	High	Moderate
Ideal for	Inexpensive less potent netbs	Potent, costly herbs	Essential oils	Essential oils	Essential oils bioactives	Voladie, trace halytes
Advantages	Simple, energy-efficient	No. solvents, natural oil	Citrus tolisent extracts	Essential oils, bioactives	Heat-sensitive high–vaue compounds	Fast, efficient poncíely
Disardvantages	Time consuming incomplete	Risk of thermal degradation	Locors cet efficiency	Heat-stenesie, las–satives, compoumps	Thermally stable pollu-rounds	Fast, efficient oic context degradation
Disaadvantages	Needs expertise	Risk of thermal degradation	Low stability	Not for heat-senotive compounds	Thermally stable, avk-values compounds	High cost, high pressure

Both traditional and modern methods have their own advantages and disadvantages. Traditional methods are simple and low-cost, while modern methods are more efficient and powerful. Combining both approaches can help us get the best results when working with medicinal plants.

Modern Methods – More Effective Overall:
Higher Yield & Purity: Techniques like Supercritical Fluid Extraction (SFE) and Microwave-Assisted Extraction (MAE) can extract a higher concentration of active compounds with minimal impurities.

Better Selectivity: Supercritical CO_2, for example, can be tuned (pressure/temperature) to target specific phytochemicals.

Faster Processing Time: UAE and MAE drastically reduce extraction time from hours or days to minutes.

Environmentally Friendly: Many modern methods use less solvent or use green solvents like CO_2, reducing toxic waste.

Scalability: Suitable for industrial-scale production with repeatable and controlled results.

Traditional Methods-Still Useful, but Less Efficient:
Cost-Effective for Small Scale: Methods like decoction or maceration are ideal for local, home, or small herbal preparations. Gentle on Some Compounds: Cold pressing and some forms of maceration are mild, preserving certain sensitive compounds.

Culturally Rooted: Traditional methods are often tied to ethnomedicine and still relevant in community practices.

Therefore, Modern methods are generally more effective, especially for Extracting a broad range of compounds with high efficiency. Industrial, pharmaceutical, and nutraceutical applications. Meeting regulatory standards for quality and safety.

The More Useful Method for Extraction Depends on what you're trying to Achieve: For higher efficiency, better quality, and more yield, modern extraction methods like Microwave-Assisted Extraction (MAE), Ultrasound-Assisted Extraction (UAE), and Supercritical Fluid Extraction (SFE) are more useful. These methods are faster, use less solvent, and can protect sensitive compounds better than traditional methods. For small-scale, low-cost, and simple extractions, especially in areas with limited resources, traditional methods like maceration, infusion, or decoction are more practical and useful. Overall, if you have access to equipment and trained people, modern methods are generally more useful because they: Extract more active compounds Save time Are more consistent Work well with both common and rare plants But for simple needs or traditional medicine use, traditional methods still play an important role.

CONCLUSION: The use of medicinal plants remains an essential component of healthcare, especially in regions where access to conventional medicine is limited. While traditional extraction techniques have laid the foundation for herbal medicine, advancements in extraction technology have significantly enhanced the efficiency, yield, and quality of plant-based compounds. However, both conventional and modern methods have their own strengths and limitations. A balanced approach that combines traditional knowledge with innovative techniques offers the most effective and sustainable path for harnessing the therapeutic potential of medicinal plants

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