Section A-Research paper
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An Overview of Techniques for Extracting Bioactive Substances from Plants.

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Abstract:

Since bioactive chemicals are used in a lot of commercial sectors, including the pharmaceuticals, diet, and chemicals manufacturing industries, it is necessary to devise an extraction technique that is both suitable and standardized in order to get these active substances from plant parts. Addition to the traditional approaches, various novel methods have been developed; nonetheless, there is not one method that is universally acknowledged as the standard method for extracting bioactive chemicals produced by plants. The critical input criteria that have the greatest influence on the overall effectiveness of extraction methods, whether conventional or unconventional, include consideration of the chemical nature of the plant, the chemistry of bioactive components, and the required level of scientific experience. This investigation's objective is to investigate a lot of different ways of the of pharmacologically active chemicals extraction from medicinal plants and to investigate the fundamental mechanisms that underlie each approach.

1. Introduction:

Since bioactive compounds are employed in multiple industries, including the pharmaceutical, food, and chemical sectors, it is important to develop an appropriate and standardised process of extraction for obtaining these active components from plant materials. The standard technique for extracting bioactive compounds from plants is not yet agreed upon, despite the fact that several unique ways have been discovered in addition to the old ones. The effectiveness of both traditional and nontraditional extraction processes depends upon a number of input factors, the most important of which are knowledge of the plant material, the biochemistry of bioactive substances, and the requisite degree of scientific expertise. The focus of investigation is on the principles behind various approaches of obtaining Pharmacologically active components from medically effective plants.

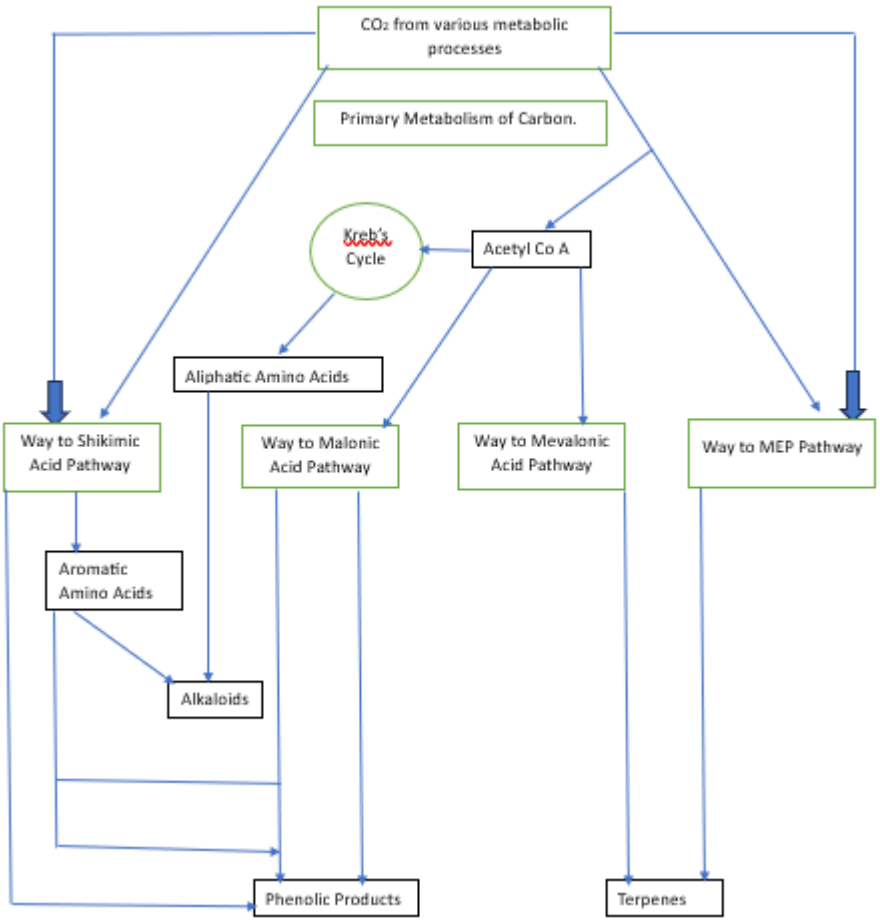
2. Bioactive compounds history and definition:

The usage of plants to benefit humans' dates back to the dawn of civilization. The discovery of plants' therapeutic capabilities transformed them from a just nutritional resource into a valuable tool for improving people's health in a wide range of societies. Thousands of recipes found in ancient Egyptian papyri demonstrate the therapeutic, cosmetic, and preservation value of coriander and castor oil. Hippocrates, Theophrastus, Celsus, Dioscorides, and many others from the ancient Greek and Roman worlds detailed the myriad medicinal use of various plants. The Romanians have a long history of using herbal remedies. For instance, Herodotus (who lived in the fifth century B.C.) recorded the usage of Leonurus cardiaca (Mother wort) by those who resided north of the Danube River. Herbal remedies were originally included in the Romanian pharmacopoeia in the 19th century, while in 1904, first institution of medical plants founded inside Cluj city [95]. The traditional usage of medicinal plants is a good example of how bioactive molecules have evolved through time. Bioactive chemicals were previously unknown to scientists, yet their applications span a wide range of fields. Secondary metabolites are often the means by which plants manufacture their bioactive substances [8]. From single-celled bacteria to multi-cellular plants, all living things rely on the biochemical processing of a wide variety of chemicals. The chemicals found in living systems may be broken down to two basic categories. One category is primary metabolites, which include nutrients including carbs, proteins, and lipids that are used for growth and the development. Secondary metabolites are a class of molecules distinct from primary metabolites that are thought to improve plants' overall survival and overcome local hurdles via interaction with their environment [32]. In other words, secondary metabolites are formed as mixtures of closely related members of a chemical family, having different chemical structures, are produced by specific taxonomic groups and have no role in growth (while they might have function for survival)[63]. Secondary metabolite production is mostly determined by the species' unique evaluation and survival requirements. Toxic chemical synthesis has developed towards diseases and herbivores to inhibit the development of neighbouring plants [17], whereas aromatic chemical synthesis by floral species attracts insects for their pollination and fertilisation. Some of the secondary metabolites have effects on biological systems and are therefore classified as bioactive. For this reason, secondary metabolites that can produce medicinal or poisonous effects in human and animal subjects is a straightforward definition of bioactive molecules in plants [8].

3. Biosynthesis and Classification of Bioactive compounds:

How biologically active compounds are classed may be profoundly affected by the motivation behind a certain classification method. For instance, biosynthetic categories, which aid in the simplification of describing biological synthetic pathways, may not correspond with breadth of classification based on the pharmacology. Croteau and his colleagues identify more than 25,000 different terpenes and terpenoids, around 12,000 different alkaloids, and almost 8,000 different compounds having phenolic ring as bioactive substances found in plants[14]. Figure 1 shows the overarching structures shared by numerous groups of bioactive compounds. Because of the biosynthetic process by which they are generated, most bioactive compounds may be grouped into one of several families, each of which has its own distinctive structural features. The four most essential pathways for the production of secondary metabolites (bioactive compounds) are the Mevalonic acid pathway (MAP), the Shikimic acid route (SAR), the malonic acid road (MAR), and the non-mevalonate (MEP) pathway [90]. The production of alkaloids necessitates the initial synthesis of aromatic amino acids, which may be obtained via the shikimic acid route. Subsequently, the synthesis of aliphatic amino acids is required, which can be achieved through the tricarboxylic acid cycle. The malonic acid route and the shikimic acid route both contribute to

the production of phenolic chemicals. The MEP and mevalonic acid pathways are responsible towards the synthesis of terpenes. In Figure 2, we see a simplified version of pathways that lead to three primary categories of bioactive chemicals. The aliphatic amino acids are synthesised via the tricarboxylic acid cycle, whereas the aromatic amino acids are synthesised through the shikimic acid route. Shikimic acid route and the malonic acid route are involved in synthesis of phenolic chemicals. Terpenes are synthesised via mevalonic acid pathway and the methyl ester transfer protein pathway. Three important classes of bioactive plant chemicals and the many mechanisms involved in their formation are summarised here as shown in the Fig. 1



4. The process of extracting bioactive substances:

Since there are significant variations between pharmacologically active chemicals of the plant species and a huge diversity of plant species are even being identified, It is critical to develop a standardised and rigorous method for filtering out these chemicals with human health advantages. The study of medicinal plants, as stated by Farnsworth et al. (1985), has progressed from the aggregation of common names for these species to their eventual commercialization. Fig. 3 is a flowchart showing the steps that must be taken into the consideration to learn about medicinal plants and the significance of different extraction techniques. Without using a suitable extraction method, it is not feasible to separate, identify, or characterise bioactive chemicals. Experimenting with different extraction techniques in differing settings is crucial for learning about extraction selectivity from various natural sources. Extracting bioactive compounds may be done in a variety of ways, some of which haven't changed much in hundreds of years. The objectives of these methods are to (A) purify the

pharmacologically compounds of interest from a complex plant sample, (B) Enhance the specificity of analytical methodologies., (C) Enhance the precision of bioassays by the augmentation of the concentration pertaining to the variable of interest., (D) transform pharmacologically active components to make them even more amenable to identification and separation, (E) supply the technique that is robust, reproducible, and resistant towards the changes in the sample material.

5. Traditional extraction methods:

There present a number of standard techniques for extracting biologically active components from plant parts. The majority of these procedures include the use of solvents, which aid in the dissolution of the target substance, in conjunction with additional solubilizing elements such as heat and/or agitation. Traditional methods for extracting biologically active components from plants include Soxhlation, maceration, and hydro distillation.

The proposition of the Soxhlet extractor was put up by German scientist Franz Ritter von Soxhlet in the year 1879. Its original purpose was lipid extraction; however, its use has since broadened. The Soxhlation method was widely used for the extraction of valuable bioactive chemicals from the sources. This model can be used to test the efficacy of novel extraction techniques. The usual sample container for dry materials is a cover. The cover is then kept over a distillation flask containing the chosen solvent. A syphon pulls up the solution when it gets too high in the thimble holder. The syphon re-collects the solution in the original container. The extracted solutes are carried by this solution back to the primary liquid. The solvent is returned to the plant solids via recycling, while the residual solute is accumulated inside the distillation flask. The extraction process is done as many as necessary until no more material can be taken out.

Maceration was the gold standard for producing homemade tonics for a long time. As a very inexpensive approach to generating bioactive compounds and essential oils, it swiftly rose to prominence. Extraction on a smaller scale often involves many maceration processes. To start, plants are crushed into a finer powder to enhance their surface area and improve their ability to combine with the solvent. The second step of the maceration procedure is to add menstruum as the appropriate solvent in a sealed container. In the third step, the marc is subjected to pressing in order to remove the occluded solutions subsequent to the removal of the liquid. The liquid that was extracted via pressing and the liquid that was recovered through straining are mixed and filtered to get rid of any impurities.

Periodically agitating the maceration process might potentially enhance the extraction yield via two mechanisms: (a) facilitating the diffusion rate and (b) displacing concentrated solution from the sample's surface, then replenishing it with new solvent. For millennia, the technique of hydro distillation has been used to extract essential oils and other therapeutic substances from plants. This procedure may be conducted prior to the dehydration of the plant material, since it does not need the use of any organic solvents. There are three distinct forms of hydro distillation that have been officially recognised: water distillation, water and steam distillation, and direct steam distillation [93]. The first step involves the introduction of plant materials into a chamber designed for distillation, followed by the addition of an appropriate quantity of water. Subsequently, the whole mixture is subjected to the process of boiling. The use of direct steam injection on the plant sample is a potential approach. The primary factor responsible for the liberation of bioactive chemicals upon application to plant tissue is the thermal energy derived from water or steam. Condensation transpires as a result of the indirect cooling of a water and oil vapour combination by water. The separation of condensed mixes of oil and bioactive chemicals from water may be

achieved by using a separator [83]. Hydro distillation is predicated upon three fundamental physicochemical mechanisms, namely hydro diffusion, hydrolysis, and thermal degradation. There is a possibility that the loss of some volatile components may occur at elevated extraction temperatures. Due to this limitation, its use is restricted to thermolabile chemical extraction on a limited scale. The efficacy of conventional extraction techniques is strongly contingent upon the meticulous choice of solvents [13]. Choosing a solvent mostly depends on the polarity of the target compound. Environmental concerns, human and animal toxicity, cost effectiveness, and practicality should all be factored into the decision of which solvent to use for extracting bioactive molecules. Table 1 displays the many extraction techniques used to get bioactive chemicals. The aforementioned methods include aided extraction, supercritical fluid extraction, and pressurised liquid extraction. The classification of some methods as "green techniques" is conducted by the United States Environmental Protection Agency (EPA) (http://www.epa.gov/greenchemistry/pubs/about_gc.html). The mitigation of pollution and accidents can be achieved by implementing strategies such as employing less hazardous chemical synthesis, adopting safer chemical design principles, utilising safe solvents and auxiliaries, incorporating energy-efficient design practises, utilising renewable feedstock, reducing the production of derivatives, employing catalysis techniques, implementing degradation prevention design measures, optimising atom economy, conducting time analysis, and embracing inherently safer chemistry principles.

6. Non-conventional extraction techniques:

Poor extraction selectivity, solvent evaporation, and heat deterioration of thermolabile chemicals are only some of the problems that rise as a result of the prolonged extraction times and the necessity for expensive, highly pure solvents [56]. Problems with traditional extraction methodologies are addressed through promising newer approaches. These tasks stand associated with innovative extraction methods. The most promising extraction methods include the use of supercritical fluids, pressurised liquids, enzymes, microwaves, pulsed electric fields, or ultrasounds. The Environmental Protection Agency (EPA) has designated some of these methods as "Green" due to their low environmental impact (more information is available on the webpage https://www.epa.gov/greenchemistry/pubs/about_gc.html). Safer chemical synthesis and design encompasses various strategies such as the utilisation of solvents and auxiliaries with minimal harm, enhanced energy efficiency, incorporation of renewable feedstocks, mitigation of byproducts and derivatives, implementation of catalysis, adoption of degradation prevention design, promotion of atom economy, application of time analysis, and prioritisation of accident prevention.

.6.1. **Ultrasound-assisted extraction (UAE):**

Human ears are incapable of hearing ultrasound waves. The range of frequency of Twenty kHz to Hundred MHz is used in chemistry. Like other waves, it causes compression and expansion in a material. The process involves cavitation, or the development, growth, and eventual collapse of bubbles. Energy is produced in large quantities by the transformation of motion into bubble heating. Suslick and Doktycz (1990) report that bubbles may reach temperatures of 5000 K, pressures of 1000 ATM, cooling and heating speeds of faster than 1010 K/s. This is foundation upon which the UAE is built. Only when solids are present in a liquid can cavitation occur. The organic and inorganic components in plant matrices are extracted by the ultrasonic energy used in UAE [37]. Ultrasound helps in the movement of plant mass and hence the penetration of solvents into plant cells. Ultrasound extraction entails fracturing the cell walls, followed by diffusion over the membrane and washing the present material [64]. The quality of a process of extraction is affected through various factors such as

sample humidity, milling intensity, size of particles, the solvent material used, time used for performing sonication. Temperature, pressure, frequency, and sonication time all play a role in ultrasound. In order to maximise system performance, it is fairly uncommon to combine UAE with more conventional approaches. To maximise extraction yields, ultrasonic technology is integrated into solvent extraction equipment [103]. UAE is a resource- and cost-saving mechanism. Extraction with ultrasound radiation allows for improved mixing, transfer of energy, temperature gradients, temperature used for extraction, selective type of extraction process, size of equipment, extraction control response time, fast startup, higher output, and fewer steps [9]. The UAE is a great herbal extractor. Rostagno and his colleagues in 2003 used mix-stirring in addition to several extraction times and solvents to remove major pharmacological ingredients from soyabean plant. The efficiency of solvent extraction was increased using ultrasound. Ultrasound was utilised by Herrera et al [37] to recover Phenolic chemicals, exemplified as rutin,, and kaempferol from the straw berries. As Li and his colleagues in 2005, extracted chlorogenic acid from fresh plant parts of Eucommia unmodish Oliv. using this technique under optimum conditions. Using optimal sonication settings [53], Yang and and his colleagues extracted the beneficial compounds rutin and quercetin from Euonymus alatus [110]. The extraction using this method was more productive than the conventional methods. Vindoline, catharanthine, and vinblastine can be extracted from Vinca rosea using ionic liquid-based technique [110]. To obtain the most anthocyanin compounds and phenolic analogues out of peels of grape fruits, the United Arab Emirates optimised the extraction temperature of the solvent under use, and time required for the process [25]. Rosmarinus officinalis' active components were more efficiently and quickly extracted using UAE based on ionic liquids than using conventional methods [112].

6.2 **Extraction with the help of enzymes (EAE):**

Some active plant chemicals in plant materials are protected from solvents by making them hydrophobic by forming hydrogen bonds, where they are distributed throughout the cellular cytosol or trapped inside the polysaccharide-lignin complexes. Pre-treatment with enzymes is an innovative and efficient technique for releasing such bound molecules which are difficult to extract and increasing production capacity of the process [79]. Enzymes, such as cellulase, alpha-amylase, and pectinase, may assist in the degradation of the cell wall, structural polysaccharides, and lipid bodies, therefore facilitating their extraction [79, 90]. Extraction techniques include extraction with water as a solvent and enzyme assistance commonly called (EAAE) and cold pressing with enzyme assistance commonly called (EACP). Common methods for oil extraction from seeds using EAAE include those developed by Rosenthal and Sharma [79, 90], and Hanmoungja and his colleagues [30]. Enzymes cause hydrolysis of seed cell-wall with help of enzymes like cellulase due to the lack of polysaccharide and protein colloids [11]. Time required for hydrolysis, water -to- solid ratio, enzyme concentration, size of particles, and nature of the plant material all have a role in the extraction process Dominguez and his colleagues found that the water content of plant materials influenced the rate of hydrolysis by using enzymes. Bhattacharjee and his colleagues recommended EACP for extracting oilseed pharmacologically active components due to its safety and lack of in flammability [8]. More free fatty acids and phosphorus can be extracted from oil processed with enzymes than in oil processed with hexane [71, 19,] EAE is green since it uses water rather than organic chemicals to extract bioactive compounds and oil [76]. Winemaking involves the breakdown of plant cell walls by enzymes, and Meyer and his colleagues found a co-relation between entire phenol output and this process [66]. Landbo and Meyer along with their colleagues found that enzymes increased the release of phenol components from plant R. nigrum pomace [46]. Five citrus fruit peels (Lisbon lemon, Valley lemon, pomelo, tangerine, and sweet orange) had their total phenolic contents extracted by EAAE using different enzymes by Li and his colleagues [53]. The greatest improvement was shown with Celluzyme

MX. Next significant conclusion from those studies was a higher concentration of enzymes led to a greater extraction of phenolic antioxidants. Using a 2:1 pectinolytic-cellulolytic enzyme combination, Maier along with his colleagues was able to extract pharmacologically active compounds like phenolic acids, non-anthocyanin flavonoids and anthocyanin flavonoids from grapes [59]. In comparison to extraction assisted with sulphites, productions were higher. When compared to a non-enzymatic control, phenolic antioxidant levels were found to be significantly higher in raspberry solid wastes after enzymatic hydro-alcoholic extraction [48]. Celluclast, pectinex, and novoferm were utilised by Gómez-Garca and his colleagues in EAE to extract phenol compounds from grapes [27]. Novoferm had the most impact. Through the use of enzyme technology, potentially useful chemicals may be extracted from byproducts obtained from agricultural industries.

6.3 **Microwave assisted extraction (MAE)**:

Different materials may have their soluble components extracted into a liquid using the novel technique of microwave-assisted extraction [73]. Electromagnetic waves within 300 MHz to 300 GHz range are termed microwaves. To construct them, two electrical and magnetic fields that move in opposing directions are essential. Polar substances may be heated directly in a microwave oven [51]. Ionic conduction and dipole rotation turn electromagnetic energy into thermal energy [42]. Due to medium's resistance, ionic conduction results in heat production. However, ions are guided by shifting field signals. Molecular collisions and heat are the results of this regular change of orientation. Separation of solutes from active sites of sample matrix under increasing temperature and pressure, diffusion of solvent across sample matrix, and release of solutes from matrix to solvent are the three sequential phases described by Alupului for microwave aided extraction [2]. Accelerating the extraction of bioactive ingredients from plant materials, decreasing temperature gradients, decreasing equipment size, and increasing extract production are all benefits of MAE [12]. MAE is superior to conventional approaches for extracting bioactive compounds. Purify organic and organometallic compounds selectively. Because MAE reduces the use of organic solvents, it is environmentally friendly [2]. When the sample is kept for 20 hrs at room temperature, MAE extracted more quantities of polyphenols and caffeine from green tea leaves in just 4 minutes than any other technology [72]. Extraction of ginseng root to obtain ginsenoside using focused MAE took just 15 minutes, compared to 10 hours using solvent extraction in order to increase the effectiveness of MAE extraction in comparison to Soxhlet and maceration[87], Dhobi and his other collegues isolated a flavolignin, silybinin, from Silybum marianum [15B]. Bioactive compounds (E- and Z-guggolsterone, cinnamaldehyde, and tannin) were extracted from a variety of plants using MAE and shown to be more quickly and easily extracted under ideal conditions by [6]. Different fractions of sorghum and maize bran and flour, which varied in terms of their hardness, were exposed to microwave-assisted extraction (MAE) with the aim of liberating phenolic acids that were bound within the samples [10]. Solvent concentration, extraction duration, and microwave power were modified to optimise flavonoids, phenolics, and electron-donating capacity in Chinese quince (Chaenomeles sinensis) MAE. [38B].

6.4 **Extraction of liquids under pressure (PLE):**

Richter et al. introduced PLE in 1996. Many various terms are used to refer to this technique depending on the setting [70]. High pressure does not cause solvent liquids to boil. Pressure helps in the extraction process. Automation has helped speed up the development of PLE-based technologies and cause reduction of solvent use and also the required extraction time. PLE requires less solvent at higher pressure and temperature. Solubility increases with the rise in and rate of mass transfer and temperature also lowers surface tension and viscosity of the solvent in use, leading a much higher rate of extraction [40]. The process is more efficient, uses less resources than the process of Soxhlet

extraction [78]. In future, PLE may take the place of supercritical fluid extraction when it comes to polar chemical extraction [43-B]. It has been suggested that PLE may be used to remove of organic contaminants in the conditions where the temperature is higher [106]. Extracting bioactive compounds through sea sponges using PLE was discovered by [40]. The process has a great use in the isolation of natural components [43-B]. Ibaezet and colleagues argue that PLE is environmentally friendly since it requires so little organic solvent [40]. PLE has been used to extract plant-based bioactive chemicals. Optimised extraction conditions prevented PLE degradation during isoflavone extraction from freeze-dried soyabeans [82]. According to research conducted by Shen and Shao (2005)[86], the compounds like sterols, terpenoids etc can be isolated using different techniques like ASE, Soxhlation, and ultrasonication. Time taken for the process of extraction is almost reduced to half, lesser solvent is required, and yield is increased when PLE is used instead of traditional techniques. Extraction of spinach flavonoids was shown to be more successful using combination of the mixture of water and ethyl alcohol in the ratio (70:30) compared to the plain water as solvent at 50-130 C. [38]. According to Luthria (2008) [58], while extracting phenolic compounds from parsley (Petroselinum crispum) flakes using PLE, temperature, the pressure, size of particles, flushing volume, static time frame, and solvent -to- solid ratio. When it came to extracting Amaryllidaceae alkaloids from jonquil (Daffodil), the optimised process found superior to process of extraction using the hot water (HSE), extraction assisted with the microwaves (MAE), and ultrasonic-assisted extraction (UAE) [68]. Ideal conditions for PLE extraction of chemicals like catechin, myricetin, gallocatechol (GCT), epicatechin gallate, caffeic acid and chlorogenic acid, and from Anatolian propolis (40 degrees Celsius, 1500 pressure for 15 minutes; were achieved. [18]

6.5 SFE (supercritical fluid extraction):

Although Hogarth and Hannay with their colleagues (1879) pioneered the application of supercritical fluid extraction (SFE), Zosel with his colleagues [111] was the first to patent SFE as a method for decaffeinating coffee. Since its introduction, supercritical fluid technology has been used in many different industries, including environmental, pharmaceuticals, polymers, and food analysis [111]. This method of decaffeinating coffee has been widely used by enterprises for decades [69].

Matter may exist in three distinct phases: the solid, the liquid, and the gas. A material can only enter its supercritical state once it reaches its critical pressure and temperature values. At Tc and Pc [41], there is no coexistence of a gaseous and liquid phase. Supercritical fluid can't be turned into a liquid since it has qualities in between those of a gas and a liquid. Supercritical fluids exhibit similar behaviour to gases in terms of diffusion, viscosity, surface tension, density, and solvation power. These features make it amenable to fast and efficient chemical extraction [7]. Oven with extraction vessel, pressure controller, and trapping vessel. Tank for mobile phase (usually CO2). Pump to pressurise gas. It's possible to employ a variety of metres, including flow, dry/wet gas, and others. A typical symmetric diagram for SFE tools is shown in Figure 4.

Carbon dioxide has the highest solubility for SFE. Carbon dioxide has a lower critical pressure of 74 bars; and a very low critical temperature (31 C; allowing for operations at moderate pressures, usually within 100 and 450 bar [95]. Due to its low polarity, carbon dioxide is not suitable for most medicines and medication samples, but it works well with lipid, fat, and non-polar substances. As discussed by Lang and wai (2001) and Ghafoor et al. (2010), chemical modifiers may be used to increase the polarity of carbon dioxide. A little increase in carbon dioxide levels may drastically change the polarity of the gas. Improved extraction may be achieved using hydrodistillation using 0.5 ml of dichloromethane (CH2Cl2) for 4 hours (Hawthorne et al., 1994). Sample and target chemical parameters, as well as historical experimental data, are used to determine the best modifier to use.

Adjustable SFE settings for the extraction of bioactive compounds from plants (Raverchon and Marco, 2006). You may get the most out of this strategy by adjusting these parameters. Temperature, pressure, particle size, moisture content, extraction duration, CO2 flow rate, and the solvent-to-feed ratio are the primary factors influencing extraction efficiency [95]; [40].

When it comes to the removal of bioactive compounds, supercritical fluids provide a number of benefits [47]. When it comes to entering sample matrices and enabling mass transfer, (1) supercritical fluids excel over liquid solvents due to their larger diffusion coefficient, reduced viscosity, and lower surface tension. SFE shortens the duration of the extraction process. Supercritical fluid reflux is used several times to remove the substance (2). Supercritical fluid is more selective than solvent in liquid phase liquid because its solvation strength is more sensitive to changes in temperature and pressure. Because it doesn't involve separating the solute from the solvent, supercritical fluid depressurization has the potential to be more effective than traditional extraction methods. (3) SFE may be used to effectively extract thermolabile compounds at room temperature. Because (4) SFE requires less sample than solvent extraction, time may be saved throughout the experiment by using SFE. Because it requires less organic solvent, SFE is better for the environment. SFE combined with online chromatography may be utilised to analyse volatile chemicals.

Reusing supercritical fluids is an efficient way to reduce garbage. 5) In a lab, an SFE scale can be calibrated to milligrams, and in an industrial context, it can be calibrated to tonnes. (6) Understanding the mechanism and process of extraction is made possible by the SFE method.

Saldaa et al. and his colleagues in (1999) used SFE at 313-343 K & 14-24 K to extract xanthine alkaloids from I. Paraguayans (maté tea leaves). At 9.5 MPa and 58.6 C, using a supercritical CO2 solution modified with 15% ethanol, the naringin flavonoid was extracted from Citrus paradise [26]. The liberation of catechin and the epicatechin exceeded 79% when polyphenols and procyanidins were extracted from seeds from grapes using supercritical fluid extraction (SFE) and a mixture of methyl alcohol and the gas carbon dioxide (40%). [44]. Catharanthus roseus leaves are rich in indole alkaloids, and Verma and his colleagues in 2008 optimised SFE to extract those compounds. Using methanol (6.6% by volume) as a modifier, the optimal conditions for catharanthine recovery lasted 40 minutes at 25 MPa and 80 MPa [100].

Conclusion:

The need to remove plant bioactive components is on the rise, and with that comes a desire in developing more effective extraction techniques. Several new extraction techniques have emerged as a result of the emergence of chromatography and the growing awareness of the need to safeguard the environment. Most non-conventional extraction techniques rely on diverse mechanisms, and improved process of extraction is the result of a number of processes, thus it is crucial to have a thorough understanding of the whole process. Scientists and engineers should be guided in their pursuit of hybridization by the materials and compounds found in plants. Several of the current methods require adequate experimental confirmation. Efficiency measurements of extraction also benefit from standardisation. The increasing value of biologically active molecules and substances rich in these bioactive chemicals, however, motivate scientists to develop even efficient cutting-edge extraction technologies.

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