Chapter

Introductory Chapter: Plant Extracts

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1. Introduction

Humans are dependent on plants for basic needs such as food, clothing, and shelter for centuries [1]. Plants have also been used as arrow and dart poisons for hunting, poisons for murder, hallucinogens used for ritualistic purposes, stimulants for endurance, and hunger suppression, as well as inebriants and medicines [1]. Medicinal plants have been a source of wide variety of biologically active compounds for many centuries and used extensively as crude material or as pure compounds for treating various disease conditions. Relatively 1–10% of plants are used by humans out of estimated 250,000–500,000 species of plants on Earth [2]. Plant-based traditional medicine plays a key role in the development and advancement of modern studies by serving as a starting point for the development of novelties in drug discovery [3]. Various modern drugs were extracted from traditional medicinal plants through the use of plant material following the ethno botanical leads from indigenous cures used by traditional medical systems [4]. In developing countries and rural societies, the use of medicinal plants is both a valuable resource and necessity, and furthermore, it provides a real alternative for primary healthcare systems [5].

Plants were once the primary source of medicines in the world and since then, plants continue to provide humans with new remedies as 50% of all drugs in clinical use in the world are derived from natural products, of which higher plants contribute 25% of the total [5, 6]. The use of plants as medicines predates written human history. Knowledge of plant use was widespread in ancient civilizations. Until the middle of the nineteenth century, plants were the main therapeutic agents used by humans, and even today, their role in medicine is still relevant. It was estimated by the WHO that around 80% of the world population relied on medicinal plants as their primary healthcare source [7] and the demand is increasing in developing countries. For example, traditional medicine (TM) practices have been used for thousands of years by people in Africa, China, India and many other countries [8]. Even in developed countries, plant-based traditional medicines are often termed complementary or alternative medicine (CAM), and their use has increased steadily. For example, in the USA alone, the total estimated that herbal sales for 2005 were $4.4 billion, a significant increase from $2.5 billion in 1995 [9].

The plant chemicals used for arrow or dart poisoning purposes are largely the secondary metabolites, which are derived biosynthetically from plant primary metabolites (e.g., carbohydrates, amino acids, and lipids) and are not directly involved in the growth, development, or reproduction of plants. Secondary metabolites can be classified into several groups according to their chemical classes, such as alkaloids, terpenoids, tannins, phenolics, and others [10]. Most of these secondary metabolites are used for plants defense against predators.

Medicinal plants are now more focused than ever because they have the capability of producing many benefits to society especially for medicinal uses. The medicinal power of these plants is due to their phytochemicals which can cause definite physiological actions on the human body. Phytochemicals are natural compounds which occur in plants such as medicinal plants, vegetables, and fruits that work with nutrients and fibers to act against diseases or more specifically to protect against diseases [11, 12]. Medicinal plants because of their accessibility and affordable health care are an important source of livelihoods for indigenous and rural populations. They are also the source of many active ingredients for modern pharmaceuticals. Between 50,000 and 80,000 flowering plants are used for medicine worldwide, many of them are collected from wild resources [12]. Herb as a group of plants was also used as food (vegetables) and flavors for hundreds of years in many parts of the world. Herbs have been traditionally regarded as natural remedies for common ailments of a human. Nearly all cultures and civilizations from ancient times to the present day have used herbal medicines which are antimicrobial sources to cure infections [13]. Conventional antifungal and antibacterial treatment of infections becomes inefficient to cure patients, providing resistance of microorganisms.

Drug	**Plant source**	**Disease to treat**	**Reference**
Galantamine	*Galanthus woronowii* Losinsk	Alzheimer's disease	[14, 15]
Apomorphine	—	Parkinson's disease	[16]
Tiotropium bromide	—	Obstructive pulmonary disease	[17]
Varenicline	—	Smoking cessation	[18–20]
Betulinic acid	Many plants	Anticancer, antibacterial, antimalarial, anti-HIV, anthelminthic, anti-inflammatory, and antioxidant properties	[21, 22]
Combretastatin A4 phosphate	*Combretum caffrum* Kuntze	Anaplastic thyroid cancer	[23]
Huperzine A	*Huperzia serrata* (Thunb. ex Murray) Trevis	Alzheimer's disease	[24]
Ingenol 3-angelate	*Euphorbia peplus* L.	Warts and actinic keratoses	[25]
Morphine	*Papaver somniferum*	Pain	[26]
Protopanaxadiol	*Panax ginseng*	Apoptotic effect on cancer cells	[27]
Harpagoside	*Harpagophytum procumbens* DC	Pain	[28]
Harpagophytum procumbens extract	*Harpagophytum procumbens*	Hip and knee osteoarthritis	[28]
Flavocoxid (Limbrel) blend of flavonoids	*Scutellaria baicalensis* Georgi and *Acacia catechu* Willd	Osteoarthritis	[1]
Ginkgo extract	*Ginkgo biloba* L.	Alzheimer's disease	[29]
Mistletoe extract (Iscador)	*Viscum album* L.	Various cancer	[30]
Sativex extract	*Cannabis sativa* L.	Neuropathic pain	[31]

Table 1.
Compounds and extracts derived from plants used as drugs or on the process of clinical trial stage.

1.1 Plant-derived drugs and various clinical trial stages

Table 1 shows compounds or extracts are drugs or on the process of clinical trial stage derived from plants and their therapeutic use.

2. Uses of plant extracts in food industry

Plants have also been used in the production of stimulant beverages, such as tea, coffee, cocoa, and cola, and intoxicants, such as wine, beer, and kava, in many cultures since ancient times. Tea (*Camellia sinensis* Kuntze) was first consumed in ancient China [1], while coffee (*Coffea arabica* L.) was initially found in Ethiopia from the region called Keffa and then cultivated in Yemen for commercial purposes in the ninth century [32]. The Aztec nobility is used to consume bitter beverages containing raw cocoa beans (*Theobroma cacao* L.), red peppers, and various herbs [32]. The active components of these stimulants are methylated xanthine derivatives, called caffeine, theophylline, and theobromine, major components of coffee, tea, and cocoa, respectively [8].

Studies have shown that a low to moderate consumption of red wine is important for reduction of mortality caused by cardiovascular disease and cancer [33]. This health benefit of wine has been suggested to be due to the presence of a compound called resveratrol present in the skin of grapes [34].

Kava, a beverage made from the root of *Piper methysticum* Roxb., has been a popular intoxicating beverage in Polynesia for centuries [35]. However, in the Western world, kava is not normally consumed directly but has gained popularity as a botanical dietary supplement to ease the symptoms of stress, anxiety, and depression [36]. A study has shown that the anxiolytic activity of kava extract may be mediated in part by the kavalactone and dihydrokavain [37].

3. Extraction methods

Medicinal plants are becoming very important due to their uses mainly as a source of therapeutic compounds that may lead to the development of novel drugs. Most of these compounds such as phenolics and flavonoids have been reported to be important for on health including cancer prevention [38]. High content of phenolic and flavonoids in medicinal plants has been correlated with their antioxidant activities that are important in prevention of the development of age-related disease, especially those related to oxidative stress [39]. Phytochemicals in medicinal plants are very important in pharmaceuticals and cosmeceutical industry [39].

Extraction is the separation of medicinally mixture of many plant metabolites, such as alkaloids, glycosides, phenolics, terpenoids, and flavonoids using selective solvents through standard procedures [40]. The aim of all solvent extraction methods is to separate the soluble plant metabolites, leaving behind the insoluble cellular marc. The following are the widely used extraction techniques.

3.1 Maceration, infusion, percolation, and decoction

Maceration extraction method is used in wine making and also used for extraction of bioactive compounds from plants [39]. Maceration involved soaking plant materials (coarse or powdered) in a stoppered container with a solvent and allowed to stand at room temperature for at least 3 days with frequent agitation [40], which is followed by pressing or straining and filtration. In conventional methods, heat is transferred through convection and conduction, and the solvent is selected based on the compound aimed to be extracted [40]. Infusion and decoction use the same principle as maceration but both are soaked in cold or boiled water [39].

Decoction is only suitable for extracting heat-stable compounds, hard plant materials such as roots and barks, and the process usually yielded more oil-soluble compounds compared to maceration and infusion [39].

3.2 Soxhlet extraction or hot continuous extraction

In this method, the sample is ground and placed in a porous bag called thimble made from a strong filter paper or cellulose. The thimble containing the sample is placed in thimble chamber of the Soxhlet apparatus. Extraction solvents are heated in the bottom flask, then vaporized into the sample thimble, condensed in the condenser, and dripped back which result in extraction of plant secondary metabolites in a good yield.

3.3 Microwave-assisted extraction (MAE)

This extraction method uses microwave energy to facilitate partition of analytes from the sample matrix into the solvent [41]. Microwave radiation interacts with dipoles of polar and polarizable materials such as solvent and a plant sample results heating near the surface of the materials and heat is transferred by conduction. Dipole rotation of the molecules induced by microwave electromagnetic disrupts hydrogen bonding enhancing the migration of dissolved ions and promotes solvent penetration into the matrix [42].

3.4 Ultrasound-assisted extraction (UAE) or sonication extraction

This method makes use of ultrasound ranging from 20 to 2000 kHz [40]. The mechanic effect of the ultrasound increases the surface contact between solvents and samples [39]. The ultrasound alters and disrupts the physical and chemical properties of the sample and facilitates release of compounds and enhancing mass transport of the solvents into the plant cells [43].

3.5 Accelerated solvent extraction (ASE)

Accelerated solvent extraction is more efficient solvent extraction method compared to maceration and Soxhlet extraction methods. This method makes use of minimum amount of solvent compared to maceration and Soxhlet extraction methods [39]. In ASE, sample is packed with inert packing material such as sand in the stainless steel to prevent sample from aggregating and blocking of the system tubing [39, 44]. The method controls temperature and pressure for each individual sample and the extraction completes in less than an hour [39].

3.6 Supercritical fluid extraction (SFE)

Supercritical fluid is a substance that shares the physical properties of both gas and liquid at its critical point. Temperature and pressure are the determinant factors that push a substance into its critical region [39]. Supercritical fluid behaves more like a gas but have the solvating characteristic of a liquid. For instance, CO_2 becomes supercritical fluid at above 31.1°C and 7380 kPa. Interest in supercritical-CO_2 extraction is quite interesting due to its excellent solvation power for nonpolar analytes. Additionally, CO_2 is readily available, cheap and has low toxicity [39]. Supercritical-CO_2 has poor solubility for polar compounds. The solubility of supercritical-CO_2 for polar compounds can be enhanced by adding small amount of ethanol and methanol [39].

3.7 Enzyme-assisted extraction (EAE)

In some plants, some phytochemicals in their matrices are dispersed in cell cytoplasm, and secondary metabolites are retained in the polysaccharide-lignin network by hydrogen or hydrophobic bonding and are not accessible with a solvent extraction process [45]. Enzymatic pre-treatment has been considered as an effective way to release bounded compounds and increase overall yield [46]. Specific enzymes such as cellulase, a-amylase, and pectinase added during extraction enhance recovery by breaking the cell wall and hydrolyzing the structural polysaccharides and lipid bodies [46, 47]. There are two approaches for enzyme-assisted extraction method namely enzyme-assisted aqueous extraction (EAAE) and enzyme-assisted cold pressing (EACP) [48]. EAAE methods have been employed mainly for the extraction of oils from various seeds [46, 49–51]. In EACP method, enzymes are used to hydrolyze the seed cell wall of a plant [52].

3.8 Extraction of volatile organic compounds

Distillation is the separation process of the components of a mixture of two or more liquids due to their difference in their vapor pressure. The aims of distillation process are to obtain an essential oil. Hydro-distillation (HD), steam distillation (SD), simultaneous distillation solvent extraction (SDE), microwave-assisted hydro-distillation (MWHD), supercritical fluid (CO_2) extraction (SFE), purge and trap, and solid phase microextraction (SPME) [53] were employed to extract volatile organic compounds from fresh plant parts. Among these techniques, HD, SD, and SDE are classical and conventional methods for sampling bioactive volatile organic compounds (VOCs). Hydrodistillation is the distillation technique carried out either by boiling the plant materials or essential oil with water by creating the steam. The composition of the oil distillates from a mixture of two liquids depends primarily upon the boiling points or the vapor pressure at the distillation temperature.

Problems connected with conventional methods include long extraction times, large amounts of solvents, and multiple steps. Additionally, many unstable volatile organic compounds may be thermally decomposed and degraded during the thermal extraction or distillation. Because of their simplicity, these methods are still in use to extract fragrance-and-aroma oils from plants. Purge and trap, SFE, and SPME have aroused much attention from analysts as they are environment friendly sampling techniques for bioactive VOCs [53].

3.8.1 Purge and trap

Purge and trap also known as dynamic headspace uses ultra-purified inert gas as the carrier gas to pass through samples continuously to carry out VOCs, and then VOCs are trapped in the trap that contains the sorbent such as Tenax [54]. The type of sorbent in the trap can be varied in order, and purge and trap can achieve high selectivity for different biological VOCs. Properly prolonging sampling time could also improve the enrichment effect [53]. This method has been employed for sampling not only VOCs but also semi-VOCs [55].

3.8.2 Solid phase microextraction

Solid phase microextraction (SPME), developed by Arthur and Pawliszyn [56] and Pawliszyn [57], has been considered as one of the best inventions in extraction of volatile organic compounds in the field of sample [53]. SPME integrates the extraction, concentration, and introduction simultaneously, and the use of this method results in reducing preparation time and simultaneously increasing sensitivity over other extractions [53]. Because of all these advantages, SPME could be considered as a simple, efficient and environment friendly sample extraction method, which has been used in the environmental [58], biological [59], pharmaceutical [60], field analyses [61], and fragrance-and-aroma study [62]. Additionally, headspace solid phase microextraction (HS-SPME) has been considered as an appropriate method for sample preparation in the fragrance and aroma analysis [62].

4. Conclusions and future trends

Plants have provided humans with many of their essential needs, including life-saving agents for centuries. As only 1–10% of the available higher plant species have been screened biologically, drug discovery from plants should remain an essential component in the search for new medicines [2], particularly with the development of highly sensitive and versatile analytical methods which include search further for convenient extraction methods in future. Botanical insecticides are also getting a lot of attentions in the integrated pest management to produce healthy fruits, vegetables, and crops [63]. Natural ingredients are also gaining popularity, and the use of plant extracts in cosmetic formulation increases [64]. A cosmetic formulation from natural origin can protect the skin against exogenous or endogenous harmful agents and help to remedy many skin-related diseases [64]. Essential oils have been used for thousands of years, as incense, perfumes, cosmetics, and for their medicinal and culinary applications [64]. This book aimed to cover aforementioned areas and others of applications of plant extracts in depth. It is recommended to conduct international multidisciplinary projects for drug discovery from natural sources, and proper utilization of plants in various areas mentioned in this book is important. Thus, there is a need for cooperative effort among scientists to make use of benefits from these resources.

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