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A COMPARATIVE STUDY OF VARIOUS OIL EXTRACTION TECHNIQUES IN PLANTS: A REVIEW

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ABSTRACT

Oil is a valuable product and is extracted from whole plant or plant part/s, like fruits, nuts and seeds for use in many household needs, like cooking, soap making, and as ingredient in other food/s. Extraction is considered as an important step to separate and identify compounds (including oils) from different plants, for which a number of techniques are available depending on the nature of the compound. The traditional oil extraction techniques, include hydrodistilation, steam distillation, solvent extraction, soxhlet extraction and hydrolytic maceration distillation. The modern oil extraction techniques in the plants, include: Supercritical Fluid Extraction (SFE), Microwave-Assisted Hydro Distillation (MWHD), Solvent Free Microwave Extraction (SFME), Ultrasound-Assisted Extraction (UAE), and Microwave Hydro Diffusion and Gravity (MHG). The present review focuses on an advancement of various oil extraction methods (traditional to modern) in plants, with a discussion on principle, mechanism and important results of each method/s.

Keywords: Extraction, microwave assisted extraction, novel methods, supercritical fluid extraction

Introduction

Oil is a valuable product and is extracted from whole plant or plant part/s, like fruits, nuts and seeds for use in many household needs (Potts and Michell 1993), like cooking, soap making, and as ingredient in other food/s. Globally, 17 types of commodity oils are available, of which four are of animal origin and the rest are of plant origin (Gayas and Kaur 2016). Out of these extracted oils, 80 percent is used for cooking or other food purposes, while 14 percent is used in oleochemical industry, and another 6 percent in animal feed (Gunstone and Hamilton 2001). Extraction is considered as an important step to separate and identify compounds (including oils) from different plants, for which a number of techniques are available depending on the nature of the compound (Stevigny *et al*. 2007). The most common techniques includes, chemical and mechanical processes like solvent extraction, steam distillation (Shirsath *et al*. 2012), extraction using alcohol with Soxhlet, hydro-distilation and maceration (Wang and Weller 2006), or multiple phase traditional Soxhlet extraction techniques (Jadhav *et al*. 2009), but, all of these are manual processes and reproducibility always remain a challenge (Shen and Shao 2005). Further, few more techniques, like pressurized liquid extraction (Kaufmann and Christen 2002, Smith 2002), microwave-assisted extraction (Kaufmann and Christen 2002), ultrasound-assisted extraction (Patist and Bates 2008), were also in use. Recently, more advanced extraction methods, like Supercritical fluid extraction (SFE) have been used, that are more appropriate, cost saving, eco-friendly and selective (Sajfrtova *et al*. 2010, Bimakr *et al*. 2012).

Perusal of the literature reveals a number of review articles, published on Soxhlet extraction, microwave-assisted extraction (MAE), ultrasound-assisted extraction (UAE), pressurized liquid extraction (PLE), Supercritical Fluid Extraction (SFE) of the whole plant/s or parts, separately (for review, see: Kaufmann and Christen 2002, Patist and Bates 2008, Tripti *et al*. 2009, Luque de Castro and Priego 2010, Sovová and Stateva 2011). The present review focuses on an

evolution of various oil extraction methods (traditional to modern) in plants, with a discussion on principle, mechanism and important results of each method/s.

2. **Extraction Techniques**: The oil extraction techniques in plants are further classified into: traditional and modern techniques.

2.1**Traditional techniques**: The traditional oil extraction techniques include hydrodistilation, steam distillation, solvent extraction, soxhlet extraction and hydrolytic maceration distillation, which are discussed below:

2.1.1 Hydrodistillation: Hydrodistillation is a most common conventional method for the isolation of essential oils. Hydrodistillation is one of the easiest and primitive methods which are used for the extraction. It is mainly used to isolate the essential oils from the medicinal as well as for aromatic plants. In this method, the essential oils was evaporated by heating a solvent mixture or a mixture of water and plant material and then vapors are liquefied in a condenser to separate essential oils from the water, respectively.

The principle is based upon isotropic distillation at atmospheric pressure and heating (during extraction process), water, oil molecules and other solvents. The time of distillation depends upon the plant material processed. Water distillation is different from steam distillation, as the plant material is fully covered with water present on the stool which is placed in the furnace. The color of hydrodistilled oil is slightly darker than manufactured by other methods.

2.1.2 Steam Distillation: It is the method used for temperature sensible plants i.e. aromatic compounds. It was used for purifying organic compounds, but still an important method in industrial sectors (Fahlbusch **et al**. 2003). The plant material is placed on alembic for steaming without maceration. The steam is injected and passes through the plant material from bottom to top in the alembic (for distillation), which opens the pores of raw material and results in the liberation of essential oils from it. The desired amount of essential oils with vapor mixture is obtained and the vapor is condensed with the help of the condenser.

2.1.3 Solvent Extraction or Liquid –Liquid extraction: It is used for liquids that do not mix, like organic solvent and waters. A waxy aromatic compound called a "concrete" is produced when plant material is treated with solvent. The oil molecules are released when concrete is assorted with alcohol. The main aim of the solvent extraction method/s is to separate a mixture which is based on their solubility. This method is used in the biodiesel and perfumes and also produces a fine fragrance than that of any other type of distillation method. Delicate plants are commonly used in the solvent extraction method. At a lower cost, it produces the highest amount of essential oils. The main disadvantage of this method is that it takes a long time, show undesirable reproducibility and the consumption of solvent is very high (Dawidowicz *et al*. 2008).

2.1.4 Soxhlet Extraction: A soxhlet extractor, a bit of laboratory equipment, was invented by Franz von soxhlet (Soxhlet et al. 1879; Harwood *et al*. 1989). It is used for the components which are less soluble in the solvent and the impurities are not soluble in that solvent. An important advantage of this extraction is that due to repeated procedures, sample remains in contact with the solvent along with their fresh portions. It prevents the saturation of solvent with the extracted material and leads to the eradication of the analytes from the extracting liquid and the temperature of the system is maintained near to the boiling point of the solvent. It is well adapted with several disadvantages, like requires many hours or days, dilution of sample with large amount of solvent, etc.

2.1.5 Cold pressing method or scariform metod: As the name indicates, oil is extracted at a very low pressure and temperature. It is the best and easiest method used for the extraction of essential oils. The oil extracted from this process is 100% pure and maintains all the properties of the plants. Cold pressing

method is a technique of mechanical extraction, in which the heat is lowered during the batching of the raw material. It is primarily utilized for the extraction of essential oil from many parts of the plant, such as flowers, seeds, fruits, lemon, tangerine oils (Arnould *et al*. 1981). During this process, the outer layer of the plant which contain oils are detached by scrubbing and then, the intact plant is pressed to crush the material out of the pulp to liberate the essential oils. The essential oils along with their material are rising to the surface and hence separated by centrifugation.

2.1.6 Hydrolytic maceration distillation: The volatile components of some plants are bounded (glycosidic linkage), so require maceration in hot or warm water before the removal of essential oils. For example, the leaves of wintergreen plant (*Gaultheria procumbens*). The leaves have a precursor Gaultheria and the enzyme primeverosidase, so the leaves are macerated in the warm water, and primeverose and free salicylate are released when the enzyme act upon the gaultherin. Some related examples are bitter almonds and brown mustard as well as garlic.

2.2 Modern Techniques: The modern oil extraction techniques in the plants, include: Supercritical Fluid Extraction (SFE), Microwave-Assisted Hydro Distillation (MWHD), Solvent Free Microwave Extraction (SFME), Ultrasound-Assisted Extraction (UAE), Microwave Hydro Diffusion and Gravity (MHG), and other modern oil extraction methods for essential oils, are discussed in details below:

2.2.1 Supercritical Fluid Extraction (SFE): The extraction is mainly from the solid as well as from liquid matrix. It is the process in which the two components are separated from one another using supercritical fluids act as the extracting solvent. Practically, the carbon dioxide is used in 90 percent of all the analytic superficial fluid extraction (SFE) for various practical reasons. CO2 has a low critical temperature (32Co) and pressure (74 bars), apart harmless, non toxic, accessible in high purity and quite at low cost and readily isolated from the extract (Rozzi *et al*. 2002). The disadvantage of the carbon dioxide is that is it do not contain polarity for polar analytes present in the extracting material (Pourmortazavi *et al*. 2007). The other disadvantage of this method is the high primary cost of the apparatus and is not easy to handled (Azwanida 2015). This method is used for the essential oil extraction, such as lemonade or other straight solvent and metal cation extraction. The high antioxidant yield is obtained as compared to other methods when the extract is prepared (Fadel *et al*. 1999). It produces a higher dispersion coefficient, yield and lower viscosity. The product produced by this method is of superior quality, with best useful and biological activities (Capuzzo *et al*. 2013). It also shows some antibacterial and antimycotic properties.

2.2.2 Microwave- Assisted Hydro Distillation (MWHD): Microwave assisted hydrodistillation is a progressive hydrodistillation technique by using a microwave oven in the separation process. The dielectric constant of water and sample are the main factors on which the productivity of microwave assisted hydrodistillation is immensely dependent (Brachet *et al*. 2002; Golmakani *et al*. 2008). The extractions of active compounds are time and solvent destroying, thermally hazardous and the analysis of innumerable constituents of the sample is finite by the extraction step in the traditional methods (Mandal *et al*. 2007). So, the drawbacks of this method can be overcome by microwave assisted hydrodistillation (MWHD) by their attractive features as they are thermoliable, lessen both the extraction time and the volume of solvent involved and also reducing the environmental effect by releasing less amount of carbon dioxide in the atmosphere (Lucchesi et al. 2004a, b; Ferhat *et al*. 2006) and this method of extraction using very little amount of energy as comparable to conventional

extraction processes (Farhat *et al*. 2009). Due to its beneficial properties, it is used to extract biological materials and act as a substitute for other extraction methods. The principle of Microwave Assisted Hydrodistillation is directed by dipole rotation and ionic conduction which occurs simultaneously with the direct influence with solvents or polar materials (Letellier *et al*. 1999).

2.2.3 Solvent Free Microwave Extraction (SFME)

Without adding any solvent the essential oil can be extracted by solvent free microwave extraction process (Lucchesi et al. 2007). This method was formulated by Cheat and co-workers (Lucchesi *et al*. 2004a, b). It depends upon the integration of both microwave heating energy and microwave dry distillation. In this method, the dry distillation of the plant is done, without using any organic solvent or water at atmospheric pressure (Filly *et al*. 2014). In this process the plant material is saturated in the water for 1 to 2 hrs to gain the moisture and then excess water is removed. Thereafter, the moistened plant material was put into the microwave oven pit and the electrical condenser was employed for collecting the extracted essential oils. The eradication potential, extracting time, temperature is restricted by the panel in the appliance. The extracted essential oil was gathered and dried by adding an anhydrous sodium sulfate solution and kept at 4°C temperature until analysis (Lucchesi *et al*. 2004a).

2.2.4 Ultrasound-Assisted Extraction (UAE): This method is also termed as Sonication Extraction. The ultrasound radiations are operated, ranging from 20 kHz to 2000 kHz. It is a superior method to attain high expensive compounds and some food by-products when utilize as sources of plant material and natural compounds (Bhaskaracharya *et al*. 2009). By using this method, we can save energy as well as in between mean temperature there is an effective extraction takes place. In 1950 at laboratory apparatus this technique was originated. (Vinatoru *et al*. 2001). By applying the ultrasound the chemical and physical properties of the plant material are changed and it breaks the cell wall; hence the solvents transport in the plant cells also the compounds are also released. This method is mainly used for thermoliable compounds from the flower parts the anthocyanin, to prevent the exposure to relatively high temperature and to lessen the extraction period. The raw material of the plant is possessed in water or solvent, i.e. Methanol or Ethanol, however it is exposed to operate ultrasound (Assami *et al*. 2012). This method is used for extracting high yield of essential oils from various parts of the plants such as flowers, seeds and leaves (Sereshti *et al*. 2012). The procedure for UAE is quite simple and it is an inexpensive equipment whether it is employed for phytochemical extraction at large and small scales.

2.2.5 Microwave Hydro Diffusion and Gravity (MHG)

It is a green process used for extracting essential oils is at atmospheric pressure, which involves the microwave heating as well as earth attraction. This method of extraction of essential oils was originated from the research along with processing scale requisitions from various varieties of plant material (Vian *et al*. 2008). As we know that this method of extraction is economical as well as adequate, but also sustainable because it does not require water and solvent, as it needs very least amount of energy. The benefits and representation of this technique are power saving method, the extraction time is very less as compared to hydroditillation (it takes only 20 mins while hydrodistillation require 90 mins) hence reducing environmental effect (Vian. *et al* 2008).

The significance of extraction of plant materials, such as fragrances, foods, flavors, fat, oils, Nutraceuticals, etc., has continuously attracted the attention of many researchers globally and prompted the discovery of modern extraction methods, such as MAE, PLE, SFE and UAE. The quality and quantity of the solvent used in recent extraction

techniques, has lowered the operation cost, and are more economical and eco-friendly. This review presents the comparison of mechanisms and principles of different extraction techniques, for better understating of the processes involved.

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