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Review Article

Extraction of Volatile and Semi-Volatile organic Compounds from Plants Samples through Micro-Extraction Techniques: A Review

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Abstract

All fruits and vegetables are essential for public health, and the variety of human diseases can be cured by some plant based materials worldwide. Thus, accepting the configuration of plant matrix has increased attention in recent years. Meanwhile, plant matrix is very composite, the separation, quantization and extraction of these diverse chemicals is challenging. In this study, we mainly focus on the different micro-extraction techniques to determinate the semi-volatile and volatile compounds such as alcohols, terpenes, hydrocarbons, aldehydes, esters, acids, phenols, pesticides and secondary metabolites from numerous plant components such as leaves, vegetables, fruits, herbs and shrubs etc. Different techniques have used such as sorbent-based micro-extraction, solid phase micro-extraction, stir-bar sorptive extraction, solvent-based micro-extraction technique, hollow fiber liquid phase micro-extraction, dispersive liquid-liquid micro-extraction, and single-drop micro-extraction technique.

1. Introduction

All fresh fruits and green vegetables constitute a significant portion of the diet because they have provided the vital nutrients like carbohydrates, vitamins etc. to human beings worldwide. In diversity of plants, some plants can play an important role to cure several diseases. The semi-volatile and volatile plant components play vital roles for the development and growth of plants like feeding of herbivores and against pathogenic microbes, competition of plant-plant, plant's defense against insect pests, and cooperative co-evolution etc. After spraying, plant protection chemicals such as pyrethorids, fungicides and organophosphorus insecticides enter the plants whereas the EOP (environmental organic pollutants) such as PAHs, pesticides move into the plant from their surrounding environment. These pollutants residues may enter in the animals and humans through feeding of plants and generate the negative consequences on their health. Therefore, in plants semi-volatile and volatile amalgams analysis like Aldehydes, alcohols, phenols, sesquiterpene, acids, ketones, hydrocarbons, esters and terpenes) and pesticides have achieved a new challenge. In recent years, health risks developed from pesticide residues and other organic pollutants such as in the environment and food have become a major threat. Various organochlorine fungicides, organophosphate insecticides and s-triazine herbicides (Chenet al., 2010 and Liu et al., 1995) are widely used for killing or controlling of weeds and plant diseases. These plant systems are very complex in nature. So, it is essential to improve the analytic methods which help to obtain the accurate information regarding the plants growth mechanism.

Generally, the preparation of plant samples comprises of extraction, cleanup and concentration. For collection of plants samples, conventional methods such as accelerated solvent extraction (ASE), Soxhlet extraction (SE) and ultrasonic extraction (UE) are used. The entire process is monotonous, time-consuming, requiring large amount of volumes of solvents which are hazardous in nature. In modern era, the micro-extraction techniques are very useful tools in the determination of volatiles and semi volatile compounds from plant samples. These techniques are very sensitive in nature, short sample pretreatment time, simple to use, low solvent usage and sometimes solvent free. Furthermore, the micro-extraction techniques can also helpful to liquid, solid and gas samples. Therefore, these techniques have become more attractive tools than the traditional techniques to extract volatile and semi-volatile compounds from certain plant media.
In this review we will discuss the sorbent-based micro-extraction technique, solid phase micro-extraction, stir-bar sorptive extraction, solvent-based micro-extraction technique, hollow fiber liquid phase micro-extraction, dispersive liquid-liquid micro-extraction, and single-drop micro-extraction technique.

1.1. Management of plant samples for Micro-extraction

Different phases of plant samples such as (gas, solid and liquid) physical and chemical properties of chemicals, experimental condition and analytical objectives and, diverse extraction approaches is widely reported in literature. The samples of plant are highly intricate with various kinds of chemicals at numerous concentrations. Intricate with different types of substances at different concentrations. Various techniques such as head space micro-extraction (HS-ME), HS-SDME(Head space single drop micro-extraction) and HS-SPME(head Space single drop micro-extraction)are used to determine the volatile chemicals without any pretreatment process of samples, and this method is applicable for different phases of samples such as solid and liquid phases. Often, it is used in the real time monitoring of plants signaling components. High volatile amalgams (ketones, sesquiterpenes and alcohols) were extracted from various plant parts such as flowers (Delle-vedove et al., 2011; Li et al., 2009 and Wiemer et al., 2009) leaves (Cordero et al., 2012 and Chen et al., 2010) and fruits (May et al., 2012; Fong et al., 2011; Barboni et al., 2010; Gonzalez et al., 2009 and kamatou et al., 2008) by using HS-ME. Similarly, the ester and sesquiterpene compounds have also been analyzed by HS-ME method. The HS-ME has been recognized as an appropriate and sensitive method for the visualization of chemical and the comparison of the 161 plant and insect emitted plant volatile compounds (Cordero et al., 2012). If sample of plant matrix is in liquid phase then low vapor pressure or elevated polar extraction
and trace levels of analytes have also been done by method of DI-SPME (direct immersion micro-extraction) (Zhang et al., 2012 and Sheehan et al., 2012). Extraction is, however, restricted by the plant sample's skin or protective exterior shield when it is solid phase, and is hard to fully contact the micro-extraction phase with plant matrix during extraction method (volume of sample phase and surface area is higher than micro-extraction). Based on equilibrium distribution, many components are widely distributed in various plant tissue. Some traditional extraction methods (such as ultrasonic extraction, immersion extraction etc.) to evaluate the inclusive levels of target chemicals in the whole plants. These traditional techniques are used as a samples pretreatment method. The extracts have concentrated in solid form, liquid form, and the sample phase in micro-extraction has utilized in diluted solution. The concentrated extracts dissolved in water, and in micro-extraction the diluted solution was used as the sample phase. Generally, the process was used in the analysis of non-polar analytes in plant dried samples.

2. Sorbent-based micro-extraction (SPME) techniques:

It may have established on the concept of sorption, Pawliszn's team created SPME as a solvent free method in 1990 (Arthur et al., 1990). Although it is an (equilibrium non-exhaustive) procedure, SPME was quickly recognized as straight forward, green and miniaturized method that incorporates sampling, extraction, concentration and cleaning in one step. Based on its benefits, SPME rapidly became one of the most commonly used methods, including environmental and biological applications and in multiple areas of analytical chemistry. In this segment, we primarily discuss fiber coating, analytic strategies and automation of SPME in plants.

2.1. Fiber coating

Fiber coating is a significant factor in SPME. Recently, various types of fiber coating have been used such as polar polyacrylate (PA), semi-polar polydimethyl siloxane-divinyl benzene (PDMS-DVB), and non-polar poly dimethylsiloxane. Commercially, they have also used for semi-volatile and volatile compounds such as ketones, aldehydes, esters, alcohols, sesquiterpene, pesticides (carbamates, nicotinoids), acids, and terpenes (Chai et al., 2012; Junior et al., 2012; Jiménez et al., 2011; Cheong et al., 2011; Huang et al., 2011; Maggi et al., 2011; Reale et al., 2011; Chun et al., 2010; Oliveira et al., 2010; Schmarr & Bernhardt 2010; Mwatseteza & Torto 2010; Ferreira et al., 2009; Serrano et al., 2009; Nunes et al., 2008; Pinho et al., 2008; and Tanaka & Komatsu, 2008) from various plant matrices such as (vegetables and medicinal plants) (Linet al., 2013; Melo et al., 2012; Huang et al., 2011; Maggi et al. 2011; Reale et al., 2011 and Chun et al., 2010; and Tanaka et al., 2008;) and fruits (Jiménez et al., 2011) in the last five year.

To enhance the fiber stability, PDMS-20HMe 18C6 and a hydroxyl-terminated SPME fiber have synthesized by Ibrahium and Zeng using a sol-gel method, respectively, to determine organo-chlorine and organo-phosphorus pesticides in vegetables (Ibrahim et al., 2010 and Zeng et al., 2008). Furthermore, few metal oxides such as graphene-supported zinc oxide, NiTi-ZrO_2 have presented into coatings of fiber to examine the compounds of volatile in fruits (*Mangifera indica*) and leaves (Gebara et al., 2011 and Zhang et al., 2012). Recently, to enhance the extraction selectivity and efficiency, a technique of hybrid fiber coating has developed. In the manufacturing phase of inorganic fiber coatings, organic adsorption materials such as PDMS and graphene were introduced (Zhang et al., 2012 and Gebara et al., 2011).

3. Analytical strategies of the solid phase micro-extraction

Typically, there are two modes of SPME in extraction methods. These include Direct immerse (DI) the coating is completely immersed in the sample matrix and HD Headspace (HD) coating is exposed to the gas-phase above the sample matrix.

3.1. Direct immerse (DI-SPME)

In the plant medium, the fiber coating submerged directly due to the DI-SPME application. Then, a pretreatment phase is crucial earlier to direct immerse method. As the fiber coating is in direct contact with the sample phase in DI-SPME, it has high Extraction efficiency, and more suitable for semi volatile compounds various types of pesticide have been regulated by using the DI-SPME technique. Such as carbamates (Yang et al., 2008) organo-phosphorus (Bagheri et al., 2012) etc. fruit and vegetable samples such as *Mangifera indica* (Filho et al., 2011 and Menezes Filho et al., 2010), *Malus domestica* (Yang et al., 2008), *Cucumis sativus* (Bagheri et al., 2012), herbs (Du et al., 2012) and *Lactuca sativa* (Melo et al., 2012) etc. The findings of the implementation show that for qualitative and quantitative determination of pesticide residues by DI-SPME in the plant matrices. Furthermore, essential oils from fruits have also been analyzed by DI-SPME method (Peng et al., 2013). If the interfering substances and target analytes are transferred together in aqueous solution from plant matrix, which reduced the enrichment factor of the fiber coating on the target chemicals will be reduced which finally influence the sensitivity of DI-SPME. For the separation of target chemicals, new fiber coatings such as single-walled carbon nano-tubes coated fibers (Wu et al., 2010), IL-linked fibers (Zhang et al., 2012), ametryn-imprinted polymer (Djozan et al., 2009), and hydroxyl-terminated PDMS (J. Zeng et al., 2008) have been settled and applied for the resolving of herbicides (Djozan et al., 2009) pesticides (Zhang et al., 2012), maize, onion (Djozan et al., 2009) and tea (Wu et al., 2010), This novel fiber has better sensitivity, stability and selectivity, but its t preparation is time intensive and costly.

4. Headspace Solid Phase Micro-extraction:

This Technique is mainly used to analyze the volatile compounds in plant matrix. In the past year, HS-SPME was used to directly eradicate the volatile organic compounds (VOCs) from plant samples such as flowers (Li et al., 2009) leaves (Cordero et al., 2012) and fruits without pretreatment method (Li et al., 2009). Furthermore, different varieties have different samples as well as the identical varieties along with diverse local samples have different VOCs (Cordero et al., 2012). The HS-SPME pretreatment process is essential to increase the HS-SPME sensitivity in analysis of plants. The objective of this pretreatment process is to stimulate the target analytes deal and increasing the entire quantity of analytes in the gas-phase, thus, improving the

effectiveness of extraction. This technique is used for the analysis of volatile compounds (ketones, alcohols, and esters, etc.) and these compounds have the boiling points ranging from 77 ºC-226 ºC such as medicinal plants (Petronilho et al., 2011) vegetables and fruit (Serrano et al., 2009). It is also used to determine pesticides oragno-phosphorous (Ibrahim et al., 2010 and Chai et al., 2008) and fenitrothion (Khani & Imani, 2012) from plant samples. The HS-SPME, uses additional methods to raise the analytes flow frequency between the gas-phase and the matrices of plant. Microave-assited is developed by Gholive to extract the volatile compound from medicinal plant (Gholiv et al., 2012). The findings exhibited that the HS-SPME technique has well suited for the research of semi-quantitative of the structure of essential oils into the samples of plant as well as observing the differences in volatile compounds of plants.

4.1. In-Vivo SPME Method

This technique is very simple and not required the pretreatment process. The real time data of the target compounds have obtained from the living organisms by this method. This method of sampling has also used to quantify the chlorinated solvents (Sheehan et al., 2012). In addition, methyl tertbutylether determine in common reed, created and implemented in vivo DI-SPME samplings (Reiche et al., 2013). For HS-SPME in vivo, plant samples in a closed system (glass chamber or a polyethylene terephthalate bag) are placed before sampling to attain true representative sample of the population. After balance, the fiber of SPME carried into the chamber for the volatile organic components collection. This method has also helped in the determination of VOCs (alcohol, esters and ketones) in trees (Baker et al., 2009), flowers (Delle-Vedove et al., 2011 and Wiemer et al., 2009) and leaves (Chen et al., 2010).

5. Stir-bar Sorptive extraction (SBSE):

In 1999, the SBSE (Stir-bar sorptive extraction) technique was established by Baltussen based upon sorptive extraction as well as SPME. This is the solvent-less sample preparation method. In SBSE, the amounts of coating and surface area are larger than those in SPME coating. The main advantage of SBSE is the accuracy of extraction efficiency than SPME. In SBSE, desorption and extraction time is usually longer than SPME, as the analytes are dispersed in the huge capacity of coating. It is a virtuous device for the volatile composition analysis such as aldehydes (Pardo-Garćıa et al., 2013; Du et al., 2010; Zunin et al., 2009 and Raffo et al., 2008) acids (Du et al., 2010 and Zunin et al., 2009), alcohol (Pardo-Garćıa et al., 2013; Martínez-Gil et al., 2012; Du et al., 2010; Zunin et al., 2009; Raffo et al., 2008, Lactone (and Martínez-Gil et al., 2011) and ketones (Pardo-Garćıa et al. 2013; Du et al., 2010; Zunin et al., 2009 and Raffo et al., 2008) etc. Furthermore, the several studies has revealed that the organic pollutants can be monitored in plant matrix by SBSE technique such as organo-chlorine (Barriada-Pereira et al., 2010), pyrethroid (Li et al., 2012), bisphenols (Cacho et al., 2012), alkyl phenols and phthalate esters (Cacho et al., 2012), fungicides (Campillo et al., 2010), triazines and hydrocarbons (Maggi et al., 2008).

5.1. Immersion SBSE:

SBSE immersion was frequently used to achieve greater extraction. By using SBSE immersion technique, mostly target compounds have exposed to exhaustive extraction. Nevertheless, owing to matrix interference, some analytes have not abundantly obtained due to a complicated matrix and coating constraints (Barriada-Pereira et al., 2010). To increase the SBSE Selectively in plants to analysed triazines (Zhong et al., 2012 Hu et al., 2010) thiabendazole (Turiel & Martín-Esteban, 2012) and sulfonylurea (Hu et al., 2010), such as vegetables (Hu et al., 2010) rice (Hu et al., 2010 and Zhong et al., 2012) and fruits thiabendazole (Turiel & Martín-Esteban, 2012). In recent years, hybrid coating has also been applied in plants for the betterment of extraction capacity. The main drawback of SBSE technique is its complications in the automation and limited number of accessible materials of coating. Additionally, it is difficult to apply directly for the solid samples.

6. Solvent-Based Micro-Extraction Techniques (LPME)

6.1. Liquid phase micro-extraction technique

This technique is widely used for the extraction of inorganic pollutants (aromatic amines, antioxidants, metals, aromatic amines, and polycyclic aromatic hydrocarbons) and organic pollutants from vegetables, juices (Matsadiq et al., 2011), water (Vinas et al., 2014), food (Tsai et al., 2009), biological samples as well the environmental samples including wastewater,

sewage, and soil etc. (Pena-Pereira et al., 2010). The three main classification of liquid phase micro-extraction (LPME): Hollow fiber LPME (HF-LPME), and Dispersive liquid-liquid micro-extraction (DLLME).

6.2. Hollow fiber LPME (HF-LPME)

In this technique, the acceptor stages and sample stages are segregated by HF, so the extraction fluid is isolated by the hollow fiber and the solvent has not contact directly with the sample. Firstly, the analytes collected from the pores of the HF into a supported fluid membrane (SLM) and then into an acceptor solution inside the fiber lumen. As the acceptor stage is protected by HF fiber, the sample can be stirred intensely deprived of any extraction stage loss, and the tiny size of the pore excludes interference from the donor solution owing to great molecules and particles. HF-LPME has many benefits such as efficient cleaning, high pre-concentration factor and cost-effectiveness. The main drawback of HF-LPME is its ability to absorb the hydrophobic substances which are present in the biological samples such as urine and plasma or create the air bubbles on fiber surface during extraction course, which can therefore affect the reproducibility of the consequences (Ocaña-González et al., 2016).

The number of stages elaborated in the system, hollow fiber (HF-LPME) divided into following categories: Two-phase HF-LPME and Three phase HF-LPME.

6.3. Two-phase HF-LPME

This is the simplest and earliest technique. Acceptor phase and SLM use the same solvent, and the most commonly used solvents (octanol, diheyl ether and toluene etc.). The extraction of organic pollutants is a main application of HF-LPME such as nicotine (Shrivas & Patel, 2010), pesticides (Sanagi et al., 2010 and Xiong & Hu, 2008), PAHs (Ratola et al., 2008) from unlike matrices such as cucumbers (Wang et al., 2012), vegetables samples (Sanagi et al., 2010 Shrivas & Patel, 2010), and tea leaves (Xiong & Hu, 2008). The HF technique was castoff for define potential allele-chemicals in Chili (Sun & wang, 2012). To increase the adsorption of acceptor phase by carbon nano-tube in acceptor phase and has been used to evaluate the carbamate pesticides in fruit samples (Zhao et al., 2011). Shrivas and Patel determined the lesser amounts of nicotine in food and vegetable samples using the technique of ultrasonic-accelerated mass transfer in two phases HF (Shrivas & Patel, 2010).

6.4. Recent Expansion in HF-LPME

6.4.1. Biological analysis

The of pharmacokinetics echinacoside in Parkinson`s disease within a rat plasma was determined by two-phase HF along with U-Shaped instrumental setup after oral administration by Zhang et al., 2014.They have used 1-octanol by way of the acceptor stage and pharmacokinetics of the normal rats were compared with Parkinson's disease models that have showed a distinction owing to the potential physiological modifications affected by Parkinson's disease (Zhou et al., 2013). Additionally, a combination of toluene and organic solvent (1-octanol, chloroform) have used as organic acceptor phase for the buprenorphine, nor-buprenorphine and naloxone withdrawal from samples of plasma (Sun et al., 2008). In another study, a HF-LPME innovative phase was found on the reverse micelle has used for the quartet in withdrawal from tomato, onion and samples of human plasma. Another novel modification in two-phase HF-LPME that is based on consuming Fe_3O_4 in samples magnet-o-fluid powder by (Zhou et al., 2014).The results have concluded that the extraction time has significantly lesser than the mode of conventional and the pre-concentration factors of magnet-o-fluidic mode were greater (Zhou et al., 2011).

6.4.2 Beverage and food samples

Many studies reported that the uses of two-phase HF-LPME in analysis of food. Rodríguez – Delgado in 2013 reported the determination of estrogens in milk using the conventional rod like two phase HF-LPME. They used 1-octanol by way of the organic extraction stage and followed by the operation by acetonitrile analyte desorption. In another research investigation in milk samples, the oestrogenic compounds have found by using a method of vortex326 aided two-phase HF-LPME (VA-HF-LPME) (Wang et al., 2008). An another study which is proposed by Huang et al., 2011 their technique was a two-phase reverse HF-LPME in which edible oil samples were chosen as the matrix of interest and the acceptor phase and SLM solvent were aquatic. To this end, poly-dopamine and poly-ethyleneiminetrans formed the PVDF fibers to alter the fibers surface features from hydrophobic to hydrophilic. The technique was used in edible oils to determine aflatoxins (Huang et al., 2011).

6.4.3. Environmental Samples

Many techniques were proposed in two phase HF-LPME, earthy-musty odorous compound

a new technique developed by Yu et al., 2014 for determination of earthy-musty compound in water samples. They have also exposed the outcomes of hollow fiber type on the extraction efficiency. Following the similar technique Cai et al., 2012 used as an n-octanol impregnated PVDF HF for the determination of organo-chlorine pesticides in ecological textiles (Zhang et al., 2009). Dynamic single-interface HF-LPME is a new technique that was developed by Varanusupakul et al., 2016 for Cr (VI) calorimetric detection. The technique of colorimetric detection has depended on the creation of a violet complex of diphenyl carbazide 274 (DCP) and chromium for further valuation through a UV- visible fiber optic spectrophotometer. In another studies, cobalt has effectively obtained by supra-molecular decanoic acid vesicles in 1-decanol. Another name of this technique is micro extraction of supra-molecular Nano solvent based liquid phase fiber (SS-HF-LPME) (Asgharinezhad & Ebrahimzadeh, 2016).

6.5. Three phase HF-LPME

In 1999, three-phase HF-LPME was introduced for the higher extraction of ionizable compounds (Pedersen-Bjergaard & Rassmussen, 1999). In this mode, the aqueous solution was normally used as an acceptor phase. On the way to reach the advanced improvement, the acceptor phase (extraction phase) and donor phase (sample phase) the pH has improved in numerous studies. It has been realistic in the analysis of plant component including phytohormones in natural coconut juice (Wu & Hu, 2009) and acid of valerenic in *Valeriana officinalis* (Mirzaei & Dinpanah, 2011). The organic solvent and multi-walled carbon Nano-tubes a supported liquid membrane by increasing the SLM surface and improves the efficiency of extraction, and this technique has applied to analyze the caffeic acid in medicinal plant samples. Nano-magnetic powder has been added to the sample solution (donor phase) to increase the analyte mass transfer rate (Yang et al., 2011). The sample solution under the applied magnetic field was stimulated in this technique. Nano-magnetic powder has a better stirring impact compared to a magnetic stirrer for the reason that has dispersed uniformly in the solution of sample. Furthermore, Esrafili and his colleague set up an automated system and used it to evaluate pyridines in cigarette smoke (Esrafili et al., 2012).

6.6. Dispersive liquid-liquid micro-extraction (DLLME):

(Rezaee et al., 2006) firstly introduced the dispersive liquid-liquid micro-extraction (DLLME) in 2006 on the basis of Liquid-liquid Micro-extraction (LLE) principle. In this process, A mixture of dispersive solvent (miscible with water and acetonitrile, acetone, and methanol) and extraction phase (less solubility in water) is hastily injected using a syringe into the aqueous sample, and tiny droplets are formed in the aqueous sample, which provides a vast interphase contact and accelerates the mass transfer of analytes. DLLME is a fast and simple micro-extraction technique with following main benefits: (1) High enrichment factor usually obtained (2) very large surface area between aqueous sample and fine droplets of the extraction solvent (3) negligible amount of solvent used. DLLME is only appropriate for fluid matrix specimens depending upon the principle of extraction. Thus, this technique is mainly used in aqueous samples. For solid samples such as target compounds and plant samples must be converted from matrix to an aqueous form prior to DLLME assessment. This technique is only suitable for semi-volatile chemicals because volatile compounds are easily lost during the transfer. Pesticides reidues have been examined in the vegetables fruit samples Such as fungicides, polychlorinated biphenyls, permethrin, carbamates, folpet, captan, andorgano-phosphorus (Matsadiq et al., 2011; Du et al., 2010 and Qiao et al., 2010). Li. et al used this strategy to determine Radix Angelicae Dahuricaecoumarin compounds (Li et al., 2012).

Although quantitative extraction can be achieved by DLLME, its implementation remains restricted. Owing to limited solvents selection in DLLME, the extraction stage collection is rigid as well as may comprise water owing to the dispersive solvent uses. In addition, the analytes must be extracted for non-liquid samples from the matrix before DLLME, and this move does not only reduce the organic solvent use as well as operating time, but it can also cause errors in the determination of outcomes.

6.7. Single-drop micro-extraction technique (SDME)

Single-drop micro-extraction (SDME), w is based on the use of a drop of acceptor phase, is the oldest LPME technique (Oliveira et al., 2010). A variety of methods and specialized equipment's

are available for this technique (Chai et al., 2012). The acceptor phase may be immersed directly into the sample solution in direct-immersion single-drop micro-extraction (DI-SDME). Liquid–liquid–liquid micro-extraction (LLLME) can also be included in this group (Mwatseteza, 2010). SDME modes can be broadly classified as two-phase or three-phase techniques, according to the number of phases of the extraction. After extraction, the drop is withdrawn and injected into an analytical device (GC, LC, CE, etc.). The SDME procedure is very simple, efficient and cost-effective, as no special equipment is required to create the drop (Pinho et al., 2008).

7. Future Direction:

Comprehensive and general overview of the micro-extraction techniques were provided regarding its basic principles, possible setups, theoretical aspects, and remarkable applications. In the current plant research, in natural environments it is significant to forecast accurately the processes happening in a composite living system which is possible only if we regulate biologically active compounds in living systems. The in-situ and on-line techniques are essential in living system analysis. In Vivo sampling technique, head space SPME and DI (direct immersion) have been introduced. The in situ analysis is restricted, due to limitation in fibers used in SPME. Furthermore, in Vivo technique analysis, (on line and in-situ analysis) is essential in many fields such as Volatile singling transport mechanism in herbivore-plant interaction, real time changes in VOCs and plant- plant communication. So, micro-extraction analysis technique will attain better result in-situ and on-line micro-extraction analysis technique in the near future.

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