# Bioactive Compounds in Natural Resources and the Extraction Methods in Different Types of Solvents for Various Applications: A Review

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**Abstract.** The increasing demand of natural resources–based products in various fields such as cosmeceutical, pharmaceutical and food industries has created a great opportunities for the global marketing. Particularly, plants and herbs has been gaining attention from the researchers due to its tremendous benefits that possess anti–oxidant, anti–cancer, anti–microbial and anti–inflammatory effects. Aiming to study the functions of bioactive compounds in natural resources for various applications, certain issues were considered such as its benefits towards the skin and health. Besides, various extraction methods; conventional and non-conventional were discussed. Conventional extraction methods were basically the methods that have been actively implemented before, however it has few limitations. On the other hands, the non–conventional ones are the improved extraction methods that have been aggressively used in the recent studies. The details of the equipment along with the operating procedures, advantage and disadvantages of each method were compared. On top of that, a wide variation of solvents in the industrial processes has been actively used in reaction systems and separation such as water, organic solvent and the newly discovered green solvent, ionic liquid. In this study, along with the benefits of natural resources and the extraction methods, the wellness of solvents that were believed to play an important role in the extraction process as it helps in maximizing the extraction yield of bioactive compounds were also discussed in details.

## 1 Introduction

Medicinal plants and herbs, also fruits were excessively used before especially in the folklore treatment of various ailments, preserving foods also as components for skin care. In many Asian countries, the used of various types of folklore medicinal plants to cure sicknesses were popular as people aware about its goodness. The therapeutic properties that possess countless benefits especially its free radical scavenging ability that can act as antioxidant is very crucial. High antioxidant effect means high capability in protecting the body and health against free radical that will eventually cause many other diseases. Besides, these bioactive compounds also important in the food industries development. It improves the organoleptic properties of vegetable origin food and can be used as natural preservatives against food degradation (Ballesteros et al., 2017).

One of many dermatologic concerns is skin aging. Apart from that, consumers are also looking for products that claims for specific benefits such as for whitening, skin firming, sun protection, wrinkles decreasing, moisturizing, oil control and many more (Korac et al., 2011). Buying a skin care products can be tricky these days, with so many different options available and endless, hard-to-pronounce ingredient lists on every face wash, lotion and scrub package. There are many potential skincare available in the market these days. However, less consumers seems to care about the ingredients of that certain product. Everybody should really keep an eye on what is being added to our products and how our skin reacts to it. Many skin care products are laden with toxic chemicals such as parabens. Parabens are extensively used as antimicrobial preservatives in food, cosmetics and pharmaceutical products due to their broad spectrum of activity, inertness and low cost (Tavares et al., 2009). By far, the most prevalent use of parabens has been in cosmetics. It was estimated that parabens were used in 13,200 formulations, and a survey done before on 215 cosmetic products found that parabens were used in 99% of leave-on products and 77% of rinse-off cosmetics (Darbre et al., 2004). According to the Cosmetic, Toiletry, and Fragrance Association (CTFA), formulations may contain mixtures of parabens (up to 0.8%) or may contain a single paraben (up to 0.4%), and industry estimates of the daily use of cosmetic products that may contain parabens were 17.76 g for adults and 378 mg for infants (CTFA 2005). Even though it has been used for years and generally considered safe, several studies concerning on the safety of parabens have been published. Previous studies by Okubo et al., 2001; Byford et al., 2002 and Darbre et al., 2002, 2003 stated that parabens can increase the growth of human breast cancer cells. As parabens can absorb rapidly through intact skin, this can cause serious issues as the products that we use will absorb right into our skin.

In order to solve this problem, various types of organic compounds and essential oils were in state of investigating in order to be used as an ingredient in a natural skin care products, in medicines and also as a compound for food preservation. These active compound can be obtained by the process of extraction. There are many extraction methods that can be apply as has been discussed in the past. The traditional methods in obtaining the essential oils are hydro-distillation (HD), and maceration also by employing Soxhlet (Gu et al., 2009). HD has been widely used for the extraction process but the time taken for the process is way too long and the yield produced is lesser yet not economical in the industrial scale. As time goes by, many researchers had found ways to improve the extraction process to make it more economical. Several approaches have been done such as microwave-assisted extraction (MAE), (Wang et al., 2010), pressurized liquid extraction (Kaufmann and Christen, 2002), subcritical water extraction (Mohammad et al., 2007), and ultrasound-assisted extraction (Porto et al., 2009) have also been applied to shorten extraction time, improve the extraction yield and reduce the operational costs (Mathialagan et al., 2014) to improve the extraction quality. In this paper, all types of popular extraction methods mentioned earlier were discussed and compared in order to obtain the essential oil also other organic compounds from the organic materials.

Apart from that, the solvent used in the extraction process plays an important role in increasing the extraction yield of the target compounds. Solvents such as water, organic solvents, and ionic liquids were actively applied in the extraction process. Ionic liquids (ILs) were widely used as an alternative to the volatile and toxic organic solvents used in the solvent extraction field. ILs, which are organic molten salts with a melting point below 100 °C, have many unique characteristics, such as negligible vapor pressure, high thermal and chemical stabilities, low flammability, and potential recoverability. Their properties are tunable through modification of their cations, anions, or functional groups, such that they possess specific physical and chemical properties (Ao et al., 2015; Olkiewicz et al., 2015; Rogers, 2007; Rogers and Seddon, 2003; Vander Hoogerstraete et al., 2015).

## 2 Type of Natural Resources with Active Compound Suitable for Various Applications

### 2.1 Skincare

Nowadays, people aware about the bad effects of the non-natural skin care products that available in the market. Along with the tremendous technology development year by year, knowledge and information can be easily access by everybody making people realised the important of using the natural resources-based skin care products. There are many natural resources especially here in Malaysia that is suitable to be used in skin care as Malaysia is famous for its biodiversity elements that have and have not yet been discovered.

Organic compounds such as curcumin, gallic acid, tannic acid, citronellol, and vitamin C are widely known for its antioxidant activity for skin whitening and other applications. These organic compounds can be found abundant here in Malaysia. Curcumin is the main compound that can be found in the turmeric (*Curcuma Longa*), tannic acid and gallic acid rich in Manjakani (*Quercus Infectoria),* citronellol can be found in the leaves of Citronella (*Cymbopogon Nardus*), and vitamin C can be found in many fruits such as lemon and pinenapple. Table 1 below shows the types and percentage of active compounds found in different kinds of herbs, plants and fruits and their benefits towards skin reported by previous works.

Table 1 Types of active compound suitable for skin care

| Bioactive compound | Functions | Percentage | References |
|---|---|---|---|
| *Citronellol* | Possess antioxidant and used as fragrance components.<br>Anticancer and antiinflammatory properties, as well as promoting wound healing.<br>Insecticides effects towards insects. | 50% in Citronella<br>18-55% in Rose<br>1.320% in Lemongrass | (Džamić et al., 2014)<br>(De Cássia Da Silveira E Sá, Andrade, & De Sousa, 2013)<br>(Baldacchino et al., 2013) |
| *Curcumin* | Known can dry up pimples, fade dark spots, | 5% in Turmeric | (Nelson et al., 2017) |

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| | slow the aging process, and protect from dangerous UV rays. | | |
| | Therapeutic applications as antimutagenic as it helps prevent new cancers caused by chemotheraphy, and antimicrobial effects as it can improve lesions. | | (Nagahama et al., 2016) |
| | Dental application as toothpaste and mouth wash. | | (Sood & Nagpal, 2013) |
| *Vitamin C* | High antioxidant and can act as skin protection (whitening), also shielding skin from damaging free radicals | 0.026% in Turmeric<br>0.053% in Lemon<br>0.020% in Potato<br>0.009% in pumpkin<br>0.005% in Beetroot<br>721% in Pineapple | (Telang, 2013) |
| *Beta-carotene (Vitamin A)* | Making the skin smooth and even-toned, decreases sebum production and thus treats acne brilliantly, decreases clustering of melanin granules and reducing brown spots or pigmentation | 0.009% in Sweet potato<br>0.005% in Pumpkin<br>0.005% in Carrot<br>10% in Pineapple | (S. K. Schagen, Zampeli, Makrantonaki, & Zouboulis, 2012) |
| *Niacin (Vitamin B3)* | Revive skin's healthy tone and texture, treating inflammatory skin conditions and protects the skin from further UV damage | 0.005% in Orange<br>0.001% in Carrot<br>0.001% in citronella<br>0.002% in turmeric | (Gehring, 2004) |

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|---|---|---|---|
| *Glycyrrhizic acid* | Helps improve collagen expression and has antioxidant activity | 5-10% in Liquorice | (Binic, Lazarevic, Ljubenovic, Mojsa, & Sokolovic, 2013) |
| *Manganese* | Have a capacity to stimulate collagen production for skin | 0.092% in Pineapple<br>0.005% in seeds of pumpkin<br>0.0056% in hazelnuts | (Schagen, 2017) |
| *Proanthocyanidin* | Helps in maintaining the integrity of elastin in the skin and act synergistically with both vitamin C and E, protect and replenish them and has the antioxidant effect | 0.050% in Grapes<br>1.500% in Cocoa<br>0.120% in Apple<br>0.180% in Almonds | (De Luca et al., 2016) |
| *Vitamin E* | Has antioxidant promise and suitable for anti-aging formulations. | 0.002% in Kiwi<br>0.001% in Pumpkin<br>0.002 in Broccoli<br>0.002% in Avocados<br>0.036% in Sunflower seeds<br>0.026% in Almonds | (Ganceviciene, Liakou, Theodoridis, Makrantonaki, & Zouboulis, 2012) |
| *Polyphenols* | High antioxidant and can act as anti-aging, helps soothe, heal and protect skin tone | 12% in Green tea<br>17.600% in Cloves<br>3-15% in Turmeric<br>64.530 % in *Quercus Infectoria* | (Ganceviciene et al., 2012) |
| *Quercetin* | Act as anti-aging and high anti-oxidant | 0.005% in Apple | (Jadoon et al., 2015) |

| | | | |
|---|---|---|---|
| | | 0.022% in Onion | |
| | | 0.233% in Caper | |
| | | 0.022% in Cocoa | |
| | | 0.006% in *Quercus Infectoria* | (Kheirandish et al., 2016) |
| *Gallic acid* | Powerful antioxidant (skin whitening) | 0.220% in *Quercus Infectoria*/ manjakani | (Kheirandish et al., 2016) |
| | | 1.860% of *Labisia pumila*/ kacip Fatimah | |
| *Tannic acid* | Skin firming & tightening also whitening | 50-70% in *Quercus infectoria*<br>13.200% in Liquorice | (Nur Syukriah, Liza, Harisun, & Fadzillah, 2014) |

2.2 Pharmaceutical and food industry

The application of plant extracts in treating human diseases and symptoms have been employed for nearly a thousand years, due to its therapeutic performance and safety. Previous studies have shown a tremendous result of the bioactive compounds such as phenolic acids, flavonoids, tannins and alkaloids from plant extracts that highly contributed in pharmaceutical applications (Garcia-Castello et al., 2015; Teng & Choi, 2013; Wong Paz, Muñiz Márquez, Martínez Ávila, Belmares Cerda, & Aguilar, 2015), as it possess diverse bioactivities such as antioxidant, anti–inflammatory, anticancer, antidiabetic, antiallergic, and antimicrobial (Chhouk, Wahyudiono, Kanda, & Goto, 2018; Pel, Kim, & Chin, 2015; Samatha, Shyamsundarachary, Srinivas, & Swamy, 2012).

In addition, bioactive compounds such as phenolic compounds, flavonoids, vitamins, carotenoids and alkaloids obtained from vegetables and fruits extract has promising application in food industry (Recharla, Riaz, Ko, & Park, 2017). It was reported that dietary fibre (from cocoa shell) was used as fat replacer muffins and to replace oil (Okiyama, Navarro, & Rodrigues, 2017), allicin (from garlic), curcumin (from turmeric) and catechines (from tea polyphenols) helps to prevent diseases including cancer, cardiovascular illness, neuronal degenerative diseases and diabetes (Recharla et al., 2017), antioxidants (from bamboo leaf) are very effective in retarding lipid oxidation and preventing food spoilage (Nirmala, Singh, Kaur, & Santosh, 2018). Some previous studies extracting bioactive compound from different plants were tabulated in Table 2, along with its total phenolic, total flavonoid content and antioxidant activity.

Table 2 Total phenolic, total flavonoid contents and antioxidant activity of plant extracts

| Plant | Total phenolic content (mg/g) | Total flavonoid content (mg/g) | Antioxidant activity (%) | References |
|---|---|---|---|---|
| *Rosmarinus officinalis* L. | 161.070 ± 3.120 | 46.630 ± 0.740 | 94.840 | (Wang et al., 2018) |
| *Polygonatum verticillatum.* | 0.126 ± 0.050 | 0.094 ± 0.004 | 42.070 | (Patra & Singh, 2018) |
| *Carpobrotus edulis*. | 151.900 ± 4.100 | 38.840 ± 0.800 | 93.710 | (Hafsa et al., 2016) |
| *Rheum moorcroftianum*. | 81.860 ± 2.310 | 103.950 ± 4.170 | 58.320 | (Pandey, Belwal, Sekar, Bhatt, & Rawal, 2018) |
| *Scirpus holoschoenus.* | 253.470 ± 18.350 | 6.620 ± 0.040 | 64.060 | (Oussaid et al., 2017) |
| *Pinus morrisonicola*. | 15.480 ± 0.610 | 15.740 ± 0.940 | 77.100 | (Chiang, Lee, Whiteley, & Huang, 2017) |
| *Rumex abyssinicus.* | 185 ± 2.840 | 154 ± 3.540 | 89.540 | (Mohammed, Panda, Madhan, & Demessie, 2017) |

# 3 Conventional Extraction Methods

The traditional methods in obtaining the essential oils are by employing Soxhlet, hydro-distillation (HD), and maceration. HD has been widely used for the extraction process but the time taken for the process is way too long and the yield produced is lesser yet not economical in the industrial scale.

## 3.1 Soxhlet Extraction

Soxhlet is a classical extractor invented in 1879 by Franz von Soxhlet originally designed for the extraction of a lipid from a solid material. It used to be implemented in determining fat in milk (Luque de castro and Priego-Capote, 2010). However, along with the increasing researches year by year, soxhlet process has been generalized for extraction in agricultural chemistry before becoming the most used tool for solid–liquid extraction in many fields like environment (Tanabe et al., 2004), foodstuffs (Mulinacci et al,. 2005 & Singh et al., 2006), and pharmaceutics (Venkat Rao et al., 2007& Devine et al., 2006). It has also been known as the universal chemical extraction process (Heleno et al., 2016). Generally, a small amount of dry sample is placed in a thimble. Then, the thimble is placed in distillation flask that contains the solvent of particular interest. After reaching to an overflow level, the solution of the thimble-holder is aspirated by a siphon where the siphon unloads the solution back into the distillation flask. The solution will carry the extracted solutes into the bulk liquid and the solute is remained in the distillation flask while the solvent is passes back to the solid bed of plant. The process runs repeatedly until the extraction is completed (Azmir et al., 2013).

This conventional method has some attractive advantages. First, the sample is repeatedly brought into contact with the fresh portions of the solvent (continuous process), thereby helping to displace the transfer equilibrium and no filtration is required after the extraction step (Subramaniam et al., 2016). Also, the system remains at a relatively high temperature by effect of the heat applied to the distillation flask reaching the extraction cavity to some extent (Luque de castro and Priego-Capote, 2010). Moreover, it is a very simple methodology that requires little training plus the basic equipment is inexpensive.

Apart from that, it also has some disadvantages such as time consuming (Niu et al., 2014) and large amount of extractant being wasted. It is not only expensive to dispose-off, but also becoming a source of additional, environmental problems. In addition, samples are usually extracted at the solvent boiling point over long periods, which can result in thermal decomposition of thermo labile target species (Virot et al,. 2007). Aside provides no agitation which would help to expedite the process, this technique is limited by extractant and difficult to automate (Luque de castro and Priego-Capote, 2010).

Despite its advantages and disadvantages, this method is still popular among researchers and has been used as starting point for the development of a variety of modifications intended to alleviate or suppress the latter while keeping or even improving the former. Figure 1 shows the configuration of conventional Soxhlet extractor.

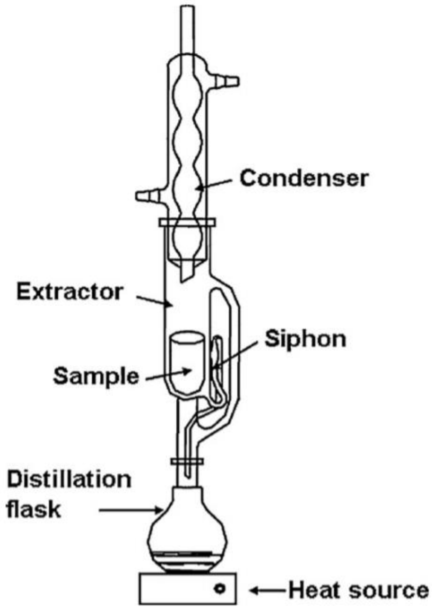


Figure 1 Conventional Soxhlet extractor (Luque de Castro and Priego-Capote, 2010)

3.2 Hydro-distillation (HD)

Hydro-distillation is one of the famous conventional extraction techniques along with soxhlet in obtaining essential oil and bioactive compounds from plants. There are three types of hydro-distillation: water distillation, water and steam distillation and direct steam distillation (Vankar, 2004). Water distillation is the one that widely used in many researches previously in extracting *Prangos ferulacea* Lindle. essential oil (Damyeh & Niakousari, 2016), recovery of bioactive compounds from *Lavandula viridis* L'Hér (Costa et al., 2012), citronella oil (Timung et al., 2016), *Piper nigrum* L. essential oil (Bagheri et al., 2014), *Aquilaria malaccensis* leaves essential oil (Samadi et al., 2016), essential oil from three aromatic herbs: basil (*Ocimum basilicum* L.), garden mint (*Mentha crispa* L.), and thyme (*Thymus vulgaris* L.) (Lucchesi et al., 2004), essential oils derived from three plants within the Lamiaceae family, marjoram (*Origanum majorana* L.), pennyroyal (*Mentha pulegium* L.), and lemon balm (*Melissa officinalis* L.) (Petrakis et al., 2014), essential oils from the leaves and stems of *Schefflera heptaphylla* (Wang et al., 2012) and essential oil of rosemary (*Rosmarinus officinalis*) (Conde-Hernandez et al., 2017). This method was done by all-glass Clevenger apparatus with heating mantle as the heating source (Damyeh & Niakousari, 2016). The plant material was extracted with distilled water placed in the round bottom flask. Parameters such as extraction time and heating mantle temperature will be considered. Indirect cooling by water condenses the vapor mixture of water and oil. Condensed mixture flows from condenser to a separator, where oil and bioactive compounds separate automatically from the water (Silva et al., 2005). Hydro-distillation involves three main physicochemical processes; Hydro-diffusion, hydrolysis and decomposition by heat (Azmir et al., 2013).

The main thing to be highlight in this process is that the product from this process when it is completed is pure without organic solvent pollution as this technique does not require the use of organic solvents, but only water (Wu et al., 2015). Even though hydro-distillation is the most frequently used method, there are several shortcomings associated with this conventional method. It took long extraction time, has potential in losing or damaging the volatile compounds and requires high energy consumption (de Rijke et al., 2006; Gavahian et al., 2012; Lo Presti et al., 2005). In addition, it does not prevent hydrolysis reactions that can degrade thermo labile compounds (Azmir et al., 2013).

Many alternatives implementation were in study state in improving this method in obtaining the pure essential oils by combining this hydro-distillation with other method such as ohmic-assisted hydro-distillation (Damyeh & Niakousari, 2016), microwave-assisted conventional hydro-distillation (Petrakis et al., 2014), advanced microwave assisted hydro-distillation (Jeyaratnam et al., 2016) and many more. Figure 2 shows the configuration of hydro-distillation Clevenger apparatus system.

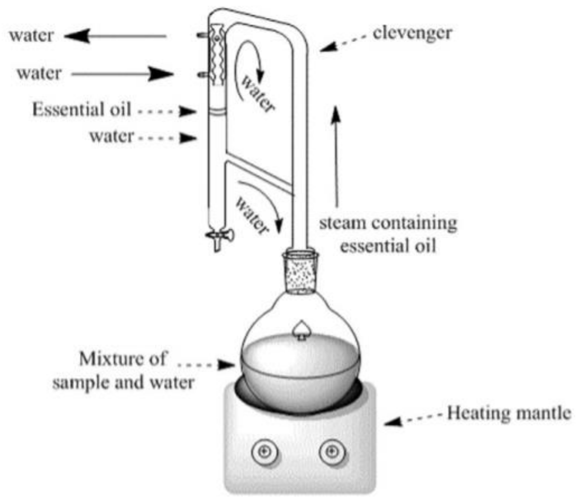


Figure 2 Hydro-distillation Clevenger apparatus system (Samadi et al., 2016)

3.3 Maceration

Maceration in the past was used in homemade preparation of tonic (Azmir et al., 2013). It gained recognition due to its inexpensive way to get essential oils and bioactive compounds. This technique is still implemented in certain industry even though it is considered one of the traditional methods same as soxhlet and hydro-distillation. Maceration technique was widely applied in rose and red wines in attempt to produce more aromatic and complex wines with better colour and body (De Santis & Frangipane, 2010; Herjavec et al, 2008). Mihnea et al, in 2015 studied the volatile content of *Mencía* wines, Cujic et al, in 2016 extracted the polyphenols from chokeberry (*Aronia melanocarpa*) dried fruit, and Lukic et al, in 2017 searched for the volatile aroma and phenol composition in Teran red wine using this technique. In a small scale extraction process of maceration, it generally consists of several steps; grinding of plant materials into small particle (increase the surface area for proper mixing with solvent), adding appropriate solvent named as menstruum in a closed vessel, let the liquid strained off while pressing the marc which is the solid residue in this extraction process to recover the large amount of occluded solutions, and filtrating the mixed then separate it from impurities (Azmir et al., 2013).

On a positive side, maceration always results in an odor similar to that in the original plant material without causing degradation of the thermo labile compounds present in the fraction due to the low extraction temperature similar to cold pressing (Wu et al., 2015). However, it has some limitations, such as time-consuming and labour-intensive procedures, extended concentration steps, and the involvement of large volumes of hazardous solvents, which may restrict the use of this method in food, cosmetic and pharmaceutical industries (Siqueira et al., 2011). It is also resulting in lower yield of phenolic compounds (Deng et al., 2017).

Over the years, various maceration procedures in the production of red wines have been studied in order to establish the selective effects of different parameters on the extraction of important grape components such as duration and temperature (Lukic et al., 2017). Several treatments such as *saignée* (Harbertson et al., 2009), cold-soak pre-fermentative maceration, carbonic maceration, delestage, (Sacchi et al., 2005), extended maceration and maceration with heating (Baiano et al., 2009) were still in studies state in improving this technique to be used in the wine extraction industry.

## 4 Non-Conventional Extraction Method

As time goes by, many researchers had found ways to improve the extraction process to make it more efficient and economical. Several approaches have been done such as microwave-assisted extraction (MAE), (Wang. et al., 2010), pressurized liquid extraction (Kaufmann and Christen, 2002), subcritical water extraction (Mohammad. et al., 2007), and ultrasound-assisted extraction (Porto. et al., 2009) have also been applied to shorten extraction time, improve the extraction yield and reduce the operational costs (Mathialagan. et al., 2014) to improve the extraction quality.

### 4.1 Ultrasonic Assisted Extraction (UAE)

Ultrasonic-assisted extraction (UAE) is an innovative technology that has been developed to replace the conventional extraction method such as soxlet, hydro-distillation and maceration. This methods have been developed for the extraction of phenolic compounds from different plant materials, including grapes and winemaking by-products such as pomace and wine lees (Carrera et al., 2012; Casazza et al., 2010; Novak et al., 2008; Tao et al., 2014), natural antioxidants from plant materials (Xu et al., 2017)) and many more. This UAE or sonification mechanism is based on air bubbles that are generated during the cavitation phenomenon which caused by dispersion of sound waves within the liquids (Sourki et al., 2017). The explosion and disruption of these bubbles will cause physical, chemical also mechanical changes by which plant tissue is destroyed allowing solvent penetration into the tissue to release the bioactive compounds (Chanioti & Tzia., 2017).

This outstanding extraction technique was able to cut down extraction time, energy and use of solvent, increase yield and quality (Bosiljkov et al., 2017) also has the capacity to improve the extraction efficiency by promoting the mass transfer and possible rupture of cell wall due to its effect of acoustic cavitation (Shirsath et al., 2012). Meanwhile, the enhanced solvent penetration into the cells leads to an increase of mass transfer (Chanioti & Tzia., 2017). Ultrasound energy for extraction also facilitates more effective mixing, faster energy transfer, reduced thermal gradients and extraction temperature, selective extraction, reduced equipment size, faster response to process extraction control, quick start-up, increased production and eliminates process steps (Azmir et al., 2013).

Nowadays, this has become one of the most famous extraction technique implemented by many researchers. There have been many positive feedback and they have been highlighted only the positive side of using UAE in replacing the conventional extraction methods which has many drawbacks. Additionally, the comparative studies revealed that UAE gave a better result than soxhlet and maceration technique (Xu et al., 2017; Safdar et al., 2016).

4.2 Microwave Assisted Extraction (MAE)

The microwave-assisted extraction (MAE) is considered as a novel method that facilitates the partition of the sample compounds into the solvent (Albuquerque et al., 2017) from a wide range of materials by using microwave energy. It is widely used for alkaloids extraction (Xiong et al., 2016), food processing application (Yanik, 2017) and phytochemicals recovery (Belwal et al., 2017). The principle of heating using microwave is based upon its direct impacts on the polar materials. The electromagnetic fields involved (electric field and magnetic field) gave energy that is converted to heat following ionic conduction and dipole rotation mechanisms (Jain, 2009). During ionic conduction, the mechanism heat is generated because of the resistance of medium to flow ion while the ions keep their direction along field signs that change frequently. This frequent change of directions at the end resulting in the collision between molecules, hence consequently generates heat. The mechanism of MAE consist of three sequential steps which are active sites of sample matrix under increased temperature and pressure, diffusion of solvent across sample matrix and release of solutes from sample matrix to solvent (Azmir et al., 2013).

MAE is found promising due to the fast heating and destruction of the biological cell structure of plant tissues under microwave conditions that provide a very powerful extraction procedure in a shorter time (Belwal et al., 2017; Yanik, 2017). It reduced consumption of energy and quantities of organic solvents. Thus, it decreases the amount of waste and makes possible to obtain better yield compared to the traditional methods of extraction (Lefsih et al., 2017).

Compared with traditional reflux extraction, soxhlet extraction and ultrasonic extraction, microwave-assisted extraction has the advantages of short extraction time, high extraction rate and good product quality (Xiong et al., 2016). Moreover, the MAE is considered a green extraction technique in terms of energy, solvents and sample preparation compared to others.

### 4.3 Pressurized Liquid Extraction (PLE)

Pressurized fluid extraction (PLE) is an extraction technique that has been developed and used successfully in universal field and industry. The application of this technique involves in evaluating the infusion of multiple pesticides from green tea (Chen et al., 2017), extractions of phytonutrients from passion fruit (Vigano et al., 2017), fractionate of ten Salvia species for functional foods and nutraceuticals (Sulniute et al., 2017), extraction of caffeine from spent coffee grounds (Shang et al., 2017), and extraction process of safflower oil (Conte et al., 2016). PLE is also known by several names such as accelerated fluid extraction (ASE), enhanced solvent extraction (ESE), and high pressure solvent extraction (HSPE). The concept of PLE is basically about the application of high pressure that facilitates the extraction process to let solvent liquid remain beyond their normal boiling point (Azmir et al., 2013). Nowadays, for extraction of polar compounds, PLE is also considered as a potential alternative technique to supercritical fluid extraction (Vigano et al., 2017; Sulniute et al., 2017; Kraujalis et al., 2017). It shows that the merge of these two methods resulting to a better extraction results.

This extraction technique was able to attract the attention of many as it leads to reduce the extraction time and amounts of solvent, which is of particular importance for high sample throughput for bioactivity assays (Feuerisen et al., 2017). On top of that, PLE gets broad reorganization as a green extraction technique due to small amount organic solvent used (Ibanez et al., 2012). In addition, PLE may be conceptualized as a process that combines temperature and pressure with liquid solvents in order to achieve a rapid and efficient extraction of analytes from several matrices (Conte et al., 2016).

In comparison to the traditional extraction, PLE is absolutely a better way to extract the target compounds as it was found to dramatically decrease time consumption and solvent used (Azmir et al., 2013). Besides, the automation techniques are the main reason for the greater development of PLE-based techniques. PLE technique requires small amounts of solvents because of the combination of high pressure and temperatures which provides faster extraction. It can promote higher analyte solubility by increasing both solubility and mass transfer rate and, also decrease the viscosity and surface tension of solvents, hence improve the extraction rate (Ibanez et al., 2012).

Based on the recent works, in order to obtain the essential oil from the organic materials such as plants, methods such as Soxhlet extraction (Kulkarni et al., 2012), Hydro-distillation (Silva et al., 2005), microwave assisted extraction (Wakte et al., 2011), ultrasound assisted extraction (Xu et alh., 2015) and pressurized liquid extraction (Osorio-Toben et al., 2014) are widely applied. Table 3 shows the comparison of extraction methods in extracting the bioactive compounds such as curcumin, demethoxycurcumin, and bisdemethoxycurcumin from turmeric that has promising effect towards skin with their percentage yield.

Table 3 Comparison of extraction methods

| | Soxhlet extraction (SE) | Hydro-distillation (HD) | Microwave assisted extraction (MAE) | Ultrasound assisted extraction (UAE) | Pressurized Liquid Extraction (PLE) |
|---|---|---|---|---|---|
| Plant | *Curcuma longa* (Turmeric) | *Curcuma longa* (Turmeric) | *Curcuma domestica* (Turmeric) | *Curcuma domestica* (Turmeric) | *Curcuma longa* (Turmeric) |
| Organic compound | Curcumin | Curcuminoids (curcumin, demethoxycurcumin, bisdemethoxycurcumin) | Curcumin, demethoxycurcumin, bisdemethoxycurcumin | Curcumin, demethoxycurcumin, bisdemethoxycurcumin | Curcuminoids (curcumin, demethoxycurcumin, bisdemethoxycurcumin) |
| Common solvent used | Methanol | Distilled water | Acetone | Ionic Liquid: 1-octyl-3-methylimidazolium bromide ([Omim]Br) | Ethanol |
| Temperature | 65$^{o}$C | - | - | - | 333 K |

| | | | | | |
|---|---|---|---|---|---|
| Time required | 7 hours | 4 hours | 5 min | 90 min | 20 min |
| Volume of solvent used/ Ratio | 250mL/ 6g | 500mL/ 150g | 60mL/ 20g<br>(1:3) | 15mL/ 0.5g | 314.500mL/ 47g<br>(13%:87%) |
| Pressure (MPa) | - | - | - | - | 10 |
| Power (W) | - | - | 60 | 250 | - |
| Percentage extraction yield (%) | 12.390 | 16.300 | 68.570 | 76.000 | 4.300 |
| Reference | Kulkarni et al., 2012 | Silva et al., 2005 | Wakte et al., 2011 | Xu et al., 2015 | Osorio-Tobon et al., 2014 |

# 5 Type of Solvents

The extracted organic compounds and essential oils also their antioxidant activity were affected by some factors such as extraction time, extraction temperature, sample to solvent ratio and pH (Dai and Mumper 2010; Thoo et al., 2013). Solvents such as water, organic solvents, and ionic liquids were actively applied in the extraction process. Ionic liquids (ILs) were widely used as an alternative to the volatile and toxic organic solvents used in the solvent extraction field. Al Othman et al., 2009; Dai and Mumper, 2010 stated that the methanol, ethanol and acetone are usually used as solvents for the extraction from the plant materials. There are some criteria that need to be considered when choosing a solvent, such as good extraction performance, low solvent solubility in the aqueous phase and acceptable solvent handling properties which means that it has a low melting point and compatible with the preferred materials of that want to be extracted (Offeman et al., 2010). On top of that, the addition of the aqueous mixtures of solvents was proven to have a better extraction result compared to the pure solvent (Goyal et al., 2010; Anwar et al., 2010; Motaal and Shaker, 2011). The isolation of the plant compounds is strongly dependent on the nature of extracting solvent. This is due to the presence of many different compounds with varied chemical characteristics also polarities which may influence the solubility in that solvent described detailed by Tomsone et al., 2012.

Dai and Mumper, 2010 from their research found that the analyte tend to be soluble at a higher temperature while, the viscosity and the surface tension of the solvents are reduced at higher temperature. This later might give the tendency to the solvent for better extraction rate. On the other hand, there are many phenolic compounds that are easily hydrolysed and oxidized which will affect the yield of phenolic extracts. Moreover, high temperature in plant extraction is usually done in order to make sure that the compounds are not deteriorate due to moisture content (Nantitanon et al., 2010; Hamrouni-Sellami et al., 2013). Hence, choosing a suitable temperature and efficient extraction method is very important to maintain the stability of the compounds. Table 4 shows the comparison of solvent used with different operating parameters. The plants discussed in the table below are the type of plants that has positive effect towards skin due to its outstanding function of bioactive compounds.

Table 4 Comparison of type of solvent on the percentage yield

| Solvent used | | Extraction method | Plant | Percentage yield (%) | Reference |
|---|---|---|---|---|---|
| Water | | Soxhlet | *Quercus Infectoria* (Manjakani) | 76.000 | Ab. Rahman et al., 2015 |
| | | HD | *Curcuma longa* (Turmeric) | 16.300 | Silva et al., 2005 |
| | | UAE | *Hibiscus-rosa sinensis* | 9.660 | Afshari et al., 2015 |
| | | UAE | *Labisia Pumila* (Kacip Fatimah) | 183.150 | Md. Salehan et al., 2016 |
| Organic solvents | Methanol | Soxhlet | *Curcuma longa* (Turmeric) | 12.390 | Kulkarni et al., 2012 |
| | Acetone | MAE | *Curcuma longa* (Turmeric) | 68.570 | Wakte et al., 2011 |
| | Ethanol | PLE | *Curcuma longa* (Turmeric) | 4.300 | Osorio-Tobon et al., 2014 |
| Ionic liquids | 1-ocyl-3-methylimidazolium | UAE | *Curcuma longa* | 76.000 | Xu et al., 2015 |

| | | | | | |
|---|---|---|---|---|---|
| | bromide | | (Turmeric) | | |
| | 1-butyl-3-methylimidazolium terrafluoroburate | MAE | *Eucalyptus camaldulensis* (river red gum) | 35.200 | Li et al., 2016 |
| | 1-butyl-3-methylimidazolium hydrogen sulphate | UAE | *Boehmeria nivea L.* (Ramie) | 96.810 | Yang et al., 2016 |

## 6 Conclusion

The use of natural resources such as herbs, plants and fruits as the ingredients in the natural-base skin care, pharmaceutical and food industry was much well known due to its tremendous properties of bioactive compounds. It is believed that the application of these natural resources is not limited in these areas only, as there is much more that need to be explore in maximised the function of bioactive compounds. In addition, the various extraction methods can be seen to be developing, aiming to improve the extraction time, amount of sample and solvent also yield. On top of that, the use of ionic liquids should also be considered in any extraction process of natural compounds as it shows positive result in the extraction process.

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