Comparative Study on Bioactive Constituents and Extraction Procedure of Malaysian Medicinal Plants: A Review

Hasmida Mohd-Nasir*1,2 Zarith Asyikin Abdul Aziz1,3 Wong Lee Peng2 Siti Hamidah Mohd-Setapar*1,2,3

1Centre of Lipid Engineering and Applied Research, Ibnusina Institute for Scientific and Industrial Research, Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Johor, Malaysia
2SHE Empire Sdn. Bhd., No. 44, Jalan Pulai Ria 2, Bandar Baru Kangkar Pulai, 81300 Skudai, Johor, Malaysia
3Department of Chemical Process Engineering, Malaysia-Japan International Institute of Technology, UTM Kuala Lumpur, Jalan Sultan Yahya Petra, Kampung Datuk Keramat, 54100 Kuala Lumpur, Malaysia
*Corresponding author. Email: hasmida.mn@utm.my; siti-h@utm.my

ABSTRACT
This article aims to provide an overview on bioactive constituents and extraction procedure used of Malaysian medicinal plants. Search on the electronic databases including ‘ScienceDirect’, ‘Scopus, and ‘Web of Science’ was done based on related keywords, ‘Malaysia’, medicinal plant and ‘extraction method’, focusing from the year 2017 to 2020. As a result, 22 medicinal plants from 29 articles have been reviewed. Modern extraction techniques have been proven to produce a high amount of phytochemical even though the extraction yield is lower than conventional procedures. The antioxidant and antimicrobial are the must-have biological properties, as they can contribute to other therapeutic values of the plants. Further investigation on the isolation of bioactive compounds and maximum implementation into modern medicine should be further explored.

Keywords: Bioactive compounds, extraction procedure, Malaysia plant extract, medicinal

1. INTRODUCTION
Malaysia is listed as one of the 12 richest countries in the world in biodiversity, where its rainforest encompasses thousands of species of vascular plants. More than 2,000 trees species have been reported including the parasitic monster flower Rafflesia arnoldii, varieties of carnivorous pitcher plants Nepenthes, hundreds different species of trees in one acre of forest (herbs, shrubs, creepers) and more [1]. From those, plants containing phytochemicals are important and have been used since ancient times due to their beneficial medicinal properties and potential benefits to human health.

Phytochemical is a secondary metabolite, which is a part of non-nutritive plants that biologically active, including phenolic, terpenoid and alkaloid [2]. It’s produced in a part or all parts of the plants. There are a lot of researches has been done to characterize the active compounds that contribute to the medicinal properties of the plants [3-5]. Antioxidant, antimicrobial, anti-inflammatory, antiviral and wound healing are among the reported health benefits resulting from the presence of the secondary metabolites in the plants.

Extraction procedure plays an important part in processing the biological active phytochemical from the plant materials. The choice of solvent, suitable temperature, pressure and more need to be carefully evaluated before choosing the proper methods. Two categories of extraction methods are established and studied, conventional and modern technique. The most commonly used route is conventional extractions that have the benefit of more yield extracted. However, the disadvantages of these methods have been pointed out such as potential co-extracted of impurities, toxic solvents contaminate the sample extract during the process, a large amount of solvent is wasted, not suitable for thermolabile compounds and long extraction time [6]. The utilization of modern extraction methods, such as microwave-assisted (MAE), ultrasound-assisted extraction (UAE) and supercritical fluid extraction (SFE), in the separation process of active constituents have overcome the problems (lower cost, high yield of compounds) [4,7]. To date, the modifications on the methods are continuously advancing. This review describes the comparative study on bioactive constituents obtained and different extraction procedure of Malaysian medicinal plants.

2. HISTORY
Medicinal plants have been tremendously used since ancient time, especially in China, India and Egypt. In Malaysia, the research has emerged from the basic...
phytochemical screening era to modern bioassays, toxicological and clinical studies. The research of the plants with medicinal properties was starting since 1950’s, by photochemical screening. The research has been growing by years, and the collaboration with foreign institution starts to take place in 1994, after the formation of Malaysia Natural Products Society. The empowerment of local medicinal plants in 7th to 10th Malaysia Plans boost the research and development of the plants; also, more research funding encourages collaborations between universities and industries [8]. To date, a great amount of industrial collaborations, in term of research and commercialization can be noticed throughout Malaysia.

![Figure 1 History of medicinal plant research and development in Malaysia](image)

### 4. RESULTS AND DISCUSSION

The World Health Organization (WHO) define medicinal plant as a plant that contains compounds which can be used as therapeutic purposes or that can synthesize useful drugs from the metabolite. Over centuries, medicinal plants have been used worldwide to fight illness and maintain health. Interestingly, approximately 85% of the world population still rely on these traditional plants as their primary healthcare mode [9], especially rural communities in Africa, parts of Asia, Central and South America. Besides, about 50% of medicinal plants are integrated into the drug for modern usage [10]. Research on medicinal plants has been increasing significantly. Table 1 shows the summarize medicinal plants studied using different extraction procedures in Malaysia. It will be discussed based on the yields and the compounds present in the plant extracts.

#### 4.1 Yield

Generally, from 2017 to 2020, most of the extraction methods used to obtain the valuable compounds in the plants are microwave and ultrasonic-assisted extraction (MAE and UAE). Both extraction methods are among several non-conventional methods that preferable due to its high efficiency, short extraction time and less material degradation [41]. On the other hand, conventional methods such as Soxhlet, maceration and soaking are less desirable since it requires high solvent volume and long extraction time. Moreover, the possibility of toxic materials will co-extracted is high. In term of extraction yield, the conventional method is observed to have more than modern techniques in most of the cases. It can be seen when extracting Vernonia amygdalina with Soxhlet and supercritical fluid extraction (SFE) [24,26]. However, the number of secondary metabolites detected using the modern technique is better. For example, asiaticoside amount extracted from Centella asiatica using MAE is higher than that of the maceration method [28]. Noted that SFE is less used might be due to the high cost of investment associated with high-pressure process [42].

#### 4.2 Phytochemicals

Table 1 also shows most of the medicinal plants contain polar compounds which responsible for biological activities of the plants. According to the solubility theory of ‘like-dissolve-like’, more polar solvents are used for the extraction of these compounds [15,25,27,31,43]. It is important to note that plant part used as a starting material also take part in the determination of the type of solvent and
| Scientific Name            | Local Name | Part Used | Extraction Method/Solvent | Yield   | Major Compounds                                                                 | Therapeutic values/ Function                        | Ref   |
|---------------------------|------------|-----------|---------------------------|---------|--------------------------------------------------------------------------------|-----------------------------------------------------|-------|
| *Piper betle*             | Sirih      | Leaf      | UAE/ Ethanol              | 13.71%  | Hydroxycavicol (0.012 mg/mL) Eugenol (0.067 mg/mL) Isoeugenol (9.993 mg/mL)   | Inhibit lipid peroxidation Analgesic Anti-inflammatory | [11]  |
|                           |            |           | Maceration/ Ethanol       | 10.96%  | Present of tannins and steroids                                                  |                                                     |       |
|                           |            |           | SFE/ CO₂                  | 4.56%   | Eugenol (8.21%)                                                                  |                                                     | [12]  |
| *Carica papaya Linn.*     | Betik      | Leaf      | SFE/ Ethanol              | 5.35%   | α-tocopherol (24.67%) Squalene (7.89%) Linolenic acid (7.70%) Campesterol (4.37%) | Antioxidant power in blood Reducing peroxidation levels Antifungal Antibacterial Larvicidal Treat dengue fever | [13]  |
| *Phaleria macrocarpa*     | Mahkota dewa | Fruit    | UAE/ Water, Methanol, Ethanol | NA      | Mangiferin (28.6 mg/g)                                                           | Antidiabetic Anti-inflammation Antioxidant           | [14]  |
| *Quercus infectoria*      | Manjakani  | Gall      | Aqueous decoction         | NA      | Tannic acid (2233.82 ± 1.311 mg/g)                                               | Anti-inflammation Antioxidant Wound healing          | [15]  |
|                           |            |           | UAE (Bath-type)/ Water    | NA      | Tannic acid (9920.05 mg/kg) Gallic acid (1103.441 mg/kg)                          |                                                     | [16]  |
|                           |            |           | UAE (Probe-type)/ Water   | NA      | Tannic acid (10542.45 mg/kg) Gallic acid (1287.816 mg/kg)                         |                                                     |       |
| *Ficus deltoidea*         | Mas cotek  | Leaf      | MAHD/ Water               | NA      | Vitexin (33.40 ± 0.98% w/w)                                                      | Antioxidant Hypoglycemic Antinociceptive             | [17]  |
| Plant         | Organ       | Extraction Method         | Yield (%) | Major Products                                                                 | Applications                                                                                         |
|--------------|-------------|---------------------------|-----------|--------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------|
| *Eurycoma longifolia* | Root       | UAE/ Ultrapure water       | 9.54%     | Isovitexin (11.38 ± 0.86% w/w), Vitexin (15.0% w/w), Isovitexin (7% w/w)         | Treat erectile dysfunction, Enhance muscular ability, Improve spermatogenesis                           |
|              |             | Conventional heat assisted | 9.76%     | Eurycomanone                                                                     | Increase sexual desire, Enhance muscular ability, Improve spermatogenesis                            |
|              |             | MAE/ Water                | 7.33%     | Protein (16.878 ± 1.186%)                                                       | Enhance muscular ability, Improve spermatogenesis                                                   |
| *Trigonella-Foenum Graecum* | Seed       | Soxhlet/ Hexane           | 5.55%     | Linoleic acid (54.13%), Palmitic acid (16.21%)                                  | Anti-diabetic, Anti-inflammation, Anti-cancer                                                        |
|              |             | MAE/ Ethanol              | 26.03%    | Linoleic acid (28.27%), 15,16-Dehydroestrone methyl ether (12.89%), Laevulic acid- trimethylsilyl ester (8.55%) | Antioxidant, Lower cholesterol level                                                                 |
| *Vernonia amygdalina* | Leaf       | Soxhlet/ Petroleum ether (PEE), Ethyl Acetate (EAE), Methanol (ME) | Yield pattern: ME > EAE > PEE | High total flavonoid and phenolic content | Treat diabetes and other gastrointestinal problems, Anti-oxidant, Anti-inflammatory, Renoprotective, Anti-tumour, Anti-oxidant, Antimicrobial, Anti-diabetic activities |
| Plant                        | Part                        | Extraction Method          | Percentage | Main Components                                      | Activities                                      |
|-----------------------------|-----------------------------|----------------------------|------------|------------------------------------------------------|-------------------------------------------------|
| **Phyllanthus niruri**      | Dukung anak | Stems and aerial | SFE/ CO₂ | 1.241%      | Phenolic Aldehyde, Flavonoids                      | Caryophyllene (31.47%), Humulene (14.6%)         |
|                             |                             |                            |            | Gallic Acid                                         | Treat ulcer, inflammation, kidney and gallbladder stones |
|                             |                             |                            |            | Corilagin                                           | Wound healing                                    |
|                             |                             |                            |            | Ellagic acid                                        | Cure diabetes and jaundice                        |
| **Centella asiatica**       | Pegaga | Whole plant | MAE/ Solvent-free | 3.02%      | Asiaticoside (158.8 μg/mL)                         | Anti-ulcer                                       |
|                             |                             | Maceration                  |            | Asiaticoside (2.56 μg/mL)                          | Anti-amnesic                                      |
|                             |                             | Soxhlet/ Methanol            |            | Asiaticoside (1-3 mg/mL)                           | Anti-stress                                       |
|                             |                             | Subcritical water            |            | Asiaticoside (10 mg/g)                             | Antimicrobial                                     |
|                             |                             | Enzymatic pre-treatment, microwave | | | Regenerate brain and nerve cells                   |
|                             |                             | Soxhlet/ Methanol, Ethanol, Water | 7.30% (Ethanol) | Asiaticoside (27.10%) | Anti-Parkinson's disease treatment |
|                             |                             |                            | 5.00% (Methanol) | | Prevent cold-induced gastric ulcer               |
|                             |                             |                            | 3.30% (Water)    | | Anti-inflammatory                                 |
|                             |                             |                            |            | Asiaticoside (2.56 μg/mL) | Antioxidant                                      |
|                             |                             |                            |            | Asiaticoside (1-3 mg/mL) | Wound healing                                    |
| **Alternanthera sessilis**  | Keremak merah | Leaf | Soxhlet/ Water, Ethanol, Ethyl acetate, Hexane | 12.11% (Water)  | Ferulic acid                                     | Reduced risk of oxidative stress |
|                             |                             |                            | 4.55% (Ethanol) | | Free radical scavengers                           |
|                             |                             |                            | 1.81% (Ethyl acetate) | | Anti-inflammatory                                 |
|                             |                             |                            | 1.41% (Hexane)   | Rutin                               | Anti-ulcer                                      |
|                             |                             |                            |            | Quercetin                                           | Anti-inflammatory                                |
|                             |                             |                            |            | Apigenin                                            | Analgesic                                        |
|                             |                             |                            |            | NA                                                 |                                                 |
|                             |                             |                            |            | Asiaticoside (2.56 μg/mL) | Anti-inflammatory |
|                             |                             |                            |            | Asiaticoside (1-3 mg/mL) | Anti-ulcer                                      |
|                             |                             |                            |            | Asiaticoside (10 mg/g) | Anti-inflammatory |
|                             | Stem                       | Soxhlet/ Water, Ethanol, Ethyl acetate, Hexane | 22.24% (Water) | NA | Anti-inflammatory |
|                             |                             |                            | 3.34% (Ethanol) | | Anti-ulcer                                      |
|                             |                             |                            | 5.17% (Ethyl acetate) | | Anti-inflammatory | Anti-cancer |
|                             |                             |                            | 0.02% (Hexane)   | | Anti-cancer                                      |
| **Persicaria tenella**      | Daun kesum | Plant (Fresh) | Liquid biphasic flotation/ Alcohol-Salt | 9.42%      | Gallic acid                                       | Antioxidant                                      |
|                             |                             |                            |            | Rutin                                               | Anti-proliferative                                |
|                             |                             |                            |            | Cournaric acid                                     | Anti-cancer                                      |

[26] [27] [28] [29] [30] [31]
| Plant                        | Part     | Extraction Method | Purity | Compounds                                      | Properties                                                   |
|-----------------------------|----------|-------------------|--------|-----------------------------------------------|-------------------------------------------------------------|
| *Mitragyna speciosa*        | Leaf     | SFE/ CO\textsubscript{2}, Ethanol | 1.36% (CO\textsubscript{2}) 0.48% (CO\textsubscript{2} + Ethanol) | Quercetin, Anti-inflammatory, Anti-angiogenic, Anti-vesicular, Anti-fungal, Anti-ulcer, Anti-hyperlipidaemic, Anti-acetylcholinesterase |
| *Piper sarmentosum*         | Leaf     | Soxhlet/ Methanol  | ≈10%   | Dydimin, Quercetin, Amurensin, Hesperidin, Difuol | Neuroprotective, Antioxidant, Anticancer, Antidiabetic, Antiviral, Antihepatotoxic, Anti-inflammatory, Allergenic |
| *Clinacanthus nutans*       | Leaf     | SFME/ Water       | NA     | Polyphenols                                   | Anti-apoptotic, Antioxidant, Control menstrual pain, Pain relief, Treat skin rashes, Treat anemia and jaundice, Antidiabetic |
| **Lindau**                  | Root     | Solvent extraction/ Methanol, Ethyl acetate | NA     | Lupeol (94.21%), Betulin (1.38%), Stigmasterol (1.33%) | Anti-apoptotic, Antioxidant, Control menstrual pain, Pain relief, Treat skin rashes, Treat anemia and jaundice, Antidiabetic |
| *Scurrula Ferruginea*       | Leaf     | Soaking/ Methanol, Acetone, Benzene Deionized water | 80% Acetone > 80% Methanol > 100% Methanol > Water | Phenolic compounds | Antifungal, Antibacterial, Treat shingles, malaria, Wound healing |

[32] Treat muscle pain, fever, wounds, diarrheal, cough, hypertension. Combat fatigue, Enhance tolerance to hard work.

[33] Neuroprotective.

[34] Anti-apoptotic, Antioxidant.

[35] Control menstrual pain, Pain relief, Treat skin rashes, Treat anemia and jaundice, Antidiabetic.

[36] Antifungal, Antibacterial, Treat shingles, malaria, Wound healing.
| Plant Name                     | Part          | Extraction Method     | Component (w/w)                        | Function                                                                 |
|-------------------------------|---------------|-----------------------|----------------------------------------|-------------------------------------------------------------------------|
| Bridelia stipularis           | Stem          | Soxhlet/ Methanol; Fractionation/ Hexane, Chloroform, Ethyl Acetate | >100% acetone 1.71% (Hexane) 0.63% (Chloroform) 0.34% (Ethyl acetate) Oxalic acid (24.98%) 4-13decanol (6.36%) | Release hypertension Protective medicine after childbirth Ease urination pain | [37] |
| Momordica charantia           | Fruit         | UAE/ Aqueous ethanol  | 28.00 ± 2.5%  NA                       | Antiviral Prevent/ treat fever, polydipsia, diarrhea, colic, infections, diabetes, eczema | [38] |
| Piper nigrum                  | Seed          | Microwave reflux extraction/ Water Heat reflux technique/ Water | NA 1.32%  Piperine (5.64 w/w) Piperine (37.85%) Caryophyllene (8.97%) Sabinene (5.76%) Limonene (4.51%) β-bisabolene (1.66%) | Anti-inflammatory Antibacterial Anti-cold Anti-rheumatic | [39] |
| Piper nigrum                  | Seed          | Heat reflux technique/ Water | 1.40%  Piperine (42.29%) Caryophyllene (10.36%) Sabinene (7.94%) Limonene (6.47%) β-bisabolene (2.42%) |                                                                 | [40] |

UAE: Ultrasonic assisted extraction; SFE: Supercritical fluid extraction; MAHD: Microwave-assisted hydrodistillation; MAE: Microwave assisted extraction; SFME: Solvent-free microwave extraction; CO₂: Carbon dioxide; GAE: Gallic acid equivalent; QE: Quercetin equivalent; NA: No available data
determination of quantity and secondary metabolites of the extract [44]. The data in the table presents that if the samples are leaf (Piper betle), root (Eurycoma longifolia), gall (Quercus infectoria) and stem (Phyllanthus niruri), the polar solvent is utilized solvent in the extraction process. Meanwhile, seed as starting material (Trigonella Foenum Graecum) use non-polar solvent during the process. The observation tells that the state of the obtained extract (oil, colourless) yielded more non-polar compounds than the extracts from leaf, stems, etc. which high in viscosity and colour present. Non-polar compounds include fatty acids (linoleic acid, linolenic acid), α-tocopherol, and squalene, whereas polar compounds are phenolic, flavonoid, etc.

4.3 Choice of Extraction Methods

There are a variety of extraction methods that have been applied in the research of medicinal plants, from conventional to modern, depending on the several factors that can affect the diffusivity and solubility of the desired materials. Careful consideration on the selection of plant nature, particle size of starting materials, moisture content, solvent polarity, solvent-to-solid ration, extraction temperature, pressure and time will enhance the extraction efficiencies, as well as affecting the choice of extraction methods [45]. For instance, theoretically, smaller particle size will be yielded better yield than a larger one, and high solvent-solid-ration will increase the efficiency of the extraction process. Besides, the targeted compounds and the intended use of the final products also influence the selection of the methods [46]. There are four basic mechanisms of the extraction process discussed by Zhang et. al [43], which are: 1) solvent penetration into the solid particle, 2) solute dissolves in the solvents, 3) solute diffuse out from the solid, 4) extracted solutes are obtained. Table 2 demonstrates the principles, strengths and limitations of commonly used extraction procedures in medicinal plants researches [4,45,47-49].

| Extraction Methods | Principle | Strength | Limitation |
|--------------------|-----------|----------|------------|
| Maceration, Percolation, Decoction | -Involve soaking method, -Heat is transfer through convection and conduction, -Target compounds depending on extraction solvent | -Easy and simple methods, -Suitable for thermolabile compounds, -Temperature and choice of solvent can be altered to enhance the extraction process | -Large volume of extraction solvent, -Prolonged extraction time, -Organic waste, -May co-extracted impurities, -Low extraction efficiency |
| Soxhlet | -Automatic continuous extraction method, -Temperature is dependent on boiling point of extraction solvent | -High extraction yield, -High efficiency than maceration, -Complete/exhaustive extraction process | -Large volume of extraction solvent, -Prolonged working time, -Can cause thermal degradation due to high temperature, -May co-extracted impurities, -Exposure to hazardousflammable organic solvents, -Potential toxic emission, -Limited to dry and finely divided solid |
| Microwave assisted | -Microwave generate heat by the interaction between the polar solvent and organic components in the plant matrix, -Involve ionic conduction and dipole rotation mechanisms | -High yield and quality of targeted compound, -Provide homogenous heating, -Improved extraction rate, -Decreased thermal degradation | -Poor efficiency for non-polar and volatile compounds, could be improved by solvent-free microwave extraction, -Limited to small molecule phenolic compounds |
| Method                        | Advantages                                                                 | Disadvantages                                                                 |
|-------------------------------|-----------------------------------------------------------------------------|-------------------------------------------------------------------------------|
| Ultrasonic assisted           | - Use ultrasonic wave energy in the process (20 – 2000 kHz)                | - May produce reactive oxygen species during cavitation and cause compound degradation |
|                               | - Ultrasound in the solvent produces cavitation that increases the surface contact between solute-sample and permeability of cell walls | - Ultrasound energy > 20 kHz can affect phytochemicals through free radicals’ formation |
|                               | - Speed up dissolution and diffusion of the solute and heat transfer, improves extraction efficiency |                                                                                |
| Supercritical fluid           | - Use supercritical fluid (SF) as extraction solvent                       | - Major drawback is the high cost of equipment set-up/operation               |
|                               | - SF have similar solubility to liquid, similar diffusivity to gas          |                                                                                |
|                               | - Solvation properties dramatically change at a critical point with a slight change of pressure or temperature |                                                                                |
|                               | - Carbon dioxide commonly used as a solvent due to its selectivity, low critical pressure and temperature, non-toxic, suitable to extract thermolabile compound |                                                                                |
| Subcritical water             | - Extraction process using hot water as solvent at a specific pressure to maintain the liquid state at a critical temperature between 100 - 374°C at critical pressure (1–22.1 MPa) | - Need high temperature to reach subcritical water state                        |
|                               | - Provide mass transfer through diffusion and convection process            | - Thermal degradation may occur at high temperature                            |
|                               | - Energy supplied can interrupt the bonding of adhesive (solute-matrix) and cohesive (solute-solute) by reduction of activation energy required for the desorption process |                                                                                |
| Pressurized liquid/           | - Works under high pressure and temperature                                 | - High cost of investment                                                      |
| Pressurized solvent/          | - Increase efficiency of the extraction process by the                      | - Not suitable for thermolabile compounds                                       |
| Accelerated solvent           |                                                                           |                                                                                |
combine effects of elevated pressure
- Application of pressure to remains solvent liquid state during extraction beyond its normal boiling point
- Includes filtration and clean-up of compounds from solid samples that accelerate extraction of the compounds from solid particle

4. CONCLUSION AND FUTURE PERSPECTIVE

This review demonstrates the researches done on Malaysian medicinal plants, including their bioactive compounds and extraction procedure implemented. There is a clear increasing pattern of interest in the extraction and compound detection of medicinal plants. Modern extraction methods are more preferable to yield high purity of the desired compounds, depending on the polarity of solvent use. Pharmacological studies revealed that the naturally occurring secondary metabolites of the plants display antioxidant and antimicrobial properties that contribute to other important therapeutic values. This review suggests further research need to be performed to determine the specific bioactive compounds which have potential in respective activities, upscaling the extraction process, more industrial collaborations as well as more integration of these plants in modern medicine. With these, it increases the income generation of the farmers and will benefit Malaysia economy besides can produce an individual with healthy wellbeing by the consumption of our natural products.

ACKNOWLEDGMENT

This work was supported by Universiti Teknologi Malaysia PDRU grant (04E22), GUP COE (04G03), and CRG (08G09).

REFERENCES

[1] F.A. Mustapha, J. Jai, F. Hamidon, A.I. Md. Sharif, N. Mohd Yusof, Antimicrobial agents from Malaysian plants and their potential use in food packaging material: Review, Chem. Eng. Res. Bull. 19 (2017) 57-66. DOI: https://doi.org/10.3329/cerb.v19i0.33797

[2] I.D. Ciocan, I.I. Bara. Plant products as antimicrobial agents, Analele Științifice ale Universității, Alexandru Ioan Cuza, Secțiunea Genet. și Biol. Mol. TOM VIII. 8 (2007) 151–156. DOI: https://doi.org/10.3109/9781420019919-17

Alkaloids

- Leaves, Roots
- SFE, MAE

Polyphenolics

- Fruits, Leaves
- SFE, MAE

Polysaccharides

- Roots, Fruits
- SFE, MAE, UAE

Anthocyanins

- Leaves, Fruits

Table 2 Preferred extraction method and plant parts for different chemical classes of phytochemicals

Flavonoids

- Leaves, Fruits
- SFE, MAE

Carotenoids

- SFE, PLE

Saponins

- Roots, MAE

Oils

- MAE, SFE

4.4 Bioactivities

The medicinal plant serves as pharmacological importance to human through bioactive components in the plants. To date, most studied pharmacological activities are antioxidant and antimicrobial since these are the basic properties of medicinal plants that later contributes to other biological activities as well such as anti-inflammatory, antidiabetic, analgesic and wound healing. Free radicals which exist in the body can cause cancer, heart disease, inflammation, diabetes, ageing, and more [50]. Supplementary antioxidants, for instance, phenolic compounds and terpenoids, are important alongside with barrier system in the human body. Besides, reports say that microorganisms have developed resistance to many antibiotics [51], thus the demand of medicinal plant extracts and the isolated compounds which possess antimicrobial properties against microorganisms has been increased [52].
[3] A. Alsarhan, N. Sultana, A. Al-Khatib, M.R. Abdul Kadir, Review on some Malaysian traditional medicinal plants with therapeutic properties, J. Basic Appl. 10 (2014) 149-159. DOI: https://doi.org/10.6000/1927-5129.2014.10.20

[4] N.N. Azwanida, A review on the extraction methods use in medicinal plants, principle, strength and limitation, Med. Aromat. Plants. 4(3) (2015) 1000196. DOI: https://doi.org/10.4172/2167-0412.1000196

[5] F.I. Abu Bakar, M.F. Abu Bakar, N. Abdullah, S. Endrini, A. Rahmat, A review of Malaysian medicinal plants with potential anti-inflammatory activity, Adv. Pharmacol. Sci. 2018 (2018) 8603602. DOI: https://doi.org/10.1155/2018/8603602

[6] W.L. Peng, H. Mohd-Nasir, S.H. Mohd Setapar, A. Ahmad, D. Lokhat, Optimization of process variables using response surface methodology for tocopherol extraction from Roselle seed oil by supercritical carbon dioxide, Ind. Crops Prod. 143 (2020) 111886. DOI: https://doi.org/10.1016/j.indcrop.2019.111886

[7] H. Mohd-Nasir, L. Md Salleh, A.R. Ismail, S. Machmudah, Solubility correlation of gall (Quercus infectoria) extract in supercritical CO2 using semi-empirical equations, Asia-Pac. J. Chem. Eng. 12 (2017) 790-797. DOI: https://doi.org/10.1002/apj.2118

[8] I. Jantan, Medicinal plant research in Malaysia: Scientific interests and advances, Jurnal Sains Keshatan Malaysia. 2(2) (2004) 27-46.

[9] N. González, Development of natural product drugs in a sustainable manner, Proceedings of the FAPRONATURA 2015, Lecture-06, J. Pharm. Pharmacogn. Res. 3(Suppl. 1) (2015) S6, Topes de Collantes, Sancti Spiritus: CSF.

[10] F. Jamshidi-Kia, Z. Lorigooni, H. Amini-Khoei, Medicinal plants: Past history and future perspective, J. HerbMed. Pharmacol. 7(1) (2018) 1-7. DOI: https://doi.org/10.15171/jhmp.2018.01

[11] A. Ali, X.Y. Lim, CH. Chong, S.H. Mah, B.L. Chua, Optimization of ultrasound-assisted extraction of natural antioxidants from Piper betle using response surface methodology, LWT-Food Sci Technol. 89 (2018) 681-688. DOI: https://doi.org/10.1016/j.lwt.2017.11.033

[12] N.H. Arsad, M.A. Che Yunus, Z. Idham, Optimization and effect of supercritical carbon dioxide extraction conditions on global oil yield and eugenol from Piper betle leaves, Mal. J. Fund. Appl. Sci. 13(4) (2017) 680-684. DOI: https://doi.org/10.11113/mjfas.v13n4.926

[13] Y.H. Chai, S. Yusup, M.S.H. Ruslan, B.L.F. Chin, Supercritical fluid extraction and solubilization of Carica papaya linn. leaves in ternary system with CO2+ ethanol solvents, Chem. Eng. Res. Des. 156 (2020) 31-42. DOI: https://doi.org/10.1016/j.cherd.2020.01.025

[14] Y.P. Lim, S.F. Pang, M.M. Yusoff, S.K.A. Mudalip, J. Gimbin, Correlation between the extraction yield of mangiferin to the antioxidant activity, total phenolic and total flavonoid content of Phaleria macrocarpa fruits, J. Appl. Res. Med. Aromat. Plants, 14 (2019) 100224. DOI: https://doi.org/10.1016/j.jarmap.2019.100224

[15] M.Z. Ilyia Arina, Y. Harisun, Effect of extraction temperatures on tannin content and antioxidant activity of Quercus infectoria (Manjakanji), Biocatal. Agric. Biotechnol. 19 (2019) 101104. DOI: https://doi.org/10.1016/j.bcab.2019.101104

[16] N. Sukor, R. Jusoh, S.A. Rahim, N. Kamarudin, Ultrasound assisted methods for enhanced extraction of phenolic acids from Quercus Infectoria galls, Materials Today: Proceedings. 5 (2018) 21990-21999. DOI: https://doi.org/10.1016/j.matpr.2018.07.060

[17] M.N. Che Isa, A. Ajit, A. Naila, A.Z. Sulaiman, Effect of microwave assisted hydrodistillation extraction on extracts of Ficus deltoidea, Materials Today: Proceedings. 5 (2018) 21772-21779. DOI: https://doi.org/10.1016/j.matpr.2018.07.031

[18] H.E.E.A. Elhag, A. Naila, A.H. Nour, A. Ajit, A.Z. Sulaiman, B. Abd Aziz, Optimization of protein yields by ultrasound assisted extraction from Eurycoma longifolia roots and effect of agitation speed, J. King Saud Univ. Sci. 31 (2019) 913-930. DOI: https://doi.org/10.1016/j.jsus.2018.05.011

[19] H.E.E.A. Elhag, A. Ajit, A.Z. Sulaiman, Optimization and kinetic modelling of total water extracts and water soluble proteins in root extracts of Eurycoma apiculata by microwave assisted extraction, Materials Today: Proceedings. Article in Press. DOI: https://doi.org/10.1016/j.matpr.2019.11.137

[20] S. Akbari, N.H. Abdurahman, R.M. Yunus, O.R. Alara, O.O. Abayomi, Extraction, characterization and antioxidant activity of fenugreek (Trigonella-Foenum graecum) seed oil, Materials Science for Energy Technologies. 2 (2019) 349-355. DOI: https://doi.org/10.1016/j.mset.2018.12.001

[21] S. Akbari, N.H. Abdurahman, R.M. Yunus, F. Fayaz, Microwave-assisted extraction of saponin, phenolic and flavonoid compounds from Trigonella foenum-graecum seed based on two level factorial design, J. Appl. Med. Res. Aromat. Plants, 14 (2019) 100212. DOI: https://doi.org/10.1016/j.jarmap.2019.100212

[22] K. Tunasamy, N. Suryadevara, T. Athimoolam, Screening of Vernonia amygdalina leaf extracts for antioxidant and antimicrobial activity, Materials Today:
Proceedings, 16 (2019) 1809-1818. DOI: https://doi.org/10.1016/j.matpr.2019.06.055

[23] O.R. Alara, N.H. Abdurahman, S.K. Abdul Mushalip, O.A. Olalere, Microwave-assisted extraction of Vernonia amygdalina leaf for optimal recovery of total phenolic content, J. Appl. Med.Res. Aromat. Plants. 10 (2018) 16-24. DOI: https://doi.org/10.1016/j.jarnmap.2018.04.004

[24] O.R. Alara, N.H. Abdurahman, C.I. Ukaegbu, Soxhlet extraction of phenolic compounds from Vernonia cinerea leaves and its antioxidant activity, J. Appl. Med. Res. Aromat. Plants. 11 (2018) 12-17. DOI: https://doi.org/10.1016/j.jarnmap.2018.07.003

[25] O.R. Alara, N.H. Abdurahman, C.I. Ukaegbu, N.H. Azhari, Vernonia cinerea leaves as the source of phenolic compounds, antioxidants, and anti-diabetic activity using microwave-assisted extraction technique, Ind. Crop Prod. 122 (2018) 533-544. DOI: https://doi.org/10.1016/j.indcrop.2018.06.034

[26] B.W.B. Kueh, S. Yusup, N. Osman, Supercritical carbon dioxide extraction of Melaleuca caujapiti leaves for herbicides allelopathy. Optimization and kinetics modelling, J. CO2 Util. 24 (2018) 220-227. DOI: https://doi.org/10.1016/j.jcou.2018.01.005

[27] N. Hassim, M. Markom, M.I. Rosli, S. Harun, Scale-up criteria and economic analysis for supercritical fluid extraction of Phyllanthus niruri, Chem. Eng. Process. 139 (2019) 920199. DOI: https://doi.org/10.1016/j.cpe.2019.03.011

[28] F.N. Idris, M.M. Nadzir, S.R. Abd Shukor, Optimization of solvent-free microwave extraction of Centella asiatica using Taguchi method, J. Environ. Chem. Eng. Article in press. DOI: https://doi.org/10.1016/j.jece.2020.103766

[29] F.N. Idris, M.M. Nadzir, Antimicrobial Activity of Centella Asiatica on Aspergillus Niger and Bacillus Subtilis, Chem. Eng. Trans. 56 (2017) 1381-1386. DOI: https://doi.org/10.3303/CET1756231

[30] U.H.A.M. Hazli, A. Abdul-Aziz, S. Mat-Junid, C.F. Chee, Solid-liquid extraction of bioactive compounds with antioxidant potential from Alternanthera sessilis (red) and identification of the polyphenols using UHPLC-QqQ-MS/MS, Food Res. Int. 115 (2019) 241-250. DOI: https://doi.org/10.1016/j.foodres.2018.08.094

[31] S.R. Chia, Y.S. Hew, Y.J. Loh, V.V. Devadas, K.W. Chew, P.L. Show, Extraction of phenolic compounds from fresh and wilt kesum plant using liquid biphasic flotation, Sep. Purif. Technol. 242 (2020) 116831. DOI: https://doi.org/10.1016/j.seppur.2020.116831

[32] N. Tohar, J.A. Shilpi, Y. Sivasothy, S. Ahmad, K. Awang, Chemical constituents and nitric oxide inhibitory activity of supercritical carbon dioxide extracts from Mitragyna speciosa leaves, Arab J. Chem. 12 (2019) 350-359. DOI: https://doi.org/10.1016/j.arabjc.2016.09.005

[33] C.F. Bactiar, N.A. Mohd Fahmi, LC-MS Analysis of phytocomponents in the methanol extract of Piper Sarmentosum Leaves, Pharmacogn. J. 11(5) (2019) 1071-1076. DOI: https://doi.org/10.5530/pj.2019.11.167

[34] S.N.S. Othman, A.N. Mustapa, K.H.K. Hamid, Total phenol content of Clinacanthus nutans Lindau (C.nutans) medicinal plant extracted using vacuum solvent-free microwave extraction (SFME), IOP Conf. Ser.: Mater. Sci. Eng. 736 (2020) 022054. DOI: https://doi.org/10.1088/1757-899X/736/2/022054

[35] P.L. Teoh, A.Y.F. Cheng, M. Liu, G.P. Kaling, F.N. Chua, B.E. Cheong, Chemical composition and cytotoxic properties of Clinacanthus nutans root extracts, Pharma. Biol. 55(1) (2017) 394-401. DOI: https://doi.org/10.1080/13880209.2016.1242145

[36] V.T. Justine, M. Mustafa, S.S. Kankara, R. Go, Effect of drying methods and extraction solvents on phenolic antioxidants and antioxidant activity of Scurrula ferruginea (Jack) Danser (Loranthaceae) leaf extracts, Sains Malays. 48(7) (2019) 1383-1393. DOI: https://doi.org/10.17576/jsm-2019-4807-07

[37] S.K. Yusufzai, M.S. Khan, F.L. Hanry, M. Rafatullah, B.B. Elison, GC-MS analysis of chemical constituents and in vitro antioxidant activity of the organic extracts from the stem of Bridelia stipularis, Sains Malaysia. 48(5) (2019) 999-1009. DOI: https://doi.org/10.17576/jsm-2019-4805-08

[38] N.M. Hani, A.E. Torkamani, S.Z. Abidin, W.A.K. Mahmood, P. Juliano, The effects of ultrasound assisted extraction on antioxidative activity of polyphenolics obtained from Momordica charantia fruit using response surface approach, Food Biosci. 17 (2017) 7-16. DOI: https://doi.org/10.1016/j.fbio.2016.11.002

[39] O.A. Olalere, N.H. Abdurahman, R.b.M. Yunus, O.R. Alara, S. Akbar, Evaluation of optimization parameters in microwave reflux extraction of piperine oleoresin from black pepper (Piper nigrum), Beni-Suef Univ. J. Basic Appl. Sci. 7 (2018) 626-631. DOI: https://doi.org/10.1016/j.bjbas.2018.07.006

[40] O.A. Olalere, N.H. Abdurahman, R.b.M. Yunus, O.R. Alara, Multi-response optimization and neural network modeling for parameter precision in heat reflux extraction of spice oleoresins from two pepper cultivars (Piper nigrum), J. King Saud Univ. Sci. 31 (2019) 789-797. DOI: https://doi.org/10.1016/j.kjus.2017.09.010
[41] N. Flórez, E. Conde, H. Domínguez, Microwave assisted water extraction of plant compounds, J. Chem. Technol. Biot. 90 (2015) 590–607. DOI: https://doi.org/10.1002/jctb.4519

[42] S. Chen, A. Marston, H. Stuppner, Extraction techniques for plant materials, in: Handbook of Chemical and Biological Plant Analytical Methods, Wiley, New Jersey, 2014.

[43] I. Montes, C. Lai, D. Sanabria, Like dissolves like: A guided inquiry experiment for organic chemistry, J. Chem. Educ. 80(4) (2003) 447. DOI: https://doi.org/10.1021/ed080p447

[44] N.S. Ncube, A.J. Afolayan, A.I. Okoh, Assessment techniques of antimicrobial properties of natural compounds of plant origin: Current methods and future trends, Afr. J. Biotecnol. 7(12) (2008) 1797-1806. DOI: https://doi.org/10.5897/AJB07.613

[45] Q. Zhang, L. Lin, W. Ye, Techniques for extraction and isolation of natural products: A comprehensive review, Chin. Med. 13(20) (2018). DOI: https://doi.org/10.1186/s13020-018-0177-x

[46] A.R. Abubakar, M. Haque, Preparation of medicinal plants: Basic extraction and fractionation procedures for experimental purposes, J. Pharm. Bioallied Sci. 12(1) (2020) 1-10. DOI: https://doi.org/10.4103/jpbs.JPBS_175_19

[47] T. Belwal, S.M. Ezzat, L. Rastrelli, I.D. Bhatt, M. Daglia, A. Baldi, H.P. Devkota, I.E. Orhan, J.K. Patra, G. Das, C. Anandharamakrishnan, L. Gomez-Gomez, S.F. Nabavi, S.M. Nabavi, A.G. Atanasov, A critical analysis of extraction techniques used for botanicals: Trends, priorities, industrial uses and optimization strategies, Trends Analyt. Chem. 100 (2018) 82-102. DOI: https://doi.org/10.1016/j.trac.2017.12.018

[48] J. Giacometti, D.B. Kovacevic, P. Putnik, D. Gabric, T. Bilusic, G. Kresic, V. Stulic, F.J. Barba, F. Chemat, G. Barbosa-Canovas, A.R. Jambrak, Extraction of bioactive compounds and essential oils from mediterranean herbs by conventional and green innovative techniques: A review, Food Res. Int. 113 (2018) 245-262. DOI: https://doi.org/10.1016/j.foodres.2018.06.036

[49] J. Zhang, C. Wen, H. Zhang, Y. Duan, H. Ma, Recent advances in the extraction of bioactive compounds with subcritical water: A review, Trends Food Sci. Technol. 95 (2020) 183-195. DOI: https://doi.org/10.1016/j.tifs.2019.11.018

[50] S. Chanda, M. Kaneria, R. Nair, Antibacterial activity of Psoralea Corylifolia L. seed and aerial parts with various extraction methods, Res. J. Microbiol. 6(2) (2011) 124–131. DOI: https://doi.org/10.3923/rjm.2011.124.131

[51] M. Raza, Fozia, R. Ali, A. Wahab, H. Iqbal, H. Ullah, S. Ahmad, I. Ahmad, S.M. Shah, Comparative antibacterial study of Convolvulus arvensis collected from different areas of Khyber Pakhtunkhwa, Pakistan, Int. Res. J. Pharm. 3 (2012) 220–222.

[52] A. Al-Rifai, A. Aqel, T. Al-Warhi, S.M. Wabaidur, Z.A. Al-Othman, A.Y. Badjah-Hadj-Ahmad, Antibacterial, antioxidant activity of ethanolic plant extracts of some Convolvulus species and their DART-ToF-MS profiling, Evid. Based Complementary Altern. Med. 2017 (2017) 5694305. DOI: https://doi.org/10.1155/2017/5694305