Ionic Liquid-Based Microwave-Assisted Extraction: Fast and Green Extraction Method of Secondary Metabolites on Medicinal Plant

Islamudin Ahmad, Arry Yanuar1, Kamarza Mulia2, Abdul Mun‘im1

Department of Pharmaceutical Sciences, Faculty of Pharmacy, Mulawarman University, Samarinda, East Kalimantan, 1Department of Pharmaceutical Sciences, Faculty of Pharmacy, Universitas Indonesia, 2Department of Chemical Engineering, Faculty of Engineering, Universitas Indonesia, Depok, West Java, Indonesia

ABSTRACT

Background: Ionic liquid-based microwave-assisted extraction (IL-MAE) is one of the non-conventional extraction methods that has been developed and applied in recent years. Some studies have reported the success of this approach for extracting the target compound (secondary metabolites) from medicinal plants optimally. Objective: This review paper aimed to provide detail information about the application of the IL-MAE method as a fast and green extraction of a secondary metabolite from the medicinal plant. Materials and Methods: The literature published on IL-MAE was searched and collected using online resources from the electronic databases including Google Scholar, DOAJ, PubMed, ScienceDirect, and Scopus. Results: This review highlights the role of IL as a green solvent, the basic principles, mechanisms of MAE, and its utilization of natural product extraction. Furthermore, this review explained about the application of the IL-MAE method to extract secondary metabolite (particularly the targeted compound) from a medicinal plant, and a brief extraction mechanism of IL-MAE using Fourier-transform infrared spectroscopy and scanning electron microscopy. Conclusion: The application of IL-MAE method has successfully performed to extract the targeted secondary metabolite from a natural product, where the extraction process to be rapid, efficient, and green.

Key words: Ionic liquid-based microwave-assisted extraction, ionic liquids, medicinal plant, microwave-assisted extraction, secondary metabolite

INTRODUCTION

Exploration of the active constituents of natural products has been done for a long time. However, the resultant products are still relatively small that can be used commercially. Scientific research on natural products (especially traditional medicine), ranging from the search for raw materials, production processes, to the test of efficacy and toxicity has been done so far. Problems in the development of raw materials from nature are still constrained by different quality depending on various conditions.

The natural products (plants, animals, and microorganisms) are a sustainable source in nature that is known to be beneficial to humans for thousands of years. The diversity of species from natural products is still a primary source of ideas for the development of new drugs, functional food, and food additives.[1] In general, the active compound of the natural product is a secondary metabolite produced through biological pathways of various biosynthetic pathways and is obtained using an appropriate extraction procedure.[2,3] The active constituents of natural products can be extracted by multiple conventional and nonconventional extraction techniques.[4,5] Most of these methods based on exploration of different solvent strengths.

Application of green chemistry principles to explore the potential of active constituents from natural products continues to rise, in this case, the use of molten salt liquid as a solvent.[6] Ionic liquids (ILs) were selected because they are nonflammable, stable at high temperature, nonvolatile, nontoxic, and have the flexibility to adjust the physicochemical properties of the target compound.[7] Furthermore, economic and environmental impact standpoint should even be considered in the selection of solvents.[8] Ionic liquid-based microwave-assisted extraction (IL-MAE) is one of the non-conventional methods of extraction that has been developed and applied in recent years. The principle of using the IL-MAE is the same as the principle of the MAE method, only differing in the principle and type of solvent used. Success in applying this technique to obtain the optimal of target constituents has been widely reported including resveratrol extraction of Polygonum cuspidatum Sieb.et.Zucc.,[9] phenolic alkaloid extraction of Nelumbo nucifera Gaertn.,[10] Essential oils extraction of some plant, namely Illicium verum, Caminum cyminum,[11] Schisandra chinensis,[12] Cinnamomum spp.,[13] quercetin and kaempferol extraction from Toona sinensis and Rosa sinensis,[14] flavonoid extraction from...
Ionic liquid as a green solvent for extraction
Knowledge of the solubility properties of the target constituents in the natural products is essential to know for the extraction and separation process to maximally succeed. Some potential components of natural products (especially medicinal plant) have low solubility in water then usually used organic solvents such as alcohols, ethers, ethyl acetate, alkanes, chloroalkanes, and other organic solvents. However, the selection of such solvents can be selected if the targeted or already literature constituents are known. If the information is not available, then it should follow the principle of “like dissolves like.”[19]

The widely accepted and understood polarity concept based on the polarity definition is the number of all intermolecular (specific and nonspecific interactions) between the solvent and the potential of the solute, this interaction produces a chemical reaction.[20] It can be regarded as both a physical and chemical phenomenon consisting of Coulomb interaction, dipole-dipole interactions, hydrogen bond interactions, and acid-base donor-acceptor interactions. Associated with the polarity of ILs depends on the nature of the components, usually in the range of dipolar nonhydrogen-bond-donation solvents (DMF, DMSO, and acetonitrile) to polar hydrogen-bond-donation solvents (primary alcohols, water).[19,20] Furthermore, other significant factors affect such as boiling point and melting point, density, viscosity, and surface tension of the solvents.[21] The ILs can be considered as “self-assembly amphiphiles” that form an H-bonded-polymeric network becomes a common structure pattern as a solid and liquid phase.[22,23]

The ILs or room temperature ionic liquid is a promising candidate that can meet the above requirements which consist entirely of stable organic cations and inorganic or organic anions, can be seen in Table 1 which is liquid at room temperature and has unique properties, such as high thermal stability, nonflammability, and low chemical reactivity.[24-27] Because of these uniqueness that has properties with the viscosity, fine-tunable density, polarity, and miscibility with common organic solvents, which are highly applicable in areas such as analytical chemistry,[28] catalysts and synthesis,[29,30] electrochemistry,[10] and most importantly, ILs can be applied in the separation process (extraction) from natural products.[31-34]

The selection of solvents with the approach of the principle of green chemistry in exploring the constituent target and potential of active compound from natural products continue to rise, in this case, the use of ILs as a green solvent.[6] The ILs can be employed as a solvent because they have the flexibility of ions combinations (cations and anions) to adjust the physicochemical properties of the target constituents and can be considered possible substitutes to replace volatile and toxic organic solvents whereas ILs otherwise.[7,21] Besides to the physicochemical properties of ILs that affect the extraction results, several other considerations regarding the overall process, economic and environmental impacts standpoint should also be considered.[8,33,35-37]

The ILs as solvents are widely used for extracting secondary metabolite (especially polyphenols and alkaloids) from natural products such as 1-butyl-3-methyl imidazolium chloride [BMIM] Cl, 1-butyl-3-methyl imidazolium bromide [BMIM] Br, 1-butyl-3-methyl imidazolium tetrafluoroborate [BMIM] BF4, 1-butyl-3-methyl imidazolium dihydrogen phosphate [BMIM][H2SO4], 1-butyl-3-methyl imidazolium hydrosulfate [BMIM][HSO3], 1-ethyl-3-methyl imidazolium bromide [EMIM] Br, 1-hexyl-3-methyl imidazolium bromide [HMIM] Br, 1-octyl-3-methyl imidazolium bromide [OMIM] Br, and other types.[9,36,37-40] In general, the increased ability to attract certain chemical constituents may increase with the increase in hydrophobicity of the solvents used.[41] Furthermore, the hydrogen bonding capability of ILs is also a factor affecting extraction by considering anions.[37,41]

Toxicity and environmental impact standpoint
Since the introduction of green chemistry, especially in this case, the use of ILs as an alternative solvent, at that time also there have been concerns related to toxicity and environmental impact by the originators of ILs solvent. In the last 10 years, research efforts have focused on increasing biodegradability and examining the toxicity reduction of ILs.[41] Furthermore, some studies have reported on ILs, where anions have limited effects on the level of ion biodegradation and the most

<table>
<thead>
<tr>
<th>Ionic Liquids (ILs)</th>
<th>Abbreviation</th>
<th>Melting point °C</th>
<th>Density (g/mL)</th>
<th>Viscosity (cP)</th>
<th>BM</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-ethyl-3-methylimidazolium tetrafluoroborate</td>
<td>(EMIM) (BF4)</td>
<td>6</td>
<td>1.248</td>
<td>66</td>
<td>197.8</td>
</tr>
<tr>
<td>1-ethyl-3-methylimidazolium hexafluorophosphate</td>
<td>(EMIM) (PF6)</td>
<td>58-62</td>
<td>1.373</td>
<td>450</td>
<td>256.13</td>
</tr>
<tr>
<td>1-butyl-3-methylimidazolium tetrafluoroborate</td>
<td>(BMIM) (BF4)</td>
<td>–82</td>
<td>1.208</td>
<td>233</td>
<td>225.80</td>
</tr>
<tr>
<td>1-butyl-3-methylimidazolium hexafluorophosphate</td>
<td>(BMIM) (PF6)</td>
<td>10</td>
<td>1.373</td>
<td>400</td>
<td>284.18</td>
</tr>
<tr>
<td>1-butyl-3-methylimidazolium bromide</td>
<td>(BMIM) Br</td>
<td>60</td>
<td>1.134</td>
<td>Solid</td>
<td>218.9</td>
</tr>
<tr>
<td>1-butyl-3-methylimidazolium chloride</td>
<td>(BMIM) Cl</td>
<td>89</td>
<td>1.120</td>
<td>Solid</td>
<td>146.50</td>
</tr>
<tr>
<td>1-butyl-3-methylimidazolium trifluoromethanesulfonate</td>
<td>(BMIM) (CF3SO3)</td>
<td>16</td>
<td>1.290</td>
<td>90</td>
<td>260.0</td>
</tr>
<tr>
<td>1-butyl-3-methylimidazolium bis(trifluoromethylsulfonil) amide</td>
<td>(BMIM) (Ntf2)</td>
<td>–8</td>
<td>1.404</td>
<td>48</td>
<td>433.0</td>
</tr>
<tr>
<td>1-allyl-3-methylimidazolium tetrafluoroborate</td>
<td>(AMIM) (BF4)</td>
<td>–88</td>
<td>1.231</td>
<td>321</td>
<td>240.02</td>
</tr>
<tr>
<td>1-hexyl-3-methylimidazolium tetrafluoroborate</td>
<td>(HMIM) (BF4)</td>
<td>–82</td>
<td>1.075</td>
<td>211</td>
<td>254.08</td>
</tr>
<tr>
<td>1-butyl-3-methylimidazolium hexafluorophosphate</td>
<td>(HMIM) (PF6)</td>
<td>–61</td>
<td>1.304</td>
<td>800</td>
<td>312.0</td>
</tr>
<tr>
<td>1-octyl-3-methylimidazolium tetrafluoroborate</td>
<td>(OMIM) (BF4)</td>
<td>–79</td>
<td>1.11</td>
<td>440</td>
<td>281.2</td>
</tr>
<tr>
<td>1-octyl-3-methylimidazolium chloride</td>
<td>(OMIM) (Cl)</td>
<td>1.000</td>
<td>16,000</td>
<td>230.50</td>
<td></td>
</tr>
<tr>
<td>N-methylpyrrolinium bis(trifluoromethylsulfonil) amide</td>
<td>(MPPyr) (Ntf2)</td>
<td>0</td>
<td>1.44</td>
<td>39</td>
<td>416</td>
</tr>
<tr>
<td>Ethylammonium formate</td>
<td>(NH4HCO3)</td>
<td>–10</td>
<td>0.99</td>
<td>11.5</td>
<td>91</td>
</tr>
<tr>
<td>N-butylpyrrolinium bis(trifluoromethylsulfonil) amide</td>
<td>(BMPyrrol) (Ntf2)</td>
<td>–50</td>
<td>1.4</td>
<td>71</td>
<td>422</td>
</tr>
</tbody>
</table>

ILs=Ionic liquid
important component is a cation. The toxicity of ILs is strongly influenced by its lipophilicity associated with the length of the straight chain alkyl and its branching degree and also is affected by its anionic properties. Peric et al. have undertaken toxicity assay studies of the proic ILs (derived from aliphatic and organic acid) and the aprotic ILs (imidazolium and pyridinium) groups to aquatic organisms, as well as tests on the enzyme acetylcholinesterase and mouse leukemia cell (IPC-18), with proic ILs activity >100 mg/L, and aprotic ILs weaker than proic IL.

The main reason for believing that ILs with non-toxic and non-volatile properties, make these solvents potential as a green solvent can be an alternative material or substitute for conventional organic solvents. Unfortunately, this green image is misplaced and recently awakened the consciousness of the chemists, especially those who work in the field of green chemistry. Pham et al. have reported that some cations and anions have toxic properties that harmful. However, the risk of harm can be reduced by combining a specific cation and anion into an IL solvent. On the other hand, combining different functional groups makes it complicated to investigate toxicity because it has functional groups that potentially cytotoxic. Although ILs may help in reducing the risk of air pollution, however, its release to the aquatic environment can cause severe water contamination due to its potential toxicity and its uncontrollable biodegradability. It has a relatively stable form of an ILs so that it can cause accumulation in the aquatic environment. Related environmental impacts and toxicities have been described in more detail in some literature. However, with nonflammable properties and reproducible, so that the utilization of ILs as a green solvent becomes more economical and eco-friendly.

Microwave-assisted extraction

The development of non-conventional extraction methods has been widely practiced. The MAE method is one of the non-conventional methods that is quite easy to apply to extract the target constituent from natural products. Kaufmann and Christen have explained the mechanism of extraction process of the MAE method in more detail and has been clarified by Mandal et al., Routry and Orsat, Périno-Issartier et al., Zhang, et al., and Sagarika, et al. As can be seen in Figure 1 that has been described by Périno-Issartier et al., in the MAE method involves three steps: (1) separation of solutes from the active side of the sample matrix due to increased temperature and pressure; (2) solvent diffusion across the matrix sample; and (3) the solute release of the matrix sample by the solvent. Based on these mechanisms, some advantages of MAE methods such as rapid extraction, reducing gradient thermal, and increase the extract yields. In addition, the MAE method is also recognized as a green technology because it reduces the use of solvents.

The principle of heating using microwave energy is based on the direct effects of microwaves on material molecules. The transformation of electromagnetic energy occurs through two mechanisms, namely, ionic conduction and dipole rotation in both solvents and samples. In many applications, these two mechanisms co-occur, which effectively convert microwave energy to thermal energy.

Application of MAE method to extract secondary metabolites of the natural product has been successfully reported. Some studies have been reported including essential oil extraction from C. curassavica, polyphenols and caffeine extraction from green tea leaves, flavonoid extraction of Radix Astragali, phenolics compound extraction of peanut skins and wine lees, phenolic compound extraction from Gordionia axillaris, bioactive alkaloid extraction of Stephania sinica and N. nucifera, polyphenolics compound extraction from selected medicinal herbs grown in Turkey (including Hypericum scabrum L., Papaver fugax Poiret var. platydicus Cullen, and Achillea verniculaxis Trin.), optimization of green tea waste extraction, extraction of active compound from P. pelludica (L.) Kunth, and others.

Application of ionic liquid-based microwave-assisted extraction to extract secondary metabolites from herbal plant

The use of the IL-MAE method in the development of extraction method to obtain the optimum targeted compound of natural products. As has been described by Bogdanov at chapter 7 in the book entitled “Green Chemistry and Sustainable Technology: Alternative Solvent for Natural Products Extraction,” some essential factors must be considered to obtain optimal results in the extraction process from natural materials as shown in Figure 2. One of the critical factors to think and focus on this review article is the selection of extraction methods (especially the MAE methods). The utilization of MAE method combined with ILs as a green solvent has been successful and has been done since 2007, although the use of ILs as a solution has been applied since 2003. The IL-MAE method has advantages over other conventional means, besides provides higher yields and shorter extraction time but has also examined economics and environmental impact standpoint as a green solvent. For example, research has been conducted by Du et al. shows that resveratrol extraction using ILs is better than using conventional methods as well as MAE methods with conventional organic solvents (methanol), as well as in other plant species such as Psidium guajava and Smilax china. As for the other target group, compounds also successfully performed such as alkaloids, polyphenols, flavonoids, essential oils, and other. The optimum condition of IL-MAE depends on the sample matrix of plant and the type of ILs selected, but some terms that are parameters in the optimization process of the IL-MAE [Table 2] include microwave power, ILs concentration, liquid-solid ratio, extraction time, temperature, pH, particle size of samples matrix, and so on.
Table 2: Application of ionic liquid-based microwave-assisted extraction to extract the targeted compound from the herbal plant

<table>
<thead>
<tr>
<th>Herbal plant</th>
<th>Targeted compound</th>
<th>IL used</th>
<th>IL-MAE method and optimum condition</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polygonum cuspidatum Sieb.et.Zucc.</td>
<td>Trans-resveratrol</td>
<td>[BMIM] Br</td>
<td>2.5 M [BMIM] Br, temperature of 60°C, extraction time of 10 min, particle size of 0.3-0.4 mm, liquid–solid ratio of 20 ml/g</td>
<td>[9]</td>
</tr>
<tr>
<td>Illicium verum</td>
<td>Essential oils</td>
<td>[BMIM][PF₄]</td>
<td>[BMIM][PF₄], microwave power of 440 W, temperature of 100°C, particle size&lt;0.4 mm, liquid–solid ratio of 20:1.5 (ml/g)</td>
<td>[11]</td>
</tr>
<tr>
<td>Cinnamomum cinnamomum</td>
<td>Essential oils</td>
<td>[BMIM][PF₄]</td>
<td>[BMIM][PF₄], microwave power of 440 W, temperature of 100°C, extraction time of 20 min, particle size&lt;0.4 mm, liquid–solid ratio of 20:1.5 (ml/g)</td>
<td>[11]</td>
</tr>
<tr>
<td>Cinnamomum spp.</td>
<td>Essential oils Proanthocyanidins</td>
<td>[BMIM] Br</td>
<td>0.5 M [BMIM] Br, microwave power of 230 W, extraction time of 15 min, and liquid–solid ratio of 10 ml/g</td>
<td>[13]</td>
</tr>
<tr>
<td>Rosa sinensis</td>
<td>Quercetin</td>
<td>[OMIM] Br</td>
<td>2.5 M [OMIM] Br, temperature of 70°C, extraction time of 20 min, and liquid–solid ratio of 40 ml/g</td>
<td>[14]</td>
</tr>
<tr>
<td>Scutellaria baicalensis Georgi</td>
<td>Flavonoids</td>
<td>[OMIM] Br</td>
<td>1.0 M [OMIM] Br, microwave power of 400 W, extraction time of 90 min, liquid–solid ratio of 6 ml/g</td>
<td>[16]</td>
</tr>
<tr>
<td>Peperomia pellucida (L) Kunth</td>
<td>Total polyphenolic content</td>
<td>[BMIM] BF₄, [BMIM] Cl, [BMIM] Br, [EMIM] Br</td>
<td>0.79 mol/L [BMIM] BF₄, extraction time of 18.5 min, liquid–solid ratio of 10.72 ml/g, and microwave power 270 W</td>
<td>[18]</td>
</tr>
<tr>
<td>Radix puerariae</td>
<td>Isoflavone</td>
<td>[BMIM] Br</td>
<td>0.8 mol/L [BMIM] Br, microwave power of 600 W, extraction time of 5 min, temperature of 80°C, and liquid–solid ratio of 20 ml/g</td>
<td>[41]</td>
</tr>
<tr>
<td>Nelumbo nucifera Gaertn</td>
<td>Phenolic alkaloid ([l]ensine, isolensine, and neferine)</td>
<td>[BMIM][BF₄], [HMIM][BF₄], [EMIM][BF₄]</td>
<td>1.5 M [BMIM][BF₄] and 1 M [HMIM][BF₄], microwave power of 280 W, extraction time of 1.5 min, liquid–solid ratio of 15 and 10 (ml/g), respectively</td>
<td>[10]</td>
</tr>
<tr>
<td>Nelumbo nucifera</td>
<td>N-nornuciferine, O-nornuciferine, Nuciferine</td>
<td>[HMIM] Br</td>
<td>1 M [HMIM] Br, microwave power of 280 W, extraction time of 2 min, liquid–solid ratio of 30 ml/g</td>
<td>[76]</td>
</tr>
<tr>
<td>Dysosma versipellis</td>
<td>Podophyllotoxin</td>
<td>[BMIM][BF₄]</td>
<td>0.6 g/mL [BMIM][BF₄], temperature of 50°C, extraction time of 10 min, liquid–solid ratio of 10 ml/mg</td>
<td>[81]</td>
</tr>
<tr>
<td>Sinopodophyllum hexandraum</td>
<td>Podophyllotoxin</td>
<td>[DEMIM][BF₄]</td>
<td>0.8 g/mL [DEMIM][BF₄], temperature of 60°C, extraction time of 10 min, liquid–solid ratio of 10 (ml/g)</td>
<td>[81]</td>
</tr>
<tr>
<td>Diphyleia sinensis</td>
<td>Podophyllotoxin</td>
<td>[AMIM][BF₄]</td>
<td>0.4 mg/mL [AMIM][BF₄], temperature of 50°C, extraction time of 15 min, liquid–solid ratio of 10 (ml/mg)</td>
<td>[81]</td>
</tr>
<tr>
<td>Rosmarinus officinalis</td>
<td>Carnosic acid Rosmarinic acid</td>
<td>[OMIM] Br</td>
<td>1 M [OMIM] Br, microwave power of 700 W, extraction time of 15 min, liquid–solid ratio of 12 (ml/g)</td>
<td>[82]</td>
</tr>
<tr>
<td>Schisandra chinensis</td>
<td>Essential oils Lignan</td>
<td>[C₄₅][MIM] Br</td>
<td>0.25 M [C₄₅][MIM] Br, presoaking for 4 hours, microwave power of 385 W, extraction time of 40 min, and liquid–solid ratio of 12 ml/g</td>
<td>[12]</td>
</tr>
<tr>
<td>Myrica rubra</td>
<td>Quercetin</td>
<td>[BMIM][HSO₄]</td>
<td>2.0 M [BMIM][HSO₄], temperature of 70°C, extraction time of 10 min, and liquid–solid ratio of 30 ml/g</td>
<td>[83]</td>
</tr>
<tr>
<td>Bauhinia championii (Benth)</td>
<td>Myrcetin</td>
<td>[BMIM] Br</td>
<td>2.0 M [BMIM] Br with 0.8 mol/L HCl, temperature of 70°C, extraction time of 10 min, particle size of&lt;0.30 mm, and liquid–solid ration of 30 ml/g</td>
<td>[84]</td>
</tr>
<tr>
<td>Dryopteris fragrans</td>
<td>Phloroglucinols</td>
<td>[OMIM] Br</td>
<td>0.75 [OMIM] Br, microwave power of 600 W, extraction time of 7 min, and liquid–solid ratio of 12 ml/g</td>
<td>[85]</td>
</tr>
<tr>
<td>Lemon Peels</td>
<td>Pectin</td>
<td>[BMIM] Br</td>
<td>0.1 M [BMIM] Br, temperature of 60°C, extraction time of 8 min, and liquid–solid ratio 20 ml/g</td>
<td>[86]</td>
</tr>
<tr>
<td>Cajanus cajan</td>
<td>Glycoside Flavonoid</td>
<td>[BMIM] Br</td>
<td>1.0 M [BMIM] Br, temperature of 60°C, extraction time of 13 min, and liquid–solid ratio of 20 ml/g</td>
<td>[87]</td>
</tr>
<tr>
<td>Pseudo-nitzschia calliantha H. Andr</td>
<td>Phenolic compound</td>
<td>[BMIM] BF₄</td>
<td>0.5 M [BMIM] BF₄, microwave power of 700 W, temperature of 40°C, extraction time of 15 min, and liquid–solid ratio 20 ml/g</td>
<td>[88]</td>
</tr>
</tbody>
</table>

Contd...
Mechanism of ionic liquid-based microwave-assisted extraction method on extraction process

The mechanism of the IL-MAE method was first reported by Du et al. with measuring the kinetic of polyphenolic constituent extraction using an ILs as a green solvent. The mechanism of extraction was conducted using Fourier-transform infrared spectroscopy and scanning electron microscopy (SEM), by observing the extent of damage to the cell surface of the sample matrix. A study carried out by Du et al. showed similar mechanisms for quercetin and kaempferol extraction from T. sinensis and R. sinensis using IL-MAE with (BMIM) Br and (OMIM) Br. Ahmad et al. demonstrated that the surface and cell wall structures of P. pellucida sample was visibly destroyed after IL-MAE and maceration extraction treatment [Figure 3]. A synergic reaction between microwave irradiation and the penetration of ILs solvent combination causes damage to the surface of the cell wall so that the secondary metabolite constituent contained in the sample matrix can pass through the damaged cell gap. The effect of extraction condition factors using the IL-MAE method in more detail on the extent of damage to the wall of the sample matrix was described in some literature. 

Based on Figure 3, the SEM analysis results show significant physical changes in the plant tissue after treatment with different solvents. It was demonstrated differences in cell wall surface changes in samples that have been extracted using the IL-MAE method compared to maceration method and the untreated sample, whereas the ratio of the rate of surface changes of the cell wall the untreated sample and after the maceration extraction is not significantly different. The result of the SEM analysis correlates with the yields value (total polyphenol content) generated by the maceration extraction and the IL-MAE extraction.

ILs, but not in water, with the assumptions that anions of ILs can interact with hydroxyl protons from cellulose, and the coupling of cations to the side chain and oxygen binder strongly in peeling conditions. Payal et al. have also performed quantum chemical calculations on a group of solvent molecules to dissolve cellulose units, with the hypothesis that all intramolecular hydrogen bonds have been explicitly deleted on the ILs media because of the strong interaction of hydrogen bonds between cellulose and ILs. Thus, cell walls are easily damaged with ILs using heat extraction. That is the reason why extraction methods with heating or other non-conventional methods based on ILs take a short time compared to conventional organic solvent-based extraction methods. Therefore, the ILs solvent can be used as an alternative or green solvent which continues to be developed primarily for extracting the active components of medicinal plants with the aid of non-conventional extraction methods.

CONCLUSION

The application of IL-MAE method has been successfully performed to extract the targeted secondary metabolite from a natural product and provides higher yields and extraction rate with less solvent, short time (rapid), and energy consumption compared with conventional extraction method.

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Conflicts of interest
There are no conflicts of interest.

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