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REVIEW ARTICLE

EFFECT OF EXTRACTING SOLVENT ON PHENOLIC CONTENT AND ANTIOXIDANT ACTIVITY OF OENANTHE JAVANICA: A REVIEW

Noor Azalina Musa[a], Noor Haslinda Noor Hashim[a,b]*

[a]Department of Plant Science, Kulliyyah of Science, International Islamic University Malaysia, Kuantan 25200, Pahang, Malaysia.
[b]Sustainable Agriculture and Green Technology Research Unit (AG-Tech), Kulliyyah of Science, International Islamic University Malaysia, Kuantan 25200, Pahang, Malaysia.
**Corresponding Author Email :noorhaslinda@iium.edu.my*

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ABSTRACT

Oenanthe javanica or water dropwort, is a medicinal plant that exhibits a great potential for antioxidant activity and is capable of scavenging free radical ions associated with various diseases. Although *O. javanica* extracts have shown antioxidant properties, there is a gap in research concerning the selection of suitable solvents for extracting antioxidant compounds from this plant. Therefore, this review aims to identify the most effective solvent for the preparation of antioxidant-rich *O. javanica* extracts. Based on the data obtained from online articles and journals through several academic databases, our findings indicate that various solvents give notable outcomes on the *O. javanica* extracts in terms of extract yield, total phenolic content and antioxidant activity. Ethanol, methanol and water are among the frequently solvents utilised for *O. javanica* extraction. Hot water extract exhibited the highest extraction yield from *O. javanica*. Meanwhile, 50% methanol extract demonstrate the highest TPC with 621 ± 63 mg GAE/100 g using the Folin-Ciocalteu method. On the other hand, methanol extracts of *O. javanica* produced the highest antioxidant potential with 97.09% of DPPH scavenging activity with the IC_{50} of 30µg/ml. It can be noted that phenolic compounds including phenolic acids and flavonoids as well as carotenoids are among the compounds that contributed to the antioxidant activity of *O. javanica* extracts This review hopes to serve as a valuable resource for researchers engaged in solvent-based extraction and phenolic content analysis from *Oenanthe javanica*, as well as offering insights that can guide future investigations in optimizing the extraction of valuable antioxidant compounds from this plant.

KEYWORDS

Oenanthe javanica, water dropwort, solvent extraction, Antioxidant, Total phenolic content

1. INTRODUCTION

Phenolic compounds are the most important class of secondary metabolites present in all plants (Hu et al., 2022). It has a high antioxidant potential that contributes to the health benefits for humans due to its capability to scavenge free radicals and donate hydrogen atoms, electrons or chelate metal cations (Minatel et al., 2017). The positions and number of the hydroxyl groups along with the aromatic ring substitutions, influence the antioxidant activity of phenolic compounds (Chen et al., 2020). Phenolic and flavonoid compounds have been associated with numerous pharmacological activities, including anti-inflammatory, antidiabetic, antimicrobial, anti-allergic, antithrombotic, anti-pathogenic, and vasodilatory effects (Comunian et al., 2017). Reactive oxygen species (ROS), which encompass chemically reactive oxygen-containing molecules are produced within living organisms as a natural by-product of cellular metabolism and are also influenced by various environmental factors. ROS includes superoxide radical anion ($O_2^{\bullet-}$), hydrogen peroxide (H_2O_2), alkoxyl (RO·), peroxyl (ROO·), nitric oxide (NO·) and ozone (O_3) (Mehta & Gowder, 2015). The imbalance between ROS production and antioxidant leads to oxidative stress, which has numerous detrimental effects on important cellular structures and contributes to conditions such as cancer, diabetes, atherosclerosis and cardiovascular diseases (Pizzino et al., 2017). In order to alleviate the effects of oxidative stress on an individual's health, antioxidant compounds are employed to prevent or reduce cell damage caused by free radicals and unstable molecules produced within the body (Pizzino et al., 2017).

The utilisation of plants, including herbs, shrubs, or trees, as sources of medicinal remedies for various disorders and diseases has been practiced for a long time ago due to their great therapeutic potential (Karole et al., 2019). *Oenanthe javanica* (Blume) DC, commonly known as water dropwort, is a small perennial herb belonging to the Apiaceae family. It is cultivated in tropical and temperate regions of Asia and has been employed in various ethnomedical systems, especially in China, Korea and Japan (Lu and Li, 2019). Traditionally, *O. javanica* has been used in alleviating jaundice, hypertension, fever, cold, abscesses, swellings, abdominal pain, leucorrhea and urination problems (Chan et al., 2016). In addition, the plant is consumed as a salad or seasoning in Southeast Asia due to its strong celery-like flavour leaves. Previous pharmacological studies revealed that *O. javanica* exhibits antioxidant, anti-diabetic, anti-inflammatory, alcohol detoxification, anti-coagulant, hepatoprotective and enhancing memory activity (Bhaigyabati et al., 2017). *O. javanica* has also demonstrated photoprotective activity against UVB-induced collagen disruption and inflammation, suggesting its potential application in the treatment of photodamaged skin (Her et al., 2019). Abundant phytochemical compounds have been identified from *O. javanica* such as hyperoside, persicarin, isorhamnetin, chlorogenic acid, caffeic acid, 5-O-caffeoylquinic acid, butanedioic acid and gallic acid (Ai et al., 2016; Lee et al., 2017).

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In order to study the plant's potential, one of the most important factors is the extraction process. The extraction yield and biological activity of the resulting extract are influenced not only by the extraction technique but also by various factors, including the choice of extraction solvent, temperature and duration, and the geographical location of the plant. However, it is widely acknowledged that the choice of solvent for extraction is the most influential factor determining extraction efficiency (Deng et al., 2017). The selectivity, solubility, safety and polarity of the solvent are the main factors to be considered when selecting an appropriate solvent for extracting desired compounds from plant materials (Bergs et al., 2013). Thus, it is important to select a suitable extraction solvent for specific plant material to achieve higher extraction yield and biological activities. Therefore, this review focuses on elucidating the effects of different solvents on the extraction yield, total phenolic content and antioxidant potential of *O. javanica*. Moreover, this review aims to enhance the understanding of *O. javanica,* ultimately contributing to the improvement of the quality of its bioactive compounds.

2. Phytochemical Constituents

Phytochemical compounds exhibit various biological activities and contribute to a plant's aroma, flavour and colour, as well as are responsible for plant protection and reproduction by attracting insects for pollination. Moreover, phytochemicals also play an important role in providing health benefits for humans (Saxena et al., 2013). Phytochemicals can be classified into six major categories including carbohydrate, lipid, phenolic compound, terpenoid, alkaloid and other nitrogen-containing compounds (Huang et al., 2016). According to Mendoza and Silva, phytochemicals are classified into each category based on their chemical structures, biosynthetic origin and solubility properties (Mendoza and Silva, 2018).

The phytochemical studies conducted on *O. javanica* revealed a rich diversity of bioactive compounds. Among these are flavonoids, flavonoid glycosides and flavonols, including apigenin, quercetin, isorhamnetin-3-O-galactoside, persicarin, isorhamnetin, hyperoside and kaempferol (Lu and Li, 2019). Hyperoside and persicarin were identified to be the major compounds isolated from the methanolic extracts of *O. javanica* (Ahn and Lee, 2017; Lee et al., 2017; Ma et al., 2010). Flavonoids and flavonoid glycosides from *O. javanica* contain free phenolic hydroxyl groups at the 5, 7, and 4′-position, while a majority of the compounds are substituted at the 3 and 3′-position (Lu and Li, 2019). Additionally, phenolic compounds such as chlorogenic acid, caffeic acid, 5-O-caffeoylquinic acid, butanedioic acid and gallic acid have been successfully extracted using a mixture of aqueous ethanol (70% and 75%) (Ai et al., 2016; Seok-Jun et al., 2013). Further analysis of hydrophilic extracts of the plant has revealed the presence of chlorogenic acid, rhamnosyl galactoside, hyperoside, rutin, and isoquercitrin, while lipophilic extracts contained lutein, α-tocopherol, and γ-tocopherol (Ogita et al., 2016). Coumarins have been found in all parts of *O.javanica* plant including the root, stem and leaves with major furanocoumarins such as xanthotoxin, isopimpinelin, and bergapten identified via GC-MS analysis (Kim et al., 2016). *Oenanthe javanica* is also a valuable source of essential oils, contributing to its aromatic profile. Gas chromatography-olfactometry analyses have revealed key aromatic compounds such as *p*-cymene, *α*-terpinolene, (*E*)-caryophyllene, (*Z*, *E*)-*α*-farnesene and *α*-terpinene (Seo and Baek, 2005). Another study on the leaves of *O. javanica* identified a significant number of sesquiterpenes comprising of ß-sesquiphelladiene, germacrene D, α-copaene, (Z)-caryophyllene, and α-cuprene (Pattiram et al., 2011).

3. Factors Affecting Antioxidants Activity

Extraction is a process/method to separate the desired phytochemical constituents from raw materials using a suitable solvent with standard procedures (Azwanida, 2015). This initial step in phytochemical processing is important for identifying bioactive compounds within plant materials (Dhanani et al., 2017). Extraction techniques can be classified into two categories, which conventional and non-conventional extraction methods. The most common conventional techniques are maceration, percolation and soxhlet extraction methods. While non-conventional or green extraction methods include supercritical fluid extraction, microwave-assisted extraction and pressurized liquid extraction have been utilized in the extraction of natural products recently (Zhang et al., 2018). Despite the selection of extraction methods, the extraction yield of plant samples is commonly influenced by several factors, including the choice of solvent, temperature, pH, the composition of the sample and the extraction duration (Do et al., 2014). Bioactive compounds in plants exhibit varying polarities and chemical characteristics, leading to differences in their solubility in specific solvents (Turkmen et al., 2006). Therefore, the careful selection of an appropriate solvent for extraction is crucial to ensure the obtainment of high-yield extracts with desired biological activities from biomass materials (Ye et al., 2015).

3.1 Effects of Extracting Solvent/ Technique on the Extraction Yield of *O. javanica*

Previous studies have reported the use of various organic solvents, including ethanol, methanol, water, and mixtures of these solvents (70%, 75% and 80%) for the extraction of biologically active compounds from *O. javanica.* Different extraction techniques have also been employed as tabulated in Table 1.

Table 1: Effects of extracting solvent/technique on the extraction yield of *O. javanica.*

No	Extraction Method	Drying Method	Extraction Solvent	Extraction Yield (%)	Ref.
1	Blend	Air-dried + fan	Aqueous	5.19	Huda-Faujan et al., 2007
2	Maceration	Dried	Hot aqueous	23.2	Choi et al., 2011
			80 % ethanol	22.2	
3	Reflux	Dried	75 % ethanol	1.50	Han et al., 2008
4	Maceration	Fresh	70 % ethanol	5.82	Lee et al., 2017
5	Soxhlet	Freeze-drying	70 % ethanol	14.5	Seok-Jun et al., 2013)
6	Maceration	Oven-drying (37 °C)	100 % Methanol	0.66	Huda-Faujan et al., 2009
7	Maceration	Oven-drying (50 °C)	100 % Methanol	7.83	Lee et al., 2011

The highest extraction yield from O. javanica were achieved using hot water and 80% ethanol utilising maceration technique, resulting in extraction yield of 23.2 % and 22.2 %, respectively (Choi et al., 2011). This finding aligned with the research on the extraction of polyphenols from green, black, and mate teas by (Filip and Ferraro, 2003; Khokhar and Magnusdottir, 2002). Water emerges as an excellent choice for extraction due to its environmental acceptability, widespread availability, and non-toxic nature (Ong et al., 2006). However, its excessive polarity and limited solubility in most organic compounds have led to its infrequent use in plant component extraction. Additionally, temperature adjustments can be employed to manipulate the physicochemical characteristics of water, including polarity, viscosity, and surface tension, thereby enhancing its extraction efficiency. Elevating the temperature disrupts the hydrogen bonds that constitute water's structure, reducing its polarity (Vergara-Salinas et al., 2015). temperature alterations aid in releasing desired compounds from samples by reducing water's surface tension and viscosity, facilitating deeper solvent penetration into the matrix (Teo et al., 2008; Yu et al., 2008).

On the other hand, hydro-alcoholic solvents are considered to be a good option for extracting biologically active chemicals from plants due to their selectivity and wide range of polarities (Jacotet-Navarro et al., 2018). Ethanol, as a polar solvent, contains hydroxyl groups that readily engage in hydrogen bonding with solutes (Abdul Razak et al., 2012). Moreover, solvents with higher polarity are more effective in quantitatively recovering phenolic compounds compared to nonpolar solvents (Vieito et al., 2018). Furthermore, the extraction yield of O. javanica is influenced by the extraction temperature. Substantial variations in results were observed even when the same solvent (100 % methanol) and drying method (oven drying) were employed (Huda-Faujan et al., 2009; Lee et al., 2011). It appears that plant extraction efficiency is particularly sensitive to temperatures ranging from 40 °C to 50 °C. Additionally, factors such as drying time, drying process, temperature, air relative humidity, and airflow speed can contribute to the disparities in results (Nguyen et al., 2015). Overall, variations in the extraction yield of O. javanica can be attributed to diverse extraction techniques, sample preparation methods, and other parameters influencing extraction efficiency (Zhang et al., 2018).

3.2 Effects of Different Solvents on the Total Phenolic Content of *O. javanica*

Total phenolic content provides a great ability for estimating the cumulative presence of all phenolic compounds, encompassing anthocyanins, flavonoids and non-flavonoids phenolic compounds within biomass materials (Benvenuti et al., 2006). The Folin-Ciocalteu assay is the most straightforward and widely recognised technique for quantifying total phenolic content (Agbor et al., 2014). Table 2 presents an overview of the total phenolic content (TPC) of *O. javanica* extracts obtained using various extracting solvents.

Ethanol and methanol in various concentrations are the most frequently employed extraction solvents for *O. javanica,* as depicted in Table 2. Among the TPC assays conducted, the 50% methanol extract of fresh samples yielded the highest TPC, with 621 ± 63 mg GAE/100 g. It is worth noting that aqueous mixtures of organic solvents are widely recognized as effective solvents for extracting polyphenols from sample materials (Venkatesan et al., 2019). Various solvent mixtures are known to yield varying overall polarities, influencing the selection of phytochemicals that are extracted (Do et al., 2014). Generally, polar solvents are the preferred choice for extracting polyphenols from biomass materials, owing to their enhanced solubility of these compounds in the extraction solvent.

Table 2: Total phenolic content of *O. javanica*.

No.	Solvent	Extraction Method	Drying Method	Total Phenolic Content	Ref.
1	Aqueous	Blend	Air dried + fan	19.96 mg TAE/100 g	Huda-Faujan et al., 2007
2	Aqueous	Maceration	Air dried	2.66 mg GAEq/100g	Srivastava & Vankar, 2012
	Ethyl acetate			2.61 mg GAEq/100g	
3	Aqueous	Soxhlet	Shade dried	48.81 ± 0.02 mg GAE /g	Bhaigyabati et al., 2017
	Methanol			41.86 ± 0.06 mg GAE /g	
4	70 % ethanol	Ultrasonic extraction	Freeze dried	37.50 mg GAE/g	Hwang et al., 2011
5	70 % ethanol	Soxhlet	Freeze dried	88.9 ± 0.46 mg GAE/g	Seok-Jun et al., 201)
6	75 % ethanol	Reflux	Dried	523.7 ± 23.4 mg GAE/g	Ai et al., 2016
7	75 % Ethanol	Reflux	Dried	52.3 mg GAE/100g	Han et al., 2008
8	95 % ethanol	Maceration	Air dried	38.75 ± 4.44 mg of GAE/g	Rafat et al., 2010
9	Methanol	Maceration	Freeze dried	1070.00 ± 81.32 (µmol GAE/g)	Kwon et al., 2006
10	Methanol	Maceration	Oven Dried	7.41 mg TAE /100 g	Huda-Faujan et al., 2009
11	Methanol	Maceration	Oven dried	44.70 mg GAE/g	Lee et al., 2011)
12	50 % Methanol	Orbital shaker	Fresh	621 ± 63 mg GAE/100 g	Chan et al., 2016
13	50 % dimethylforma-mide	Orbital shaker	Oven dried	239.23 ± 6.10 mg GAE/100g	Kongkachuichai et al., 2015

GAE; gallic acid equivalents, TAE; tannic acid equivalents

Numerous research suggests that water is a favourable choice for extracting phenols from most species. The higher polarity and shorter molecular chain of water enable the more effective extraction of polar bioactive compounds (Abdul Razak et al., 2012). This has been demonstrated by a study conducted which found that water extract of *O. javanica* yielded higher phenolic content compared to methanol extract by (Bhaigyabati et al., 2017). In addition, observed that aqueous solvent was superior to ethyl acetate in extracting phenolic compounds from plants (Srivastava and Vankar, 2012). However, the difference between the listed results also might be different in their phenolic content, as the studies were conducted in a different geographical region with distinct conditions, methods of extraction and sample preparation, which can influence the phytochemical constituents in the samples (Bhaigyabati et al., 2017; Kumar et al., 2013).

3.3 Effect of Different Solvents on the Antioxidant Activity of *O. javanica*

A considerable number of analyses have been carried out to evaluate the antioxidant potential of *O. javanica*, with the DPPH radical scavenging method being a commonly employed technique in assessing the antioxidant potential of this plant, as depicted in Table 3. Results from this assay proved that *O. javanica* has great antioxidant activity, attributable to the presence of various phytochemicals in the extracts, mainly flavonoids and phenols (Bhaigyabati et al., 2017). There was a wide range of antioxidant activities of *O. javanica* extracts obtained from different extraction solvents.

Table 3: Antioxidant activity of *O. javanica* based on DPPH radical scavenging assay

No.	Extraction Method	Drying Method	Extraction solvent	DPPH scavenging activity (%inhibition or IC_{50})	Ref.
1	Soxhlet	Freeze dried	70 % ethanol	72.2 %	Seok-Jun et al., 2013
2	Maceration	Air dried	95 % ethanol	56.87 %	Rafat et al., 2010
3	Orbital shaker	Fresh	50 % methanol	5.08 mg/ml	Chan et al., 2016
4	Ultrasonic extraction	Freeze dried	70 % ethanol	1.07 mg/mL	Hwang et al., 2011
5	Soxhlet	Shade dried	Methanol	97.09 % (30 µg/ml)	Bhaigyabati et al., 2017
	70 % ethanol	Ultrasonic extraction	Distilled water	83.94 % (73.2 µg/ml)	Hwang et al., 2011
6	Maceration	Dried	Hot water	41.7 ± 1.2 %	Choi et al., 2011
	75 % ethanol	Reflux	80 % ethanol	50.9 ± 2.1 %	Ai et al., 2016
7	Maceration	Air dried	Aqueous	36.2 %	Srivastava & Vankar, 2012
	95 % ethanol	Maceration	Ethyl acetate	14.3 %	Rafat et al., 2010

The antioxidant potential of extracts is strongly influenced by the type of extraction solvent used, primarily due to the varying polarities of antioxidant compounds (Boeing et al., 2014). Bhaigyabati et al., 2017 found that the methanol extract of *O. javanica* exhibited higher antioxidant potential, with 97.09% DPPH scavenging activity compared to the aqueous extract, which demonstrated 83.94% DPPH scavenging activity. In addition, hot water extract showed a lower percentage of DPPH scavenging activity (41.7±1.2 %) than ethanol extract (50.9±2.1 %) (Choi et al., 2011). Moreover, water is considered to have greater antioxidant potential than ethyl acetate, with 36.2 % and 14.3 % of DPPH scavenging activity, respectively (Srivastava and Vankar, 2012). These findings suggest that methanol is the most potent solvent for extracting antioxidant compounds, possibly because of its ability to establish hydrogen bond interactions between the polar sites of the solvent and antioxidant

molecules, enhancing solvation. Despite ethanol and methanol having similar polarities, methanol appears more effective, possibly due to the longer existence of the ethyl radical in ethanol compared to the methyl radical in methanol, resulting in a slower solvation process (Boeing et al., 2014). To proposed that employing aqueous mixtures of organic solvents, such as ethanol, methanol, and acetone with water as the extraction solvent, enhances the antioxidant efficacy of extracts compared to using only water or organic solvents (Venkatesan et al., 2019). This statement is supported by the data in Table 3, showing stronger DPPH scavenging activity in 70% ethanol with a lower IC50 value of 1.07 mg/mL, indicating higher scavenging potential. Other studies also reported that O. javanica extracted using 70% ethanol and 95% ethanol exhibited scavenging activities of 72.2% and 56.87%, respectively (Rafat et al., 2010; Seok-Jun et al., 2013). However, other factors, such as sample source, extraction method, and sample preparation techniques, may also contribute to variations in the antioxidant activity of *O. javanica*, resulting in differences in the extracted bioactive compounds (Li et al., 2012).

3.4 Antioxidant Compounds Isolated from *O. javanica*

Free radicals as well as reactive oxygen species (ROS) and reactive nitrogen species (RNS), play an important role in many biological functions and defense mechanisms. They act as signaling molecules and protect cells against pathogenic and infectious agents, thereby benefiting overall health (Birben et al., 2012). However, excessive formation of free radicals can lead to oxidative stress and tissue damage, contributing to various adverse health effects (Santos-Sánchez et al., 2019; Huyut et al., 2017). Exogenous antioxidants encompass several crucial classes of compou nds including polyphenols (flavonoids, stilbenes and anthocyanins), carotenoids (carotenes and xanthophylls) and vitamins (vitamin C and E). Among these, polyphenols and carotenoids have been extensively studied and acknowledged for their diverse therapeutic effects including antibacterial, anti-inflammatory, anticancer and anti-aging (Manach et al., 2004). Table 4 provides an overview of the antioxidant compounds isolated from O. javanica extracts. In fact, plant extract exists as a combination of various phytochemical compounds with different natures including chemical structure, polarities, spectral characteristics and glycosidic linkages (Mtewa et al., 2018). Several techniques, such as High-Performance Liquid Chromatography (HPLC) and Nuclear Magnetic Resonance (NMR) spectroscopy, have been employed to identify these antioxidant compounds in *O. javanica* (Sasidharan et al., 2011; Umaru et al., 2018).

Table 4: Antioxidant compounds isolated from *Oenanthe javanica*

No.	Antioxidant compound	Identification Method	Ref.
	Phenolic Acids		
1	Caffeic acid	HPLC	Choi et al., 2011
2	Gallic acid, catechin, chlorogenic acid, and caffeic acid.	HPLC	Hwang et al., 2011
3	Chlorogenic acid, caffeic acid, 5-O-caffeoylquinic acid, butanedioic acid and gallic acid	HPLC	Ai et al., 2016
4	Caffeic acid, chlorogenic acid, p-coumaric acid, isochlorogenic acid A, isochlorogenic acid B	HPLC-ESI-QTOF- MS	He et al., 2020
	Flavonoids		
5	Persicarin	HPLC	Lee et al., 2017;
6	Isorhamnetin, persicarin, adenosine, hyperoside	NMR	Jo et al., 2008
7	Quercetin, rutin, hyperoside, kaempferol-3-O-rutinoside, isorhamnetin, isohamnetin-3- O- luteoloside, and apigenin	HPLC-ESI-QTOF-MS	He et al., 2020
	Carotenoids		
8	Lutein, β-carotene	HPLC	Kongkachuichai et al., 2015; Fatimah et al., 2012

Based on Table 4, phenolic acid, flavonoids and carotenoids have been reported for the antioxidant potential of *O. javanica* (Bhaigyabati et al., 2017). In most studies, antioxidant activity of *O. javanica* extracts is strongly associated with the presence of phenolic compounds. Phenolic acids are renowned for their potent antioxidant properties, play an important role in scavenging excessive free radicals that can lead to cell damage and various diseases (Chen et al., 2020). Their antioxidant efficacy is attributed by the presence of phenolic hydroxyl groups, which directly engage in free radical neutralization. The number of phenolic hydroxyl groups in these compounds is directly proportional to their antioxidant potential, as hydroxyl groups serve as electron donor (Wright et al., 2001).

Several phenolic acids compounds have been identified from *O. javanica*, including caffeic acid, gallic acid, catechin, chlorogenic acid, caffeic acid, 5-O- caffeoylquinic acid, butanedioic acid, p-coumaric acid, isochlorogenic acid A and isochlorogenic acid B. Caffeic acid, for instance, has been shown to effectively eliminate reactive oxygen species (ROS), thereby protecting hepatic cells from damage caused by H_2O_2 treatment (Choi et al., 2011). Besides, chlorogenic acid, caffeic acid, 5-O-caffeoylquinic acid, butanedioic acid and gallic acid identified from *O. javanica* are associated with antioxidant potential and hepatoprotective effects (Ai et al., 2016).

Flavonoids, a well-studied class of polyphenol, possess remarkable antioxidant properties. The antioxidant potential of flavonoids is due to their ability to protect cells against oxidative stress, modulating enzyme receptors, and contributing to cardiovascular protection (Pietta, 2000). *Oenanthe javanica* extracts have been associated with protection against cardiovascular diseases due to their ability to increase antioxidant enzyme levels and reduce low-density lipoproteins and its ability to reduce low-density lipoproteins (Ma et al., 2010). Among flavonoid found in *O. javanica* are persicarin, isorhamnetin, hyperoside, quercetin, rutin, hyperoside, kaempferol-3-O-rutinoside, luteoloside and apigenin (Table 4). Persicarin was reported to possess neuroprotective effects (Ma et al., 2010).

Isorhamnetin, isolated from the aerial part of *O. javanica*, has demonstrated potent free radical scavenging activity (Jo et al., 2008). Moreover, quercetin, rutin, hyperoside, kaempferol-3-O-rutinoside, isorhamnetin, isohamnetin-3-O- luteoloside, and apigenin identified through HPLC-ESI-Q-TOF-MS from aqueous extract of O. javanica, are associated with hypoglycemic activity. Kaempferol-3-O-rutinoside, has been reported to prevent oxidative stress in diabetic mice (He et al., 2020). Apigenin contributes to glucose and lipid metabolism management and endothelial unction improvement in diabetic mice by reducing oxidative stress and inflammation (Ren et al., 2016). Meanwhile, quercetin is known for its protection against oxidative damage caused by ˙OH, O2˙ and H2O2 (Asaduzzaman and Asao, 2018).

Carotenoids also contribute to the antioxidant activity of *O. javanica* (Fatimah et al., 2012; Haoujar et al., 2019; Kongkachuichai et al., 2015). Their ability to scavenge the free radicals and singlet oxygen species is attributed to their conjugated polyunsaturated chain and hydroxyl group that modified the reactivity of the compounds (Santos-Sánchez et al., 2019; Kongkachuichai et al., 2015). Compounds such as lutein and β-carotene have been also identified from *O. javanica* extract using HPLC (Fatimah et al., 2012; Kongkachuichai et al., 2015). The chemical structure and the interaction of β-carotene with biological membranes are said to be responsible for the antioxidant activity by extinguishing the singlet oxygen efficiently (Nimse and Pal, 2015). Meanwhile, lutein, which is associated with eyesight, accumulates in the retina involved in scavenging light-induced free radicals preventing the formation of several diseases associated with eyes such as cataracts (Wootton-Beard and Ryan, 2011).

4. Conclusion

Phenolic compounds have been reported to be the main compound responsible for the antioxidant activity in *O. javanica* due to a strong relationship with the antioxidant potential. However, the extraction yield, total phenolic content and antioxidant activity of *O. javanica* can be influenced by various factors including environmental factors, storage

conditions and post-harvesting processes, which involve pre-extraction treatment and extraction parameters. In most factors, extraction solvents are considered the main factors affecting the extract yield and biological activity of the compound. The selection of a suitable solvent is very crucial since various phenolic compounds possess different polarities and chemical characteristics resulting in different solubility potentials in a particular solvent. The need to carry out more studies on the effect of different solvents on the antioxidant potential of the plants is urged so that improved extract yields, phenolic compound and antioxidant activity could be obtained. Accordingly, it will assist the researchers in exploring the antioxidant potential of the extract for their commercial purposes and facilitate the implementation of their great potential in the pharmaceutical and food industry.

Conflict of Interest

The authors declare no conflict of interest.

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