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ORIGINAL ARTICLE

Phytochemical investigation and antioxidant activities of methanol extract, methanol fractions and essential oil of *Dillenia suffruticosa* leaves

Muhammad Dawood Shah [a,b], Jaya Seelan Sathiya Seelan [c], Mohammad Iqbal [a,*]

[a] *Biotechnology Research Institute, Universiti Malaysia Sabah, Jalan UMS, 88400 Kota Kinabalu, Sabah, Malaysia*
[b] *Borneo Marine Research Institute, Universiti Malaysia Sabah, Jalan UMS, 88400 Kota Kinabalu, Sabah, Malaysia*
[c] *Institute for Tropical Biology and Conservation, Universiti Malaysia Sabah, Jalan UMS, 88400 Kota Kinabalu, Sabah, Malaysia*

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Abstract Oxidative stress has been known as a key factor of many disorders affecting human beings. Reactive oxygen species (ROS) attack vital biomolecules, weakening their functioning, thus exacerbating diseases. To attenuate oxidative stress-associated diseases a novel approaches of antioxidant therapies have been anticipated. Antioxidants have the potential to inhibit the propagation and formation of ROS. *Dillenia suffruticosa* is a medicinal plant, used by the local people for the treatment of various ailments. The study aimed to evaluate the phytochemical screening, antioxidative activity, total phenolic and flavonoid contents of methanol extract, fractions and essential oil of *D. suffruticosa*. Furthermore, the analysis of phytochemicals was done using gas chromatography and mass spectrometry (GCMS). The result showed the existence of alkaloids, anthraquinones, flavonoids, phytosterol, saponins, tannins, triterpenoids and steroids in the methanol extract and fractions of *D. suffruticosa*. The butanol fraction and methanol extract showed high phenolic (379.00 ± 9.25 and 277.00 ± 3.50 mg/g) and flavonoid values (74.44 ± 2.18 and 34.83 ± 0.71 mg/g) as compared to ethyl acetate, n-hexane and chloroform fractions. The scavenging capacity of butanol fraction and methanol extract was also higher than other fractions. GCMS analysis indicated the presences of various compounds in methanol extract, fractions and essential oil including methyl glycolate, lauryl acetate, phenol, 2,4-bis (1,1-dimethylethyl), 9,12-octadecadienoic acid, hexadecanoic acid, methyl ester, methyl stearate, phenol, benzyl alcohol, 3-hexen-1-ol, acetate

* Corresponding author.
E-mail address: miqbal@ums.edu.my (M. Iqbal).
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and phytol. Thus, methanol extract, fractions and essential oil of *D. suffruticosa* leaves mainly contain vital phytochemical and shows good antioxidant activity.

1. Introduction

Reactive oxygen species (ROS) and reactive nitrogen species (RNS) such as superoxide ($O^{\bullet}_2$), hydroxyl ($OH^{\bullet}$), peroxyl radical ($ROO^{\bullet}$), alkoxy radical ($RO^{\bullet}$), nitrogen dioxide ($NO^{\bullet}_2$) and nitric oxide ($NO^{\bullet}$) play a dual role, both helpful and harmful (Halliwell, 2005; Nordberg and Arnér, 2001; Valko et al., 2007). In low quantity they are required by the body for immune system responses, however, overproduction of these molecules cause oxidative stress and nitrosative stress (Dröge, 2002). The oxidative stress causes significant damage to lipids (Ylä-Herttuala, 1999), DNA (Marnett, 2000) and protein (Stadtman and Levine, 2006) biomolecules which further lead to various chronic diseases including diabetes mellitus, cardiovascular, cancer, rheumatoid arthritis, cataracts, respiratory, ageing, hepatic damages etc (Mantena et al., 2008; Nordberg and Arnér, 2001; Pham-Huy et al., 2008; Phaniendra et al., 2015; Prakash et al., 2007; Valko et al., 2007). Hence maintenance of a balance between oxidant and antioxidant intracellular systems is vital for cell function, regulation, and adaptation to diverse growth conditions (Nordberg and Arnér, 2001). Phytochemical compounds of the medicinal plants with antioxidant activities have the potential to scavenge ROS and RNS in the human body and delay or inhibit the development of oxidative stress-associated maladies (Miller et al., 2000; Shah et al., 2017; Velmurugan et al., 2018). The antioxidant effects of natural products vary depending on their content of vitamin C, phenolic components, carotenoids, vitamin E and flavonoids (Saura-Calixto and Goñi, 2006; Zhang et al., 2015).

Dillenia suffruticosa (Griff ex Hook.f. & Thomson) Martelli (Dilleniaceae) is a medicinal plant, locally known as ''Simpoh air'' (Corners, 1997). The plant is mostly found on alluvial places such as swamps, mangroves, riversides or eroded soil, wasteland, forest edges, and native to Malaysia, Singapore, Brunei, Indonesia, and Sri Lanka (Corners, 1997; Kaore and Kaore, 2014; Shiew et al., 1985). The local people in Sabah Malaysia use the plant for various purposes. The Ibans use the plant to relieve stomach pain, the Dusun use for the treatment of fever and headache while the Kedayans use it for a post-childbirth tonic drink (Chiam, 2011). The plant has been reported with antimicrobial and anticancer properties. The antimicrobial properties of the methanol extracts of the plant have been reported against *Bacillius subtilis*, *Bacillus cereus*, *Candida albicans*, and *Pseudomonas aeruginosa* (Wiart et al., 2004). The chromatographic fractions of *D. suffruticosa* extract have been reported with the potential to prevent the proliferation of cancer cell through the induction of apoptosis (Armania et al., 2013; Saiful Yazan and Armania, 2014).

Regardless of the availability of several synthetic drugs applied to counter oxidative stress, the adverse side effects and high costs related to them limit their usefulness (Lourenço et al., 2019). Thus alternative nontoxic, natural and affordable antioxidants are required to manage oxidative stress, thereby thwarting the associated diseases (Liu et al., 2018). Hence, this study was designed to investigate the in vitro antioxidant activities of methanol extract, fractions and essential oil of *D. suffruticosa* in the quest for cheap and safer antioxidant sources.

2. Materials and methods

2.1. Sample collection

Both mature and young leaves of the plant were collected on a sunny day (9 am., 1 pm., and 5 pm) in September 2019 with maximum temperature 33 °C and min temperature 24 °C from the lower land of Papar, Sabah. Malaysia. The young leaves were 5 to 10 cm in length with reddish colour while the mature leaves were 12 to 35 cm in length with dark green colour. The plant was shrubby and 5 to 6 m tall. The identification of the leaves was done by Mr. Johnny Gisil, a botanist at the Institute of Tropical Biology and Conservation (ITBC) Herbarium, Universiti Malaysia Sabah and voucher of the specimen (MDS 002) was deposited (Fig. 1).

2.2. Extraction and fractionation

The leaves of the plant were washed with tap water, clean from contamination and oven-dried at 37 °C for 3–4 days. Dried leaves were ground to a fine powder using a heavy-duty grinder. Plant powder about 60 g was extracted with pure methanol (300 ml) using the Soxhlet method at 50–60 °C and 72 h. The methanol residues were removed from the extract using a vacuum rotary evaporator. The dried methanol crude extract was further fractionated with solvents according to increasing order of polarity starting with n-hexane, ethyl acetate, chloroform and butanol in a separatory funnel. The solvents were removed from the fractions under vacuum. The samples were kept at minus 80 °C for 24 h and then lyophilized using a freeze drier. The freeze-dried samples were then stored in the freezer for further studies (Osadebe et al., 2012).

2.3. Extraction of essential oil by hydrodistillation

For the extraction of essential oil from *D. suffruticosa,* 100 g of leaves were subjected to hydro distillation for 3 h by a Clevenger apparatus. At the end of the distillation, an aqueous phase (aromatic water) and an organic phase (essential oil) were noticed. The essential oil was collected, dried under anhydrous sodium sulphate and stored in sealed vials at 4 °C until further use (Atti-Santos et al., 2005).

Fig. 1 Dillenia suffruticosa.

2.4. Radical scavenging activity using the DPPH method

Different concentrations ranging from 0.012 to 0.50 mg/g of methanol extract, fractions and essential oil the plant was diluted with distilled water at various ratios. Further 0.3 ml of each dilution was mixed with 2.7 ml of DPPH (150 μM) prepared in methanol and left in the dark for 1 h. The absorbance was recorded at 512. Ascorbic acid was employed as a positive control (Brand-Williams et al., 1995).

2.5. Determination of total phenolic content

Briefly, the test sample (0.2 ml) was treated with 1.5 ml of Folin-Ciocalteu reagent in a tube and mixed thoroughly. After 5 min, 1.5 ml sodium carbonate (60 g/l) was added to the mixture and mixed thoroughly. Finally, the samples were kept for 90 min at room temperature in the darkness. The absorbance was recorded at 725 nm using a spectrophotometer. Gallic acid was used as a positive control (Velioglu et al., 1998).

2.6. Determination of total flavonoid content

Briefly, the test samples (0.25 ml) were mixed with 1.25 ml of distilled water and 0.075 ml of sodium nitrate (5%). The mixture was well shaken and kept for 6 min in a dark place. Further, the mixture was vortexed after the addition of 0.15 ml of aluminium chloride (10%) and kept for 5 min at room temperature. Finally, 0.5 ml of sodium hydroxide (4%) was added to the mixture, followed by the addition of distilled water to obtain a final volume of 2.5 ml. The mixture was shaken strongly and absorbance was recorded at 510 nm against the blank. Catechin was used as a positive control (Zou et al., 2004).

2.7. Preliminary phytochemical screening

The preliminary phytochemical screening of the methanol extract and methanol fractions (1 mg/ml) of *D. suffruticosa* was carried out to access the presence or the absence of different phytochemical components such as alkaloids, steroids, flavonoids, triterpenoids, saponin, tannins, anthraquinones and phytosterol (Harborne, 1998).

2.8. Gas chromatography-mass spectrometry (GC–MS) analysis of D. Suffruticosa

GCMS analysis for the methanol extract, fractions and essential oil of *D. suffruticosa* were performed using GCMS system consisting of an Agilent 7890A gas chromatograph system coupled with an Agilent 5975C mass spectrometry detector as described by Shah et al., (2014). Briefly, 1 μL of the reconstituted sample was injected into an Agilent J&W HP-5MS capillary column (30 m × 0.25 mm × 0.25 μm) with purified helium gas used as a carrier gas. The split less mode was selected for all analysis and identification of compounds was carried out by matching the MS spectral against the built-in National Institute of Standards and Technology (NIST) library (version 2011).

2.9. Statistical analysis

All the experiments were conducted in triplicates. The values are expressed as the mean ± standard deviation (SD). The statistical analyses were done using SPSS 25.0 windows statistical package software (SPSS Inc., Chicago, IL). Significant differences between extract, fractions and essential oil were analysed using one-way analysis of variance (ANOVA) followed by Tukey's multiple comparisons test.

3. Results

3.1. The percentage (%) yield, calculated effective concentration (EC_{50}), total phenolic and flavonoid contents of methanol extract, fractions and essential oil of D. Suffruticosa

The % yields, EC_{50}, total phenolic and flavonoid contents of methanol extract, fractions and essential oil of *D. suffruticosa* are revealed as shown in Table 1. The methanol extract showed a high % yield followed by n-hexane, butanol, ethyl acetate and chloroform fractions. The essential oil of the plant indicated high EC_{50} value while butanol fraction showed low EC_{50} value as compare to hexane, ethyl acetated and chloroform fractions and methanol extract. The butanol fraction indicated high phenolic and flavonoid contents followed by methanol extract and other fractions of the plant sample (Table 1).

3.2. DPPH free radical scavenging activity of methanol extract, fractions and essential oil of D. Suffruticosa

The DPPH free radical scavenging activity of the *D. suffruticosa* methanol extract, fractions and essential oil was determined at different concentrations ranging from 0.012 to 0.5 mg/g. The methanol extract and butanol fraction showed high % DPPH scavenging activity followed by ethyl acetate, hexane and chloroform fraction and essential oil (Fig. 2).

3.3. Phytochemical analysis methanol extract and methanol fractions of D. Suffruticosa

The presence of various phytochemicals such as alkaloids, anthraquinones, flavonoids, phytosterol, saponins, tannins, triterpenoids and steroids in the methanol extract and fractions of *D. suffruticosa* is revealed in Table 2. Alkaloids were detected strongly in methanol extract and all the fractions. Anthraquinones were noticed only in the chloroform and butanol fractions and methanol extract while absent in hexane and ethyl acetate fractions. Flavonoids were noticed strongly in butanol fractions and methanol extract as compared to other fractions. Phytosterols were detected in methanol extract and fractions except for butanol. Saponins were strongly detected in methanol extract and fractions except for butanol. Triterpenoids were absent in butanol fraction while strongly present in the hexane fraction and methanol extract as compared to ethyl acetate and chloroform fractions. Steroids were also absent in butanol fractions while strongly present in the methanol extract and other fractions.

Table 1 Percentage yield, EC_{50}, total phenolic and flavonoid content of *methanol* extract, fractions and essential oil of *D. suffruticosa*.

Extract/fractions	Percentage (%) yield	EC50 (mg/g)	Total phenolic content (mg/g)	Total flavonoid content (mg/g)
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
Methanol extract	9.27 ± 0.75	0.216 ± 0.001	277.00 ± 3.50	34.83 ± 0.71
Hexane fraction	5.77 ± 0.83[a]	0.230 ± 0.002[a]	206.50 ± 3.34[a]	26.56 ± 1.45[a]
Ethyl acetate fraction	0.91 ± 0.18[b]	0.231 ± 0.000[b]	234.33 ± 3.46[b]	32.49 ± 1.92
Chloroform fraction	0.58 ± 0.06[c]	0.271 ± 0.000[c]	129.33 ± 4.28[c]	20.88 ± 1.66[c]
Butanol fraction	1.05 ± 0.10[d]	0.074 ± 0.000[d]	379.00 ± 9.25[d]	74.44 ± 2.18[d]
Essential oil	0.50 ± 0.08[e]	2.27 ± 0.001[e]	ND	9.78 ± 1.13 [,e]

Each value represents the mean ± SD of 3 replicates. Different letters with each mean a statistical difference.

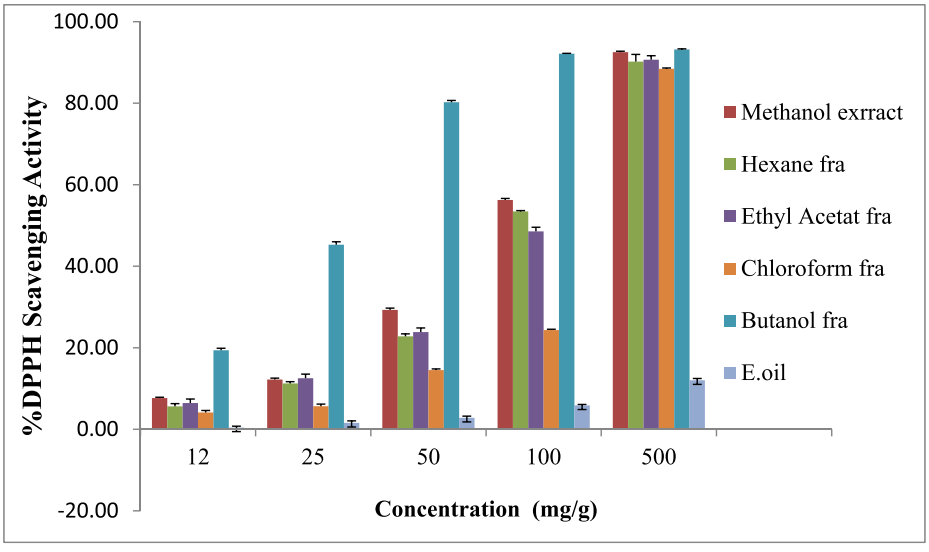

Fig. 2 Radical scavenging activity of *D. suffruticosa* methanol extract, methanol fractions and essential oil by DPPH method.

Table 2 The analysis of phytochemical in the methanol extract and fractions of *D. suffruticosa*.

Phytochemicals	Extract/fractions				
	Hexane fraction	Ethyl acetate fraction	Chloroform fraction	Butanol fraction	Methanol extract
Alkaloids	+ +	+ +	+ +	+ +	+ +
Anthraquinones	–	–	+	+	+
Flavonoids	+	+	+	+ +	+ +
Phytosterols	+	+	+	–	+
Saponins	+ +	+ +	+ +	–	+ +
Tannins	–	+	+	+	+ +
Triterpenoids	+ +	+	+	–	+ +
Steroids	+ +	+ +	+ +	–	+ +

+ = present; + + = Strong present; – = absent.

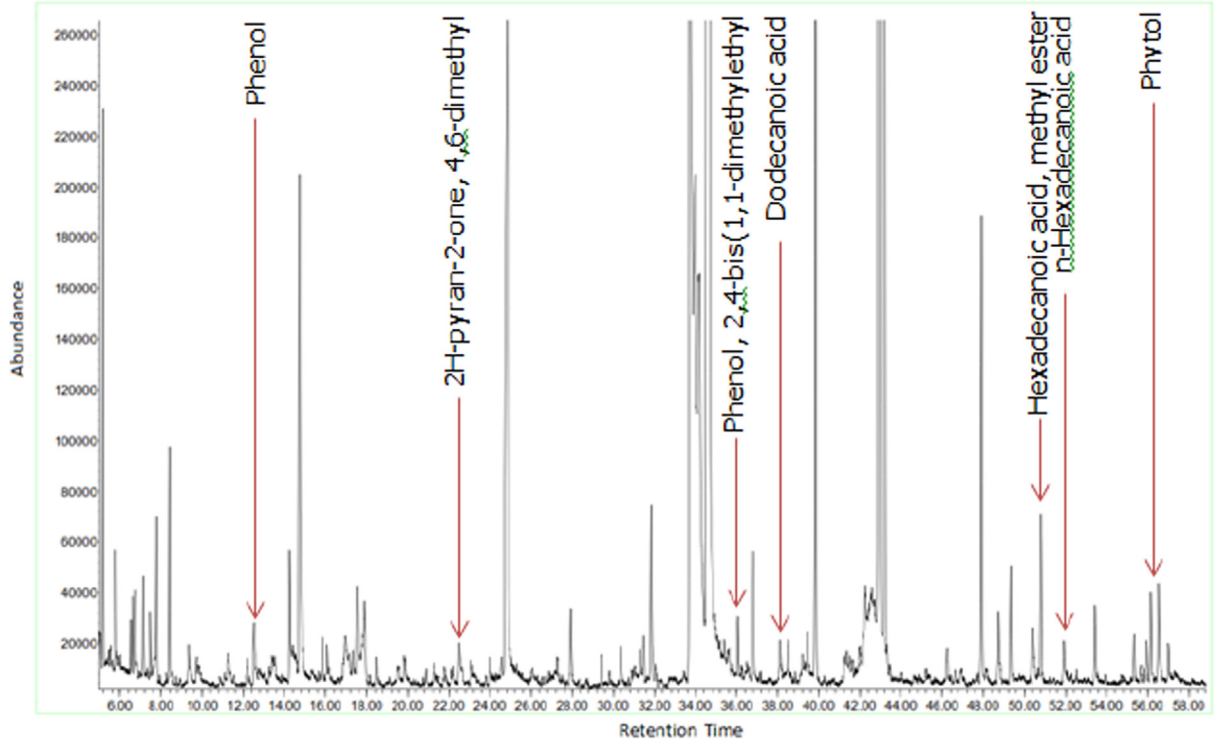

Fig. 3a GC–MS chromatogram of the methanol extract of *D. suffruticosa*.

3.4. GCMS analysis of methanol extract, fractions and essential oil of D. Suffruticosa

3.4.1. GC–MS chromatogram of methanol extract, fractions and essential oil of D. Suffruticosa

Figs. 3a-3f indicates the GC–MS chromatogram of various bioactive compounds detected in methanol extract, fractions and essential oil of *D. suffruticosa*.

3.4.2. List of phytochemical compounds detected in the methanol extract, fractions and essential oil of D. Suffruticosa

The retention time, compound name and area percentage (%) of the phytochemicals compound detected in the methanol extract, fractions and essential oil of *D. suffruticosa* by GCMS are shown in Table 3. In the methanol extract total 19 compounds were detected while in hexane 8, ethyl acetate 11, chloroform 10 and butanol fraction 6 and essential oil 6 compounds were noticed. The structures of the identified bioactive compounds are shown in Fig. 4.

4. Discussion

Antioxidants have the potential to neutralize the actions of free radicals (Anju and Sarita, 2010). In our sample, the butanol fraction and methanol extract showed the highest antioxidant activity with EC_{50} values of 0.07 and 0.21 mg/g. The highest activity of butanol fraction and methanol extract could be due to the presence of the high amount of phenolic and flavonoid compounds. Phenolics and flavonoids are secondary plant metabolites and are widely distributed in various plants (Bonoli et al., 2004; Kaisoon et al., 2011; Tungmunnithum et al., 2018). The compounds have attracted

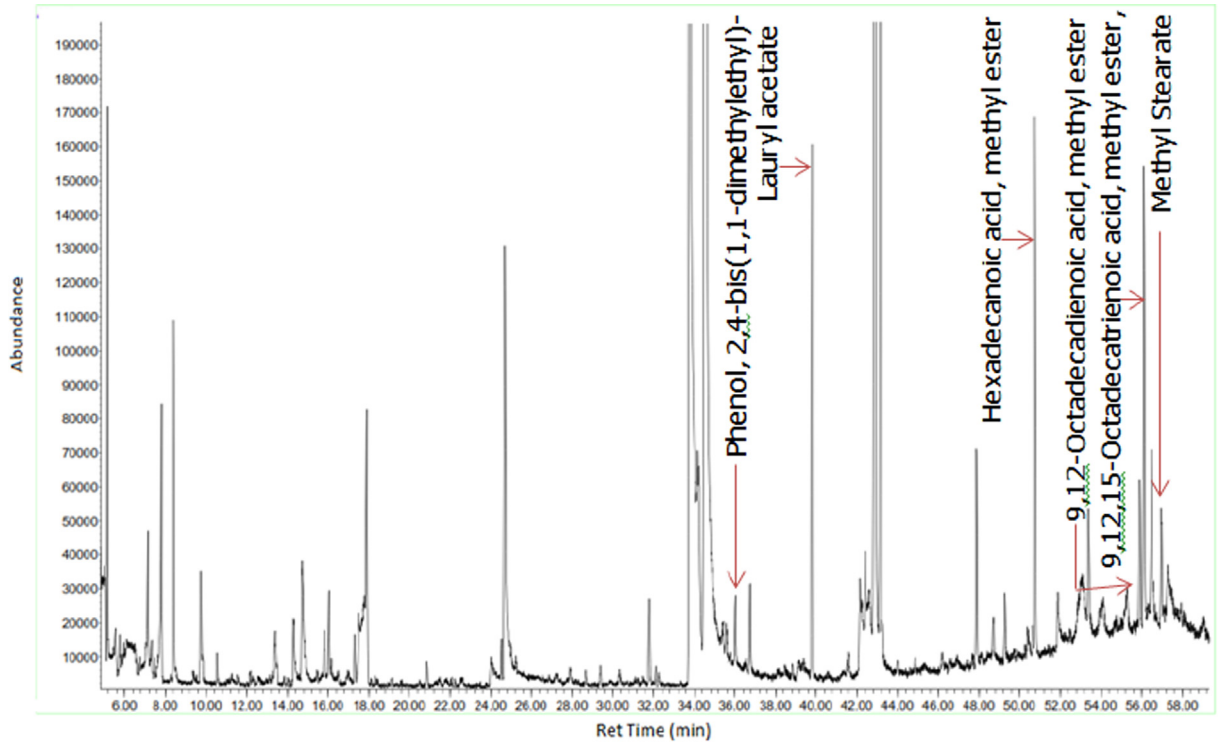

Fig. 3b GC–MS chromatogram of the hexane fraction of *D. suffruticosa* methanol extract.

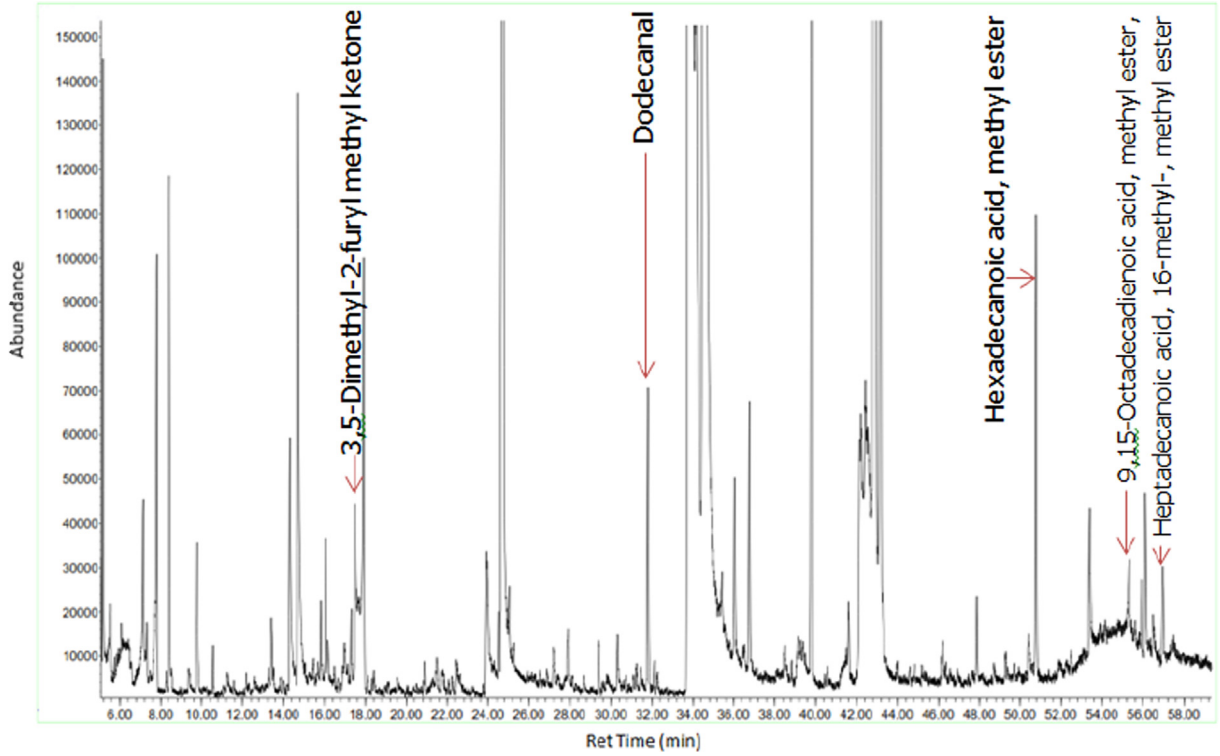

Fig. 3c GC–MS chromatogram of the ethyl acetate fraction of *D. suffruticosa* methanol extract.

great attention recently due to their potential to neutralize reactive oxygen species and other free radicals. Phenolic and flavonoid compounds display anti-tumour, anti-adhesive, antimicrobial and anti-inflammatory properties and protection against chronic diseases by the reduction of oxidative stress solely or synergistically with other phenolic-

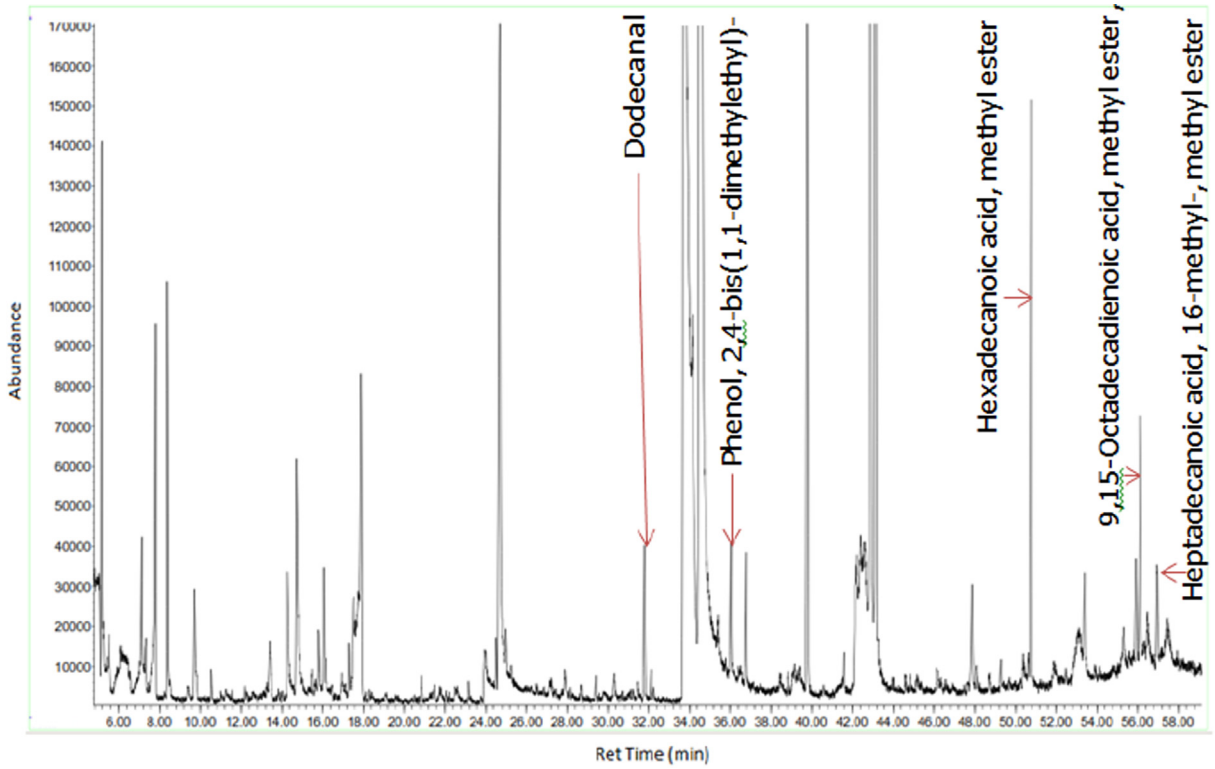

Fig. 3d GC–MS chromatogram of the chloroform fraction of *D. suffruticosa* methanol extract.

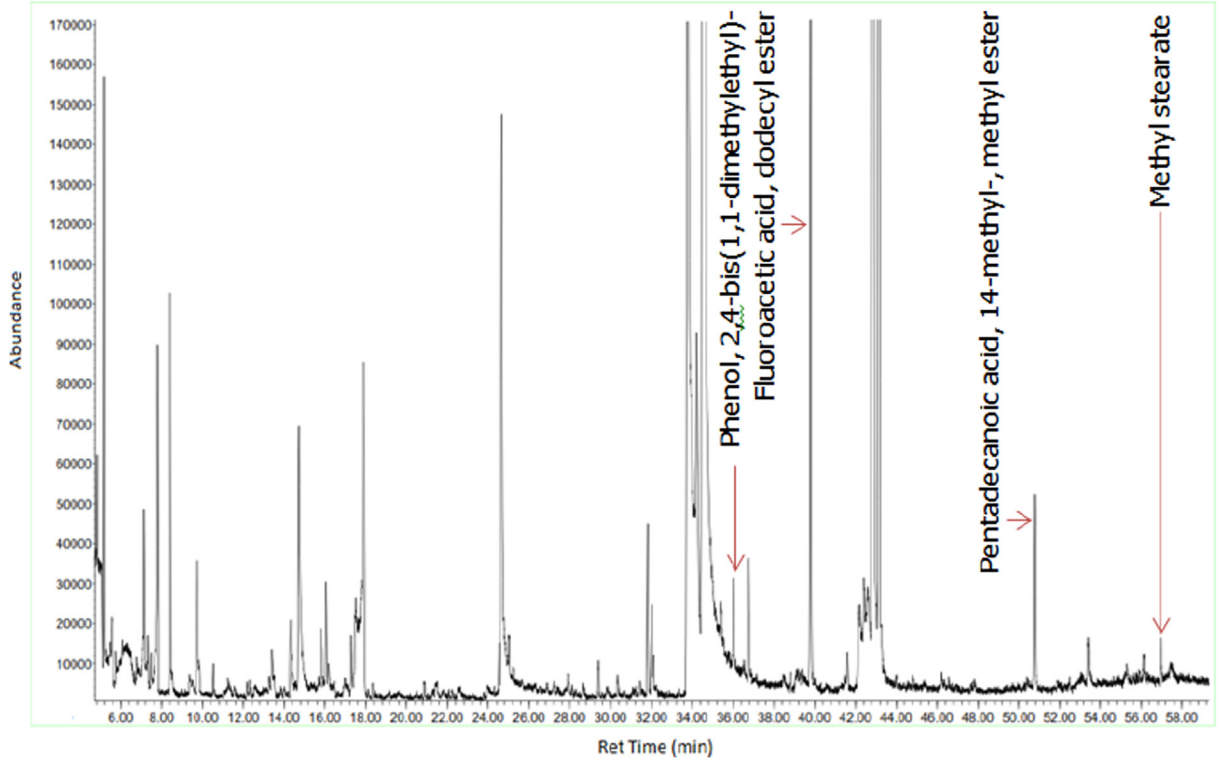

Fig. 3e GC–MS chromatogram of the butanol fraction of *D. suffruticosa* methanol extract.

containing amalgams. (Brighente et al., 2007; Kylli et al., 2011; Nemudzivhadi and Masoko, 2014; Rasmussen et al., 2005; Tungmunnithum et al., 2018). Therefore, the amount of total phenolics and flavonoids present in the methanol extract, fractions and essential oil of *D. suffruticosa* were investigated and significantly highest results were recorded

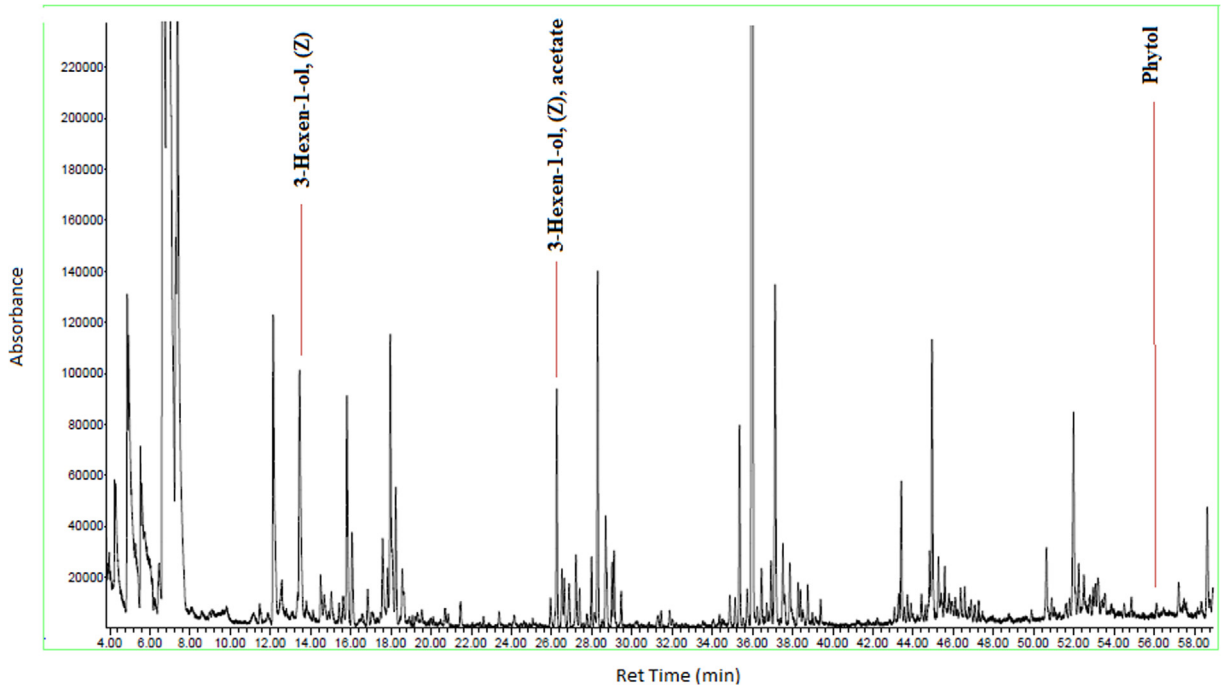

Fig. 3f GC–MS chromatogram of the chemical constituents of essential oil of *D. suffruticosa*.

in the order butanol > methanol > ethyl acetate > hexane > chloroform for total phenolics and total flavonoids. Similarly, the antioxidant activity, phenolic and flavonoid content of extract, fractions and essential oil of *Commelina nudiflora* (Commelinaceae), *Dillenia indica* (Dilleniaceae), Ballota limbata (Lamiaceae) plant have also been reported (Abdille et al., 2005; Shah and Iqbal, 2018; Waheed et al., 2014). Further, the preliminary phytochemical analysis revealed that *D. suffruticosa* methanol extract and its fraction are very rich in phytochemical compounds (alkaloids, anthraquinones, flavonoids, phytosterol, saponins, tannins, triterpenoids and steroids). These phytochemical compounds have potential health-promoting effects including antioxidant, anti-inflammatory, antitumor, anti-HIV, anticholinesterase, antibacterial etc. (Dillard and German, 2000; Hussain et al., 2019, 2018; Kuo et al., 2009; Othman et al., 2019; Panche et al., 2016; Patel and Savjani, 2015). Anthraquinones possess antioxidant, antiparasitic and anticancer properties (Dave and Ledwani, 2012; Yadav et al., 2019). The current results demonstrated that anthraquinones were noticed only in the butanol of *D. suffruticosa*. Alkaloids have been reported to possess antimicrobial, anti-inflammatory, neuroprotective effects (Hussain et al., 2018; Peng et al., 2019). Tannins have been reported with neuroprotection (Hussain et al., 2019). Plant-derived steroids have been reported with anti-inflammatory properties (Patel and Savjani, 2015). Phytosterol and saponins have been reported to have hypocholesterolemic and anti-diabetic effects (Edeoga et al., 2005; Moreau et al., 2002). While triterpenoids have been reported with antitumor and anti-HIV properties (Kuo et al., 2009). The strong presence of phytosterol, saponins and triterpenoids were noticed in methanol extract and its fractions excluding butanol fraction. The above mentioned bioactive compounds have been also detected in the solvent extract and fractions of *C. nudiflora* and B. limbata (Shah and Iqbal, 2018; Waheed et al., 2014).

The GCMS analysis indicated the presence of various bioactive compounds in the methanol extract, fractions and essential oil of *D. suffruticosa* such as benzyl alcohol, 2 h-Pyran-2-one, 2,4-bis (1,1-dimethylethyl), dodecanoic acid and 4,6-dimethyl, phenol. These compounds have been reported with antioxidant, antimicrobial (Dasgupta and Humphrey, 1998; Lee and Shibamoto, 2002; Lee et al., 2005), antifungal (Mikhlin et al., 1983), anti-cancer (Ajayi et al., 2011; Rajaram et al., 2013) anti-inflammatory and anti-viral properties (Appendino et al., 2007). In addition to this, hexadecanoic acid, ethyl ester, n-hexadecanoic acid and phytol are also found in the methanol extract, fractions and essential oil of *D. suffruticosa*. These compounds have also been noticed in other plant extracts and reported with antioxidant, anticancer, anti-inflammatory, anti-microbial, hypocholesterolemic diuretic, hemolytic and hepatoprotective activities (Ajayi et al., 2011; Bülent Köse et al., 2007; Kumar et al., 2010). The above-mentioned compounds haven been also reported in the extract of *Plumbago zeylanica* (Plumbaginaceae.) (Ajayi et al., 2011), *Peganum harmala* (Peganaceae) (Moussa and Almaghrabi, 2016), *Broussonetia luzonica* (Moraceae) (Casuga et al., 2016), *Ocimum basilicu* (Lamiaceae) and *Thymus vulgaris* (Lamiaceae) plants (Kuete, 2017; Kumar et al., 2016; Lee et al., 2005).

These findings, therefore, imply that the studied plant extract, fractions and essential oil mainly contain vital phytochemical and shows good antioxidant activity. Thus the plant could be of considerable interest in the development of natural alternative source to reduce the damaging effects caused by oxidative stress.

Table 3 The phytochemical compounds detected in the methanol extract, fractions and essential oil of *D. suffruticosa* by GCMS.

Extract/Fractions/ Essential oil	No	Retention Time	Compound name	Area (%)
Methanol	1.	4.25	Methyl Glycolate	2.95
	2.	7.44	2-Furanmethanol	0.77
	3.	12.52	Phenol	1.39
	4.	14.26	Benzyl Alcohol	2.04
	5.	17.09	Undecane	11.97
	6.	22.5	2 h-Pyran-2-One, 4,6-Dimethyl-	1.19
	7.	30.35	1-Undecanol	0.78
	8.	31.48	Tetradecane	0.62
	9.	31.83	Tridecanal	0.03
	10.	33.71	Cyclododecane	35.78
	11.	34.19	1-Dodecene	19.46
	12.	36.06	Phenol, 2,4-Bis(1,1-Dimethylethyl)	0.83
	13.	36.8	n-Tridecan-1-ol	1.98
	14.	38.01	Dodecanoic acid	0.84
	15.	39.83	Lauryl acetate	12.26
	16.	42.57	3-Chloropropionic acid, heptadecyl	1.28
	17.	50.79	Hexadecanoic acid, methyl ester.	2.66
	18.	51.9	n-Hexadecanoic acid	0.96
	19.	56.51	Phytol	2.13
Hexane	1.	17.78	Undecane	7.81
	2.	33.76	Cyclodecane	21.76
	3.	36.03	Phenol, 2,4-bis(1,1-dimethylethyl)-	3.62
	4.	39.79	Lauryl acetate	18.04
	5.	50.75	Hexadecanoic acid, methyl ester	19.05
	6.	55.91	9,12-Octadecadienoic acid, methyl ester	5.95
	7.	56.11	9,12,15-Octadecatrienoic acid, methyl ester, (Z,Z,Z)-	18.17
	8.	56.96	Methyl stearate	5.59
Ethyl acetate	1.	17.5	3,5-Dimethyl-2-furyl methyl ketone	17.68
	2.	17.69	Undecane	11.61
	3.	31.8	Dodecanal	17.05
	4.	35.45	1,4-Benzenedicarboxylic acid, dimethyl ester	11.29
	5.	38.46	Chloroacetic acid, tridecyl ester	3.55
	6.	50.75	Hexadecanoic acid, methyl ester	26.39
	7.	55.92	9,15-Octadecadienoic acid, methyl ester, (Z,Z)-	6.17
	8.	56.96	Heptadecanoic acid, 16-methyl-, methyl ester	6.26
	11.	56.96	Methyl stearate	6.20
Chloroform	1.	4.73	2,2-Dimethoxybutane	0.81
	2.	17.78	Undecane	3.54
	3.	31.8	Dodecanal	1.87
	4.	33.7	Cyclododecane	76.86
	5.	36.03	Phenol, 2,4-bis(1,1-dimethylethyl)-	1.69
	6.	39.79	Fluoroacetic acid, dodecyl ester	0.31
	7.	50.75	Hexadecanoic acid, methyl ester	7.50
	8.	55.916	E,Z-1,3,12-Nonadecatriene	1.75
	9.	56.11	9,12,15-Octadecatrienoic acid, methyl ester, (Z,Z,Z)-	4.09
	10.	56.97	Heptadecanoic acid, 16-methyl-, methyl ester	1.58
Butanol	1.	17.89	Undecane	35.53
	2.	31.8	Dodecanal	12.95
	3.	36.03	Phenol, 2,4-bis(1,1-dimethylethyl)-	10.35
	4.	39.79	Fluoroacetic acid, dodecyl ester	56.66
	5.	50.75	Pentadecanoic acid, 14-methyl-, methyl ester	15.50
	6.	56.97	Methyl stearate	4.53
Essential oil	1.	6.85	3-Hexen-1-ol, (Z)	19.95
	2.	13.44	3-Hexen-1-ol, acetate, (Z)	10.39
	3.	18.24	Decane, 3,7-dimethyl-	1.24
	4.	26.02	Hexadecane	1.21
	5.	56.46	Phytol	1.74
	6.	17.78	Undecane	7.81

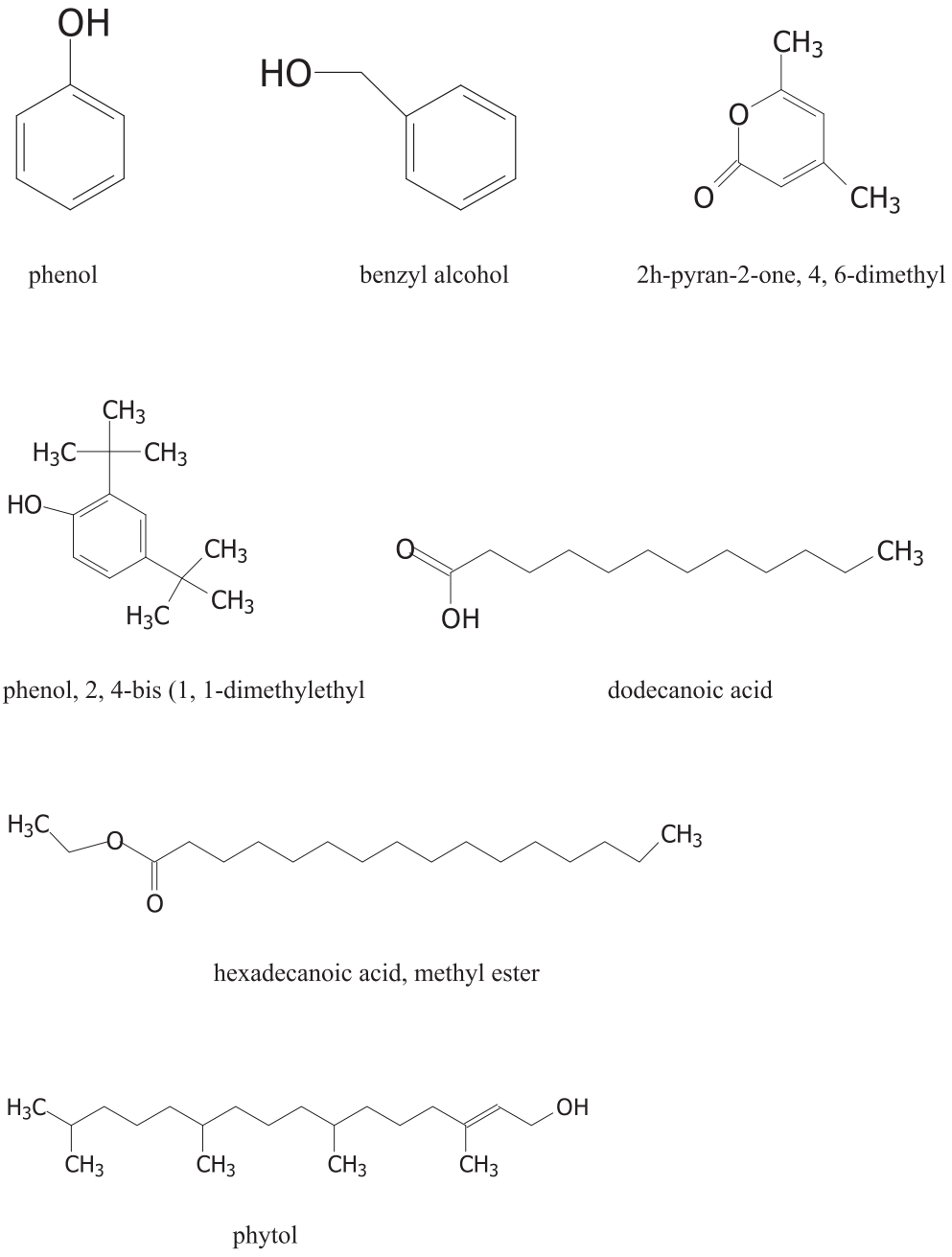

Fig. 4 Structure of the identified bioactive compounds in the methanol extract, fractions and essential oil of *D suffruticosa*.

5. Conclusion

The methanol extract, methanol fractions and essential oil of *D. suffruticosa* indicated good in vitro DPPH radical scavenging activity and high values of phenolic and flavonoid contents. The preliminary screening revealed the presence of vital phytochemicals such as alkaloids, flavonoids, anthraquinones, steroids, tannins, phytosterol, triterpenoids and saponins. Further, the GCMS analysis of methanol extract, methanol fractions and essential oil of the plant indicated various bioactive compounds including 3-hexen-1-ol, acetate, phytol, methyl glycolate, lauryl acetate, phenol, 2,4-bis (1,1-dimethylethyl), 9,12-octadecadienoic acid, hexadecanoic acid, methyl ester, methyl stearate, phenol and benzyl alcohol. These compounds have been reported with antioxidant properties. Thus, the methanol extract, methanol fractions and essential oil of the studied plant can be potential antioxidant compound sources and alternatives for the management of oxidative stress-associated disorders. The current research work endorses further studies leading to isolation and characterization of the pure antioxidant compounds, particularly those able to attenuate oxidative stress and related maladies.

Declaration of Competing Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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