

HOSTED BY



ELSEVIER

Contents lists available at ScienceDirect

Asian Pacific Journal of Tropical Medicine

journal homepage: <http://ees.elsevier.com/apjtm>Review <http://dx.doi.org/10.1016/j.apjtm.2017.03.015>Medicinal and biological values of *Callistemon viminalis* extracts: History, current situation and prospectsMohamed Z.M. Salem¹✉, Mervat EL-Hefny², Ramadan A. Nasser¹, Hayssam M. Ali^{4,5}, Nader A. El-Shanhorey³, Hosam O. Elansary²¹Forestry and Wood Technology Department, Faculty of Agriculture (El-Shatby), Alexandria University, Alexandria, Egypt²Department of Floriculture, Ornamental Horticulture and Garden Design, Faculty of Agriculture (EL-Shatby), Alexandria University, Alexandria, Egypt³Department of Botanical Gardens Research, Horticultural Research Institute (ARC), Alexandria, Egypt⁴King Saud University, College of Science, Department of Botany and Microbiology, PO Box 2455, Riyadh 11451, Saudi Arabia⁵Agriculture Research Center, Horticulture Research Institute, Sabahia Horticulture Research Station, Department of Timber Trees Research, Alexandria, Egypt

ARTICLE INFO

Article history:

Received 15 Jul 2016

Received in revised form 20 Oct 2016

Accepted 15 Nov 2016

Available online 6 Mar 2017

Keywords:

Callistemon viminalis

Antibacterial activity

Antioxidant activity

Antifungal activity

Essential oils

Biological activities

ABSTRACT

Callistemon viminalis (*C. viminalis*) is a plant that has been reported to have various medicinal values such as antibacterial, antifungal, antioxidant activities and other pharmaceutical and insecticidal properties. This review covers the potentials, applications and properties of different extracts from different parts (branches, flowers, fruits, bark, leaves) of *C. viminalis*. Furthermore, the chemical structures of the bioactive compounds were reported for biological activities. All the results supported the traditional uses of *C. viminalis* in folk medicine. In addition, some researches supported the use of *C. viminalis* extracts for the preparation of metal oxide nanoparticles.

1. Introduction

Callistemon belongs to family Myrtaceae, consists of 34 species, and is characterized for its cylindrical, brush like flowers resembling traditional bottlebrush. *Callistemon viminalis* (*C. viminalis*) (weeping bottlebrush) is a small tree or shrub native to Australia, and reaching 4 m high in temperate areas where its natural occurs [1–3]. Ecologically, *Callistemon* species as a farm tree are planted for forestry plantations or ornamental purposes [1], and for weed control [4]. In traditional Chinese medicine pills, *C. viminalis* is used for treating hemorrhoids [5,6]. Hot drink locally ‘tea’ in Jamaica from *C. viminalis* has been used for the treatment of gastro-enteritis, diarrhea and

skin infections [7]. *C. viminalis*, native to New South Wales, Australia, is an herb that has been used by natives for a long time to treat gastro-enteritis, diarrhea and skin infections [8].

Dozen phytochemical researches have been carried out on *C. viminalis* extracts, and showed that the plant is rich in phenolics, triterpenoids, flavonoids, saponins, steroids, alkaloids, tannin, carbohydrates, amino acids and proteins compounds [2,9–12].

Perusal of reports related to essential oils (EOs) from leaves included 1,8-cineole (47.9%–82.0%) as the predominant constituent of EO [13–20]. Sesquiterpene lactones showed good activity against *Saccharomyces cerevisiae*, *Bacillus subtilis* (*B. subtilis*), *Staphylococcus aureus* (*S. aureus*), and *Escherichia coli* (*E. coli*) [21]. Terpenoid compounds extracted from *C. viminalis* were characterized by sharp taste, anti-microorganisms, food conserved, analgesic for pain and tonics [21].

Different solvents extraction as well as EOs from *C. viminalis* grown in different regions around the world,

✉First and corresponding author: Mohamed Z.M. Salem, Forestry and Wood Technology Department, Faculty of Agriculture (El-Shatby), Alexandria University, Alexandria, Egypt.

E-mails: mohamed-salim@alexu.edu.eg, zidan_forest@yahoo.com

Peer review under responsibility of Hainan Medical University.

showed a good antibacterial, antifungal and antioxidant activity [11,16,18–25]. For example, *n*-hexane of leaf extracts showed potential activity against skin pathogen *S. aureus*, *Streptococcus pyogenes* and the enteric *Bacillus cereus*, while less activity was found against than intestinal pathogen (*Shigella sonnei*, *Salmonella enteritidis* and *E. coli*) [24]. Crude water extract (1 mg/mL) reduced biofilm of *Pseudomonas aeruginosa* (*P. aeruginosa*) formation up to 89% [26].

Because extracts of *C. viminalis* are rich in polyphenols and flavonoids content, they have advantages for nanoparticle synthesis which showed good eliminating in the process of maintaining cell cultures [27–29]. The nanoparticles were successfully synthesized using *C. viminalis* leaf extract or flower as reducing agent and stabilizer for nanoparticles. Aqueous (Aq) leaf extract of *C. viminalis* was used to synthesis gold nanotriangles, which was performed in minutes rather than hours, under very mild conditions [30] as well as metal oxide nanoparticles [27]. Therefore, the present review article summarizes the medicinal and biological values of *C. viminalis* extracts.

2. Taxonomy of *C. viminalis*

C. viminalis belongs to kingdom of Plantae, subkingdom of Tracheobionta, superdivision of Spermatophyta, division of Magnoliophyta, class of Magnoliopsida, order of Myrtales. *C. viminalis* is a genus of *Callistemon* in the family of Myrtaceae. Its species include *Metrosideros viminalis* Sol. ex Gaertn., *C. viminalis* (Sol. ex Gaertn.) G. Don, *Melaleuca viminalis* (Sol. ex Gaertn.) Byrnes.

3. Extraction methods

3.1. EOs extraction

Clevenger-type apparatus, a hydro-distillation method, was used to extract the EOs from the different plant parts for 3 h. The obtained oils were dried over anhydrous Na₂SO₄, and stored at 4 °C. GC/MS was used to analyze the chemical compositions of EOs [18,25,31].

3.2. Different solvents extraction

Zubair *et al* [32] diagramed simple method for the extraction of the grinded fine powder of leaves using different solvents with different polarities. Salem *et al.* [33] explained the extraction with methanol (MeOH) from leaves and branches and its successive fractionations in different solvents with ethyl acetate, chloroform and then with *n*-butanol saturated with water and the remaining was Aq fraction. Furthermore, fruits and bark were extracted with MeOH and further fractionated by petroleum ether, CH₂Cl₂ and EtOAc [34]. The plant material could be extracted using hot water, freeze-dried and stored at –20 °C until needed [26]. Other study revealed that the dried ground plant material could be extracted using distilled water in a water bath at 70 °C for 1.5 h to afford the Aq extract [24].

3.3. Extraction with *n*-hexane

Pulverized leaves could be extracted using *n*-hexane in a Soxhlet apparatus [32].

4. Pharmacological and biological activities

4.1. Antibacterial and antifungal activities

Different extracts of *C. viminalis* including Aq, MeOH and *n*-hexane extracts showed potential activity against some bacterial strains, where the MeOH extract observed good activity against the methicillin-resistant *S. aureus* with inhibition zone value of 25.61 ± 2.11 mm than that the non-methicillin-resistant *S. aureus* (inhibition zone [17.41 ± 1.10] mm) [24]. The extracts' potency is attributed to different chemical compositions of *C. viminalis* [35]. Remarkable antimicrobial activity of the EO was found against *S. aureus*, *Enterobacter cloacae*, and *Streptococcus faecalis*, with minimum inhibitory concentrations (MICs) value of 0.08, 0.63, and 0.63 mg/mL, respectively, while the smallest activity was found against *Serratia marcescens* (MIC 5 mg/mL) and *P. aeruginosa* (MIC 5 mg/mL) [16,18].

Aq extract of *C. viminalis* inhibited nematode death by *P. aeruginosa* strains (PAO1 and PA14) without host toxicity, which suggesting further development as anti-infectives [26]. The extracts dissolved from the inflorescence of *C. viminalis* in water and ethanol extracts have been reported strong antibacterial against *Chromobacterium violaceum* and *Agrobacterium tumefaciens* [23]. Aq extracts of flowers and leaves have been shown an antibacterial activity [16]. Most extracts from the branches did not show measurable activity against the growth of some phytopathogenic potato soft rot bacteria [11].

Good to moderate antimicrobial activity of methanol leaf extract (MEOHLE) was found [25]. The EO, MeOH extracts, and ethyl acetate fraction extracted from the leaves exhibited high significant activity against *B. subtilis*, *B. cereus*, *Micrococcus luteus*, *Sarcina lutea* and *S. aureus*, *E. coli*, *Serratia marcescens*, *Salmonella typhi*, *Proteus vulgaris* and *P. aeruginosa*.

The Aq and alcoholic extracts from leaves have antibacterial activity against *S. aureus*, *Streptococcus Pneumonia*, *Staphylococcus epidermidis*, *Klebsilla pneumonia*, *Klebsiella oxytaci*, *Proteus vulgaricus*, and *E. coli*, however, the watery extract was more potent than ethanol extract against pathogenic bacteria [36].

The EO from leaves of *C. viminalis* showed some antifungal activities against *Botrytis cinerea*, *Fusarium oxysporum*, and *Fusarium solani* [19]. The crude extracts of aerial parts (leaves and flowers) of *C. viminalis* had very high activity against *Candida albicans* and *Candida kefyr*, in addition, to their activities against G⁺ ve and G⁻ ve bacteria [37]. The inhibitory actions of the extracted alkaloids from *C. viminalis* were more effective against *Oscillatoria limnetica*, and *Anabaena cylindrical* increased along with the concentrations revealing a regular pattern [38]. MEOHLE, which confirmed the presence of steroid, terpenoids, flavonoids, tannin and alkaloids was exhibited significant activity against *E. coli*, *S. aureus*, *Aspergillus niger* and *C. albicans* [39].

The MIC values of *C. viminalis* active extracts against the bacterial strains *Pasturella multocida*, *E. coli*, *B. subtilis*, and *S. aureus* and the fungal strains *Alternaria alternata*, *Ganoderma lucidum*, were ranged from 0.52 to 12.0 mg/mL [40]. Strong antibacterial activity of leaf crude extracts from *C. viminalis* against *B. subtilis* was found (inhibition zone 14.67 mm with MIC 0.312 mg/mL) but not active against the fungi *Aspergillus flavus*, *A. niger*, *Cladosporium oxysporum*, and *Penicillium oxalicum* [41]. The MeOH extract of

C. viminalis bark showed moderate activity against the incubated wood with the *Trichoderma harzianum*, *Alternaria tenuissima* and *Fusarium culmorum* [42,43]. Antibacterial activity from leaves, flower, stem with bark MeOH, ethyl acetate, *n*-hexane and distilled water extracts against *B. subtilis* were 13.0 mm, 8.0 mm, 11.0 mm, 0 mm; 15.5 mm, 13.0 mm, 12.5 mm, 13.5 mm; and 8.5 mm, 0 mm, 0 mm, 7 mm, respectively, and all the extracts did not show activity against *E. coli* [44].

Other antibacterial activity was assayed in the manner of Anti-quorum sensing activity (QS). The Aq and ethanol extracts (inflorescences part) and the Aq extract (leaves) have strong anti-QS activity [23]. The Aq extracts caused a significant inhibition of LasA protease, LasB elastase, pyoverdine production, and biofilm formation and caused the inhibition of QS genes and QS-controlled factors, with marginal effects on *P. aeruginosa* and *Agrobacterium tumefaciens* growth [23,45].

4.2. Haemolytic activity

The haemolytic activity of *C. viminalis* extracts against human blood erythrocytes (RBCs) was studied and the lysis percentage of RBCs was found to be in the range of 1.95%–6.33%, which could be a potential source of therapeutic drugs [40]. The haemolytic effect of Leaves' MeOH extract was found in the range of 1.79%–4.95% [32]. The order of % haemolysis of various extracts were chloroform > ethylacetate > 90% MeOH > 95% MeOH > absolute MeOH > petroleum ether > *n*-butanol. The effects of *C. viminalis* leaves alcoholic extract on renal profile test for infected rabbits with *Streptococcus pneumonia* were found to be significant variation in level of blood urea nitrogen, creatinine, creatinine kinase and uric acid [36].

4.3. Anthelmintic activity

In vitro the EOs of *C. viminalis* showed good Anthelmintic activity, which produced greater efficacy against earthworms (*Pheretima posthuma*) and tapeworms (*Taenia solium* Linn.) than piperazine phosphate, additionally, the activity against hookworms (*Bunostomum trignocephalum*) was comparable to that of hexylresorcinol [46–48].

4.4. Insecticidal activity

The EO of *C. viminalis* showed moderate activity in killing of the stored-grain insects namely, *Sitophilus oryzae*, *Tribolium castaneum* and *Rhyzopertha dominica* [49]. The isolated compound viminadione A from the aerial parts exhibited moderate insecticidal activity against *Musca domestica*, *Aphis fabae* and *Thrips tabaci* compared to pyrethrum extract, while viminadione B was less active [50,51].

The highest concentrations of EO from dried leaves applied on grains (0.40 μ L/g) and on filter paper discs (0.251 μ L/cm²) caused 72.6% and 80% mortality rates, respectively, against *Acanthoscelides obtectus*, a major *Phaseolus vulgaris* pest of stored beans in Cameroon, while both powder and acetonic extract showed no activity against the insects at the tested concentration [52]. Furthermore, EO showed activity against adults of *Acanthoscelides obtectus* and *Callosobruchus maculatus* [31].

C. viminalis leaf extracts observed a potential larvicide activity, where the isopropanol extract was highly effective against *Aedes albopictus* larvae with LC₅₀ value of 71.34 ppm [53]. In addition, slightly attractancy at 50 ppm with almost 2-fold egg lying in treated bowls was found. Fruits, bark and leaf MeOH extracts showed values of LC₅₀ of 6.2 ppm, 32 ppm and 40 ppm, respectively, against the vector of schistosomiasis, *Biomphalaria alexandrina* snails. The site of action reported from the extracts against insects found by histopathological studies was localized gland [54]. The MeOH extracts showed schistosomicidal activity (LC₅₀ \leq 15 μ g/mL) [55]. Leaf and twigs EO of *C. viminalis* demonstrated strong acaricidal and repellent activities on two-spotted spider mites in both dipping and choice tests with mortality of 71.2% \pm 16.3% against *Tetranychus urticae* female adults [56]. The fumigant oil with LC₁₀, LC₃₀ and LC₅₀ values were 8.42, 15.86 and 24.60 μ L/L air against *Ephesia kuehniella* larvae and the topical LD values were 4.28, 9.64 and 16.91 μ g/insect. In addition, the oil caused a drastic reduction in total hemocyte count of treated larvae in a dose-dependent manner at all time intervals [57].

5. Phytochemical screening of *C. viminalis* and antioxidant activities

From the literature, screening of phytochemicals from *C. viminalis* leaf extracts showed the presence of glycosides flavonoids, alkaloids, proteins, carbohydrate, saponins, tannin, and phenols, where these compounds have been reported to own potential biological activities [2,11–13,58,59]. The presence of these chemical groups refers to the bioactivity of the extracts from *C. viminalis*, also these groups have been previously shown good antibacterial, antifungal, and antioxidant activities. *C. viminalis* oil exhibited strong 2,2-diphenyl-1-picrylhydrazyl (DPPH) scavenging activity, with IC₅₀ values of 72.98 μ g/mL [20].

The total phenolic contents in MeOH extract and ethyl acetate (EtOAc), butanol (*n*-BuOH), and Aq fractions were 44.30 \pm 3.78, 69.10 \pm 3.50, 14.32 \pm 2.32 and 17.21 \pm 1.13 mg GAE/g extract, respectively. The total flavonoid contents were 45.36 \pm 2.03, 28.55 \pm 2.06, 10.12 \pm 1.33 and 18.34 \pm 1.36 mg CE/g extract with MeOH extract and EtOAc, *n*-BuOH, and Aq fractions, respectively. The total antioxidant activity (TAA%) was ranged between 8.70% \pm 1.15% (Aq fraction) and 88.60% \pm 1.51% (EO) [33].

The ferric reducing ability of plasma (FRAP) power was almost same as ascorbic acid [60,61]. The reducing capacity of a compound Fe⁺³/ferricyanide complex to the ferrous form may serve as indicator of its antioxidant capacity [62,63]. Among some extracts (MeOH extract and EtOAc, chloroform and Aq fractions), leaves EO exhibited the highest TAA% (88.60% \pm 1.51%) comparable to Gallic acid as a standard compound (80.00% \pm 2.12%) [33].

The TAA% of the crude extract, petroleum ether, CH₂Cl₂ and EtOAc fractions together with the compounds 6, 7, 9, 10, 11, 12 and 13 presented in Table 1 [34] showed good antioxidant activities compared to ascorbic acid. MeOHLE contained appreciable levels of total phenolic contents ([0.27–0.85] GAE mg/g) and total flavonoid contents ([2.25–7.96] CE mg/g), and the IC₅₀ ([28.4–56.2] μ g/mL) and % inhibition of linoleic acid peroxidation (40.1%–70.2%) was reported [37]. The correlation between different antioxidant assays and oxidation parameters observed from EO observed that MeOHLE was more potent regarding to enhance the

Table 1Chemical constituents of extracts and essential oils from *C. viminalis*.

Part	Main chemical components	Extract type	Action	References
Leaves	1,8-Cineole (64.53%), α -Pinene (9.69%), α -Terpineol (7.90%)	EO	Antibacterial activity	[11]
Leaves	1,8-Cineole (61%), α -Pinene (24%), and menthyl acetate (5.3%)	EO	Antibacterial activity	[17,19]
Leaves	1,8-Cineole (71.77%), α -Pinene (11.47%), Terpinen-4-ol (3.185)	EO	Antibacterial and antifungal activities	[20]
Leaves	1,8-Cineole (65.92%), α -Pinene (12.34%)	EO	Antioxidant, antiviral activities	[21]
Leaves, flowers	1,8-Cineole, α -Pinene and α -Terpineol were found in concentrations of 50.4%, 25.8% and 8.7% in the EOs obtained from the leaves and 48.8%, 24.5% and 3.9% in the EOs obtained from the flowers	EO	Antitumoral activity	[64]
Red flower	Pelargonidin-3,5-diglucoside, Cyanidin-3,5-diglucoside, Kaempferol, β -pinene, 1,8-cineol; Pyrogallol; Catechol, Betulinic acid, α -amyrin, Oleanolic acid, β -sitosterol	Aqueous extract	Synthesis of nanoparticles	[31]
Shade dried leaves	2,5,5,6,8a-Pentamethyl-trans-4a,5,6,7,8,8a-hexahydrogamma-chromene (27.60%), (10E,12E)-10,12-tetradecadienyl acetate (11.62%), Z-7-tetradecenal (4.98%), 1,3-cyclohexadiene (3.97%)	<i>n</i> -Hexane	Antioxidant activity	[32]
Fruits and bark	3,4-Dihydro-2-(hydroxymethyl)-4-methyl-2H-pyrrol-2-ol (5) with the known compounds lupeol (1), octacosanol (2), β -sitosterol (3), betulin (4), betulinic acid (6), ursolic acid (7), corosolic acid (8), β -sitosterol-3-O- β -D-glucoside (9), methyl gallate (10), gallic acid (11), catechin (12), ellagic acid (13) and 3-O-acetylursolic acid (14) (compound 14 isolated from bark and not detected in fruits) (Figure 2)	Total extracts, petroleum ether (1–4), CH ₂ Cl ₂ (5–9) and EtOAc (10–13) fractions	Antioxidant activity	[35]
Aerial parts	Tetramethylcyclohexenedione, viminadione A and viminadione B		Insecticidal activity	[51]
Aerial parts	(i) Gallic acid, (ii) Me gallate, (iii) quercetin 3-O- β -L-arabinofuranoside (avicularin), (iv) quercetin 3-O- α -D-galacto-pyranoside (hyperin), (v) quercetin 3-O- α -L-rhamnopyranoside (quercitrin), (vi) quercetin 3-O- β -D-glucuronopyranoside, (vii) quercetin, (viii) 1-O-galloyl- β -D-glucopyranose (glucogallin), and (ix) 2,3,5-(S)-flavogallonoyl-4,6-(S)-hexahydroxydiphenoyl-D-glucopyranose (castalagin)	Aqueous methanol extract	Hepatoprotective activity	[65]
Leaves	3-O- α -L-Arabinopyranoside hederagenin, Hederagenin 3-O- β -glucopyranosyl-(1 \rightarrow 2)- β -D-xylopyranoside	<i>n</i> -Hexane, ethyl acetate, <i>n</i> -butanol	Antibacterial, antifungal, antioxidant activities	[66]
Leaves	3-Hydroxy-20(29)-lupen-28-oic acid (betulinic acid)	Ethyl acetate	High antisickling activity	[66]
Fruits	(\pm)-Calliviminones A and B, two Diels–Alder adducts of polymethylated phloroglucinol and myrcene			[67]
Fruits	with unprecedented spiro-[5.5] undecene skeleton Calliviminones CH (1–6), six novel Diels–Alder adducts of a polymethylated phloroglucinol derivative and acyclic monoterpene (myrcene) (Figure 3)	Nitric oxide production in lipopolysaccharide-induced		[68]

oxidative stability of sunflower oil [32]. In addition, the IC₅₀ of DPPH radical scavenging was 28.4–56.2 μ g/mL [32].

Aq MeOH extract (Aq-MeOH) of aerial parts showed a significant reduction in elevated alanine aminotransferase, aspartate aminotransferase and alkaline phosphatase serum enzyme levels as compared with paracetamol group. In addition, the Aq-MeOH extracts showed a significant scavenging activity using the DPPH method [69].

6. Nanoparticles synthesis using extracts of *C. viminalis*

Plant extracts provide advancement over chemical and physical method as it is environmentally benevolent, simple, inexpensive, easily scaled up for large-scale synthesis and

further there is no need to use high pressure, energy, temperature and toxic chemicals [30,65,70]. A green method for the synthesis of stable gold nanoparticles (Au NPs) has been done under very mild conditions using Aq leaf extract (AqLE) of *C. viminalis* [30] with a triangular gold nanoparticles form, and does not require any of the conventional stabilizing ligands.

For the first time, gold nanoparticles and Sm₂O₃ nano-scaled particles prepared with AqLE and red flowers extract from *C. viminalis*, respectively, were well characterized by X-ray Diffraction (XRD), Transmission electron microscopy (TEM), quasi-elastic light scattering, Ultraviolet (UV)–visible spectroscopy, Raman and X-rays photoelectron spectroscopy techniques [30,71]. The antimicrobial potential of plant protein-coated HgO nanoparticles still prevailed as it was present in the pure uncoated bulk HgO, however, the crude extract did not

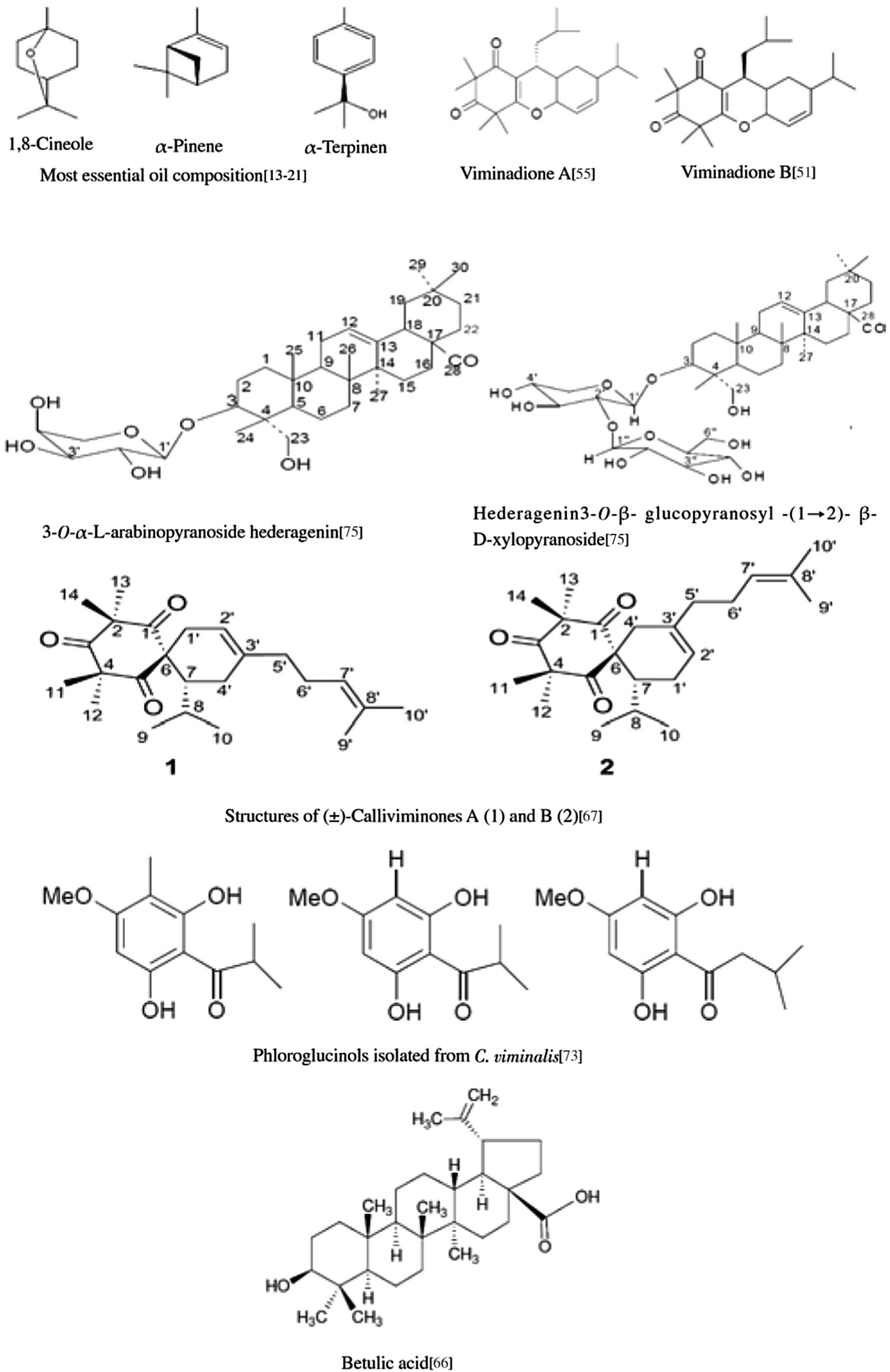


Figure 1. Some of the isolated and identified chemical composition from extracts of *C. viminalis* [73].

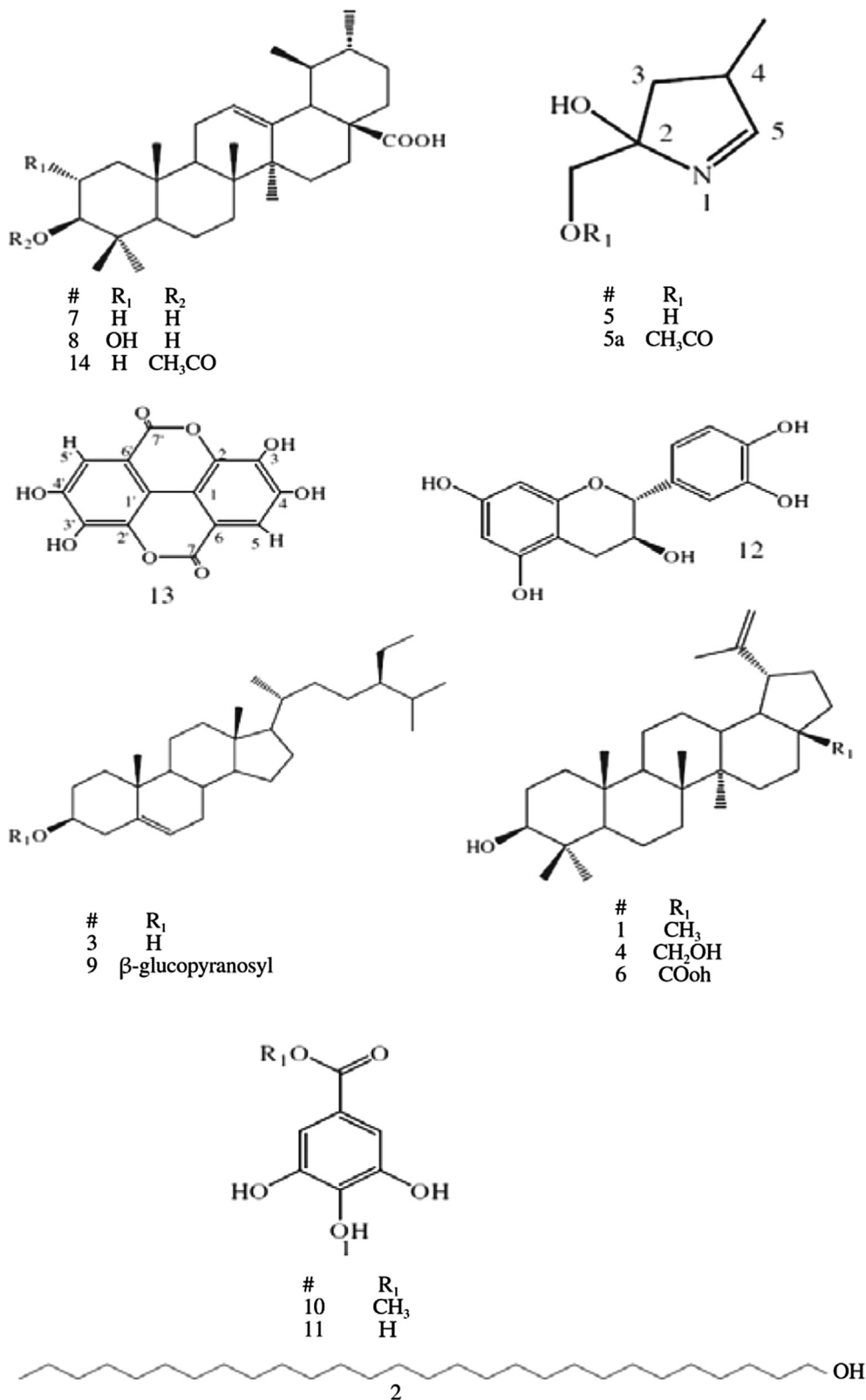


Figure 2. Structure of the isolated compounds (1–14) from fruits [34].

show any antibacterial activity. The AqLE of *C. viminalis*, used for the synthesis of silver nanoparticles, inhibited the growth of *E. coli*, *S. aureus*, *Klebsiella pneumoniae* and *Salmonella typhimurium* [29]. Recent study showed that red dye extracts obtained from *Callistemon* red flowers, which are rich in flavonoids, saponins, steroids, alkaloids and triterpenoids were used for single-phase α -Cr₂O₃ nanoparticles' green synthesis [72].

7. Other biological activities

The EO showed good antiviral activity with TC₅₀ (50% cytotoxic concentration) value 676.35 μ g/mL with significant lower toxicities towards the RC-37 cells with C₅₀ (inhibitory concentration for 50% of plaques) for Herpes simplex virus 1 (HSV-1) (63.73 μ g/mL) and selectivity index (=TC₅₀/IC₅₀) was 10.61 [20]. With the antitumoral activity, the cytotoxic

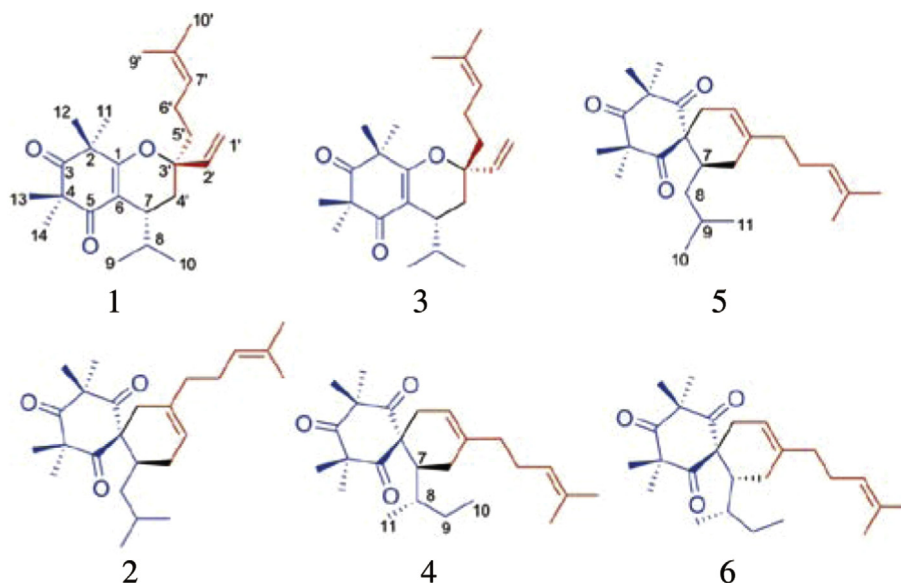


Figure 3. Calliviminones C–H: six new hetero- and carbon-Diels–Alder adducts with unusual skeletons from the fruits of *C. viminalis* [67].

activity of the EO was observed only in melanoma cultures (HT144), where the cultures treated for 48 h with EO (leaves and flowers) at 200 µg/mL reduced the viability by 40% and 25%, respectively. Thus, the antiproliferative activity of the EO (leaves) was more pronounced than the EO (flowers) in cells derived from melanoma [74].

8. Chemical composition of extracts and their biological activities

Literature from different regions around the world showed that the plant has many different chemical compositions in their different parts (leaves, flower, fruits, wood, bark). Some of the isolated compounds from different parts of the plant and obtained from different extracts are presented in Table 1.

Most of the studies were focused on the EO composition of *C. viminalis* and it was shown that there were differences in the quantities of the main compound of the oil even in the same country. The leaf EO of *C. viminalis* from Egypt showed the presence of 1,8-cineole (eucalyptol) as the main compound with 47.9% [15], 64.53%, 71.77% [19] and 65.92% [20]. In the South Africa, it was 83.2% [18]. In addition, linalool, limonene, terpinen-4-ol, α -terpineol, α -pinene, and menthyl acetate were also reported [18–20].

Furthermore, it was reported that the compounds 1,8-cineole, α -pinene and α -terpineol were found in concentrations of 50.4%, 25.8% and 8.7% in leaves EOs and 48.8%, 24.5% and 3.9% in flowers EOs, respectively [74].

Figure 1 showed some of the isolated compounds as raised in the literature. The isolated phloroglucinols from *C. viminalis*, which have been observed good antibacterial activity against *E. coli* and *B. subtilis* also, have antiviral and antioxidant activities [66,75] (Figures 2 and 3).

9. Concluding remarks and research needs

From the above survey about the biological effects of extracts from different parts of *C. viminalis*, it can be concluded that the

EOs and extracts as well as the isolated compounds have a potent biological activity (antibacterial, antifungal, antiviral, haemolytic, anthelmintic, and insecticidal activities) and a good media for nanoparticle synthesis. The research needs to use these extracts in commercial scale in the production of pharmaceutical purposes.

Conflict of interest statement

We declare that we have no conflict of interest.

References

- [1] Spencer RD, Lumley PF. Callistemon. In: Harden GJ, editor. *Flora of New South Wales*, vol. 2. Sydney, Australia: New South Wales University Press; 1991, p. 168-173.
- [2] Wrigley JW, Fagg M. *Bottlebrushes, paperbarks and tea trees and all other plants in the Leptospermum alliance*. Sydney, Australia: Angus & Robertson; 1993, p. 352.
- [3] Goyal PK, Jain R, Jain S, Sharma AA. Review on biological and phytochemical investigation of plant genus *Callistimon*. *Asian Pac J Trop Biomed* 2012; 2(3): S1906-S1909.
- [4] Wheeler GS. Maintenance of a narrow host range by *Oxypos vitiosa*: a biological control agent of *Melaleuca*. *Biochem Syst Ecol* 2005; 33(4): 365-383.
- [5] Ji T. *Traditional Chinese medicine pills for treating hemorrhoid*. 2009. CN 101352524 A 20090128.
- [6] Islam MR, Ahamed R, Rahman MO, Akbar MA, Al-Amin M, Alam KD, et al. *In vitro* antimicrobial activities of four medicinally important plants in Bangladesh. *Eur J Sci Res* 2010; 39(2): 199-206.
- [7] Cowan MM. Plant products as antimicrobial agents. *Clin Microbiol Rev* 1999; 12(4): 564-582.
- [8] Elliot WR, Jones DL. *Encyclopedia of Australian plants*, vol. 2. Australia: Lothian Publishing Company; 1982.
- [9] Varma RS, Parthasarathy MR. Triterpenoids of *Callistemon lanceolatus* leaves. *Phytochemistry* 1975; 14(7): 1675-1676.
- [10] Wollenweber E, Wehde R, Dorr M, Lang G, Stevens JF. C-methyl flavonoids from the leaf waxes of some Myrtaceae. *Phytochemistry* 2000; 55(8): 965-970.
- [11] Ashmawy NA, Behiry SI, Ali HM, Salem MZM. Evaluation of *Tecoma stans* and *Callistemon viminalis* extracts against potato soft

- rot bacteria in vitro. *J Pure Appl Microbiol* 2014; **8**(Suppl 2): 667-673.
- [12] Das AK, Marwal A, Sain D, Pareek V. One-step green synthesis and characterization of plant protein-coated mercuric oxide (HgO) nanoparticles: antimicrobial studies. *Int Nano Lett* 2015; **5**(3): 125-132.
- [13] Brophy JJ, Forster PI, Goldsack RJ, Hibbert DB, Punrueckvong A. Variation in *Callistemon viminalis* (Myrtaceae): new evidence from leaf essential oils. *Austral Syst Bot* 1997; **10**(1): 1-13.
- [14] Brophy JJ, Lassak EV, Toia RF. The volatile leaf oils of two cultivars of *Callistemon viminalis*. *J Proc R Soc NSW* 1986; **118**(Pt 1 and 2): 101-104.
- [15] Mahmoud II, Marzouk MSA, Moharram J, Nolte J, Fobbe R, Saleh MI. Chemical composition of the Egyptian *Callistemon lanceolatus* DC. and *Callistemon viminalis* (Gaertner loudan) oils. *Bull Fac Pharm* 2000; **40**(1): 119-122.
- [16] Srivastava SK, Ahmad A, Jain N, Aggarwal KK, Syamasunder KV. Essential oil composition of *Callistemon viminalis* leaves from India. *Flavour Fragr J* 2003; **13**(5): 361-363.
- [17] Ayoub NA, El-Ahmady SA, Singab ANB, Al-Azizi MM, Kubeczka KH. Chemical composition and antimicrobial activity of the essential oils from *Eucalyptus cinerea*, *Callistemon viminalis* and *Calothamnus quadrifidus* (Myrtaceae). *Trade Sci Inc* 2007; **3**(1): 28-34.
- [18] Oyedeji OO, Lawai OA, Shade FO, Oyedeji AO. Chemical composition of antibacterial activity of the essential oils of *Callistemon viminalis* from South Africa. *Molecules* 2009; **14**(6): 1990-1998.
- [19] Badawy MEI, Abdelgaleil SAM. Composition and antimicrobial activity of essential oils isolated from Egyptian plants against plant pathogenic bacteria and fungi. *Ind Crop Prod* 2014; **52**(1): 776-782.
- [20] Romeilah RM, Fayed SA, Mahmoud GI. Antioxidant and antiviral activities of essential oils from *Callistemon viminalis* and *Schinus molle* L. *Res J Pharm Biol Chem Sci* 2016; **7**(1): 1982-1993.
- [21] Jawad AM, Jaffer HJ. *In vitro* antimicrobial activity of total sesquiterpene lactones and phenols from some Iraqi plants. *Um Salama Sci J* 2008; **5**(1): 80-83.
- [22] Tyler VE, Brady LR, Robbert JE. *Pharmacognosy*. 9th ed. Philadelphia: Lea and Febiger; 1988, p. 56-58.
- [23] Adonizio AL, Downum K, Bennett BC, Mathee K. Anti-quorum sensing activity of medicinal plants in southern Florida. *J Ethnopharmacol* 2006; **105**(3): 427-435.
- [24] Delahaye-Mckenzie C, Rainford L, Nicholson A, Mitchell S, Lindo J, Ahmad M. Antibacterial and antifungal analysis of crude extracts from the leaves of *Callistemon viminalis*. *J Med Biol Sci* 2009; **3**(1): 1-7.
- [25] Abdullah E, Raus RA, Jamal P. Evaluation of antibacterial activity of flowering plants and optimization of process conditions for the extraction of antibacterial compounds from *Spathiphyllum canni-folium* leaves. *Afr J Biotechnol* 2011; **10**(81): 18679-18689.
- [26] Adonizio A, Leal SM, Ausubel FM, Mathee K. Attenuation of *Pseudomonas aeruginosa* virulence by medicinal plants in a *Caenorhabditis elegans* model system. *J Med Microbiol* 2008; **57**(Pt 7): 809-813.
- [27] Hussain S, Akrema, Rahisuddin, Khan Z. Extracellular biosynthesis of silver nanoparticles: effects of shape-directing cetyltrimethylammonium bromide, pH, sunlight and additives. *Bioprocess Biosyst Eng* 2014; **37**(5): 953-964.
- [28] Akrema, Rahisuddin. Biomediated unmodified silver nanoparticles as a green probe for Cu²⁺ ion detection. *Sens Lett* 2015; **13**(11): 953-960.
- [29] Rahisuddin, Akrema. Extracellular synthesis of silver dimer nanoparticles using *Callistemon viminalis* (bottlebrush) extract and evaluation of their antibacterial activity. *Spectros Lett* 2016; **49**(4): 268-275.
- [30] Kumar P, Singh P, Kumari K, Mozumdar S, Chandra R. A green approach for the synthesis of gold nanotriangles using aqueous leaf extract of *Callistemon viminalis*. *Mat Lett* 2011; **65**(4): 595-597.
- [31] Ndomo F, Tapondjou LA, Ngamo LT, Hance T. Insecticidal activities of essential oil of *Callistemon viminalis* applied as fumigant and powder against two bruchids. *J Appl Entomol* 2010; **134**(4): 333-341.
- [32] Zubair M, Hassan S, Rizwan K, Rasool N, Riaz M, Zia-Ul-Haq M, et al. Antioxidant potential and oil composition of *Callistemon viminalis* leaves. *Sci World J* 2013; **2013**. 489071; <http://dx.doi.org/10.1155/2013/489071>.
- [33] Salem MZM, Ali HM, El-Shanhorey NA, Abdel-Megeed A. Evaluation of extracts and essential oil from *Callistemon viminalis* leaves: antibacterial and antioxidant activities, total phenolic and flavonoid contents. *Asian Pac J Trop Med* 2013; **6**(10): 785-791.
- [34] Gohar AA, Maatooq GT, Gadara SR, Aboelmaaty WS. One new pyrroline compound from *Callistemon viminalis* (Sol. Ex Gaertner) G. Don Ex Loudon. *Nat Prod Res* 2013; **27**(13): 1179-1185.
- [35] Balandrin MF, Kjocke AJ, Wurtele E. Natural plant chemicals: sources of industrial and mechanical materials. *Science* 1985; **228**(4704): 1154-1160.
- [36] Abd AJ. Studying of antibacterial effect for leaves extract of *Callistemon viminalis* in vitro and vivo (urinary system) for rabbits. *J Kerbala Univ* 2012; **10**(2): 646-654.
- [37] Abdul-Sahib SS. [Antagonistic study of *Callistemon viminalis* extracts against some pathogenic microorganisms]. College of Science - Baghdad University; 2008 [Thesis]. In Arabic.
- [38] Mabhiza D, Chitemerere T, Mukanganyama S. Antibacterial properties of alkaloid extracts from *Callistemon citrinus* and *Vernonia adoensis* against *Staphylococcus aureus* and *Pseudomonas aeruginosa*. *Int J Med Chem* 2016; <http://dx.doi.org/10.1155/2016/6304163>.
- [39] Shinde PR, Patil PS, Bairagi VA. Pharmacognostic, phytochemical properties and antibacterial activity of *Callistemon citrinus viminalis* leaves and stems. *Int J Pharm Pharm Sci* 2012; **4**(Suppl 2): 173-182.
- [40] Saleem A, Nasir S, Rasool N, Bokhari TH, Rizwan K, Shahid M, et al. *In vitro* antimicrobial and haemolytic studies of *Kalanchoe pinnata* and *Callistemon viminalis*. *Int J Chem Biochem Sci* 2015; **7**: 29-34.
- [41] Sundis MA, Baharuddin S. Inhibitory activity of plant extracts against microbes isolated from sick building. *Health Environ J* 2012; **3**(2): 61-73.
- [42] Mansour MMA, Abdel-Megeed A, Nasser RA, Salem MZM. Comparative evaluation of some woody trees methanolic extracts and Paraloid B-72 against phytopathogenic mold fungi *Alternaria tenuissima* and *Fusarium culmorum*. *Bio Res* 2015; **10**(2): 2570-2584.
- [43] Mansour MMA, Salem MZM. Evaluation of wood treated with some natural extracts and Paraloid B-72 against the fungus *Trichoderma harzianum*: wood elemental composition, *in vitro* and application evidence. *Int Biodeterior Biodegr* 2015; **100**: 62-69.
- [44] Abdullah E, Raus RA, Jamal P. Extraction and evaluation of antibacterial activity from selected flowering plants. *Am Med J* 2012; **3**(1): 27-32.
- [45] Adonizio AL, Kong KF, Mathee K. Inhibition of quorum sensing-controlled virulence factor production in *Pseudomonas aeruginosa* by South Florida plant extracts. *Antimicrob Agents Chemother* 2008; **52**(1): 198-203.
- [46] Garg SC, Kaseria HL. Anthelmintic activity of the essential oil of *Callistemon viminalis*. *Fitoterapia* 1982; **53**(5-6): 179-181.
- [47] Srivastava SK, Ahmad A, Jain N, Aggarwal KK, Syamasunder KV. Essential oil composition of *Callistemon citrinus* leaves from the lower region of Himalayas. *J Essent Oil Res* 2001; **13**(5): 359-361.
- [48] Veerakumari L. Botanical anthelmintics. *Asian J Sci Tech* 2015; **6**(10): 1881-1894.
- [49] Lee BH, Annis PC, Tumaalii F, Choi WS. Fumigant toxicity of essential oils from the Myrtaceae family and 1,8-cineole against 3 major stored-grain insects. *J Stored Prod Res* 2004; **40**(5): 553-564.
- [50] Khambay BPS, Beddie DG, Hooper AM, Simmonds MSJ, Green PWC. New insecticidal tetradecahydroxanthenediones from *Callistemon viminalis*. *J Nat Prod* 1999; **62**(12): 1666-1667.
- [51] Khambay BPS, Beddie DG, Hooper AM, Simmonds MSJ. Isolation, characterisation and synthesis of an insecticidal

- tetramethyltetrahydrochromenedione-spiro-bicyclo[3.1.1] cycloheptane from two species of Myrtaceae. *Tetrahedron* 2003; **59**(36): 7131-7133.
- [52] Ndomo AF, Tapondjou AL, Tendonkeng F, Tchouanguep FM. Evaluation des propriétés insecticides des feuilles de *Callistemon viminalis* (Myrtaceae) contre les adultes d'*Acanthoscelides obtectus* (Say) (Coleoptera; Bruchidae). *Tropicicultura* 2009; **27**(3): 137-143.
- [53] Yadav R, Tyagi V, Tikar SN, Sharma AK, Mendki MJ, Jain AK, et al. Differential larval toxicity and oviposition altering activity of some indigenous plant extracts against dengue and chikungunya vector *Aedes albopictus*. *J Arthropod Borne Dis* 2014; **8**(2): 174-185.
- [54] Gohar AA, Maatooq GT, Gadara SR, Aboelmaaty WS, El-Shazly AM. Molluscicidal activity of the methanol extract of *Callistemon viminalis* (Sol. ex Gaertner) G. Don ex Loudon fruits, bark and leaves against *Biomphalaria alexandrina* snails. *Iran J Pharm Res* 2014; **13**(2): 505-514.
- [55] Yousif F, Wassel G, Boulos L, Labib T, Mahmoud K, El-Hallouty S, et al. Contribution to *in vitro* screening of Egyptian plants for schistosomicidal activity. *Pharm Biol* 2012; **50**(6): 732-739.
- [56] Roh HS, Lee BH, Park CG. Acaricidal and repellent effects of myrtacean essential oils and their major constituents against *Tetranychus urticae* (Tetranychidae). *J Asia Pac Entomol* 2013; **16**(3): 245-249.
- [57] Ghasemi V, Khoshnood Yazdi A, Zaker Tavallaie F, Jalali Sendi J. Effect of essential oils from *Callistemon viminalis* and *Ferula gummosa* on toxicity and on the hemocyte profile of *Ephesthia kuehniella* (Lep.: Pyralidae). *Arch Phytopathol Plant Prot* 2014; **47**(3): 268-278.
- [58] Deeba F, Abbas N, Aftab T, Zehra S, Khan RA. Evaluation of phenolic compounds in some locally available flowering plants. *Eur J Pharm Med Res* 2015; **2**(5): 1361-1371.
- [59] Salem MZM, Zidan YE, Mansour MMA, El Hadidi NMN, Abo Elgat WAA. Evaluation of usage three natural extracts applied to three commercial wood species against five common molds. *Inter Biodeter Biodegr* 2016; **110**: 206-226.
- [60] Kumar S, Kumar D, Prakash O. Evaluation of antioxidant potential, phenolic and flavonoid contents of *Hibiscus tiliaceus* flowers. *Pak J Pharm Sci* 2009; **22**(3): 282-286.
- [61] Das A, Jaman K, Singh V. Antimicrobial and antioxidant activities of *Callistemon viminalis* leaf extract. *Pharmacologyonline* 2008; **3**: 875-881.
- [62] Yildirim A, Mavi A, Oktay M, Kara AA, Algur OF, Bilaloglu V. Comparison of antioxidant and antimicrobial activities of *Tilia argentea* Desf Ex DC), Sage (*Salvia triloba* L.), and Black Tea (*Camellia sinensis*) extracts. *J Agr Food Chem* 2000; **48**(10): 5030-5034.
- [63] Xing R, Liu S, Yu HH, Guo ZY, Li Z, Li PC. Preparation of high-molecular weight and high-sulfate content chitosans and their potential antioxidant activity *in vitro*. *Carbohydr Polym* 2005; **61**(2): 148-154.
- [64] Kubo I, Kinoshori I, Yokokawa Y. Tyrosinase inhibitors from *Anacardium occidentale* fruits. *J Nat Prod* 1994; **57**(4): 545-551.
- [65] Parveen M, Ahmad F, Malla AM, Azaz S. Microwave-assisted green synthesis of silver nanoparticles from *Fraxinus excelsior* leaf extract and its antioxidant assay. *Appl Nanosci* 2016; **6**(2): 267-276.
- [66] Tshibangu DST. *Phytochemical and anti-drepanocytosis studies of Cajanus cajan, Callistemon viminalis, Melaleuca bracteata var. revolution gold and Syzygium guineense*. Westville, Durban, South Africa: School of Chemistry, University of KwaZulu-Natal; 2010, p. 170 [Thesis].
- [67] Wu L, Luo J, Zhang Y, Zhu M, Wang X, Luo J, et al. Isolation and biomimetic synthesis of (±)-calliviminones A and B, two novel Diels-Alder adducts, from *Callistemon viminalis*. *Tetrahedron Lett* 2015; **56**(1): 229-232.
- [68] Wu L, Luo J, Wang XB, Li RJ, Zhang YL, Kong LY, et al. Six new hetero- and carbon-Diels-Alder adducts with unusual skeletons from the fruits of *Callistemon viminalis*. *RSC Adv* 2015; **5**(114): 93900-93906.
- [69] El Dib RA, El-Shenawy SM. Phenolic constituents and biological activities of the aerial parts of *Callistemon viminalis* (Sol. ex Gaertner) G. Don ex Loudon. *Bull Fac Pharm (Cairo Univ)* 2008; **46**: 223-235.
- [70] Pauksch L, Hartmann S, Rohnke M, Szalay G, Alt V, Schnettler R, et al. Biocompatibility of silver nanoparticles and silver ions in primary human mesenchymal stem cells and osteoblasts. *Acta Biomater* 2014; **10**(1): 439-449.
- [71] Sone BT, Manikandan E, Gurib-Fakim A, Maaza M. Sm₂O₃ nanoparticles green synthesis via *Callistemon viminalis* extract. *J Alloy Comp* 2015; **650**(11): 357-362.
- [72] Sone BT, Manikandan E, Gurib-Fakim A, Maaza M. Single-phase α-Cr₂O₃ nanoparticles' green synthesis using *Callistemon viminalis* red flower extract. *Green Chem Lett Rev* 2016; **9**(2): 85-90.
- [73] Bloor SJ. Antiviral phloroglucinols from New-Zealand *Kunzea* species. *J Nat Prod* 1992; **55**(1): 43-47.
- [74] de Oliveira CM, das Graças Cardoso M, Ionta M, Soares MG, de Andrade Santiago J, da Silva GÁF, et al. Chemical characterization and *in vitro* antitumor activity of the essential oils from the leaves and flowers of *Callistemon viminalis*. *Am J Plant Sci* 2015; **6**(16): 2664-2671.
- [75] Désiré DJ. *Etude phytochimique et activités biologiques de quatre espèces Camerounaises de la famille des Myrtaceae: Eucalyptus saligna Sm., Callistemon viminalis W., Syzygium guineense W. et Syzygium aromaticum M. et P.* Faculté des Sciences de l'Université de Neuchâtel; 2005, p. 218 [Thesis].