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Chapter

Sesquiterpene from Myanmar Medicinal Plant (*Curcuma comosa*)

Khun Nay Win Tun, Nanik Siti Aminah, Alfinda Novi Kristanti, Hnin Thanda Aung and Yoshiaki Takaya

Abstract

Curcuma comosa (Zingiberaceae) is widely grown in tropical and subtropical areas of Asia, like Thailand, Indonesia, Malaysia, and Myanmar. In Myanmar, the rhizome of *Curcuma comosa* is called Sa-nwin-ga, and local people had used it as a traditional medicine for stomach ache, diabetes mellitus, and hypertension. This species produces secondary metabolites of phenolic and nonphenolic groups. Phenolic groups like diarylheptanoids and flavonoids. While nonphenolics are terpenoids, especially sesqui- and monoterpenes. In this chapter, the group of sesquiterpene compounds from *Curcuma comosa* starts from the isolation technique, followed by the elucidation of the molecular structure, and their activity tests have been discussed.

Keywords: *Curcuma comosa*, Myanmar, sesquiterpenes, Zingiberaceae, Sa-nwin-ga

1. Introduction

Terpenes are formally derived from the carbon backbone of isoprene and based on the polymers of the active building blocks head-to-tail and tail-to-tail. Virtually all parts of the plant, especially flowers, leaves, fruits, and roots, contain different quantities of terpenes and terpenoids which are separated by means of methods such as distillation, extraction and other techniques. More than 30,000 terpenes and terpenoids are known to date. Their role in nature is still unknown and undergoes further research. Essential oils play an important role in defense and signaling as a product of plant secondary metabolism. Today, herbs and spices have an important role to play in disease prevention. In vitro trials have shown that terpenes can inhibit or sometimes induce pathways that regulating cell division, cell proliferation and detoxification [1]. *Curcuma comosa* (Zingiberaceae), widely grown in tropical and subtropical area of Asia, like Thailand, Indonesia, Malaysia, and Taunggyi (Shan State of Myanmar). It is popularly known for its beneficial effect in human health, being traditionally used in folk medicine in Asian countries, including Myanmar, Malaysia, Indonesia, and Thailand. In Taunggyi, the rhizome of *Curcuma comosa* is called **Sa-nwin-ga** and local people had used as a traditional medicine for stomach ache, diabetes mellitus and hypertension. In Thailand, the

rhizome of *Curcuma comosa* is called **Waamchak mod luuk** and had been used for the treatment of reproductive disorders in women, and for relief of unpleasant menopausal symptoms among postmenopausal women. Phytochemical investigations of this plant led to the isolation of several compounds. Two major groups of structures reported constituents include sesquiterpenes and diarylheptanoids [2, 3].

2. Classification of terpenes

Terpenes are typically classified according to the number of biogenetically derived isoprene units (**Figure 1**). (i) Hemiterpenes: They are made up of C_5 unit or 1 residues of isoprene. (ii) Monoterpenes: They are made up of C_{10} unit or 2 residues of isoprene. (iii) Sesquiterpenes: They are made up of C_{15} unit or 3 residues of isoprene. (iv) Diterpenes: They are made up of C_{20}unit or 4 residues of isoprene. (v) Sesterterpenes: They are made up of C_{25} unit or 5 residues of isoprene. (vi) Triterpenes: They are made up of C_{30} unit or 6 residues of isoprene. (vii) Tetraterpenes: They are made up of C_{40} unit or 8 residues of isoprene [4, 5].

2.1 Sesquiterpenes

Sesquiterpenes can be classified into five sub-groups (**Figure 2**): (i) germacrane-type sesquiterpenes, (ii) guaiane-type sesquiterpenes, (iii) bisaborane-type sesquiterpenes, (iv) carabrane-type sesquiterpenes, and (v) eudesmane-type sesquiterpenes [6].

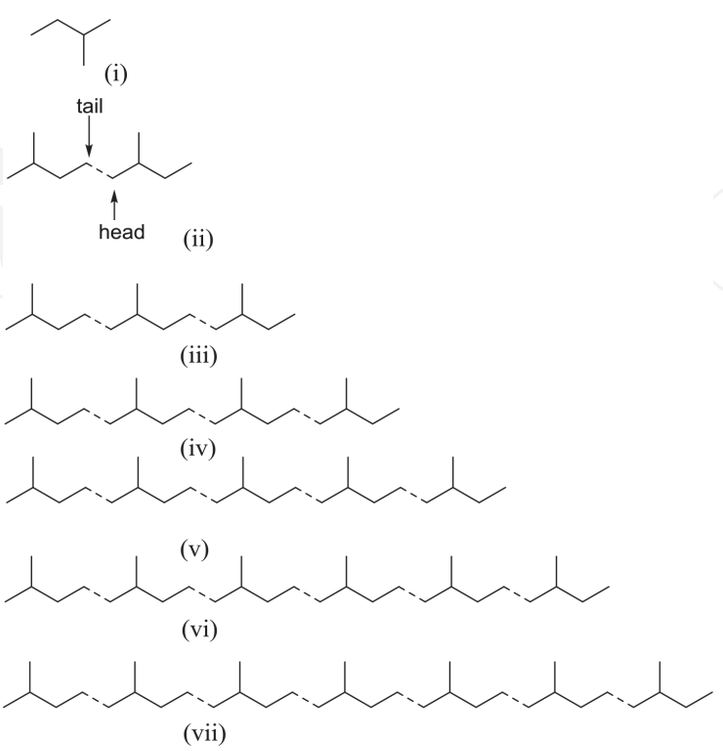

Figure 1.
Classification of terpenes [4].

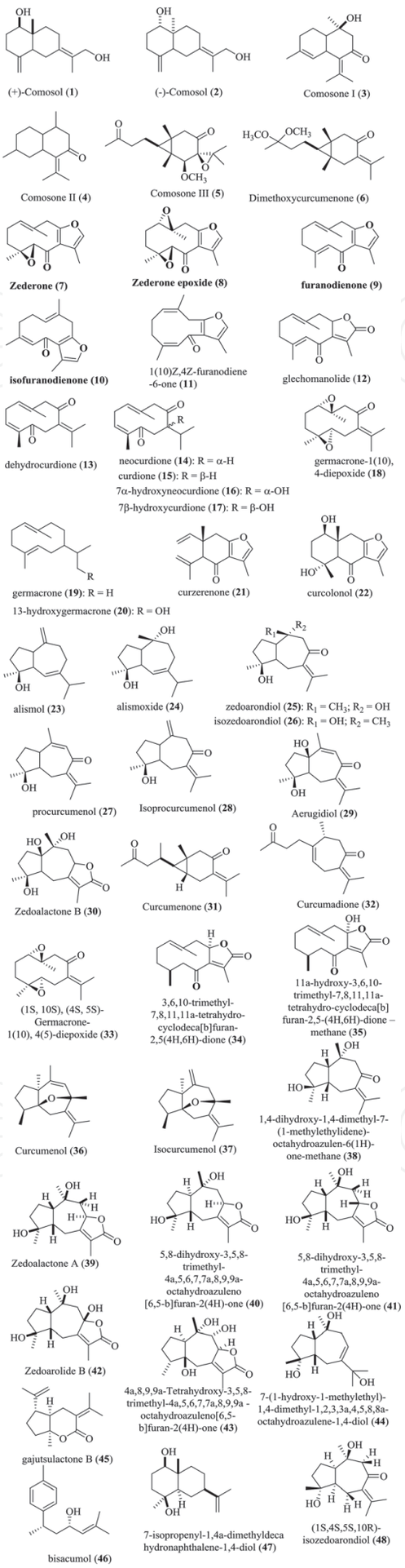

Figure 2.
Sesquiterpenes (1-48) from Curcuma comosa *[6, 18–20].*

3. Sample collection and preparation

Plant material may be obtained from fresh or dried plant parts such as leaves, barks, stem barks, roots, rhizomes, fruits, and flowers. The plant materials were dried at room temperature. These were cut into small pieces. The air-dried samples were kept in a covered glass container to protect them from humidity and light prior to extraction.

3.1 Extraction

Plant materials are an immensely complicated system containing a broad range of natural compounds. The most relevant techniques can effortlessly be used for especially selective and reliable extraction of specific components found in complex matrices. These techniques comprise maceration, percolation, decoction, reflux extraction, soxhlet extraction, pressurized liquid extraction, ultrasonic extraction, (sonication), microwave-assisted extraction (MAE), accelerated solvent extraction (ASE), supercritical fluid extraction (SFE), pulsed electric field extraction, enzyme assisted extraction, hydro distillation, and steam distillation. The point of the method for extraction is to optimize the number of goal compounds and to realize most biological activity [7, 8].

3.2 Examination of the crude extract

Analytical TLC was used to examine the composition of the unrefined extracts. The visualizations were assisted either by the UV detection of the TLC or by anisaldehyde dipping, accompanied by warming at 100°C. The TLC has been changed more than once by altering solvent processes to achieve the best separation [9].

3.3 Fractionation

Fractionation is the method of classification by physical or chemical characteristics of a specific sample of an analyte or group of analytes. Raw extracts can contain thousands of compounds in a complicated mix. It would not be possible to produce a single compound from crude extract with a single separation procedure. It is therefore also important to divide the crude extract into different fractions that contain a similar group of polarities or molecular compounds [10].

3.4 Isolation and purification

Solvent extraction and partition accompanied by column chromatography (CC), vacuum-liquid chromatography (VLC), thin-layer chromatography (TLC), high-performance liquid chromatography (HPLC), and gas chromatography–mass spectrometry (GCMS) are the prevalent separation techniques for sesquiterpenes. Resembling extraction, the most significant factor to be considered before choosing an isolation protocol is the nature of the goal compound(s) present in the crude extracts or fractions. Chromatography is a technique that allows qualitative and quantitative analysis to separate, identify and purify the mixture of a compound. Chromatography is based on the concept under which the mixed molecules deposited on or in the solid and fluid stationary phases are separated with the aid of a mobile phase. The stationary phase normally employed is silica gel with the mobile the solvent(s) of choice to fractionate or extract bioactive compounds [11–13].

3.5 Structure elucidation

A mixture of physical (melting point, CD and alpha-D) and spectroscopic (UV, IR, 1D-, 2D- NMR, and HR-MS) techniques have typically used to characterize the structures of the isolated pure sesquiterpenes. UV–Vis spectroscopy is widely used in analytical chemistry for the measurement of various analyze, such as strongly multiple bonds or aromatic conjugation within molecules, bioprocess, and fermentation of food production. Fourier-transform infrared (FTIR) spectroscopy is an effective method to classify the functional groups found in the sesquiterpenes compound. Nuclear magnetic resonance (NMR) may be the capable spectroscopy that gives complete data on atomic structure and is well appropriate for the identification of simple molecules. NMR spectroscopy is primarily partitioned into one dimensional (1D-NMR) and two-dimensional techniques (2D-NMR). The ^{1}H-NMR and ^{13}C-NMR one-dimension techniques provide information about the numbers and types of protons and carbon atoms in the sesquiterpenes compound. There are five 2D-NMR techniques commonly used to determine the sesquiterpenes structure, double quantum filtered correlated spectroscopy (DQF-COSY), nuclear Overhauser enhancement spectroscopy (NOESY), heteronuclear multiple-bond correlation (HMBC), heteronuclear single-quantum correlation spectroscopy (HSQC)/heteronuclear multiple-quantum coherence (HMQC), rotating frame Overhauser enhancement spectroscopy (ROESY), and total correlation spectroscopy (TOCSY) [13–16].

4. Sesquiterpenes from *C. comosa*

Xu et al., isolated six new sesquiterpenes (**1-6**) from the EtOAc soluble portion of the methanol rhizomes extract of *C. comosa* by using silica gel column chromatography, octa decyl silica (ODS) column chromatography, and high-performance-liquid-chromatography (HPLC) [17]. Qu et al., also isolated 26 known compounds (**7-32**) from the EtOAc soluble layer of the methanol rhizomes extract of *C. comosa* by using silica gel column chromatography, octa decyl silica (ODS) column chromatography, and high-performance-liquid-chromatography (HPLC) [18]. Khine isolated 25 sesquiterpenes (**7**, **15**, **24-28**, and **30-47**) from the hexane extract and *n*-butanol fraction of *C. comosa* by using different chromatographic techniques [6]. In our previous work, 3 known sesquiterpenes (**25**, **36**, and **48**) were isolated from the MeOH soluble fraction of *C. comosa* by using vacuum-liquid chromatography and successive repeated column chromatography [19]. The physical and spectroscopic data of the isolated compounds are depicted in **Table 1**.

5. Biological activities

Several studies have reported that *Curcuma comosa* have been successfully used for various diseases **Table 2**.

6. Conclusion

Work on natural products has recently experienced rapid expansion due to improvement in isolation techniques and the design of synthesis methods and also for the identification of a wide range of biological properties of these compounds. In

Compound	Physical and spectral data
(+)-Comosol (**1**) [17]	A colorless oil; $[\alpha]_D^{23}$ +34.7° (*c* = 0.2, $CHCl_3$); IR (cm^{-1}): 3420, 2936, 1655, 1541, 754. ^1H NMR (600 MHz, $CDCl_3$) δ_H: 0.80, 1.79 (each 3H, s H_3-14, 13), 1.16, 1.99 (1H each, both m, H_2-10), 1.59, 1.82 (1H each, both m, H_2-3), 1.73 (1H, br d, J = *ca*. 12 Hz, H-6), [1.88 (1H, dd, J = 13.0, 11.7 Hz), 2.53 (1H, br d, J = *ca*. 13 Hz), H_2-7], [1.94 (1H, dd like, J = 13.7 Hz), 2.67 (1H, br d, J = ca. 14 Hz), H_2-9], 2.10, 2.32 (1H each, both m, H_2-4), 3.39 (1H, dd, J = 11.6, 4.1 Hz, H-2), 4.16 (2H, s, H_2-12), 4.57, 4.82 (1H each, both br s, H_2-15). ^{13}C NMR (150 MHz, $CDCl_3$) δ_C: 40.5 (C-1), 79.1 (C-2), 31.4 (C-3), 34.1 (C-4), 148.8 (C-5), 48.1 (C-6), 28.1 (C-7), 136.5 (C-8), 25.0 (C-9), 38.3 (C-10), 125.4 (C-11), 63.4 (C-12), 16.4 (C-13), 9.8 (C-14), 107.0 (C15). EI-MS m/z: 236 [M^+] (6), 218 [M -H_2O]$^+$ (100). HR-EI-MS m/z: 236.1771 (Calcd for $C_{15}H_{24}O_2$: 236.1776).
(−)-Comosol (**2**) [17]	A colorless oil; $[\alpha]_D^{22}$ −34.7° (*c* = 0.2, $CHCl_3$); IR (cm^{-1}): 3420, 2936, 1655, 1541, 754. ^1H NMR (600 MHz, $CDCl_3$) δ_H: 0.80, 1.79 (3H each, both s, H_3-14, 13), 1.16, 1.99 (1H each, both m, H_2-10), 1.59, 1.82 (1H each, both m, H_2-3), 1.73 (1H, br d, *J* = *ca.* 12 Hz, H-6), [1.88 (1H, dd, J = 13.0, 11.7 Hz), 2.53 (1H, br d, *J* = *ca.* 13 Hz), H2-7], [1.94 (1H, dd like, *J* = 13.7 Hz), 2.67 (1H, br d, *J* = *ca.* 14 Hz), H_2-9], 2.10, 2.32 (1H each, both m, H_2-4), 3.39 (1H, dd, *J* = 11.6, 4.1 Hz, H-2), 4.16 (2H, s, H_2-12), 4.57, 4.82 (1H each, both br s, H_2-15). ^{13}C NMR (150 MHz, $CDCl_3$) δ_C: 40.5 (C-1), 79.1 (C-2), 31.4 (C-3), 34.1 (C-4), 148.8 (C-5), 48.1 (C-6), 28.1 (C-7), 136.5 (C-8), 25.0 (C-9), 38.3 (C-10), 125.4 (C-11), 63.4 (C-12), 16.4 (C-13), 9.8 (C-14), 107.0 (C-15). EI-MS *m/z*: 236 [M^+] (6), 218 [M - H2O]$^+$ (100). HR-EI-MS *m/z*: 236.1771 (Calcd for $C_{15}H_{24}O_2$: 236.1776).
Comosone I (**3**) [17]	A colorless oil; $[\alpha]_D^{25}$ +15.4° (*c* = 0.80, MeOH). UV λ_{max} (MeOH) nm (log ε): 221 (3.78). IR (cm^{-1}): 3420, 2936, 1655, 1541, 754. ^1H NMR (600 MHz, $CDCl_3$) δ_H: 1.22, 1.74 (1H each, both m, H_2-2), 1.34, 1.65, 1.92, 1.92 (3H each, all s, H_3-14, 15, 12, 13), 1.92 (2H, m, H_2-3), 1.96 (1H, m, H-1), 2.35 (1H, dd, *J* = 18.3, 1.6 Hz, H-9b), 2.50 (1H, d, J = 18.3 Hz, H-9a), 3.74, 5.33 (1H each, both br s, H-6, 5). ^{13}C NMR (150 MHz, $CDCl_3$) δ_C: 43.9 (C-1), 23.5 (C-2), 29.6 (C-3), 134.8 (C-4), 121.6 (C-5), 36.0 (C-6), 134.3 (C-7), 203.4 (C-8), 51.5 (C-9), 72.9 (C-10), 141.6 (C-11), 22.4 (C-12) 22.5 (C-13), 27.6 (C-14), 23.7 (C-15). EI-MS m/z: 234 (M^+) (28), 216 (M - H_2O)$^+$ (30), 43 (M - 191) (100). HR-EI-MS m/z: 234.1616 (Calcd for $C_{15}H_{22}O_2$: 234.1620).
Comosone II (**4**) [17]	A colorless oil; $[\alpha]_D^{27}$ +10.1° (*c* = 0.70, MeOH). UV λ_{max} (MeOH) nm (log ε): 237 (3.77). IR (cm^{-1}): 1665, 1651, 1515, 1439, 1379, 754. ^1H NMR (600 MHz, $CDCl_3$) δ_H: 1.58, 1.87, 1.93, 2.06 (3H each, all s, H_3-15, 13, 14, 12), 1.82 (2H, m, H_2-3), 1.83, 2.20 (1H each, both m, H_2-2), 2.75 (1H, m, H-1), 3.76 (1H, br s, H-6), 4.92 (1H, br s, H-5), 5.90 (1H, s, H-9). ^{13}C NMR (150 MHz, $CDCl_3$) δ_C: 38.3 (C-1), 25.3 (C-2), 26.0 (C-3), 135.1 (C-4), 122.0 (C-5), 39.8 (C-6), 1333.5 (C-7), 191.8 (C-8), 130.8 (C-9), 158.6 (C-10), 141.8 (C-11), 23.0 (C-12), 21.9 (C-13), 20.8 (C-14), 23.5 (C-15). EI-MS m/z: 216 (M^+) (100). HR-EI-MS m/z: 216.1509 (Calcd for $C_{15}H_{20}O$: 216.1514).
Comosone III (**5**) [17]	A colorless oil; $[\alpha]_D^{24}$ +23.9° (*c* = 0.5, MeOH). IR (cm^{-1}): 1713, 1092. ^1H NMR (600 MHz, $CDCl_3$) δ_H: 0.79 (1H, ddd, *J* = 8.1, 5.4, 5.4 Hz, H-1), 1.13 (1H, t like, *J* = *ca*. 5 Hz, H-5), 1.18, 1.21, 1.39, 2.17 (3H each, all s, H_3-12, 14, 13, 15), 1.64, 1.76 (1H each, both m, H_2-2), 2.56 (2H, t, *J* = 7.6 Hz, H_2-3), 2.68, 2.77 (1H each, both d, *J* = 19.9 Hz, H_2-9), 3.43 (3H, s, OCH_3-6), 3.88 (1H, d, *J* = 4.1 Hz, H-6). ^{13}C NMR (150 MHz, $CDCl_3$) δ_C: 25.9 (C-1), 23.09 (C-2), 43.3 (C-3), 208.0 (C-4), 30.4 (C-5), 79.3 (C-6), 69.9 (C-7), 204.9 (C-8), 47.2 (C-9), 18.8 (C-10), 62.6 (C-11), 19.4 (C-12), 20.8 (C-13), 19.3 (C-14), 30.0

Compound	Physical and spectral data
	(C-15), 57.7 (C-16). EI-MS m/z: 280 [M^+] (2), 265[M - Me]$^+$ (3), 139 [M - 141]$^+$ (100). HR-EI-MS m/z: 280.1676 (Calcd for $C_{16}H_{24}O_4$: 280.1674).
Dimethoxycurcumenone (**6**) [17]	A colorless oil; $[\alpha]_D^{25}$ −10.1° (*c* = 1.4, MeOH). UV λ_{max} (MeOH) nm (log ε): 255 (3.59). IR (cm^{-1}): 1682, 1601, 1458, 1375, 1055, 853. ^{1}H NMR (600 MHz, $CDCl_3$) δ_H: 0.47, 0.66 (1H each, both m, H-1, 5), 1.13, 1.23, 1.79, 2.10 (3H each, all s, H_3-14, 15, 13, 12), 1.34, 1.65 (2H each, both m, H_2-2, 3), 2.51, 2.56 (1H each, both d, *J* = 15.6 Hz, H2-9), 2.83 (2H, br s, H_2-6), 3.15, 3.15 (3H each, both s, OCH_3-4). ^{13}C NMR (150 MHz, $CDCl_3$) δ_C: 24.7 (C-1), 23.9 (C-2), 36.7(C-3), 101.3 (C-4), 24.1 (C-5), 28.0 (C-6), 128.2 (C-7), 201.7 (C-8), 49.0 (C-9), 20.0 (C-10), 147.0 (C-11), 23.4 (C-12), 23.4 (C-13), 19.1 (C-14), 20.9 (C-15), 48.0 (C-16), 48.0 (C-17). EI-MS m/z: 280 [M^+] (3), 85 [M – 195]$^+$ (100). HR-EI-MS m/z: 280.2046 (Calcd for $C_{17}H_{28}O_3$: 280.2038).
Zederone (**7**) [20, 21]	Colorless plates; melting point: 153 ∼ 154°C; $[\alpha]_D^{20}$ +220° (*c* = 0.10, $CHCl_3$). UV λ_{max} (MeOH) nm (log ε): 232 (5010), 285 (2450). IR (cm^{-1}) 1662. ^{1}H NMR (400 MHz, $CDCl_3$) δ_H: 1.56 (3H, br.s, H_3-15), 1.30 (3H, s, H_3-14), 2.07 (3H, s, H_3-13), 7.04 (1H, br.s, H-12), 3.66, 3.70 (2H, m, H_2-9), 3.77 (1H, s, H-5), 1.24, 2.27 (2H, m, H_2-3), 2.24, 2.46 (2H, m, H_2-2), 5.46 (1H, d, J = 11.8 Hz, H-1). ^{13}C NMR (100 MHz, $CDCl_3$) δ_C: 131.2 (C-1), 24.7 (C-2), 38.0 (C-3), 64.0 (C-4), 66.6 (C-5), 192.2 (C-6), 123.2 (C-7), 157.2 (C-8), 41.9 (C-9), 131.1 (C-10), 122.2 (C-11), 138.1 (C-12), 10.3 (C-13), 15.2 (C-14), 15.8 (C-15). MS m/z: 246 (M^+, 18%), 188 (15), 175 (100), 161, 119 (50), 43 (27). HR-TOF-MS m/z: 247.0889 ($C_{15}H_{18}O_3$).
Zederone epoxide (**8**) [22]	White amorphous powder;$[\alpha]_D^{25}$ +38.3° (*c* = 0.3, MeOH). ^{1}H NMR (500 MHz, $CDCl_3$) δ_H: 7.08 (1H, br. s, H-12), 3.78 (1H, s, H-5), 3.68 (1H, d, *J* = 17.0 Hz, H-9a), 2.93 (1H, br. d, *J* = 10.0 Hz, H-1), 2.82 (d, J = 17.0 Hz, H-9b); 2.41 (1H, br. d, J = 11.0 Hz, H-3a), 2.21 (1H, br d, J = 14.0 Hz, H-2a), 2.16 (3H, s, H_3-13), 1.52 (1H, m, H-2b), 1.47 (1H, m, H-3b), 1.32 (3H, s, H_3-14), 1.15 (3H, s, H_3-15). ^{13}C NMR (125 MHz, $CDCl_3$): 189.8 (C-6), 156.1 (C-8), 138.4 (C-12), 123.4 (C-11), 122.6 (C-7), 69.0 (C-1), 63.6 (C-4), 63.2 (C-5), 57.9 (C-10), 39.5 (C-9), 36.1 (C-3), 23.8 (C-2), 16.8 (C-14), 15.3 (C-15), 10.5 (C-13). EI-MS: 262 (18.2, Mþ), 43 (100,$C_3H_7^+$).
Furanodienone (**9**) [23, 24]	Colorless prisms; melting point 87 ∼ 88°C. UV λ_{max} (EtOH) nm (ε): 241 (9150), 269 (6800). IR (cm^{-1}) 1664, 1608, 1231, 1013, 755. ^{1}H NMR (400 MHz, $CDCl_3$) δ_H: 5.15 (1H, dd, *J* = 11.4, 4.1 Hz, H-1), 2.16 (1H, td, *J* = 12.4, 3.5 Hz, H-2α), 2.30 (1H, td, *J* = 12.4, 4.1 Hz, H-2β), 1.85 (1H, td, *J* = 11.4, 4.1 Hz, H-3α), 2.44 (1H, ddd, *J* = 11.4, 6.9, 3.4 Hz, H-3β), 5.78 (1H, br s, H-5), 3.66 (1H, br d, *J* = 14.5 Hz, H-9α), 3.70 (1H, br d, *J* = 14.5 Hz, H-9β), 7.05 (1H, br s, H-12), 2.11 (3H, s, H_3-13), 1.97 (3H, s, H_3-14), 1.28 (3H, s, H_3-15). ^{13}C NMR (100 MHz, $CDCl_3$) δ_C: 130.5 (C-1), 26.4 (C-2), 40.6 (C-3), 145.8 (C-4), 132.4 (C-5), 190.0 (C-6), 123.9 (C-7), 156.5 (C-8), 41.7 (C-9), 135.4 (C-10), 122.0 (C-11), 138.0 (C-12), 9.5 (C-13), 18.9 (C-14), 15.7 (C-15). MS m/z: 230 (M^+, 47%), 150 (50), 122 (100), 94 (26), 81 (48).
Isofuranodienone (**10**) [24, 25]	Needles; melting point: 70-71°C; .$[\alpha]_D$ ±0°145º (*c* = 10.0). UV λ_{max} (EtOH) nm (ε): 223 (4.17), 248 (3.95). IR (KBr) cm^{-1}: 1667. ^{1}H NMR ($CDCl_3$, 400 MHz), δ_H: 5.25 (1H, br t, *J* = 8.6 Hz, H-1), 1.78 (1H, m, H-2α), 2.09 (1H, m, H-2β), 2.20 (1H, m, H-3α), 2.25 (1H, m, H-3β), 5.84 (1H, br s, H-5), 3.03 (1H, d, *J* = 14.5 Hz, H-9α), 3.57 (1H, d, *J* = 14.5 Hz, H-9β), 7.05 (3H, br s, H-12), 2.16 (3H, br s, H_3-13), 1.73 (3H, s, H_3-14), 1.63 (3H, s, H_3-15). ^{13}C NMR ($CDCl_3$, 100 MHz), δ_C: 123.9 (C-1), 26.1 (C-2), 36.3 (C-3), 141.1 (C-4), 129.0 (C-5), 193.8 (C-6), 123.9 (C-7), 161.5 (C-8), 32.8 (C-9), 134.0

Compound	Physical and spectral data
	(C-10), 122.1 (C-11), 138.4 (C-12), 9.5 (C-13), 22.6 (C-14), 19.1 (C-15). MS m/z: 230 [M^+], 122 (100%).
1(10)Z,4Z-furanodiene-6-one (**11**)	No data
Glechomanolide (**12**)	No data
Dehydrocurdione (**13**) [26, 27]	Colorless needles; melting point 40-42°C.$[\alpha]_D^{23}$ +145° (*c* = 1.1, MeOH): $[\theta]_{303}$ +13,671. UV λ_{max} (EtOH) nm (ε): 207 (1.16). IR ($CHCl_3$) cm^{-1}: 1742, 2934, 1680, 1453, 1375. ^{1}H NMR (400 MHz, $CDCl_3$) δ_H: 5.13 (1H, t, *J* = 8.24 Hz, H-1), 2.10 (2H, m, H_2-2), 2.0 (2H, m, H_2-3), 2.38 (1H, m, H-4), 3.21/3.29 (each 1H, dd, *J* = 16.48 Hz, H_2-6), 3.06/3.23 (each 1H, dd, *J* = 11.44 Hz, H_2-9), 1.76 (3H, s, H_3-12), 1.73 (3H, s, H_3-13), 1.01 (3H, d, *J* = 6.88 Hz, H_3-14), 1.3 (3H, s, H_3-15). ^{13}C NMR (100 MHz, $CDCl_3$) δ_C: 133.0 (C-1), 26.4 (C-2), 34.2(C-3), 46.4(C-4), 211.1(C-5), 43.4(C-6), 129.3(C-7), 207.2(C-8), 57.0(C-9), 129.9(C-10), 137.0(C-11), 21.0(C-12), 22.1 (C-13), 18.4(C-14), 16.3(C-15). MS m/z: 234 (M^+) ($C_{15}H_{22}O_2$).
Neocurdione (14) [27]	Colorless needles; melting point 45-47°C (hexane). .$[\alpha]_D^{23}$ −190° (*c* = 2.1, $CHCl_3$): CD (*c* = 0.022, MeOH): $[\theta]_{301}$ −29,230. UV λ_{max} (EtOH) nm (ε): 203 (3.73). IR (KBr) cm^{-1}: 1696, 1682, 1395, 1282. ^{1}H NMR ($CDCl_3$): 0.92 (3H, d, *J* = 6.6 Hz, H_3-14), 0.98 (3H, d, *J* = 6.8 Hz, H_3-12 or −13), 1.03 (3H, d, J = 6.8 Hz, H_3-13 or −12), 1.67 (3H, s, H_3-15), 5.18 (1H, br t, *J* = 7.0 Hz, H-1). ^{13}C NMR ($CDCl_3$) δ_C: 131.1 (C-1), 25.5 (C-2), 32.8 (C-3), 45.8 (C-4), 210.2 (C-5), 42.4 (C-6), 52.6 (C-7), 212.5 (C-8), 55.3 (C-9), 129.1 (C-10), 30.9 (C-11), 20.2 (C-12), 21.1 (C-13), 18.2 (C-14), 18.2 (C-15). MS m/z: 236.1763 [M^+] (Calcd for $C_{15}H_{24}O_2$ 236.1777).
Curdione (**15**) [23, 27, 28]	Colorless prisms; melting point 53-54°C (MeOH).$[\alpha]_D^{23}$ +214° (*c* = 1.6, MeOH). CD (*c* = 0.0033, $CHCl_3$) $[\theta]_{309}$ +26,655. IR (KBr) cm^{-1}: 1690, 1460, 1420, 1170, 1060. ^{1}H NMR ($CDCl_3$, 400 MHz), δ: 5.14 (1H, br s, H-1), 2.08-2.13 (2H, m, H_2-2), 1.56 (1H, m, H-3α), 2.08-2.13 (1H, m, H-3β), 2.30 (1H, br s, H-4), 2.37 (1H, dd, *J* = 16.4, 1.5 Hz, H-6α), 2.65 (1H, m, H-6β), 2.88 (1H, ddd, *J* = 16.4, 8.5, 7.8 Hz, H-7), 2.91 (1H, d, *J* = 10.7 Hz, H-9α), 3.04 (1H, d, J = 10.7 Hz, H-9β), 1.85 (1H, m, H-11), 0.85 (3H, d, J = 6.5 Hz, H_3-12), 0.92 (3H, d, J = 6.5 Hz, H_3-13), 0.95 (3H, d, *J* = 6.9 Hz, H_3-14), 1.62 (3H, s, H_3-15).^{13}C NMR ($CDCl_3$, 100 MHz) δ_C: 131.5 (C-1), 26.3 (C-2), 34.0 (C-3), 46.7 (C-4), 214.6 (C-5), 44.2 (C-6), 53.5 (C-7), 211.1 (C-8), 55.8 (C-9), 129.2 (C-10), 29.9 (C-11), 21.1 (C-12), 19.8 (C-13), 18.5 (C-14), 16.5 (C-15). EI-MS m/z (rel. Int.): 236 (2), 208 (1), 180 (33), 167 (28), 109 (52), 95 (23), 83 (13), 69 (100), 55 (76). MS m/z 236[M^+] $C_{15}H_{24}O_2$.
7α-hydroxyneocurdione (**16**)	No data
7β-hydroxycurdione (**17**)	No data
Germacrone-1(**10**),4-diepoxide (**18**) [6]	White powder; melting point 84-86°C.$[\alpha]_D$ = +71.17° (*c* = 0.14, MeOH). UV (MeOH) λ_{max} nm (log ε): 256 (4.22), 315 (2.30). IR (KBr) cm^{-1}. 1678, 1645. ^{1}H NMR (400 MHz, $CDCl_3$) δ_H: 1.143 (3H, s, H_3-14), 1.26-1.32 (1H, m, H-3b), 1.444 (3H, s, H_3-15), 1.45-1.50 (1H, m, H-2b), 1.794 (3H, s, H_3-12), 1.862 (3H, s,H_3-13), 2.02-2.08 (1H, m, H-2a), 2.19-2.24 (1H, m, H-3a), 2.260 (1H, dd, *J* = 14.2/ 10.8 Hz, H-6b), 2.644 (1H, d, *J* = 10.8 Hz, H-9b), 2.652 (1H, dd, *J* = 10.9/2.2 Hz H-5), 2.855 (1H, dd, *J* = 14.2/2.2 Hz, H-6a), 2.918 (1H, d, *J* = 10.8 Hz, H-1), 3.007 (1H, *J* = 10.8 Hz, H-9a). EI-MS m/z: 124.9 (100), 122 (80). ^{13}C NMR (500 MHz, $CDCl_3$) δ_C: 61.3 (C-1), 22.8 (C-2), 35.7 (C-3), 60.1 (C-4), 64.0 (C-5), 29.2 (C-6), 134.3 (C-7), 207.2 (C-8), 54.5 (C-9), 58.4 (C-10), 137.8 (C-11), 22.9 (C-12), 20.8 (C-13), 15.5 (C-14), 17.3 (C-15). HR-ESI-MS: $C_{15}H_{22}O_3Na[M + Na]^+$ calcd. 273.14611 found 273.14575.

Compound	Physical and spectral data
Germacrone (**19**) [20, 27]	Colorless prisms; melting point: 53-54°C (MeOH). IR (cm^{-1}): 1679, 1665, 1445, 1294, 1135. ^{1}H NMR (400 MHz, $CDCl_3$) δ_H: 1.62 (3H, s, H_3-15), 1.43 (3H, s, H_3-14), 1.76 (3H, s, H_3-13), 1.73 (1H, s, H-12), 3.42, 2.95 (2H, dd, *J* = 11, 3.68 Hz, H_2-9), 2.86 (2H, m, H_2-6), 4.71 (1H, d, *J* = 11 Hz, H-5), 2.15 (2H, m, H_2-3), 2.08, 2.35 (2H, m, H_2-2), 4.94 (1H, d, J = 11.8 Hz, H-1). ^{13}C NMR (100 MHz, $CDCl_3$) δ_C: 132.8 (C-1), 24.0 (C-2), 38.1 (C-3), 126.0 (C-4), 125.4 (C-5), 29.3 (C-6), 129.0 (C-7), 208.0 (C-8), 56.0 (C-9), 135.1 (C-10), 137.0 (C-11), 20.0 (C-12), 22.4 (C-13), 15.6 (C-14), 16.8 (C-15). MS m/z: 218 (M^+) ($C_{15}H_{22}O$).
13-hydroxygermacrone (**20**) [29]	Colorless oil ($CHCl_3$); IR (KBr) cm^{-1}: 3452, 1679. ^{1}H NMR (400 MHz, $CDCl_3$) δ_H: 4.95 (1H, br. d, *J* = 10.8 Hz, H-1), 4.63 (1H, dd, *J* = 10.0, 3.2 Hz, H-5), 4.25 (1H, d, J = 12.4 Hz, H-13a), 4.13 (1H, d, *J* = 12.4 Hz, H-13b), 3.40 (1H, d, *J* = 10.4 Hz, H-9a), 2.95 (1H, d, *J* = 10.4 Hz, H-9b), 2.92 (2H, overapped, H_2-6), 2.33 (1H, m, H-2a), 2.14 (1H, m, H-3a), 2.04 (1H, m, H-3b), 1.89 (1H, m, H-2b), 1.78 (3H, s, H_3-12), 1.59 (3H, s, H_3-15), 1.40 (3H, s, H_3- 14). ^{13}C NMR (100 MHz, $CDCl_3$) δ_C: 133.08 (C-1), 24.03 (C-2), 38.02 (C-3), 135.70 (C-4), 124.94 (C-5), 28.55 (C-6), 131.43 (C-7), 207.32 (C-8), 55.48 (C-9), 126.20 (C-10), 139.80 (C-11), 17.73 (C-12), 62.65 (C13), 15.56 (C-14), 16.60 (C-15). EI-MS m/z: 234.
Curzerenone (**21**) [30, 31]	Yellowish oil. 1H-NMR (400 MHz, $CDCl_3$) δ: 7.07 (1H, brs, H-11), 5.81 (1H, brs, H-5), 5.18 (1H, t, *J* = 7.5 Hz, H-1), 3.72 (2H, AB-system, *J* = 15 Hz, H-9a, 9b), 2.20 (3H, d, *J* = 1.5 Hz, H_3-13), 1.76 (3H, d, *J* = 1.5 Hz, H_3-14), 1.31 (3H, s, H_3-15), 1.60–2.48 (4H, m, H_2-2 and H_2-3). ^{13}C-NMR (100 MHz, $CDCl_3$) δ: 130.5 (C-1), 26.4 (C-2), 41.6 (C-3), 145.7 (C-4), 132.4 (C-5), 189.7 (C-6), 122.2 (C-7), 156.5 (C-8), 40.6 (C-9), 135.4 (C-10), 138.1 (C-11), 123.7 (C-12), 9.5 (C-13), 18.9 (C-14), 15.7 (C-15). ESI-MS m/z: 231 $[M + H]^+$ ($C_{15}H_{18}O_2$, M = 230).
Curcolonol (**22**) [32]	Colorless prisms (acetone); melting point 183-184°C; $[\alpha]_D^{25}$ = 0° (*c* = 2.0, EtOH). IR (cm^{-1}): 3420, 2934, 2872, 1723, 1653, 1562, 1426, 1381, 1275, 1126, 1067, 1040, 922, 742. ^{1}H NMR (500 MHz, Acetone-d_6) δ_H: 3.69 (1H, m, H-1), 1.73 (1H, m, H-2 eq), 1.63 (1H, m, H-2ax), 1.58 (2H, m, H_2-3), 2.61 (1H, s, H-5), 3.03 (d, *J* = 17 Hz, H-9 eq), 2.84 (d, *J* = 17 Hz, H-9ax), 7.29 (1H, br s, H-11), 2.14 (3H, d, *J* = 1.3 Hz, H_3-13), 1.40 (3H, s, H_3-14), 0.97 (3H, s, H_3-15). ^{13}C NMR (50 MHz, Acetone-d_6) δ_C: 77.9 (C-1), 28.8 (C-2), 39.3 (C-3), 71.5 (C-4), 62.8 (C-5), 198.4 (C-6), 119.8 (C-7), 167.6 (C-8), 40.3 (C-9), 45.4 (C-10), 140.6 (C-11), 119.6 (C-12), 9.1 (C-13), 25.0 (C-14), 15.0 (C-15). EIMS m/z (rel int) 264 [m] + (13, 249 (29), 246 (15), 231 (5), 228 (5), 213 (12), 163 (100), 135 (35), 122 (37), 107 (31), 94 (14); HR-EI-MS m/z: 264.1354 (calcd for $C_{15}H_{20}O_4$, 264.1362).
Alismol (**23**) [33, 34]	Colorless oil; (+)-alismol: $[\alpha]_D^{25}$ = +38.8° (*c* = 0.80, $CHCl_3$,), (−)-alismol: $[\alpha]_D^{25}$ = −38.6° (*c* = 0.80, $CHCl_3$). ^{1}H NMR (600 MHz, $CDCl_3$) δ_H: 0.99 (3H, d, J = 6.9 Hz), 1.00 (3H, d, *J* = 6.9 Hz), 1.25 (3H, s), 1.72 -1.80 (2H, m), 1.92 (1H, m), 1.99-2.08 (1H, m), 2.02-2.09 (1H, m), 2.19-2.25 (1H, m), 2.25-2.28 (1H, m), 2.03 (2H, m), 2.51 (1H, m), 4.71 (1H, s), 4.77 (1H, s), 5.55 (1H, s). ^{13}C NMR (400 MHz, $CDC1_3$) δ_C: 47.3 (C-1), 24.7 (C-2), 40.2 (C-3), 80.7 (C-4), 55.0 (C-5), 121.3 (C-6), 149.8 (C-7), 30.0 (C-8), 37.1 (C-9), 153.9 (C-10), 37.4 (C-11), 21.5, 21.3 (C-12 and C-13), 24.1 (C-14), 106.5 (C-15). MS: m/z %: 220 $[M^+]$(6), 205 (12), 202 (10), 187 (16), 177 (18), 162 (53), 159 (52), 149 (18), 147 (37), 145 (16), 134 (25), 131 (23), 119 (100), 117 (30), 107 (39), 105 (47), 93 (48), 91 (76), 85 (9), 81 (15), 79 (36), 77 (28), 71 (15), 69 (14), 67 (16), 55 (25),53 (16), 43 (87), 41 (38).

Compound	Physical and spectral data
Alismoxide(**24**) [33, 35]	Colorless crystals, mp 138–141°C;$[\alpha]_D^{20}$ = +9.3 (c 0.9 $CHCl_3$,). ^1H NMR (400 MHz, $CDCl_3$) δ_H: 5.44 (1H, br d, J = 3.0 Hz, H-6), 0.98, 1.0 (3H each, d, *J* = 6.9 Hz, H_3-12, −13), 1.25, 128 (3H each, s, H_3-14, −15). ^{13}C NMR (100 MHz, $CDCl_3$): δ_C: 50.5 (C-1), 21.4 (C-2), 40.3 (C-3), 80.0 (C-4), 50.1 (C-5), 121.3 (C-6), 149.4(C-7), 25.0 (C-8), 42.5 (C-9), 75.2 (C-10), 37.2 (C-11), 21.1 (C-12), 21.2 (C-13), 22.4 (C-14), 21.3 (C-15). MS: m/z (%): 220 (M^+ -H_2O)(7), 205 (9), 202 (4), 187 (9), 177 (12), 162 (66), 159 (28), 149 (20), 147 (38), 134 (34), 121 (23), 119 (53), 107 (34), 105 (24), 93 (42), 91 (30), 85 (12), 81 (14), 79 (28), 77 (16), 71 (12), 69 (12), 55 (20), 43 (100), 41 (24).
Zedoarondiol (**25**) [27]	Colorless needles; melting point 134°C ($CHCl_3$);$[\alpha]_D^{23}$ = −44° (*c* = 1.0, MeOH). CD (*c* = 0.03, MeOH): $[\theta]_{321}$− 6468. UV (MeOH) λ_{max} nm (log ε): 258 (3.86). IR (cm^{-1}): 3420, 1662, 1604. ^1H NMR ($CDCl_3$) δ_H: 1.18 (3H, s, H_3-14 or −15), 1.20 (3H, s, H_3-15 or −14), 1.84 (3H, s, H_3-12, or −13), 1.94 (3H, s, H_3-13 or −12), 2.60 (1H, d, *J* = 13.0 Hz, H-9β), 2.98 (1H, d, *J* = 13.0 Hz, H-9α). ^{13}C NMR ($CDCl_3$) δ_C: 55.9 (C-1), 22.9 (C-2), 28.5 (C-3), 79.9 (C-4), 52.0 (C-5), 39.7 (C-6), 134.6 (C-7), 202.9 (C-8), 59.8 (C-9), 72.7 (C-10), 142.1 (C-11), 21.9 (C-12), 22.2 (C-13), 22.7 (C-14), 20.6 (C-15). MS m/z: 252 (M^+) ($C_{15}H_{24}O_3$).
isozedoarondiol (**26**) [27]	Colorless needles; melting point 150-156°C.$[\alpha]_D^{23}$ = −147.2° (*c* = 0.8, MeOH). CD (*c* = 0.003, MeOH): $[\theta]_{313}$ −6323. UV (MeOH) λ_{max} nm (log ε): 258 (3.86). IR (cm^{-1}): 3420, 1662, 1604. ^1H NMR ($CDCl_3$) δ_H: 1.23 (3H, s, H_3-14), 1.42 (3H, s, H_3-15), 1.86 (3H, s, H_3-12 or −13), 2.03 (3H, s, H_3-13 or −12), 2.42 (H, d, *J* = 16.0 Hz, H-9β), 3.21 (H, d, *J* = 16.0 Hz, H-9α). 53.4 (C-1), 25.2 (C-2), 27.4 (C-3), 82.4 (C-4), 51.7 (C-5), 37.0 (C-6), 134.0 (C-7), 203.0 (C-8), 50.2 (C-9), 73.2 (C-10), 143.7 (C-11), 22.1 (C-12), 22.8 (C-13), 25.0 (C-14), 32.2 (C-15). MS: *Anal*. Calcd for $C_{15}H_{24}O_3$: C, 71.39; H, 9.59. Found: C, 71.65: H, 9.52.
Procurcumenol (**27**) [26, 36]	Viscous oil;$[\alpha]_D^{24}$ = +218.5° (*c* = 0.15, MeOH). UV (MeOH) λ_{max} nm (log ε):248 (3.90), 275 (3.75). IR (cm^{-1}): 3430, 1646. ^1H NMR (500 MHz, $CDCl_3$) δ_H: 1.24 (3H, s, H_3-14), 1.75 (3H, s, H_3-13), 1.78 (3H, s, H_3-12), 1.88 (3H, s, H_3-15), 2.18 (1H, dd, *J* = 16.0, 13.0 Hz, H-6α), 2.38 (1H, ddd, J = 10.5, 10.0 Hz, H-1), 2.61 (1H, br d, J = 16.0 Hz, H-6β), 5.88 (1H, br s, H-9). ^{13}C NMR (100 MHz, $CDCl_3$) δ_C: 50.5 (C-1), 26.9(C-2), 39.9 (C-3), 80.3 (C-4), 53.9 (C-5), 28.6 (C-6), 136.9 (C-7), 199.2(C-8), 129.2 (C-9), 155.1(C-10), 136.3 (C-11), 21.3 (C-12), 22.4(C-13), 23.4 (C-14), 24.3 (C-15). ESI-MS m/z: 235 $[M + H]^+$. $C_{15}H_{20}O_2$. GC MS: RT 29.36 min, 234(M^+, 6.08), 158(35), 121(84), 105(100), 93(60), 43(79).
Isoprocurcumenol (**28**) [26]	Colorless oil; UV (MeOH) λ_{max} nm (log ε): 205 (1.83). IR (CHCl3) cm^{-1}: 3450, 1674, 1610. ^1H NMR (400 MHz, $CDCl_3$) δ_H: 3.22 (1H, q, *J* = 14.68 Hz, H-1), 1.21 (2H, m, H_2-2), 1.39 (2H, m, H_2-3), 1.40 (1H, m, H-5), 2.81 (2H, d, *J* = 14.2 Hz, H_2-6), 2.16 (2H, s, H_2-9), 1.92 (3H, s, H_3-12), 1.82 (3H, s, H_3-13), 1.24 (3H, s, H_3-14), 4.90 (2H, br S, H_2-15). ^{13}C NMR (100 MHz, $CDCl_3$) δ_C: 51.2 (C-1), 24.7(C-2), 28.2 (C-3), 77.4 (C-4), 58.9 (C-5), 39.8 (C-6), 134.5 (C-7), 203.0 (C-8), 53.8 (C-9), 141.3 (C-10), 143.9 (C-11), 21.9 (C-12), 22.8 (C-13), 24.4 (C-14), 111.6 (C-15). $C_{15}H_{20}O_2$. GC mS: RT 29.36 min, 234 (M^+, 6.08), 158(35), 121(84), 105(100), 93(60), 43(79).
Aerugidiol (**29**)	No data
Zedoalactone B (**30**) [37]	Oil; $[\alpha]_D$ +177.7° (*c* = 0.4, MeOH). UV (MeOH) λ_{max} nm (log ε): 273 (4.33). IR (KBr) cm^{-1}: 3400, 2970, 2940, 2880, 1740, 1660, 1630. ^1H NMR (500 MHz, pyridine-d_5) δ_H: 2.06 (1H, ddd, *J* = 8.0, 11.5,

Compound	Physical and spectral data
	13.1 Hz, H-2α), 3.10 (1H, ddd, *J* = 2.0, 9.0, 13.1 Hz, H-2β), 2.15 (1H, ddd, *J* = 2.0, 8.0, 11.5 Hz, H-3α), 2.41 (1H, ddd, *J* = 9.0, 11.5, 11.5 Hz, H-3β), 3.35 (1H, dd, *J* = 3.0, 12.8 Hz, H-5), 3.21 (1H, ddd, *J* = 1.5, 12.8, 17.4 Hz, H-6α), 3.08 (1H, ddd, *J* = 1.5, 3.0, 17.4 Hz, H-6β), 6.09 (1H, s, H-9), 1.71 (3H, d, *J* = 1.5, H_3-13), 1.75 (3H, br s, H_3-14), 1.90 (3H, s, H_3-15), 7.12 (s, 1-OH), 6.22 (s, 4-OH), 6.02 (s, 10-OH). ^{13}C NMR (125 MHz, pyridine-d_5) δ_H: 75.1 (C-1), 35.7(C-2), 41.5(C-3), 79.5(C-4), 50.3 (C-5), 22.0 (C-6), 151.2 (C-7), 148.5 (C-8), 118.8 (C-9), 82.7 (C-10), 125.8 (C-11), 170.2 (C-12), 8.4 (C-13), 23.7(C-14), 26.1 (C-15). EIMS m/z: $[M]^+$ absent, 262 $[M - H_2O]^+$ (13), 244 $[M - 2H_2O]^+$ (33), 226 $[M - 3H_2O]^+$ (100), 211 $[M - 3H_2O - CH_3]^+$ (66). HR-MS, found: $[M\text{-}H_2O]^+$, 262.1195. $C_{15}H_{18}O_4$ requires $[M - H_2O]^+$, 262.1205.
Curcumenone (**31**) [26]	Colorless oil. IR ($CHCl_3$) cm^{-1}: 1679, 1715. UV (MeOH) λmax nm (log ε): 205(1.28). ^{1}H NMR (400 MHz, $CDCl_3$) δ_H: 0.43 (1H, dt, *J* = 4.56, 7.32 Hz, H-1), 1.64 (2H, q, *J* = 7.32 Hz, H_2-2), 2.47 (2H, t, *J* = 7.36 Hz, H_2-3), 0.67 (1H, q, *J* = 4.56 Hz, H-5), 2.8 (2H, m, H_2-6), 2.52 (2H, d, *J* = 15.6 Hz, H_2-9), 2.07 (3H, s, H_3-12), 1.77 (3H, s, H_3-13), 2.12 (3H, s, H_3-14), 1.10 (3H, s, H_3-15). ^{13}C NMR (100 MHz, $CDCl_3$) δ_C: 24.1 (C-1), 23.4(C-2), 44.0(C-3), 209.0(C-4), 24.2(C-5), 28.0(C-6), 128.1(C-7), 201.9(C-8), 49.0(C-9), 20.2(C-10), 147.6(C-11), 23.5(C-12), 23.5(C-13), 30.1(C-14), 19.1(C-15). $C_{15}H_{22}O_2$. GC MS: RT 28.9, 234(M^+, 13.5), 176(78), 163(29), 161(48), 149 (43), 133 (37), 107(32), 91(29), 68(91), 67(75), 43(100).
Curcumadione (**32**) [38]	Colorless oil; $[\alpha]_D$ +63.3° (*c* = 0.15, MeOH). UV λ_{max} (EtOH) nm (ε): 207 (1.16). ^{1}H NMR (400 MHz, $CDCl_3$) δ_H: 1.07 (3H, d, *J* = 6.8 Hz, H_3-15), 1.80, 1.99 (3H each, s, H_3-12, −13), 2.14 (3H, s, H_3-14), 5.52 (1H, t, *J* = 6.6 Hz, H-5). ^{13}C NMR (100 MHz, $CDCl_3$) δ_C: 140.0 (C-1), 27.8(C-2), 42.6(C-3), 208.1(C-4), 121.1(C-5), 30.2(C-6), 134.7 (C-7), 205.1(C-8), 48.6(C-9), 35.0(C-10), 143.7(C-11), 19.1(C-12), 22.6(C-13), 22.2(C-14), 19.1(C-15). MS m/z: 234.1625 (M^+) (calcd for $C_{15}H_{22}O_2$: 234.1620).
(1S, 10S), (4S, 5S)-Germacrone-1(10), 4(5)-diepoxide (**33**) [6]	^{1}H NMR (500 MHz, $CDCl_3$) δ_H: 2.92 (1H, d, J = 10.8 Hz, H-1), 2.06, 1.46 (m, H_2-2), 2.21, 1.28 (2H, m, H_2-3), 2.65 (1H, dd, J = 10.9, 2.2 Hz, H-5), 2.86 (dd, J = 14.2, 2.2 Hz, H-6a), 2.26 (dd, J = 14.2, 10.8 Hz, H-6b), 3.01 (d, J = 10.8 Hz, H-9a), 2.64 (d, J = 10.8 Hz, H-9b), 1.79 (s, H_3-12), 1.86 (s, H_3-13), 1.14 (s, H_3-14), 1.44 (s, H_3-15). ^{13}C NMR (500 MHz, $CDCl_3$) δ_C: 61.3 (C-1), 22.8 (C-2), 35.7 (C-3), 60.1 (C-4), 64.0 (C-5), 29.2 (C-6), 134.3 (C-7), 207.2 (C-8), 54.5 (C-9), 58.4 (C-10), 137.8 (C-11), 22.9 (C-12), 20.8 (C-13), 15.5 (C-14), 17.3 (C-15).
3,6,10-trimethyl-7,8,11,11-atetrahydrocyclodeca[b]furan-2,5(4H,6H)-dione (**34**) [6]	$[\alpha]_D$ +35.2° (*c* = 0.15, MeOH). ^{1}H NMR (500 MHz, $CDCl_3$) δ_H: 4.92 (1H, br s, H-1), 2.06, 2.20 (2H, m, H_2-2), 1.72, 2.04 (2H, m, H_2-3), 2.44 (1H, m, H-4), 3.36 (2H, m, H_2-6), 4.92 (1H, br s, H-8), 2.04, 2.94 (m, H_2-9), 1.85 (3H, s, H_3-13), 1.09 (3H, d, J = 6.7 Hz, H_3-14), 1.82 (3H, s, H_3-15). ^{13}C NMR (500 MHz, $CDCl_3$) δ_C: 133.4 (C-1), 27.3 (C-2), 35.9 (C-3), 48.0 (C-4), 208.2 (C-5), 41.6 (C-6), 155.2 (C-7), 79.7 (C-8), 46.1 (C-9), 128.9 (C-10), 128.9 (C-11), 173.5 (C-12), 9.2 (C-13), 18.6 (C-14), 16.0 (C-15).
11a-hydroxy-3,6,10-trimethyl-7,8,11,11a-tetrahydrocyclodeca [b]furan-2,5(4H,6H)-dione-methane (**35**) [6]	^{1}H NMR (500 MHz, $CDCl_3$) δ_H: 4.88 (1H, d, J = 10.7 Hz, H-1), 2.00, 2.20 (2H, m, H_2-2), 1.65, 2.10 (2H, m, H_2-3), 2.45 1H, (m, H-4), 3.58 (d, J = 15.4 Hz, H-6a), 3.30 (d, J = 15.7 Hz, H-6b), 2.93 (1H, d, J = 13.4 Hz, H-9a), 2.31 (1H, d, J = 13.4 Hz, H-9b), 1.86 (3H, s, H_3-13), 1.06 (3H, d, J = 6.8 Hz, H_3-14), 1.93 (3H, s, H_3-15). ^{13}C NMR (500 MHz, $CDCl_3$) δ_C: 133.8 (C-1), 27.2 (C-2), 36.0 (C-3), 47.8 (C-4), 209.6 (C-5), 40.2 (C-6), 154.6 (C-7), 106.9 (C-8), 49.7 (C-9), 130.5 (C-10), 129.9 (C-11), 172.3 (C-12), 9.2 (C-13), 18.4 (C-14),

Compound	Physical and spectral data
	16.5 (C-15). HR-ESI-MS: 287.12547[M + Na]$^+$, calcd. For $C_{15}H_{20}O_4Na$ 287.1253802.
Curcumenol (**36**) [19]	Colorless crystals; melting point: 98-100°C. IR (cm^{-1}): 3371, 3321, 1695, 1658, 1274. ^{1}H NMR (600 MHz, $CDCl_3$) δ_H: 1.95 (1H, m, H-1), 1.96 2H, (m, H_2-2), 1.90 (2H, m, H_2-3), 1.93 (1H, m, H-4), 2.11, 2.66 (each, 1H, d, J = 16.9 Hz, H_2-6), 5.77 (1H, s, H-9), 1.60 (3H, s, H_3-12), 1.82 (3H, s, H_3-13), 1.03 (3H, d, J = 6.4 Hz, H-14), 1.67 (3H, s, H-15).^{13}C NMR (151 MHz, $CDCl_3$) δ_C: 51.3 (C-1), 27.6 (C-2), 31.2 (C-3), 40.4 (C-4), 85.7 (C-5), 37.3 (C-6), 137.4 (C-7), 101.5 (C-8), 125.6 (C-9), 139.2 (C-10), 122.2 (C-11), 22.3 (C-12), 18.9 (C-13), 11.8 (C-14), 20.9 (C-15).
Isocurcumenol (**37**) [6]	^{13}C NMR (400 MHz, $CDCl_3$) δ_C: 53.0 (C-1), 28.6 (C-2), 31.0 (C-3), 41.9 (C-4), 87.4 (C-5), 39.2 (C-6), 134.1 (C-7), 104.0 (C-8),36.4 (C-9), 145.4 (C-10), 127.2 (C-11), 22.8 (C-12), 19.2 (C-13), 12.7 (C-14), 112.5 (C-15).
1,4-dihydroxy-1,4-dimethyl-7-(1-methylethylidene) octahydroazulen-6(1H)-one-methane (**38**) [6]	^{1}H NMR (400 MHz, $CDCl_3$) δ_H: 1.16 (s), 1.26 (s), 1.81 (s), 1.89 (s), 1.50-1.80 (m), 2.51 (d, J = 11.7), 2.83 (d, J = 15.6), 2.92 (d, J 11.7). ^{13}C NMR (400 MHz, $CDCl_3$) δ_C: 54.7 (C-1), 21.4 (C-2), 28.0 (C-3), 80.4 (C-4), 50.1 (C-5), 39.9 (C-6), 135.8 (C-7), 205.6 (C-8), 57.3 (C-9), 71.5 (C-10), 140.0 (C-11), 22.0 (C-12), 22.9 (C-13), 22.0 (C-14), 30.0 (C-15).
Zedoalactone A (**39**) [6]	^{1}H NMR (500 MHz, $CDCl_3$) δ_H: 2.71 (1H, m, H-1), 1.85 (1H, m, H-2a), 1.49 (1H, m, H-2b), 1.80 (2H, m, H_2-3), 2.00 (1H, ddd, J = 13.3, 6.6, 3.7 Hz, H-5), 2.71 (1H, m, H-6a), 1.85 (1H, m, H-6b), 4.92 (1H, ddq, J = 6.9, 2.6, 2.0 Hz, H-8), 2.33 (1H, dd, 16.0, 6.9 Hz, H-9a), 2.09 (1H, ddd, J = 16.0, 2.6, 0.7 Hz, H-9b), 1.83 (3H, d, J = 2.0 Hz, H_3-13), 1.34 (3H, s, H_3-14), 1.24 (3H, s, H_3-15). ^{13}C NMR (500 MHz, $CDCl_3$) δ_C: 51.5 (C-1), 24.5 (C-2), 37.1 (C-3), 816 (C-4), 50.8 (C-5), 24.9 (C-6), 161.4 (C-7), 80.8 (C-8), 35.7 (C-9), 73.5 (C-10), 122.5 (C-11), 175.5 (C-12), 8.0 (C-13), 25.0 (C-14), 31.8 (C-15).
5,8-dihydroxy-3,5,8-trimethyl-4a,5,6,7,7a,8,9,9a-octahydroazuleno[6,5-b]furan-2 (4H)-one (**40**) [6]	^{1}H NMR (500 MHz, $CDCl_3$) δ_H: 1.97 (1H, m, H-1), 1.82 (m, H-2a), 1.70 (m, H-2b), 1.70 (2H, m, H_2-3), 1.58 (1H, ddd, J = 13.0, 9.0, 2.8 Hz, H-5), 2.30 (1H, dd, J = 15.7, 2.8 Hz, H-6a), 2.06 (1H, dd, J = 14.7 13.3 Hz, H-6b), 5.13 (1H, d, J = 11.2 Hz, H-8), 2.31 (1H, dd, 14.7, 2.7 Hz, H-9a), 1.76 (1H, dd, J = 14.7, 11.3 Hz, H-9b), 1.81 (3H, dd, J = 1.7, 1.7 Hz, H_3-13), 1.28 (3H, s, H_3-14), 1.25 (3H, s, H_3-15). ^{13}C NMR (500 MHz, $CDCl_3$) δ_C: 53.2 (C-1), 23.5 (C-2), 41.2 (C-3), 80.4 (C-4), 48.1 (C-5), 29.8 (C-6), 162.4 (C-7), 79.0 (C-8), 46.3 (C-9), 72.6 (C-10), 122.2 (C-11), 174.2 (C-12), 8.7 (C-13), 23.5 (C-14), 24.0 (C-15).
5,8-dihydroxy-3,5,8-trimethyl-4a,5,6,7,7a,8,9,9a-octahydroazuleno[6,5-b]-furan-2(4H)-one (**41**) [6]	^{1}H NMR (500 MHz, $CDCl_3$) δ_H: 2.86 (1H, dddd, J = 12.3, 7.9, 5.1, 1.4 Hz, H-1), 1.81 (m, H-2a), 1.34 (m, H-2b), 1.72 (2H, m, H_2-3), 2.23 (1H, m, H-5), 2.72 (1H, m, H-6a), 2.23 (1H, m H-6b), 5.28 (1H, dqd, 11.7, 1.8, 1.7 Hz, H-8), 2.28 (1H, ddd, J = 13.7, 3.4, 1.7 Hz, H-9a), 1.68 (1H, dd, 13.7, 11.7 Hz, H-9b), 1.79 (3H, dd, 1.8, 1.4 Hz, H_3-13), 1.40 (3H, s, H_3-14), 1.32 (3H, s, H_3-15). ^{13}C NMR (500 MHz, C_5D_5N) δ_C: 53.1 (C-1), 24.9 (C-2), 37.8 (C-3), 80.7 (C-4), 48.4 (C-5), 24.9 (C-6), 165.4 (C-7), 79.8 (C-8), 41.2 (C-9), 71.2 (C-10), 121.3 (C-11), 174.9 (C-12), 8.8 (C-13), 25.8 (C-14), 32.4 (C-15).
Zedoarolide B (**42**) [6]	^{1}H NMR (400 MHz, C_5D_5N) δ_H: 3.38 (1H, ddd, 3.7, 7.6, 7.6 Hz, H-1), 1.98 (1H, m, H-2a), 1,79 (1H, m, H-2b), 2.08 (1H, m, H-3a), 1.97 (1H, m, H-3b), 2.64 (1H, ddd, J = 3.7, 3.7, 12.8 Hz, H-5), 2.82 (1H, dd, J = 3.7, 12.8 Hz, H-6a), 2.43 (1H, dd, J = 12.8, 12.8 Hz, H-6b), 2.86 (1H, Abq, J = 15.5 Hz, H-9a), 2.80 (1H, Abq, J = 15.5 Hz, H-9b), 1.81 (3H, s, H-13), 1.44 (3H, s, H-14), 1.58 (3H, s, H-15). ^{13}C

Compound	Physical and spectral data
	NMR (400 MHz, C_5D_5N) δ_C: 53.1 (C-1), 25.3 (C-2), 38.2 (C-3), 80.7 (C-4), 52.4 (C-5), 24.6 (C-6), 161.5 (C-7), 106.9 (C-8), 44.0 (C-9), 72.1 (C-10), 122.7 (C-11), 173.7 (C-12), 8.0 (C-13), 25.6 (C-14), 32.5 (C-15).
4a,8,9,9a-Tetrahydroxy-3,5,8-trimethyl-4a,5,6,7,7a,8,9,9a-octahydroazuleno[6,5-b]-furan-2(4H)-one (**43**) [6]	^{1}H NMR (400 MHz, C_5D_5N) δ_H: 3.74 (1H, dd, J = 5.0, 3.8 Hz, H-1), 1.77 (2H, m, H_2-2), 2.36 (1H, dddd, J = 11.4, 11.4, 10.7, 6.8 Hz, H-3a), 1.43 (1H, m, H-3a), 2.05 (1H, qd, J = 7.3, 6.8 Hz, H-4), 3.28 (1H, d, J = 15.6 Hz, H-6a), 2.87 (1H, dq, J = 15.6, 1.7, H-6b), 3.99 (1H, s, H-9), 1.87 (3H, d, J = 1.7 Hz, H_3-13), 0.71 (3H, d, J = 7.3 Hz, H_3-14), 1.47 (3H, s, H_3-15). ^{13}C NMR (400 MHz, C_5D_5N) δ_C: 43.3 (C-1), 25.0 (C-2), 33.2 (C-3), 42.9 (C-4), 92.2 (C-5), 32.2 (C-6), 158.8 (C-7), 108.6 (C-8), 81.1 (C-9), 82.0 (C-10), 126.9 (C-11), 172.4 (C-12), 8.7 (C-13), 14.2 (C-14), 19.7 (C-15). MS: m/z 303.12047, $[M - H_2O + Na]^+$. HR-MS 303.12047 $C_{15}H_{22}O_6$.
7-(1-hydroxy-1-methylethyl)-1,4-dimethyl-1,2,3,3a,4,5,8,8a-octahydroazulene-1,4-diol (**44**) [6]	^{1}H NMR (400 MHz, C_5D_5N) δ_H: 3.48 (m, H-1), 1.96 (1H, m, H-2a), 1.78 (1H, m, H-2b), 2.02 (1H, m, H-3a), 1.85 (1H, m, H-3b), 2.41 (dd, J = 12.8, 4.9 Hz, H-5), 2.52 (1H, d, J = 13.9 Hz, H-6a), 2.15 (1H, dd, J = 13.9, 12.8 Hz, H-6b), 6.16 (1H, br dd, J = 8.4, 5.2 Hz, H-8), 2.78 (91H, J = 14.2, 5.2 Hz, H-9a), 2.27 (1H, dd, J = 14.2, 8.4 Hz, H-9b), 1.57 (3H, s, H_3-12), 1.57 (3H, s, H_3-13), 1.62 (3H, s, H_3-14), 1.36 (3H, s, H_3-15). ^{13}C NMR (400 MHz, C_5D_5N) δ_C: 54.2 (C-1), 25.5 (C-2), 37.5 (C-3), 80.9 (C-4), 49.4 (C-5), 26.2 (C-6), 150.9 (C-7), 118.8 (C-8), 35.4 (C-9), 70.6 (C-10), 72.7 (C-11), 29.2 (C-12), 29.4 (C-13), 26.3 (C-14), 31.6 (C-15).
Gajutsulactone B (**45**) [6]	^{1}H NMR (300 MHz, $CDCl_3$) δ_H: 2.88 (ddd, 6.4, 6.4, 9.8 Hz, H-1), 2.06 (1H, m, H-2a), 1.86 (1H, m, H-2b), 1.90 (m, H-3), 2.30 (m, H-5), 2.50 (d, H-6a), 2.24 (d, H-6b), 5.01 (br s, H-9a), 4.84 (br s, H-9b), 2.18 (3H, s, H-12), 1.86 (3H, s, H-13), 1.78 (3H, s, H-14), 1.22 (3H, s, H-15). ^{13}C NMR (300 MHz, $CDCl_3$) δ_C: 42.4 (C-1), 26.2 (C-2), 38.0 (C-3), 85.3 (C-4), 45.7 (C-5), 25.7 (C-6), 120.4 (C-7), 167.5 (C-8), 111.9 (C-9), 145.2 (C-10), 151.8 (C-11), 23.3 (C-12), 23.5 (C-13), 25.2 (C-14), 19.9 (C-15).
Bisacumol (**46**) [6]	^{13}C NMR (300 MHz, $CDCl_3$) δ_C: 144.2 (C-1), 127.2 (C-2), 129.3 (C-3), 135.7 (C-4), 129.3 (C-5), 127.2 (C-6), 36.1 (C-7), 46.1 (C-8), 67.1 (C-9), 128.6 (C-10), 135.0 (C-11), 18.4 (C-12), 26.0 (C-13), 23.3 (C-14), 21.3 (C-15).
7-isopropenyl-1,4a-dimethyldecahydronaphthalene-1,4-diol (**47**) [6]	^{1}H NMR (500 MHz, $CDCl_3$) δ_H: 3.27 (1H, dd, 12.7, 4.2 Hz, H-1), 1.87 (1H, m, H-2a), 1.62 (1H, m, H-2b), 1.72 (1H, m, H-3a), 1.5 (1H, ddd, J = 14.1, 14.1, 4.5 Hz, H-3b), 1.07 (1H, dd, 12.4, 2.6 Hz, H-5), 1.68 (1H, m, H-6a), 1.94 (1H, m, H-6b), 1.62 (1H, m, H-8a), 1.45 (1H, m, H-8b), 1.87 (1H, m, H-9a), 1.11 (1H, dd, J = 13.2, 3.7 Hz, H-9b),1.76 (3H, s, H_3-12), 4.74 1H, (H-13, Z), 4.71 (1H, H-13, E), 1.16 (3H, s, H_3-14), 1.05 (3H, s, H_3-15). ^{13}C NMR (500 MHz, $CDCl_3$) δ_C: 79.7 (C-1), 26.8 (C-2), 39.4 (C-3), 71.4 (C-4), 50.4 (C-5), 25.6 (C-6), 46.1 (C-7), 26.4 (C-8), 39.3 (C-9), 38.9 (C-10), 150.5 (C-11), 20.7 (C-12), 108.6 (C-13), 30.0 (C-14), 12.6 (C-15).
(1S,4S,5S,10R)-isozedoarondiol (**48**) [19]	Yellow oil. IR (cm^{-1}): 3394, 1701, 1665, 1612. ^{1}H NMR (600 MHz, $CDCl_3$) δ_H: 2.79 (1H, m, H-1), 1.63 (2H, m, H_2-2), 1.73 (2H, m, H_2-3), 2.02(1H, d, J = 12.9 Hz, H-5), 2.52, 1.91 (each, 1H, d, J = 13.9 Hz, H_2-6), 2.30 (1H, dd, J = 16.1, 1.2 hz, H-9a), 3.34 (d, J = 16.1 Hz, H-9b), 1.97 (3H, s, H_3-12), 1.88 (3H, s, H_3-13), 1.39 (3H, d, J = 6.4 Hz, H-14), 1.19 (3H, s, H-15).^{13}C NMR (151 MHz, methanol-d_4) δ_C: 51.2 (C-1), 24.6 (C-2), 36.0 (C-3), 81.7 (C-4), 52.6 (C-5), 27.0 (C-6), 134.0 (C-7), 204.7 (C-8), 49.9 (C-9), 72.5 (C-10), 143.0 (C-11), 20.9 (C-12), 21.8 (C-13), 23.4 (C-14), 31.3 (C-15).

Table 1.
Physical and spectral data of sesquiterpenes.

Sample/extract	Biological activity	References
Hexand and DCM	Nematocidal	[39]
EtOAc	Choleretic	[40]
Crude protein	Antioxidant	[41]
EtOH	Antibacterial	[42]
Hexane and EtOH	Anti-inflammatory	[43]
Hexane, EtOAc, and *n*-butanol	Antifungal	[6]
Zedoarondiol (**25**)	Cytotoxic	[19]
(1S, 10S), (4S, 5S)-Germacrone-1(10), 4(5)-diepoxide (**33**)	Cellular viability	[6]
Curcumenol (**36**)	Cytotoxic	[19]
(1S,4S,5S,10R)-isozedoarondiol (**48**)	Cytotoxic	[19]

Table 2.
Biological activities of extracts and compounds from Curcuma comosa.

this chapter, the extraction, isolation, and spectroscopic data of sesquiterpenes from *Curcuma comosa* have been discussed.

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